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Agamuthu Pariatamby
Masaru Tanaka *Editors*

Municipal Solid Waste Management in Asia and the Pacific Islands

Challenges and Strategic Solutions

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Preface

The global population was about 6 billion in 2000, and is expected to increase by 50 % in the next half-century, to reach 9 billion in 2050. To meet the needs and wants of people seeking comfortable and convenient lifestyles, countless products and goods will be supplied through distribution infrastructure. As the global economy expands, people buy more products; thus, the amount of products produced and consumed increase. During those processes, solid waste is generated, and ultimately collected by the municipalities and private waste management industry for recycling or disposal. Society generates more waste as it becomes increasingly affluent. About one fourth of worldwide solid waste is generated in Asian region now but it is expected to be about one third in 2050.

The key SWM issues in Asia and Pacific Region may be pointed out as follows:

(i) increase in the amount of municipal solid waste associated with population and economic growth;
(ii) difficulty in securing land for intermediate treatment and final disposal (due to NIMBY) leading to serious public health risks;
(iii) high but untapped potential for 3R; and other alternative treatments.

A network of solid waste management experts, the Society of Solid Waste Management Experts in Asia and Pacific Islands (SWAPI) was initiated in 2005 to aim at promoting 3Rs for solid waste namely, Reduction, Reuse and Recycling of solid waste, and improving waste management to realize a 3R Society to conserve natural resources and preserve our living environment.

As an activity of SWAPI, we are delighted to publish this book. This book, written by Asian experts in solid waste management, explores the current situation in Asian region including Pacific Islands. There are not many technical books of this kind, especially dedicated to this region of the world. The chapters form a comprehensive, coherent investigation in Municipal Solid Waste (MSW) management, including definitions used, generation, collection, transportation, treatment and disposal, and 3R activities. Several case studies from Asian nations are included to exemplify the real situation experienced. It is greatly envisaged to form an excellent source of reference in MSW management in Asia and Pacific Islands.

April 1, 2013

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Sustainable Society and Municipal Solid Waste Management

Masaru Tanaka

1 Three Major Environmental Crises Facing Mankind

Environmental issues on a global scale must be resolved by initiatives taken on a global scale. There are three major environmental crises facing mankind: the global warming crisis, resource crisis and ecosystem crisis. These crises are all closely related to waste and waste management (Fig. 1).

1.1 Global Warming Crisis

The average global temperature has risen by 0.74 °C over the past 100 years due to increased greenhouse gas emissions, including carbon dioxide. According to a scenario of societies that depend on fossil resources, the global temperature is predicted to rise by up to 6.4 °C in the next 100 years in the twenty-first century. It has been pointed out that global warming is responsible for higher temperatures, rising sea levels and the widespread melting of snow and ice, resulting in more deaths due to heat waves and increasing the risk of infectious diseases transmitted by carriers. Waste incineration emits carbon dioxide, and landfilling generates greenhouse gases like methane. We must therefore take measures for preventing global warming in waste management as well.

1.2 Resource Crisis

In the past we have mass-produced products for mass consumption in our affluent society, and consequently discharged large quantities of waste. We have consumed

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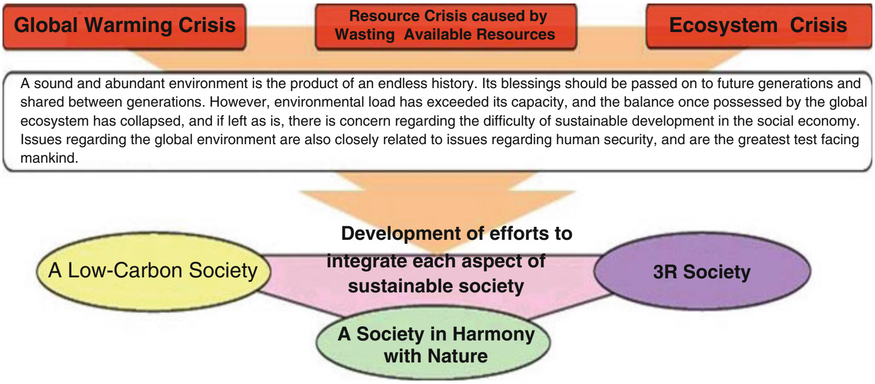


Fig. 1 Three major environmental crises. *Source* Ministry of the Environment (2007)

available resources as if they were unlimited and thereby contaminated the Earth. Major mineral resources are expected to become depleted in 30–40 years. The Ecological Footprint index, which is obtained by dividing resource consumption by the amount of natural resources available, now reaches 1.5. If developing countries consume resources to the same extent as advanced countries, the index will exceed 2. As some people have pointed out, there is a risk that countries could begin fighting over resources including recyclable waste, which would increase the amount of recyclable resources transported across borders and result in environmentally inappropriate recycling systems.

The amount of waste in our society reflects how much resources we consume, and such slogans to promote resource conservation as “a zero-waste society” and “zero emissions” are often repeated to emphasize the need for emission control and recycling.

1.3 Ecosystem Crisis

From rich ecosystems inhabited by a variety of species we receive enormous benefits, such as food, clean air and water, and healthy natural environments. However, development and other human activities have caused soil erosion, water shortages, water contamination and air pollution, thereby drastically affecting biodiversity and threatening ecosystems. Waste management can also cause such problems. For example, the city of Nagoya was planning to create a large coastal landfill in the Fujimae Tideland for waste disposal, but cancelled this plan due to the risk of seriously impacting the ecosystem there. As it has been pointed out, illegal dumping and improper disposal of waste also have adverse effects on ecosystems. There is a need to prevent damage to ecosystems caused by open dumping and the open burning of waste.

1.4 3R Society for Sustainable Society

A society in which healthy and rich natural environments, including those on a global scale as well as in local communities, are all well preserved and provide benefits to the lives of people around the world that can be handed down to future generations is called a sustainable society. To create such a society, it is necessary to (1) achieve a "Low-carbon Society" where the environmental impact is limited within the environmental capacity in order to protect the environment, (2) achieve a "A Sound Material Cycle Society" or "3R Society" that minimizes the extraction of natural resources and emissions into the natural environment to ensure the recycling of resources, and (3) achieve "A Society in Harmony with Nature" that preserves healthy ecosystems and ensures the symbiosis between nature and human beings. Available resources and the environmental capacity to absorb waste are limited, and consequently we now face the risk that our current waste management systems may threaten the existence of a sustainable society. In waste management as well as in other activities, we must make concerted efforts to achieve a 3R society that minimizes the extraction of natural resources by reducing the emission of waste and promoting the reuse and recycling of waste, a low-carbon society where greenhouse gas emissions are kept at a minimum by eliminating illegal dumping and the improper disposal of waste, and ensuring higher levels of proper waste disposal, and an society in harmony with nature that protects and preserves the natural environment. Creating a sustainable society is a goal shared by countries around the world, including Japan, and we need to obtain the participation of various stakeholders both inside and outside Japan in order to widen the circle of our activities (Fig. 2).

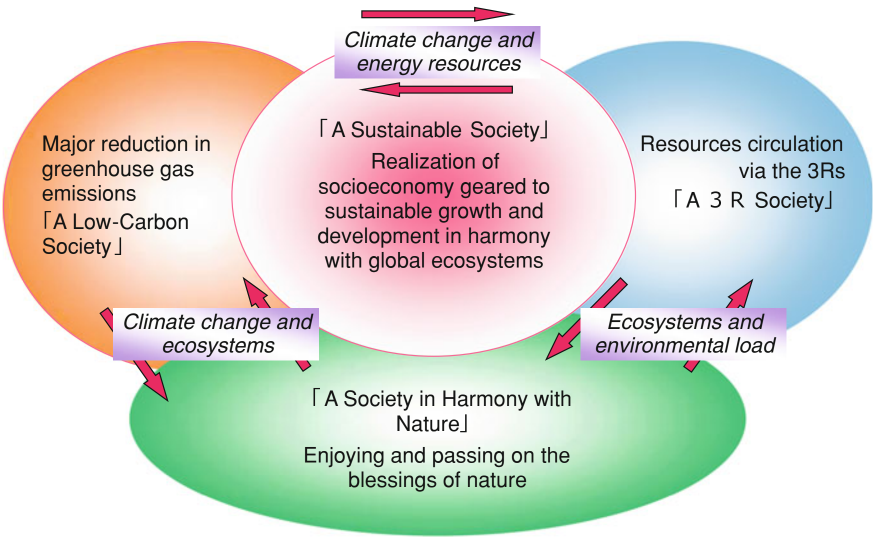


Fig. 2 Three ideal societies and interrelationship to create a sustainable society. *Source* Ministry of the Environment (2007)

2 Municipal Solid Waste Management to Create a 3R Society

2.1 MSW as the Barometer of Resource Consumption

First, we need to explain the relation between waste and a 3R society. Various products are manufactured using natural resources. Industrial waste is therefore generated in the process of manufacturing these products to support our affluent lifestyles. Besides industrial waste, we also generate municipal solid waste in our daily lives. Thus, the waste produced in our society is the barometer of the consumption of natural resources. We all wish to strive towards a better society. The twentieth century was a period of mass production, mass consumption and mass disposal, and the current pattern of development, left as it is, may cause depletion of resources and destruction of the global environment, thereby threatening the sustainability of the world in which we live. Population increase and economic growth in developing countries may exacerbate global warming, increase the consumption of resources, and further degrade the global ecosystems, causing serious food shortages and poverty problems. A sustainable society is one free from the risk of depleting resources, where ecosystems are preserved without being threatened by global warming. Against this background, we have been emphasizing the need to manage waste within the limits of resources and the environment, and calling for the creation of a recycle-based society. There is an urgent need to create a recycle-based society free from the risk of causing resources or environmental problems. In other words, a 3R society saves resources and protect the environment.

2.2 3R Society and Waste Disposal

Why then are those in charge of waste management calling for the creation of a 3R society? It is because we consume material and energy resources in our daily life and economic activities, whereby we discharge all kinds of waste in gaseous, liquid and solid forms. In other words, waste is the barometer of resource consumption, and whether we can limit the consumption of resources and reduce environmental impact critically depends on how we manage waste. Waste management therefore plays a pivotal role in creating a 3R society. The treatment of exhaust gases and contaminated water makes it possible to keep air, water and soil environments clean. Since managing the dust and sludge emitted from air and waste water treatment facilities enables us to reduce environmental impact, and promoting the 3R's [reduce (emission control), reuse and recycle] to utilize waste as recyclable resources leads to less consumption of natural resources, waste management provides the key to a 3R society (Fig. 3). We are able to contribute to the creation of a sustainable society through waste management because it represents the foundation of a sustainable society.

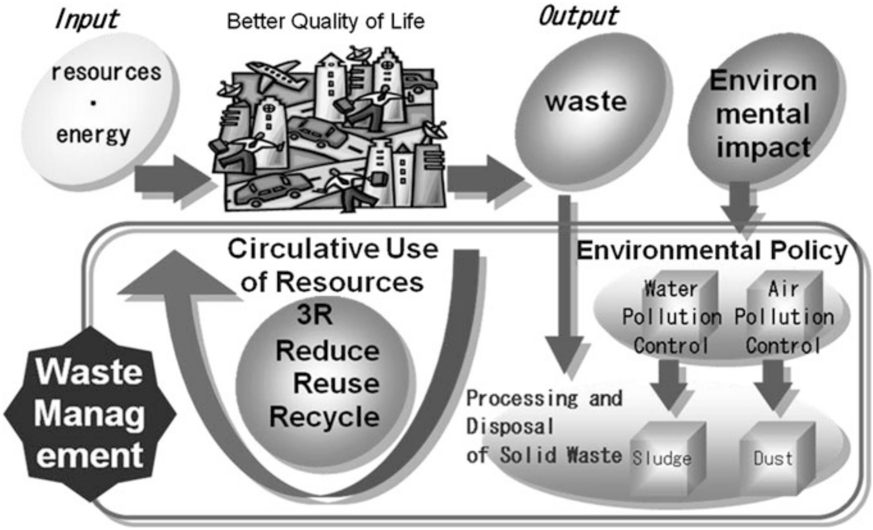


Fig. 3 Solid waste management and creating a 3R society

2.3 Working Together with People Around the World

The residents who discharge waste, local governments charged with developing and managing waste disposal plans, and manufacturers of products have been working together to implement various measures for the 3R's with the aim of creating a 3R society. Yet, there is no easy way to create a 3R society. The global population continues to grow and the globalization of economy and society is increasing the amount of resources and energy exchanged between countries. The Asia-Pacific region has achieved particularly marked economic growth over the last few decades. As a result, there has been a rapid increase in the consumption of resources, especially fossil fuels, iron and steel, leaving no doubt that the consumption of resources will continue increasing worldwide.

What then is the level of our consumption of resources compared with the current level of natural resources available on the Earth? Ecological footprints, which enable a comparison between the global consumption of resources and the natural resources available, show that global consumption was already exceeding the amount of natural resources available on the Earth in the 1970s. This is no longer a problem that can be solved by the efforts of those in charge of waste management alone. There is a need to change our society as a whole.

Although the responsibility of those charged with waste management is often highlighted in discussions about 3R society, it is impossible for waste management officials alone to create a 3R society. They need the cooperation of all sectors to develop effective measures to create a 3R society.

These considerations lead us to conclude that creating and promoting a 3R society require, besides the solid waste management sector, collaboration between various groups, including government organizations, manufacturers and consumers. It is also important to consider issues from not only a domestic perspective but also a global perspective. Global population growth and economic development will continue in the future, and in some cases, measures intended to control population growth or improve resource efficiency in developing countries may turn out to be more effective. In order to solve global problems, we need to think and work together with people around the world (Fig. 4).

2.4 3R Initiative

The 3R initiative aims to promote the "3Rs" (reduce, reuse and recycle) globally so as to build a 3R society through the effective use of resources and materials, as resources and materials circulate beyond the border. It was agreed that the proposal by Japan at the G8 Sea Island Summit in June 2004 be taken up as a new G8 initiative.

The Japanese Government launched its "New Action Plan towards a Global Zero Waste Society" in 2008. The New Action Plan is composed of actions including support for the development of strategies and policy dialogues in line with the needs of each country, contribution to global warming countermeasures through environmentally sound waste management and 3Rs, and actions to establish a Sound Material-Cycle Society (3R society) at regional levels in Asia (Ministry of the Environment 2008) (Fig. 5).

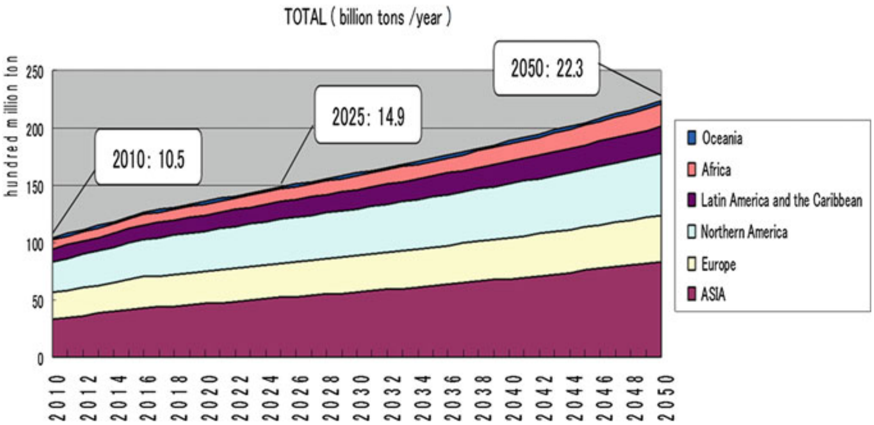


Fig. 4 Solid waste to be generated in the world (2010–2050). *Source* Tanaka (2011)

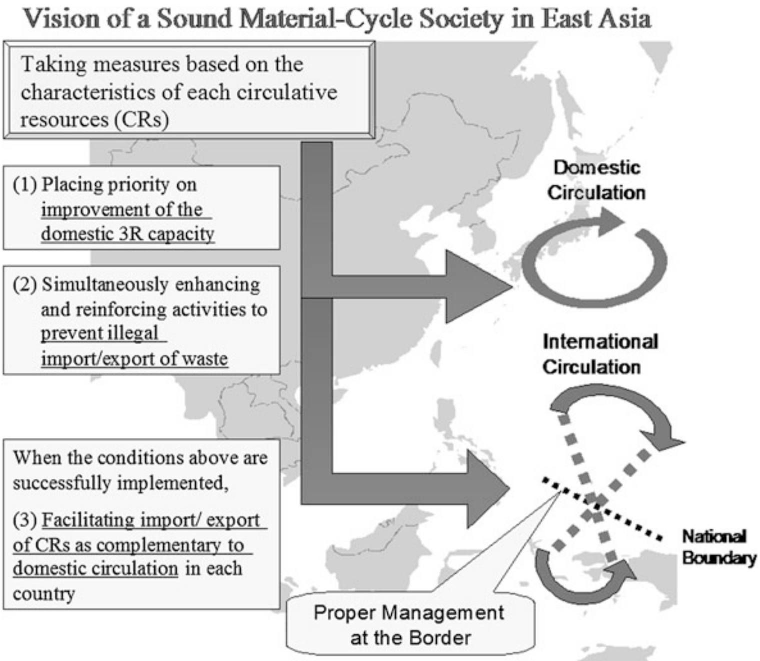


Fig. 5 Waste circulation and sound material-cycle (3R) society. *Source* Ministry of the Environment (2008)

3 Strategic Solid Waste Management

3.1 Distinction Between Environmentally Friendly Products and Other Products

Given a choice among products and services providing the same functions, consumers have come to prefer those that are more environmentally friendly. Whether a product is environmentally friendly depends on the amount of resources needed for its materials and its manufacture, distribution, consumption and disposal, as well as the level of its negative effects on health and the environment, including pollutants and greenhouse gases emitted into the air and water. Life cycle assessments (LCA), which are designed to evaluate these effects in quantitative terms, are attracting the attention of many people. In this section, we adopt this approach to evaluate waste management.

3.2 Product Life Cycle Assessment

We all desire to reflect on the past at the end of our lives and say to ourselves that we had a good life. The term “life cycle” refers to the time between birth and death, and evaluating a life cycle is known as “life cycle assessment”. Just like our lives, products that enrich our lives should also contribute to saving resources without producing negative environmental effects. To ensure this, methods have been developed to evaluate the life history of a product (i.e., time between its creation and disposal), and compare products in terms of their environmental effects. A typical example would be comparing paper diapers and cloth diapers. Since easy to use and convenient paper diapers generate an enormous amount of waste, some people believe that these products are causing serious environmental problems. However, a product life cycle assessment (PLCA) shows that contrary to our expectations, paper diapers, which can be incinerated and used as energy sources, do not waste resources as much as cloth diapers, whose repeated use requires the consumption of a large amount of water and electricity, and produces sewage to be treated. For these reasons, cloth diapers may have greater negative effects on resources and the environment than paper diapers.

3.3 Waste Management Requiring Periodic Review

All local communities process municipal solid waste using some treatment and disposal methods. Creating a 3R society for the future requires us to review various aspects of waste management and develop disposal methods designed to conserve resources more effectively, and provide better protection against pollution. It may be necessary, for example, to review the environmental effects of the procedures for waste collection and management, along with the costs involved in these procedures. Various laws make it mandatory for local governments to make revisions and adopt new measures, including revising the method of waste segregation, shifting from curb-side collection to door-to-door collection to improve the level of services, and reviewing the frequency of collection. Local governments must also review their policies to gain the understanding and cooperation of local residents. In any case, there is a need to explain to residents the reasons for choosing measures and technologies for waste management based on an analysis and assessment of the effects of the methods chosen for waste management.

3.4 Waste Life Cycle Assessment for Choosing Policies and Technologies

Proposals are often made to use various policies and technologies in order to make improvements in current waste management, but do such proposals really lead to improvements? It is becoming increasingly difficult to secure sites for final waste disposal and build intermediate treatment facilities like incineration plants. Conversely, there is also a wider range of waste disposal policies and technologies available for local communities than before, including economic means (such as take back of post consumer products by manufacturers and charging fees for waste management service), the use of recycling facilities (including screening facilities for recyclable waste and crushing facilities for bulky waste), and regional waste disposal. There are differences between local governments in terms of the choice of collection methods and frequency, as well as treatment and disposal methods and technologies. These differences are broad enough to make you wonder why there are so many choices available. For example, in local communities where final disposal sites are not available, incineration ash is used as cement material or turned into molten slag to avoid landfilling. Evaluating whether proposals as "an improvement plan" really lead to improvements entails making necessary quantitative assessments of resources, energy consumption and environmental impact for a series of waste management processes ranging from collection, transportation and intermediate treatment to final disposal [waste life cycle assessments (WLCA)], analyzing the management cost, and making quantitative comparisons of resource efficiency, environmental efficiency and economic efficiency (Fig. 6).

3.5 What are Environment-Friendly Alternatives?

"Think globally, act locally" is a slogan intended to make us realize the importance of examining issues from a global perspective without losing the sense of what we can do in our local communities. Life cycle assessments (LCAs) provide guidelines on what actual measures must be taken to solve environmental problems on a global scale. LCAs serve as a means of choosing the most desirable alternative from among those actually available, based on long-term assessments of product life from creation to disposal, and considerations of resource issues and environmental issues on a global scale.

3.6 Recycling of Stained Plastics

We often receive questions about whether plastics collected as waste should be recycled for material recovery or incinerated for energy recovery. The people asking such questions apparently assume that recycling always contributes to

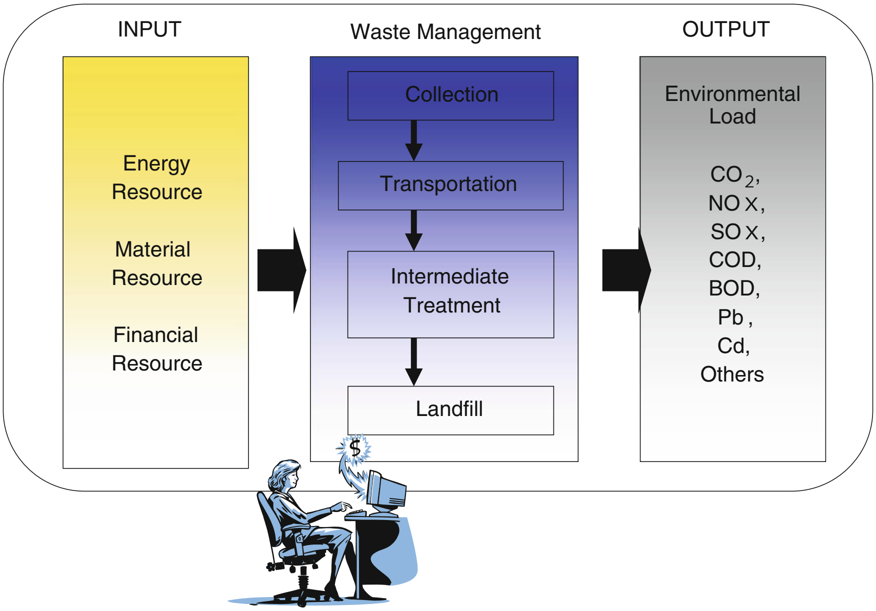


Fig. 6 Flame work of waste life cycle assessment (WLCA)

resource conservation. However, LCA results assessments of life cycles (including collection, transportation, washing, separation, processing and residue treatment) reveal that recycling for material recovery does not always contribute to resource conservation. In particular, the recycling of stained plastics for material recovery does not help conserve resources. Of course, it is no less important to make long-term assessments of costs, including costs required for the repair, maintenance and management of facilities, as well as construction costs.

3.7 Is it a Feasible Alternative?

Regardless of how desirable an alternative may appear to be, it is no more than a pie in the sky if it costs too much money to build the necessary facilities or the alternative is not possible. Some local governments, unable to dispose of waste by landfilling or incineration due to lack of appropriate landfill sites or incineration plants, are left with no choice but to collect stained plastics separately for recycling. There is a need to choose feasible alternatives. If it is physically impossible to build treatment facilities due to a shortage of funds or lack of consensus among residents, we will be left with no choice, no matter how unreasonable it may appear. However, providing explanations based on LCA results may help us achieve a consensus among related parties about an alternative that had appeared infeasible due to a lack of understanding, and put it into practice.

3.8 Desirable Waste Management Based on Life Cycle Assessment

What is the most appropriate waste management system? If we can find the best alternative in terms of management cost, the consumption of resources and environmental impact, we will have no problem. However, analyses conducted often show the best results for waste management system 1 in terms of cost, system 2 in terms of the consumption of resources, and system 3 in terms of environmental impact. For example, using machines to reduce cost entails the consumption of electricity and resources for the machines. Consequently, cost reduction requires a greater consumption of resources. Similarly, reducing environmental impact may entail a greater consumption of electricity and chemicals, thereby exerting adverse effects on cost and the consumption of resources. Such relations having advantages in one area and disadvantages in others are called trade-offs.

To choose the most appropriate waste management system given these trade-off relations, we need to focus on "moderate" levels instead of the "highest possible" levels when setting standards for such indicators as the recycling rate, and then choose the "optimum" recycling rate. For example, while using machines is a good way to reduce waste sorting cost, manual sorting offers greater advantages in terms of the consumption of resources and environmental impact. There is a need to strike a balance between cost and environmental impact when making a choice (Fig. 7). Manual operations will prove effective in reducing cost in developing countries where labor costs are relatively low. Such operations will also have less adverse impact on the environment and may lead to a lower consumption of resources.

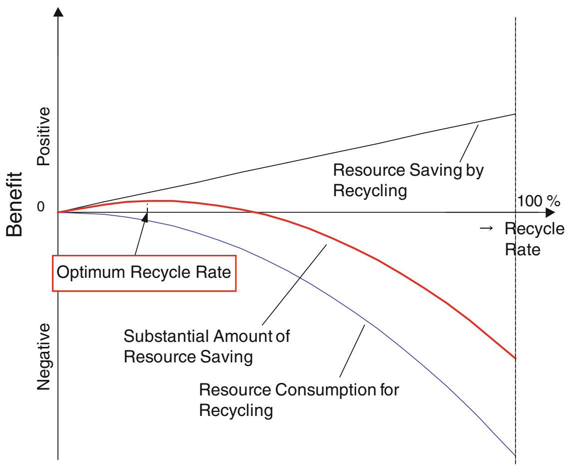


Fig. 7 Trade-off between system objectives

3.9 Standards of Judgment

Our values and standards of judgment are formed in the environment in which we grow up and are influenced by the education we receive. Whether we respond to the call for creating a recycling society depends on our values. If residents are allowed to choose a waste management system on their own, some may choose a system that minimizes the cost involved in waste management, while others may choose one more focused on the environment. Whether individuals choose to devote their time and energy to participating in separate collection or group collection varies according to the times and localities, as well as their values. It also varies according to the financial position of the local government in charge of waste management and the circumstances concerning waste disposal sites.

3.10 Is it Better to Reduce Environmental Impact?

Many people probably believe it is better to reduce environmental impact. Here, the term "environmental impact" refers to adverse effects on the environment that may cause serious problems. There is no doubt that any hazardous impact on the environment must be minimized. The question is: How are we to decide which impacts are hazardous and which are not? In advanced countries, there are "environmental standards" governing environmental qualities defined as being non-hazardous based on various kinds of scientific information and the opinions of experts. Environmental impact not exceeding such environmental standards is considered not to cause any serious problems. There are also "emission standards" defined for the amount of pollutants emitted into the environment in order to maintain environmental quality standards. Emissions below such emission standards are considered to involve no major risk of contaminating the environment, and any environmental impact not exceeding these standards is unlikely to cause any serious problems. We see no reason for reducing non-hazardous emissions below these standards, since doing so would generally require a greater consumption of resources and also increase the cost. This is true from the viewpoint of polluters, but may not be necessarily so from public perspectives, considering cumulative impacts from various sources.

Although LCA is intended to maintain emission standards and minimize environmental impact, it does not provide any standards for evaluating such reduction in environmental impact. This evaluation is left to the discretion of decision makers.

3.11 Effects of Environmental Education

We also need to emphasize the effects of environmental education, which enables us to think about environmental problems and put ideas into practice by participating in waste segregation and group collection. In that sense, the group collection of old newspapers and magazines by volunteers may be the best way to reduce the consumption of resources, environmental impact and management cost. While the separate collection of glass bottles and metal cans that cannot be incinerated in homes contributes to material recovery, it may increase the consumption of other resources and involve a high cost if performed too often. Separate collection for material recovery should be organized in a reasonable way. Most developing countries have still not reached a stage (or "optimum recycle rate") where the marginal costs of recycling become higher than the marginal benefits. So recycling should be encouraged as much as possible.

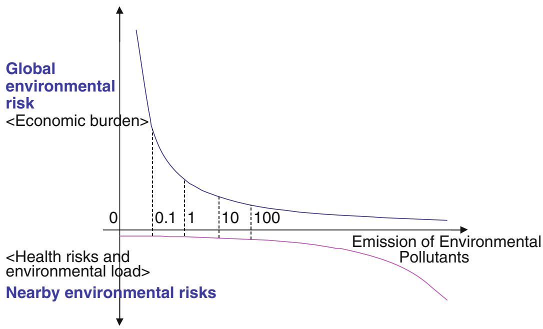
3.12 Reason Why LCA Analysis is Required in Waste Management

The procedures for waste segregation, methods of collection, collection frequency and disposal technologies vary between local communities. Given that there are different circumstances among local communities, are the current systems of waste management the best alternatives available for those communities? Local communities must now account for their policies in order to gain the understanding of the parties involved. They must specifically clarify the circumstances they are facing, the practical alternatives that are available, and the differences between these alternatives in terms of cost, consumption of resources and environmental impact, and then explain the reasons for their choices. Various considerations such as the reliability and safety of treatment technologies and systems, and social issues concerning the understanding and co-operation of residents, besides LCA result must also be given for the final decision.

3.13 Limitation of LCA and its Promotion

LCA does not include assessments of the possibility and risk of waste stored at disposal sites or pollutants contained in such waste being leaked in the future. We also need to consider trade-offs between environmental impacts on a global level (such as greenhouse gases) and environmental impacts on a local level (such as dioxins, nitrogen oxides and dust) (Fig. 8). And how can we evaluate improvements made in public health and preservation of the living environment, which are the ultimate goals of waste management? How to operate waste management systems on a stable basis and ensuring system safety are other issues deserving separate consideration.

Fig. 8 Nearby environmental risk and global environmental risk (trade-off relation between risk and cost)



The only way to promote LCA in the future is to find good examples of applying LCA and explain its advantages based on reliable data on such applications as using LCA to solve problems involved in waste management with the aim of choosing the most appropriate alternative from among a number of alternatives proposed. We need to make effective use of LCA by acknowledging its problems and limitations.

4 Key Issues in Developing Countries

The key SWM issues in developing countries may be pointed out as follows:

- increase in the amount of municipal solid waste associated with population and economic growth;
- difficulty in securing land for intermediate treatment and final disposal (due to NIMBY etc) leading to serious public health risks;
- inadequate legal, regulatory, and institutional framework, and lack of enforcement of laws and regulations;
- general lack of technical, financial, and management capacity of local governments responsible for municipal SWM;
- inadequate cost recovery; leading to vicious cycle of SWM;
- high but untapped potential for 3R; and
- need to find out appropriate and innovative approaches for improvement.

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Sustainable 3R Practice in the Asia and Pacific Regions: The Challenges and Issues

Agamuthu Pariatamby and S. H. Fauziah

1 Introduction

Population growth and pollution have resulted in rapid depletion of natural resources and environmental degradation. The global ecological footprint continues to increase every year and the average Earth bio-capacity needed in 2012 is estimated at 21 gha (Global Hectares) while sustainable footprint is only 15 gha (Sustainable Indicator Program 2006; Global footprint network 2012). In another word, each individual requires an equivalent of 1.5 planet Earth to exist today. This means that we have not only utilized our portion of the Earth's resources but also have taken the resources meant to be kept for the next generation. Figure 1 illustrates the global ecological footprint until 2050.

Thus, each individual requires the Earth's productivity and ability for 1.5 years to satisfy the need for a single year. This alarming situation indicates the unsustainable practice of consumption by the Earth's inhabitants.

The seventh Millennium Development Goals (MDG), focusing on environmental sustainability via capacity building and sound environmental decision-making requires the integration of sustainable development strategies into country policies to lessen the depletion of resources. Thus, the implementation of Reduce, Reuse and Recycle namely, 3R is one of its main approaches.

1.1 Waste Management Hierarchy

In waste management phraseology, the 3R was adopted by waste managers worldwide as the most appropriate strategy towards sustainable development. Though 4Rs (incorporating 'recover') and 5Rs (incorporating Respect and

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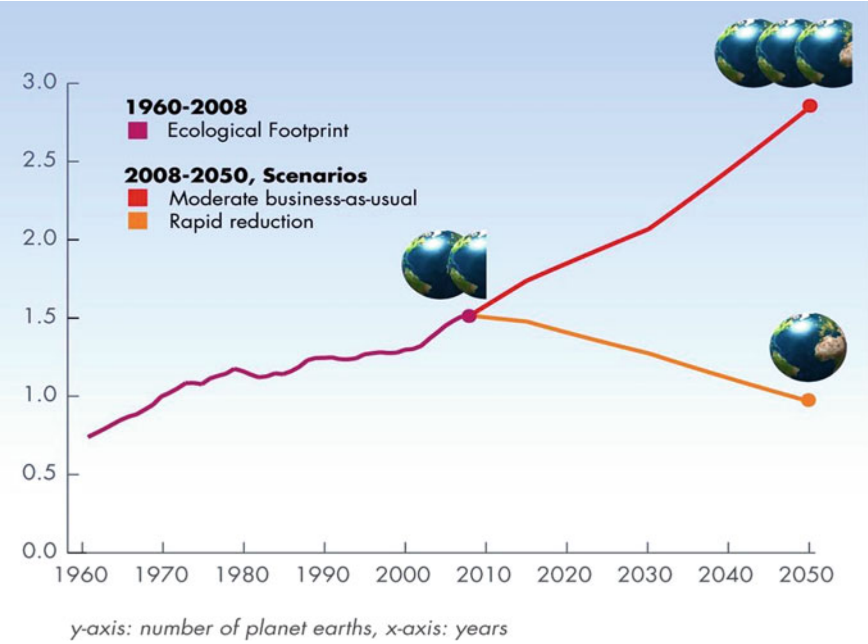

Fig. 1 Global ecological footprint (1960–2050) (Global Footprint Network 2012)

Rethink) concepts have also been introduced, the main three which connote "reduce, reuse and recycle" have always been the foundation in waste management hierarchy. It associates with the current inclination of waste management planners towards a more environmental friendly waste management concept with minimal disposal of waste. In a declining preference, the practices range from reduction strategies to the possibility of reuse, followed by recycling opportunities and finally disposal.

Under conventional circumstances, waste disposal has become the base of a waste management hierarchy with energy recovery, recycling, reusing and reducing being implemented at the minimum. Final disposal being inevitable, landfilling has become the largest component in the waste management pyramid. In addition, due to the its simple and low cost technology, landfilling is highly preferred in most developing nations, particularly in the Asia and Pacific Islands. As a result, the current waste management practice in many of these countries can be illustrated by Fig. 2.

For the future, a reverse approach is to be applied. Future waste management hierarchy will incorporate prevention before 3R and energy recovery, prior to the disposal option. It can be depicted as an inverted pyramid (Fig. 3) with the smaller tip pointing downwards.

The highest desirability within a waste management hierarchy is waste prevention. It can be achieved by not generating unwanted products in product

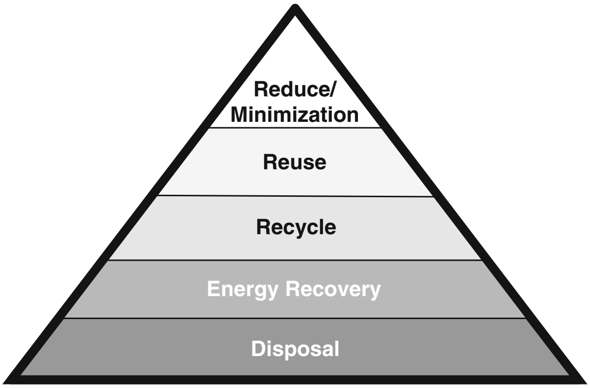

Fig. 2 Common practice of waste management in many developing countries

manufacturing or service provision, whereby the generation of waste can be "prevented". "Prevention" is closely related to "reduction" in the 3R. This is because "reduction" can be expressed as action that results in prevention or minimization of wastes. To achieve sustainable development, "reduction" is the next highest preference after "prevention" as illustrated in Fig. 3. The manufacturing/service routes will be extensively assessed and evaluated to identify waste reduction opportunities. It is usually achieved via life-cycle analysis or mass/material-balance studies. These appraisal techniques are applicable to any scale i.e. from large-scale commercial/industrial procedures to a small scale of an individual daily activity. Also, incorporating clean and efficient alternatives into the procedure help to effectively enhance "reduction" within a system.

There are several benefits gained from the assessments of waste prevention objective. From the business point of view, the foremost gain is economic which leads to higher productivity with higher efficiency in raw material utilization. This can be translated into higher profit making. Extensive analysis of a process system or product manufacturing leads to a better quality of the final product which in turn opens up the opportunity for a more competitive market. In addition, the preservation of the environment and natural resources will also create a "green" image besides achieving the objective of waste reduction.

A case study on the use of refills for shampoo and hair conditioner in Japan highlighted significant reduction of such waste generation using point-of-sales (POS) data collected by retailers (Tasaki and Yamakawa 2011). The case study reported the success in the implementation of waste prevention due to the introduction of consumer's products at a lower price. As a result, it creates business benefit both to consumers and manufacturer due to lower product price and lower manufacturing cost, respectively.

Waste prevention can also be encouraged via modification of manufactured products to promote longer usage period. Typical example is the replacement of cloth bags for plastic shopping bags. In many countries, this has been proved successful in preventing plastic bags from entering the MSW stream (Agamuthu and Fauziah 2011a, b). Nevertheless, certain consumers' products tend to have a

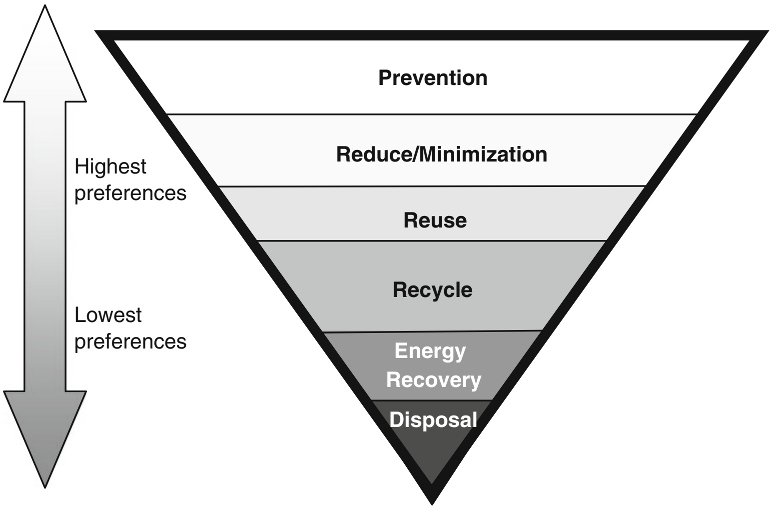

Fig. 3 The waste management hierarchy towards sustainable development

very low prevention potential. As a result, waste prevention can only achieve as high as 1–3 % of the MSW (Salhofer et al. 2008). Among such products are disposable diapers and sanitary merchandises.

Next in line to the strategy of "reduction" would be "reuse". "Reduce" has a moderate desirability in the waste management hierarchy. It is carried out when there is no possibility of preventing the generation of waste material. "Reuse" can be defined as reutilization of a waste, in its original state either for its novel purpose or a new use with no chemical or/and physical changes. Economic necessities usually drive the reutilization of wastes particularly when raw materials are more expensive and becoming scarce. However, it is only applicable to materials from limited resources such as metal. Materials from available sources will not be favoured to undergo the reuse route. Therefore, from the sustainable waste management point of view, the existence of financial incentives for wastes reutilization is essential to promote the "reuse" concept, besides creative thinking (out of the box approach) or via appropriate policy and legislation.

Similar to waste reduction, the waste reutilization approach has benefits as a result of the improvement of resource efficiency, money-saving opportunities, and environmental preservation with less utilization of resources and less generation of waste, etc. However, reutilization also yields certain disadvantages. This includes the incurrence of extra cost when certain types of waste require extra expenses for cleaning or modification prior to their reutilization. Also, these unavoidable procedures consume time besides money. In addition, the reutilization of wastes is sometimes less reliable due to wear and tear.

Limitations to reusability frequency of waste materials make it necessary for appropriate planning prior to the utilization of reusable materials in manufacturing process. As a result, it is crucial to understand the physical properties of the reused materials such that the information can be incorporated into the product design at the earliest stage of the manufacturing. Ultimately it enhances the recyclability potential of the material once it becomes waste. Recently, it was reported that Recycling Cycle of Materials (RCM) has been introduced as a means to offer technical information in the selection of material in product designs (Cândido et al. 2011).

If "Reuse" is not possible, the next option will be "Recycling". Waste recycling involves recouping of waste materials into their various components for the manufacture of new products. This third and last 3R application requires the waste to undergo physical and/or chemical changes in order to salvage valuable material within the waste material. This option has been one of the most favoured methods of solid waste disposal. Recycling creates a healthy market for basic resources for industries, particularly in the developing countries of Asia. The Ministry of Environment of Japan (2008) defined recycling as utilizing wastes as a resource. In Asia, recycling is reported to have a bearing on the inherent economic dynamics of the individuals within the industry.

2 3R Drivers in Waste Management

Drivers in waste management are factions of associated features, which unswervingly manipulate the progress of the industry. Human drivers, Economic drivers, Institutional drivers and the Environment drivers are the 3R drivers in waste management. Figure 4 shows the core groups of drivers that control the development of 3R (Agamuthu et al. 2009a, b).

The Human driver incorporates three aspects, namely increasing waste generation due to population growth, human comfort and security, and human awareness. These three aspects can promote or hinder 3Rs within a system. The first aspect within the "human driver" indicates the contribution of population growth towards the escalation of waste generation. As a result, it calls for the need to divert waste from exhausting the landfills. It is closely related to human comfort

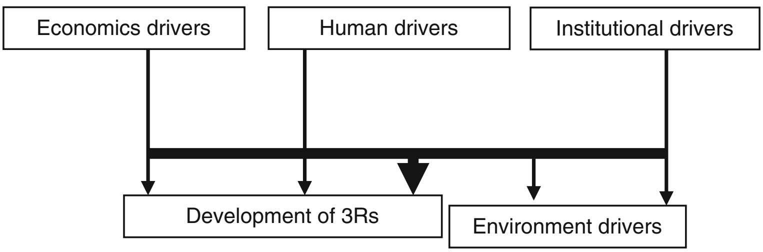

Fig. 4 Drivers in the development of 3Rs

and security as existing landfills, which are rapidly filled, pressure the waste managers to identify new landfill sites (Fauziah et al. 2007). Over-flowing landfills and improper waste management systems pose risks to human wellbeing and public health (Wilson 2006). Therefore, human comfort and security becomes the fundamental motive for sustainable waste management. The prospect of improper waste management, which will highlight potential disaster in terms of malodour, environmental degradation, aesthetics and others, will create human awareness. In addition, education and awareness of benefits of 3Rs practices will promote a positive response from the community to participate and make the 3R campaigns a success (Agamuthu and Fauziah 2008; Chenayah et al. 2007).

The Economic driver is also a key driver of the 3Rs. Available funding for a 3R operation is very crucial to ensure its success. The economics drives 3R operations by making data and information on waste composition available and accessible for future planning. In Malaysia, for example, the municipal solid waste consists of approximately 30–40 % recyclable components while more than 60 % is organic waste (Fauziah and Agamuthu 2009), whereas in other developing countries solid wastes are estimated to consist 5–15 % recyclable material and 40–80 % organic matter (Cointreau 2006). In addition to the financial aspect, the economic status of the community to be involved in the 3R operations has also become one essential economic driver. More participation can be expected when the community can benefit economically from the 3Rs practices. Low income drives people to retrieve recyclable materials to generate extra income when these materials are sold.

Economic driver also influence the availability of technologies in promoting 3Rs. Forceful research and development in the manufacturing designs promotes the invention of products with high disassembly potential (Huang et al. 2012). With suitable disassembly pattern, waste materials such as electrical and electronic equipment can be diverted from the main waste stream for recycling options.

The Institutional driver encompasses legislative, research and development and business activities. It consists mainly of activities involving participation on various activities that form an institution. Legislators must aspire to formulate or revise legislation to sort out the waste composition, cultural trait and 3R capability distinct to their locales. The discernment and management policies for waste materials evolve with the new findings from new academic research. New paradigms on waste management and planning including waste to value-added products conversion can be a holistic approach towards sustainable development (Khidzir et al. 2007). Holistic conception on public attitude and behaviour enables the development of effective policy that encourages the participation in waste prevention and reduction (Bortoleto et al. 2012). This is the result of research and development activities.

Business opportunities in relation to the practice of 3Rs enable 3R campaigns to be more successful. The "deposit system" and "take-back programs" are useful approaches to encourage 3Rs, particularly on specialized wastes such as e-waste (discarded mobile phones, empty printer/toner cartridges or used computers) and hazardous waste (batteries, pesticide containers). Consumers can return these items to the manufacturer at no charge. Options on reutilization or recycling of these materials can be explored.

The Environment driver is significant when other issues heavily influence it. Singapore and Japan, for example, practice effective 3Rs and incineration due to the lack of natural resources and land, as a result of population expansion. On the other hand, other Asian nations (with the exception of economically developed nations e.g. Japan, Singapore and the Republic of Korea), the Environment Driver has regrettably been derelict. Nevertheless, many developing countries nowadays have authorized policies subject to environmental protocols and treaties, environmental research and economic incentives to promote sustainable development and inventive 3R practices.

3 3R Practices in Selected Nations in the Asia Pacific Region

3.1 Waste Reduction

The Republic of Korea introduced a volume-based fee system in the country's waste management in 1995. The implementation is aimed at promoting waste reduction in order to reduce the amount of fees charged to the waste generators. The system managed to successfully reduce daily solid waste per capita generation by 22 % in 2003 as compared to 1994 (Ju 2005).

The Singapore Government launched a National Recycling Programme in 2001. The public was encouraged to segregate their waste by separating recyclable items from other waste over a period of 14 consecutive days. The programme accomplished a reduction in the average daily municipal wastes i.e. from 7,700 tons/day in 2001 to 7,000 tons/day in 2005 (National Environment Agency, Singapore 2006).

MDGs prompted the execution of national 3R Strategy in most developing nations (United Nation 2010). Regrettably, the response to 3R was insignificant due to inadequate orientation in governmental policy, low public awareness and the lack of pertinent technology. In developing countries like Malaysia, Vietnam, Indonesia, Bangladesh, Thailand and the Philippines, waste reduction strategies are not as successful as in the economically developed countries such as Japan, Singapore and Korea. These developing nations depicted an increasing waste generation trend from 1996 to 2008. Table 1 compares the daily per capita waste generation at present with the projection for 2025 of selected countries in the Asia Pacific region.

On average, the current per capita generation of MSW by a Malaysian is 1.3 kg daily; while in Vietnam and Laos it is approximately 0.7 kg (Troschinetz and Mihelcic 2008; Fauziah and Agamuthu 2009; Nguyen 2007). In Bangladesh and Indonesia, the average per capita generation is 0.25 kg per day and 0.75 kg per day

Table 1 Waste generation in 2009, 2011 and waste projection for 2025 in selected countries in Asia Pacific region

Country	Waste generation rate (kg/cap/day),		
	2009	2011	2025 (Projection)
Brunei	0.66	0.87	1.30
Cambodia	0.52	Not available	1.10
India	0.34	0.50	0.70
Indonesia	0.76	0.88	1.00
Laos	0.55	0.70	1.10
Malaysia	1.30	1.50	1.90
Myanmar	0.45	0.44	0.85
Philippines	0.52	1.56	0.80
Singapore	1.10	1.49	1.80
Thailand	0.64	1.76	1.95
Vietnam	0.67	1.46	1.80
Nepal	0.40	0.50	0.70
Bangladesh	0.25	0.43	0.75
Mongolia	–	0.66	0.95
China	0.80	1.02	1.70
Sri Lanka	0.2–0.9	0.37–0.73	1.00
Republic of Korea	1.00	1.24	1.40
Japan	1.10	1.70	1.70

while in India and Pakistan it is 0.4 kg per day (Pasang et al. 2007; Sujauddin et al. 2008; Troschinetz and Mihelcic 2008). The increase in the per capita waste generation is highly dependent on a country's socio-economic factors. This signifies the failure to attain the waste reduction goal in the 3R strategy among most Asian developing countries such as in Malaysia. The waste generation trend observed in selected countries in Asia Pacific region is illustrated in Fig. 5.

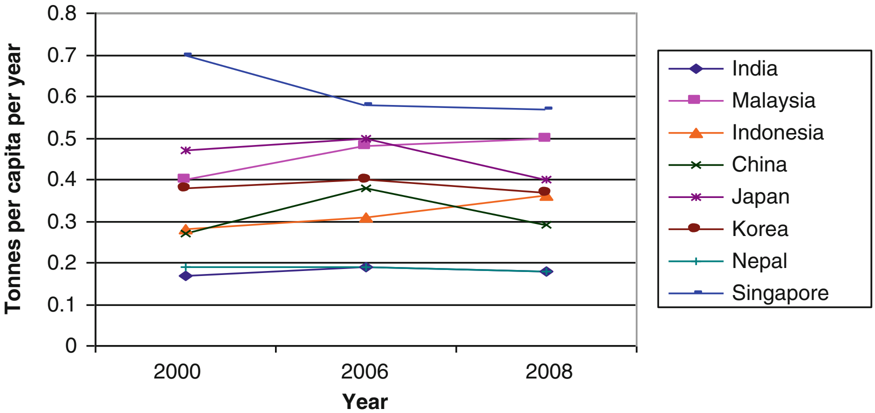

Fig. 5 Annual per capita waste generation trends in selected countries in the Asia Pacific region

3.2 Waste Reutilization

A voluntary MOU signed between the South Korean government and groups of restaurant operators, in 2002, on the utilization of reusable containers within their premises (Ju 2005) is perceived as a development in the implementation of the 1994 Act on the Promotion of Saving and Recycling Resources in Korea.

The "Reuse" concept is also applied in the utilization of reusable bags to reduce the use of plastics in Singapore. This resulted from the enforcement of direct legislations on the use of discarded materials as a strategy to promote the introduction of a packaging agreement such as Singapore-Packaging-Agreement among the companies operating in Singapore in 2007 (Tan 2008).

Recent findings by Yuan et al. (2012) had developed a dynamic model in assessing the efficiency of C&D waste management options by incorporating relevant factors including existing policies, as indicated in Fig. 6.

Such models enable the identification of possible routes to manage the waste efficiently, via waste reutilization strategy. In Taiwan, focus on waste reutilization has been given higher priority after the authorization of the Waste Disposal Act in January 2002. Taiwan's industries are encouraged to reuse and conserve resources in their manufacturing process via the establishment of Industrial Waste Exchange Information Service Center (Tsai and Chou 2004). As a result, it saved significant cost in waste treatment and disposal, as well as, convalescing productivity.

While effective legislations are in-place in the high income countries like Singapore and Japan, the legislation of the "Reuse" approach is very poor among the developing countries. Therefore, reutilization of discarded material has been inefficient. "Reuse" practices in the developing countries only exist within the informal sector. In Bangladesh and India for example, reuse of discarded medical

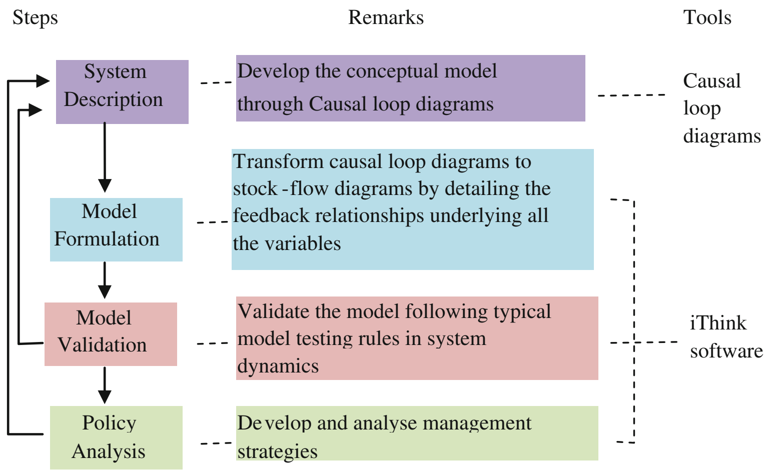

Fig. 6 Step by step development of a dynamic model for C&D waste management (Yuan et al. 2012)

and healthcare waste was reported to occur outside hospitals. In Bhutan, reusable plastics were widely utilized as wrapping materials. In Malaysia, the households reuse plastic bags, which are abundant and cheap, as secondary packaging or garbage bags. Clothing materials are reused when these materials are donated to the needy. The possibility and potential of MSW reutilization is greatly dependent on the waste composition of the given country. Figure 7 illustrates the waste composition of some selected countries in the Asia Pacific Region highlighting the presence of recyclable components in the waste stream.

Involvement of the formal sector in “Reuse” approach is very limited, particularly in the developing countries. In Bhutan for example, the Department of National Properties assembles discarded materials including cars and electronic equipment from the government agencies to be traded to private purchasers who will fix and resell the materials as reused items. In China, plastic waste is reused as raw materials in the manufacturing sector to tackle the limited resources within the rapidly expanding industrialized sectors. The Hazardous Waste Management and Handling Rules (1989/2000/2003) in India were focusing particularly on electronic waste (e-waste) reprocessing and reutilization as raw materials in the country (AIT 2004).

As in India, policy has a crucial role in promoting waste reduction, particularly among the industrial players. It is necessary for the waste reduction strategies to highlight significant advantages involving pollution reduction and consequently saving in the cost of waste treatment and pollution mitigation. It is argued that the economic benefits should be highlighted as a specific calculated payback rather than improvement in the environmental performance (Simpson 2012).

Reduction and reuse are principally more management and policy oriented rather than a technical measure. As a result, the existing challenges in the implementation of reduce and reuse programs has consequently ended with low participation, as compared to a more technological approach, such as recycling.

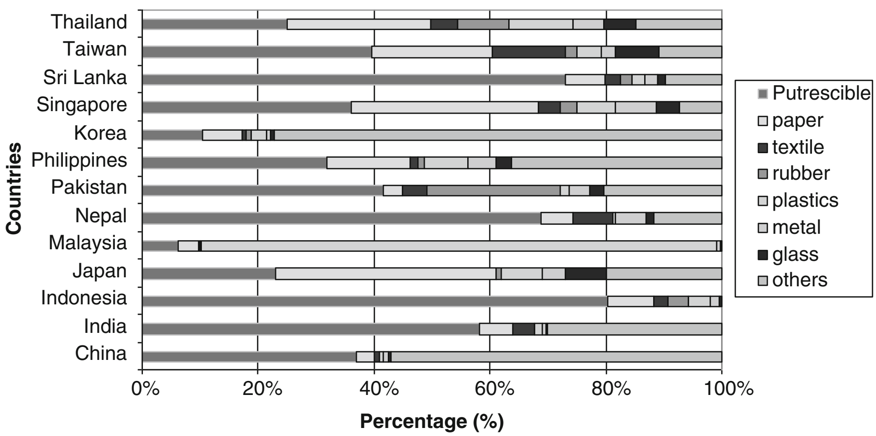

Fig. 7 Composition of waste generated by some Asian countries (Adapted from UNESCAP 2000)

3.3 Waste Recycling

To promote recycling, the 1995 South Korean volume-based fee system for the treatment or disposal of waste supplies provides a complimentary collection service for separated paper, plastics and metal. As a result, the collection of recyclables has increased to 28 million tonnes between 1995 and 2003. The decree had also been fiscally maintained by the South Korean government, which endowed low-interest/long-term loans (approximately US$500 million in 2005) (Ju 2005).

An effective policy on e-waste recycling is also available in South Korea. The e-waste generation had increased almost 100 % between 1995 and 2005 as a result of strong shopper spending and lesser lifespan duration of electronic goods. The Extended Producer Responsibility System came into effect in 2003 implying that manufacturers of electronic appliances are to bear the responsibility of recycling e-wastes. This is in line with a modicum of authority to increase prices accordingly, so as to cater for the cost burdened by the e-waste recycling scheme. As a result, a boost in the amount of e-wastes collected for recycling was achieved (e.g. computers collected and recycled increased from 17,000 units in 2002 to 149, 000 units in 2004) (Park 2006).

In Singapore, two waste recycling facilities were proposed to promote higher recycling capability and capacity, particularly of e-waste, organic waste, construction and demolition waste, ferrous waste, and plastic waste. In Singapore, there was an increase in the recycling rate from 40 % in 2000 to 48 % in 2004, with 54 % participation from the public and a substantial education commitment in schools (National Environment Agency, Singapore 2006; Ong 2005). In 2008, only 2.63 million tonnes of waste was disposed off while 3.34 million tonnes was recycled in the country (Yearbook of Statistics Singapore 2009). Currently they are targeting 60 % recycling.

Figure 8 depicts the level of recycling in selected Asian countries in 2011. The rate of recycling is highly influenced by the recycling policies in the country and the public participation. It is proven in many countries including Japan and Singapore that effective policies with stringent regulations on recycling program encourage the instillation of recycling habit among the people. Nevertheless, other factors too have significant role in promoting recycling practices. Table 2 lists the factors involved in a sustainable recycling model.

In comparison, the magnitude of accomplishment of the recycling scheme outsized the ‘reduce’ and ‘reuse’ approaches. It plays a more significant role in the informal sector than the formal practices. The Malaysian government launched the National Recycling Program in 2000 to promote and improve the recycling rate in the country. As a result the recycling rate increased to 5 % of the total waste generated. Recognizing the potential market for recyclable components, the draft Concession Agreement was drawn between the private managers and the Government to achieve waste diversion objectives and resource recovery. The intervening goals were to reach a 3 % recycling rate in 2003 and subsequently, 1 % annual increase towards 22 % recycling in 2020 (Agamuthu et al. 2009a, b).

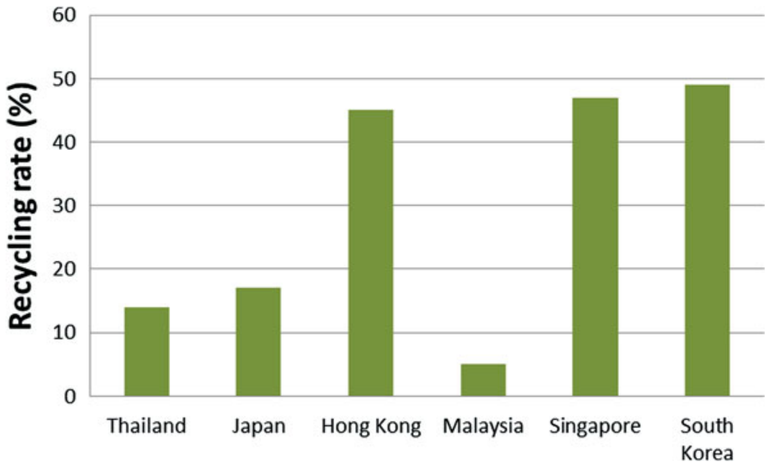

Fig. 8 The rate of recycling in some asian countries (Adapted from the World Bank 2012)

However, due to lack of public participation, the target of 7 % recycling in 2005 was not achieved. It was reported that more than 90 % of the Malaysian public is aware of recycling issues but less than 40 % actually practice recycling (Fauziah et al. 2009).

In the Philippines, the Ecological Solid Waste Management Act (2000) is endorsed to authorize and enable the shift in the country's waste management paradigm. It has incorporated various approaches to encourage 3R in the country. Among the strategies are establishing Material Recovery Facilities (MRFs), organizing recycling events, partnership and networking with various parties in marketing waste, supporting products from recycled materials, launching ecolabelling programs, and promoting ISO14001 implementation. The strategies also integrate information dissemination, reducing the use of non-environmental-friendly products and setting up exchange program connections for industrial waste. The eight strategies have enabled a boost to the recycling rate in the Philippines from 13 % in 2000 to 28 % in 2006 (Andin 2007).

Recyclables in the developing countries include plastic, metal, glass and paper. The informal recycling sector involving scavengers, rag-pickers and small enterprises are the main recycling routes for these retrievable items. In most developing countries in Asia, the general recycling route includes waste collectors, recycling vendors and recycling enterprises, as illustrated in Fig. 9.

Studies on waste composition in many developing countries indicate the high potential of recycling possibility. This is due to the presence of a high percentage of recyclable materials in the MSW stream. In 2008, Singapore recycled 48 % of the total paper waste generated, 9 % plastic waste, 94 % ferrous metal, 85 % non-ferrous metal and 18 % glass (ZeroWasteSG 2009). On the other hand, Japan recycles approximately 10 million tonnes of MSW per year (Tanaka 2008). Recycling has yet to reach its highest potential, neither in economically developed

Table 2 A sustainable recycling model (Uiterkamp et al. 2011)

Construct	Indicator	Cited in
Governmental actions	Degree of citizen participation in decision making on recycling initiatives	Brundtland (1987); Suttibak and Nitivattananon (2008); Troschinetz and Mihelcic (2009)
	Degree of self-corrective capacities of administrative system	Brundtland (1987)
	Amount of regulations on sustainable recycling	Suttibak and Nitivattananon (2008); Zotos et al. (2009)
	Degree of enforcement of regulations with respect to recycling	Suttibak and Nitivattananon (2008); Zotos et al. (2009)
Economic conditions	Degree of generation of surpluses through recycling activities	Kassim and Ali (2006); van Beukering and Curlee (11998); Medina (2000); Barton et al. (2008); Wilson et al. (2006)
	Degree of generation of technical knowledge about the recycling process	Brundtland (1987); Szirmai (2005); Wilson et al. (2006)
Social conditions	Degree of effective solutions for tensions arising of disharmonious development	Brundtland (1987); van Eerd (1997); Medina (2000); Berthier (2003); Sepúlveda et al. (2010)
	Degree of health assuring working conditions in recycling	Suttibak and Nitivattananon (2008); Sepúlveda et al. (2010); Misra and Pandey (2005); (Cointreau 2006); Wilson et al. (2006)
Production conditions	Degree of preservation of ecology in the recycling process	Kassim and Ali (2006); Misra and Pandey (2005); Sepúlveda et al. (2010); Hicks et al. (2005); Widmer et al. (2005)
Technological conditions	Degree of efforts in research and development to create sustainable recycling techniques	Brundtland (1987); Szirmai (2005)
International trade	Degree of sustainable trade in recyclables with developed countries	van Beukering and Bouman (2001); van Beukering and van den Bergh (2006); Duraiappah et al. (2002)

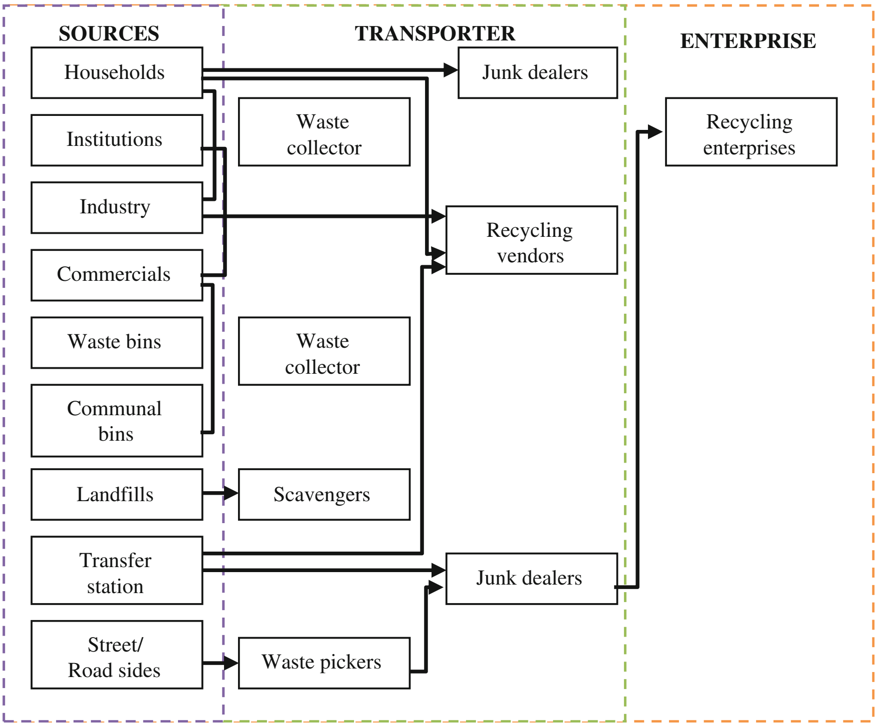

Fig. 9 General routes in material recycling in many developing countries in Asia

countries nor the economically developing countries. The failure is mainly due to the lack of legislation and policy. Nepal, particularly Kathmandu recycles 5 % of the total waste. In Bangladesh where approximately 51 % of the total plastic waste generated is recycled, 4–15 % recycling was achieved (Visvanathan and Norbu 2006). Similarly in India, the recycling rate is also high i.e. 47 % of the total plastic waste generated while in Hanoi, Vietnam it is approximately 20 % (Mutha et al. 2005; Nguyen 2007).

Since countries such as Singapore, Japan and Korea have more rigorous regulation, participation from public and private sectors are generally encouraging. Recycling practice eventually become more of a habit rather than an approach regulated by the authorities. However, in many developing countries recycling is practiced more due to economic reasons. In many cities in Asia and the Pacific region, recycling has become the source of income to the poorer and underprivileged society. As in this case, if the country is experiencing an economic shift where the standard of living is improving, recycling is no longer worth practicing (Agamuthu and Fauziah 2011a, b).

As the income generation increased, the dependency on other sources particularly recycling will be reduced and eventually diminished. The scenario is observed in many rapidly developing countries like Malaysia and Thailand, where recycling is not being practiced eagerly to generate side-income as it used to be in 1970s. Therefore, this similar trend is expected in India, Bangladesh and Pakistan when the GDP of the country begin to increase. Again, this will eventually result in low rate of recycling in these countries as in Malaysia and Thailand, which signals the potential failure of 3R implementation. Among the most common practice of recycling in many developing countries is organic waste recycling.

Organic waste contributed the largest portion (50–70 %) of MSW composition in the developing countries. The generation of organic waste in selected Asian countries is illustrated in Fig. 10.

In some countries, organic waste is usually converted to compost or undergoes anaerobic digestion for energy production. Organic waste in India, particularly animal dung, undergoes biogassification to produce energy while food waste is composted. The establishment of a 700 tonnes capacity composting plant in Dhaka, Bangladesh managed to produce 50,000 tonnes of compost by including a community-based decentralized composting project. Similarly, in Vietnam approximately 1,000 tonnes of organic waste has been composted everyday by eight centralized composting facilities with the capability to compost 30–250 kg of MSW, market waste and street waste since 1982 (Nguyen 2007). In Laos, recycling strategies are implemented via the establishment of 30 recycling banks and composting under the Integrated SWM Project and the Lao Chareon Recycling Center (Khanal and Souksavath 2005). Figure 11 depicts the percentage of composting in some Asian countries.

Various recycling strategies are implemented in the developing countries to reduce the disposal of waste into landfills. Yet, not all strategies have produced successful accomplishments. 3R strategies in many countries have failed due to various issues and challenges cropping up from the economic, political and social factors.

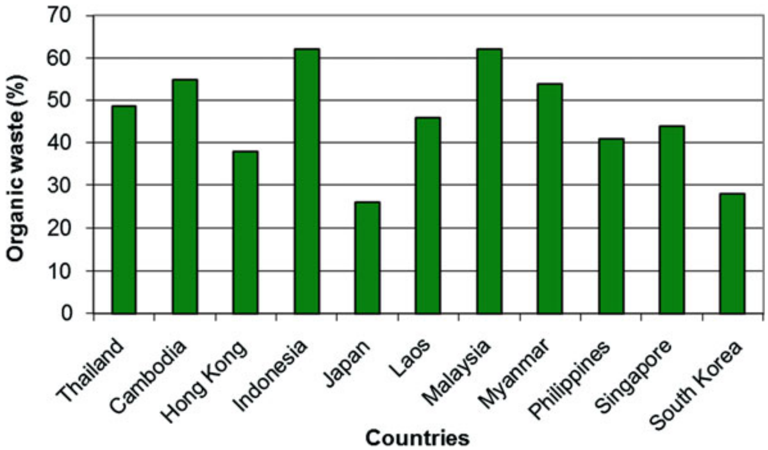

Fig. 10 Generation of organic solid waste in selected asian countries (The World Bank 2012; Enayetullah 2006; Agamuthu et al. 2004; AIT 2004*)*

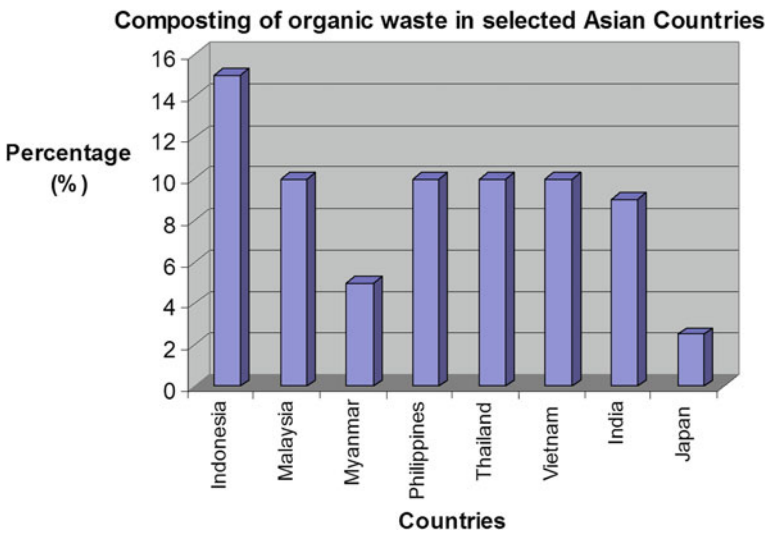

Fig. 11 Composting rate of organic waste in selected asian countries (*Source* Kaigisho 2006)

Table 3 Recyclable materials at selected Pacific Islands (adapted from Richards 2010)

Recyclables	Pacific Islands	Market for recyclables
Aluminum cans	Cook Islands, Fiji, Guam, Kiribati, Niue, Palau, Samoa, Solomon Islands, Tokelau, Vanuatu	Australia, USA, New Zealand
Scrap metals (ferrous metal)	Cook Islands, Fiji, Niue, Palau, Solomon Islands, Vanuatu	Australia, China, Hong Kong, Mauritius
Paper/cardboard	Cook Islands, Fiji, Palau	Local, Australia, New Zealand
Glass	Cook Islands, Palau	Local
Plastics	Cook Islands, Fiji, Samoa	Australia
Organic waste (composting)	Cook Islands, Fiji, Palau, Samoa, Tokelau, Tuvalu	Local

Similar scenario has been observed in many other developing nations in the Asia Pacific regions. The Pacific Islands namely Samoa, Cook Island and Tonga, traditional waste management system discourages effective 3R practice due to the improper waste storage and collection equipment, and lack of appropriate waste recycling facilities (Richards 2010). Only selective components are efficiently recycled and this depends on the demand and market price. Table 3 summaries the types of recyclables collected in the Pacific Islands.

Market value plays a crucial role in determining the recycling potential of waste materials in many developing nations thus influencing the presence or absence of such materials in the waste stream. Nevertheless, though economic factors have significant impacts on 3R practice and motivation, it is also necessary to identify other relevant issues and challenges. Subsequent paragraphs discuss the issues and challenges in 3R implementation in the Asia Pacific Region.

4 3R Issues and Challenges in the Asia Pacific Region

Goals and objectives set for 3R implementation in many countries often fall short when important issues are not appropriately addressed. The issues and challenges faced by developed and developing nations in the implementation of 3R strategies can be summarized in Table 4.

Table 4 Issues and challenges of 3R implementation in Asia Pacific countries

Issues	Challenges	
	Developed countries	Developing countries
Population growth	• Increase in waste generation. • Improvement in waste management technology	• Increase in waste generation • Premature closure of disposal sites
Policy implementation	• Stringent regulations • Effective	• Lack of enforcement • Ineffective
Changes in waste composition	• Introduction of suitable approaches such as, incineration, composting, pyrolysis etc.	• Failure in existing waste management systems.
Public participation	• High due to high awareness • Active participation-daily habits	• Low due to low awareness • Indifferent habits and refusal to change current habits.
Informal recycling such as scavengers etc.	• Absence due to safety and hygiene factors.	• An important aspect that promotes recycling • Unavoidable due to economic drivers.
Recycling strategies	• Practical, inline with governmental policy	• Mainly white paper and not applicable for the implementation of the current waste management system.
Existing waste management systems	• Promote 3R	• Mainly serve to dispose waste.

4.1 Ever Increasing Population and Volume of Wastes Generated

The unavoidable growth in the human population is invariably linked to increased waste generation as seen in China and Japan. In China, the average population growth was estimated at 0.63 % annually, between 2000 and 2006, during which the average annual generation of non-hazardous industrial solid wastes increased by 12.7 %. In the years 2000, 2003, 2004 and 2005, the average annual municipal waste generation increased by 13 % (National Bureau of Statistics, China 2007a, b; China Statistics Press 2001; World Bank 2005; United Nations Statistics Division 2007a; Organisation for Economic Co-operation and Development, 2008). In 2008, the rapid urbanization resulted in the generation of 150 million tonnes of MSW (National Bureau of Statistics, China 2008).

For Japan, similar annual population growth was noted in the same period (0.6 % between 2000 and 2004), while 1.4 % increase in total waste generated was noted as well (Statistics Bureau of Japan 2008a, b). Similarly, the population in Malaysia grew from 26.6 million in 2004 to 27.7 million in 2009 resulting in the increase in MSW generation from 17,000 tonnes/day to 23,000 tonnes/day in Peninsular Malaysia (Statistics Department of Malaysia 2010; Agamuthu et al. 2009a, b).

4.2 Lack of a Clear Policy and Necessary Enforcement

To an extent, enforcement of several aspects of 3R legislations has been lax or un-enforced. This is especially so when considering the example of trans-national movement of wastes. Despite the Basel Convention being enforced since 1992, there has been heavy movement of hazardous wastes, especially electronic wastes into Asia, notably India, China and Pakistan. These electronic wastes are manually disassembled and crudely processed with the objective of extracting recyclable materials. The imports of waste are mainly to cater for the inadequate supply of resources within the country (Mo et al. 2009).

As for e-wastes in the case of India and China, the main deficiency that has hampered enforcement in previous years is the absolute lack of a policy to govern e-wastes. There was no definition of electronic wastes as of 2006 (Ragupathy 2006; Zhou 2006). The lack of a concrete policy prevents funding from being directed. Furthermore, the general antipathy for the problems stems from a lack of awareness as to how dangerous and unsustainable the manual processing is. This can be seen in the example of China, where manual processing is still the primary method of e-wastes disposal. As a result, the Circular Economy Promotion Law was passed in August 2008 to strive towards a resource conserving society and promoting ‘circular economy’ in China (Mo et al. 2009). However, recent development sees the implementation of Environmental Protection Act of India under E-Waste (Management and Handling) Rule of 2011, in India, and the Administration Regulation for the Collection and Treatment of Waste Electrical and Electronics Products (Chinese WEEE) in 2011 in China.

4.3 High Quantity of Organic Matter in Wastes

Many countries in Asia are developing economies, which have higher percentage of organic materials in their waste streams. India and China, for example cater for more than two billion people with a rapidly growing population. It has been estimated that municipal waste generated in the urban parts of China in 2000 consisted of 41–65 % organic matter while in 2030, it is estimated that the municipal waste generated will consist of 51 % organic matter (World Bank 2005). In India approximately 960 million tonnes of solid waste was generated annually as of 2007. Approximately 37 % of the wastes were organic in nature (Pappu et al. 2007).

The intrinsically low waste separation intensity and high percentage of organic wastes calls for a significant effort in the separation of solid wastes into their recyclable components. The high percentage of organic matter in the wastes also complicates its own recycling activity as the most suitable recycling option for heterogeneous organic wastes would be composting, which is theoretically practical but not economically rewarding. The impracticality of recycling organic waste is mainly due to the absence of waste separation. Highly commingled wastes are not suitable to undergo anaerobic digestion or composting since the presence of undesirable materials such as plastic and hazardous compound can inhibit the biological processes. Thus, recycling of this vast component is not feasible unless waste separation is integrated into the system (Agamuthu and Fauziah 2011a, b).

4.4 Low Initiative from the Public to Take Part in 3R Campaigns

While 3R (or specifically recycling) campaigns depend on legislation to ensure their success, it is the public's lack of initiative to practice 3R that would cause their failure. The absence of public participation results in the failure of 3Rs that require full commitment from the waste generators, namely the public and private sectors (Agamuthu and Fauziah 2011a, b). Generally, lack of participation is due to low levels of awareness on the benefits of practicing the 3Rs. Though more than half of Malaysian population claimed to understand the concept of 3R, its practice does not even a quarter of it. This is mainly due to lack of infrastructure in addition to the 'not-bothered' attitude among many individuals (Fauziah et al. 2009). The failure rate will amplify without the encouragement or legislative instruction from the respective governments. The reduction in waste generation or increase in recycling rates will reflect the success of both government-authorized and voluntary public participation.

4.5 Low Levels of Awareness on the Benefits of Practicing the 3R

The low voluntary participation from the public in 3R campaigns could be attributed to the lack of attention to environmental issues. This is especially so in the aspects of waste reduction. Understandably, not many people have the time or the desire to assess daily routines with the objective of reducing the personal wastes generated. This is mainly due to the indifferent attitudes among many individuals (Fauziah et al. 2009). Many companies and industries conform only out of legislative requirement and a desire to maintain an ideal corporate image.

In general, waste management laws in Asia since the 1980s have advocated protection of the environment. These laws came with the necessary education campaigns but the campaigns have never progressed beyond concepts like "do not litter", "do not burn garbage" and "keep our rivers clean". Simplified current waste management taught to school children in Singapore includes concepts of recycling, environmental leadership and proactively organizing environmental activities (Ong 2005).

4.6 Little Regard for Waste Pickers and the Informal 3R Sector

Another on-going challenge is the lack of recognition for the contribution of informal waste workers. This could be attributed to many Asian countries adopting, almost totally western-style 3R campaigns. In western countries, roles of scavengers are insignificant due to the intrinsic and efficient waste separation and management systems that exist, and scavenging of wastes is in fact considered illegal. In the developing and under-developed countries of Asia, waste workers fill a niche by manually sorting, cleaning and selling recyclable wastes. Waste workers in Asia exist due to the lack of waste separation schemes and the possibility of earning a living by manually dealing with wastes. Malaysian MSW stream for example, contains approximately 40–60 % retrievable materials, which can be a significant source of income for the scavengers (Agamuthu et al. 2009a, b).

While legislation is more or less in place to outlaw or reduce scavenging activities, enforcement is quite lax. This allows waste workers to continue their activities despite their status as unrecognized, trespassers on landfills or illegal collectors of wastes. The result is that their plight and physical health goes unmonitored, despite their contribution to the 3Rs, especially to recycling. Due recognition and protection should be accorded as waste workers tend to be extremely poor and on the marginalized end of society. In the less developed countries of Asia, many waste workers are women and children. In Hanoi (Vietnam), waste workers separate an estimated 22 % of the waste that is produced. In the informal waste sector of Hanoi, 67 % and 9 % of waste workers are women and children, respectively (World Bank 2004).

4.7 3R Practices and Global Warming

IPCC estimated that landfill methane will reach 795 $MtCO_2e$ and 910 $MtCO_2e$ in 2015 and 2020, out of approximately 300 $MtCO_2e$ that comes from developing countries in South and East Asia (Agamuthu 2012). Therefore, it is imperative that proper mitigations are in place to prevent further contribution of greenhouse gas emission (GHG) into the atmosphere. Align to the effort, 3R activities which promotes sustainable waste management in many cases also enhance the reduction of GHG that contributes to global warming phenomenon. From the waste reduction practice, it resulted with less waste materials being disposed into landfills thus reduce the degradation potential of the waste materials that consequently reduce the GHG emission. This is particularly significant in dealing with the organic component of the MSW. Diversion of organic components from landfill disposal can significantly prevent the conversion of organic compound into undesired methane gas which has 21 times global warming potential than a unit of carbon dioxide.

In Japan, the passing of revised Food Recycling Law in 2007 promotes waste reutilization where food wastes are converted into value-added products among food retailers. The Law enhances the utilization food waste derived compost and animal feed among farmers (Takata et al. 2012). As a result, more recycling facilities were established to cater the need of recycling food waste as it is envisaged in a progressive economic sector. With the creation of market potential for food waste in Japan, diversion of this waste component is highly efficient thus consequently avoid the need for disposal option. Thus, it assists the reduction in GHG emission from landfills.

Similarly in Singapore, the Singapore Green Plan 2012 targeted 30 % of food waste recycling by 2012 (MEWR 2008). Khoo et al. (2010) reported that a Life Cycle Analysis (LCA) conducted showed that an anaerobic digestion system can be more environmentally favourable than a small-scale aerobic composting system and incineration. Reduction in global warming impacts can be achieved via carbon dioxide saving since biogas namely methane will be harvested for energy conversion.

5 Conclusion

In economically developed countries, the 3R strategies are successfully enabling the waste management system to thrive towards sustainable development. However, the implementation is found to be less effective in the developing countries where various issues and challenges are hurdles, which need to be overcome in order to move towards the Millennium Development Goals.

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Formalization of Informal Recycling in Low-Income Countries

Prakriti Kashyap and Chettiyappan Visvanathan

1 Introduction

Recycling is undoubtedly one of the best strategies to handle the growing volume of waste. Converting a linear resource extraction pattern into a cyclic chain by putting the waste materials into production chain is possible through recycling. Making recycling a reality, however requires basic waste management services in place, source segregation and effective collection of thus separated waste. But unfortunately, an ineffective collection, none or little source separation, poor handling and ill disposal practices are still the common realities of solid waste management in low-income countries (LICs). Most cities in transitional and developing countries use only 3–15 % of their total municipal budget on solid waste management, while the high-income countries (HICs) have larger budget allocation for urban waste management. Of which, 80–90 % of this budget is spent on waste collection alone in LICs (UN-Habitat United Nations Centre for Human Settlement 2010). Despite such high spending, waste collection rates are at 41 % in low-income countries, as compared to higher than 90 % on an average in high-income countries, which uses less than 10 % budget on waste collection (World Bank 2012). This poor collection efficiency at low income countries is attributed to various management, technology, financial, institutional and policy constraints. Despite such conditions, recycling is not totally absent in low income countries, and is often driven by the informal sector.

Drivers of waste management in developed and developing countries are different and so are the approaches taken. Recycling in low-income countries is more of a livelihood means than the deliberate efforts of waste management out of environmental consciousness. The most striking differences in waste management between low- and high-income countries are the predominant presence of informal

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sector in the former. The informal sector comprises poor and marginalised people engaged in the value chain of waste picking, sorting, collection, resale of recyclables, and small scale recycling.

People in informal recycling are often from a discrete social or ethnic group as in *Zabbaleen* in Egypt or *Dalits* (untouchable caste) in India. Informal waste sector (IWS) unlike the formal system is characterized by its small-scale, labour-intensive, unregulated and unregistered and low-technology manufacturing or low provision of services (Wilson et al. 2001). The informal recycling activities involves intensive manual labour for waste scavenging, extraction and segregation of recyclables from the mixed waste, sale of those to the junk shops and the operation of small recycling units. The informal sector operates their business without paying taxes and without any trading or operation license. Formal sector recycling operates with proper business registration and tax payment, technological advancement and large scale operation. Therefore the formal sector is recognized as a legitimate stakeholder in the solid waste management system by government authorities.

Low-or-no capital investment for informal recycling and their operation outside the regulation (both the taxes and pollution control) often are the reasons of the informal sector recycling being an attractive profitable business venture. At the same time, the very same nature of business operation makes the informal sector an illegitimate, a nuisance and a hindrance by the formal waste sector. Therefore, one way to improve recycling rate in low income countries along with securing the livelihood options is through the integration of informal sector in the formal solid waste management system. Integration of informal sector not only improves recycling rate but also provides three-fold benefits; social (improvements in working condition), economic (income, employment opportunities), and environmental (reducing waste disposal and associated pollution issues).

2 Informal Sector Waste Management and Recycling

People making a living out of waste collection and recovery are considered as "long practiced activities" in developing countries. It is reported that nearly 2 % of the urban population in low and middle-income countries depend on waste picking for their livelihood (Medina 2000). While informal sector activities vary according to socio-cultural, religious and economic circumstances. Typical characteristics include; securing livelihood by picking recoverable fractions of waste from road side collection points, transfer stations and dumpsites. As the name suggests, informal sector means working without a secured job or income, with very basic equipments to scavenge waste, with little health and safety measures, with negative social stigma attached to the profession, and the overall high vulnerability. Usually the IWS workforce comprise of rural migrants, women and children, retired elderly, lay-off workers and disable individuals who are unable to find regular jobs.

The informal sector is engaged in the waste management activities largely as a private economic activities based on valorization. In doing so, the informal recycling often recover up to one-third of the waste in self-financing way (Deutsche Gasellschaft fur Internationale Zusammenarbeit (GiZ) 2011). Presence of Informal waste sector in developing countries is often so strong that the material recovery is higher than the formal sector as shown in Table 1.

In general, recycling in low income countries operates through informal sector, to some extent by formal private recyclers, and less often by the local authorities (LAs) through public–private partnership (PPP). On voluntary basis, non-governmental organizations (NGOs) and community based organizations (CBOs) are also engaged in waste management and recycling activities. In-house or closed loop recycling within an industry also exist in big industries under the cleaner production and design for environment concepts. Figure 1 presents the recycling approaches taken in low-income countries, highlighting the key players in the recycling chain, i.e., the formal recyclers (Local Authority/Municipality and the formal private sector), and the Informal waste sector. At present, a weak interaction between the informal and formal sector exist, and this interaction needs to be strengthened by integrating the informal waste sector. Each of the approaches taken by these formal and informal sectors is explained below.

2.1 Recycling by Informal Waste Sector

Informal sector recycling operates with a chain of different actors involved in specified roles. The informal sector activities involve waste scavenging, waste collection, waste sorting, and sale and purchase of recyclables. Less often the informal sector is also directly involved in establishing and operating a recycling facility/unit.

Table 1 Comparison of material recovery by formal and informal sector in six different cities

City	Formal sector		Informal sector	
	Tonnes	Percent of total	Tonnes	Percent of total
Cairo, Egypt	433,200	13	979,400	30
Cluj, Romania	8,900	5	14,600	8
Lima, Peru	9,400	0.3	529,400	19
Lukasa, Zambia	12,000	4	5,400	2
Pune, India	–	0	117,900	22
Quezon City, Philippines	15,600	2	141,800	23

Source Scheinberg et al. (2010)

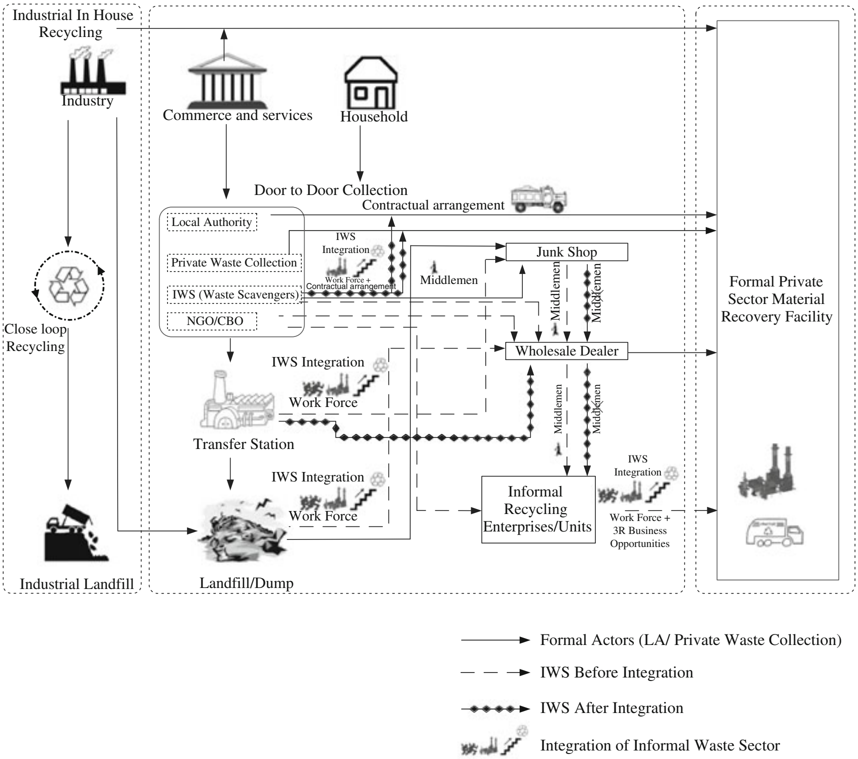

Fig. 1 Different actors and arrangements of recycling and scope for integration of the IWS

(a) **Collection of recyclables**

Informal waste collection: Informal collectors usually collect waste from door-to-door collection. This arrangement is usually visible in the low-income which are not served by municipal waste collection service. Along with the collection of overall waste, the informal sector segregates the recoverable materials and earns money by selling them. Municipal collection crew also collects secondary raw materials from the collection trucks before sending off the waste to disposal sites, as informal setting for additional income.

Waste picking: This is the most common activity of the informal waste sector, where individuals pick waste from streets, open dumps and landfills. With this activity, the informal sector is often termed as scavengers, waste/rag pickers, salvagers etc.

Itinerant waste buyers: They are basically the door-to-door collectors who exchange recyclable materials over money or barter of other domestic goods. They use bi/tricycle, cart or modern vehicles as their mode of transportation to collect waste, depending on the countries of operation.

(b) **Sale and purchase of recyclables**
Junk shops are the primary point of sale where the collected recyclables are sold by individual waste collectors. These junk shops then sell the waste to a wholesaler. Purchase of recyclables usually happens in the presence of middlemen. Presence of middlemen facilitates the sale of waste products; however, this is also one of the reasons as to why the waster collectors or junk shops are paid low wages. However, in case of a stronger network of scavengers, there are possibilities of waste pickers bypassing one of the above channels and get linked to the wholesaler or very rarely even directly to the recycling enterprises. Although the informal waste sector is not affiliated to groups and often works as individual and at most at the family level. They maintain an organizational hierarchy of division of roles, areas of waste scavenging etc. to avoid conflict. Sometimes the informal sector at all levels of waste picking and scavenging, even door-to-door service, and network to junk shops and informal recyclers is so strong that it often gives a tough competition to large scale formal recyclers for waste as feed material.

(c) **Recycling**
The actual recycling process occurs after the recycling factory/units procure recyclable materials from wholesalers. At present, the recycling unit under informal sector is limited to small and medium scale enterprises, often as backyard recycling. The informal waste dealer by-passing the informal recycling unit and directly approaching the formal recycling plants is faintly present. However, integration of informal sector can definitely strengthen this weak network into an official partnership, benefitting both the sectors.

2.2 Recycling by Formal Private Sector

Global market for waste management services (inclusive of recycling) is enormous. Formal private sectors are therefore getting attracted to this green business opportunity. Private sector in waste management and recycling gets involved in the following modality:

(a) **Contracting or sub-contracting of the waste collection and transportation services by local municipality**
Under the Public Private Participation (PPP), local authorities (LAs) usually subcontract the waste collection and management services to formal private companies. In India, through the Municipal Solid Wastes (Management and Handling) Rules, 2000, issued by the Union Ministry for Environment and Forests (MoEF), waste management service in metropolitan cities like Mumbai, Delhi, and Chennai are handed over to private waste management companies. But the public support and efficacy of such projects are under debate, mainly because of exclusion of informal sector. In another

arrangement, the formal private recycling industry enters into contractual agreements with the LAs or the formal private waste collectors to secure the waste material input for their recycling operation.

(b) **Establishment of recycling plant**
Private sector not only performs waste collection and transportation activities, but also establishes the recycling plants. Private sector's involvement in recycling is either on solo investment or in partnership with local authorities. Private companies invest their funds for the technology purchase and operation of the recycling units. Sometimes private sector is hired only to oversee the management of the recycling plants established by the LAs. Following are some examples of private sector's participation in recycling business in Asia (Visvanathan 2011):

Vietstar Lemna Eco Centre, Ho Chi Minh City (HCMC), Vietnam is 100 % foreign direct investment (FDI) from the Lemna International, Inc., U.S.A. The company is on a contractual arrangement with the HCMC Municipality to secure influx of municipal solid waste (MSW) to operate composting and plastic recycling facilities.

WMS-DOWA Incinerator, Bangpoo Industrial Estate, Thailand, utilizes non-hazardous industrial wastes and recovers steam as by-product, which is the major source of revenue for the operator, along with the waste tipping fees from the industries. The fluidized bed incinerator was funded by New Energy and Industrial Technology Development Organization (NEDO) Japan to the industrial estate authority of Thailand via Green Partnership Plan (GPP). Waste Management Siam (WMS) owned by DOWA Eco Systems Co. Ltd., Japan has taken up the operation of this incineration plant for 20 years from 2009, at a cost of 400 million THB.

Another alternative approach of private companies' entry to recycling business is the management decisions of the parent manufacturing companies to recycle their own wastes in a closed loop recycling. Such modality of recycling is considered beneficial synergistically, where the recycling plant/unit receives uninterrupted supply of waste from the parent company (as well as from other outside sources) and the end-products get consumed by the parent company hence making the recycling operation cost-effective. The parent manufacturing company benefits by producing goods at lower price by using the secondary raw materials, and also by acquiring a "green" brand image.

Polydime International (Pvt) Ltd, Sri Lanka, was established in 1998 to cater the waste disposal problem of its parent company—the manufacture of multi-layered Polyethylene films. The factory recycles Low-density polyethylene (LDPE), Linear Low Density Polyethylene (LLDP) and High-density polyethylene (HDPE) materials and produces pellets. The finished product (pellets) is used by its parent company for the manufacture of multi-layered polyethylene films. As a result, the parent company has become price competitive in the market place, as 50 % of the raw material comes from its own recycled materials. The recycling facility apart from utilizing waste materials from its parent company also buys waste through a channel of local informal waste pickers. The recycling unit encourages informal waste pickers to sell their waste to the factory by providing economic benefits such as a competitive price, provision of ‘credit’ in advance for the waste to be sold to the company. Such positive blend of informal sector into the formal private recycling activities is a noteworthy effort for co-integration and social capital building.

2.3 Community-Based Recycling

Recycling as a community activity is another common approach observed in low-income countries. The non-governmental organizations (NGOs) and community-based organizations (CBOs) are found to be engaged in small scale recycling activities, which serves as their revenue generation mechanisms from the sale of recycled end-products, such as composting from organic waste or recycled paper and plastic handicrafts etc. NGOs/CBOs contribution is equally noteworthy for organising public education and awareness activities for promoting waste reduction, reuse and recycle activities. Another remarkable role-play of the NGOs/CBOs includes mobilization of the informal waste collectors into a formal association or co-operatives. In many cases the NGOs/CBOs undertake community recycling on a project basis and sustainability and continuity comes as shortcomings once the project phases out. Nevertheless such recycling approach is hugely beneficial in educating, mobilizing, and empowering the local communities towards waste management activities.

Matale Enriched Compost Private Limited, Sri Lanka is a successful composting facility initiated with the help of local NGO *Sevanatha*. This NGO successfully diffused the decentralized composting technology developed and practiced by Waste Concern Bangladesh. Along with environmental conservation, compost production, provision of employment opportunities (especially to women), better health and working conditions are some of the other social benefits derived from this “NGO led recycling activity”.

All the three sectors (informal, formal and community) are involved in recycling activities in low-income countries, however, the issues is regarding the disintegrated approach. In order to increase the recycling efficiency, there has to be a merger among the labour force and expertise from the informal sector, the best available recycling technologies and finance from the formal private sector, and not to forget the active participation from the community.

3 Critical Issues of Informal Recycling

Informal sector recycling provides economic salvage to the certain marginalised section of the society, but a long list of problems associated of such recycling approach cannot be discounted completely. Environmental pollution created by the back-yard crude recycling practices, inadequacy of technical know-how and financial resources to set up a non-polluting recycling plant, unregulated import of hazardous waste (E-waste in developing Asian countries), health concerns, and negative social stigma are some of the major challenges in informal sector recycling.

3.1 Inappropriate Working Conditions, Irregular Income and Negative Social Stigma to the Occupation

Unhealthy and unsafe working environment and presence of child labour are common in informal sector. Usually, the children either join their parents in waste scavenging business or work independently to financially support their families. Income from waste valorisation is the main source of livelihood for informal sector. Studies show that the entire value chain of informal valorisation activities is a profitable business, with a total net profit of 130 million Euro, distributed between 73,000 informal workers in six cities namely, Cairo, Cluj, Lima, Lusaka, Quezon City and Pune (Scheinberg et al. 2010). Despite such profit, income of waste pickers at the lowest hierarchy of the informal sector is not steady. Competition for the waste scavenging and the presence of middlemen also affects the fair pricing of the recyclables, which affects the overall income! Their job and income level is further threatened by the privatization of waste collection and disposal if it is non-inclusive of the IWS. There exists a gender inequality in earning too. Men usually earn more than women due to their limited working tools and transport capacity. In Pune, female waste iterant buyers earn fourth of what males do. Nevertheless, income in the informal waste sector is up to four times higher than salaries of unskilled labour in industries (Scheinberg et al. 2010). This attracts people into waste picking business despite poor working conditions and potentially high health hazards.

Inspite of the better income opportunities the informal waste sector creates, people into waste picking activities are despised socially as “criminals”, “beggars”, “filthy” and are subjected to harassment from officials and exploitation from traders and middlemen. They also work in poor working conditions and with potential health and safety concerns. Informality is one of the reasons that add negative social stigma, exploitation and lack of regular job and income security. Formalization of informal workers can address these issues by giving legitimate recognition to the waste picking occupation and providing healthy working conditions, and regular and fair income opportunities.

3.2 Pollution from Crude Recycling

Small scale informal recycling plants normally operate with crude recycling techniques without any pollution control mechanisms in place. For example, used Lead Acid Batteries (ULAB) recycling is a typical industry causing "environmental pollution" in developing countries. Refineries of metal scrap industry could potentially cause air and water pollution. This has flagged recycling as the polluting industry. Governments find it easy to enforce pollution control regulations on big recycling companies, which also have the technology and financial capacity to deal with the problem. Small- and medium-scale industries try to dodge the government through illegal operation in scattered locations or relocation to remote areas and operating behind the walls.

3.3 Competition for Waste as "Feed"

Besides the pollution issues of small recyclers, competition for waste by formal and informal sector is another area of concerns. It has been a general trend in developing countries that informal recyclers dominate the waste collection, market of collected recyclable waste, and recycling as their cost of recycling is cheaper than that of formal recyclers. This competitiveness of informal recycler comes from non-payment of taxes and with no investment in pollution control. But with introduction of non-inclusive privatization, informal sector is usually driven off from waste collection affecting the waste valorisation and the overall income. Both the scenarios are not helpful for the overall recycling rate. Integration of the informal sector can avoid hostility between the formal and informal recycling initiatives.

4 Integrating the Informal Sector: Approaches and Examples

Informal recycling in developing countries runs parallel to formal solid waste management system. The potential positive impacts of informal sector in waste management systems cannot be ignored. Thus an integration of informal sector through formalization is necessary to gain a win–win situation to both the sectors. Integration of the informal sector can cover a broad spectrum; from mere recognition of the informal sector by local authorities and formal private sector through identification cards to waste pickers, to the full-fledged institutionalization of the informal workers into cooperatives or companies. Similarly, the approach to integration also differs according to the objectives and so does the level of formalization. Some of the approaches to integration are:

4.1 Policy Inclusion for the Informal Sector

Informal sector suffers the 'invisible' status as they are not seen as a legitimate stakeholder. Therefore, to acquire the legitimacy of the informal sector, an inclusive policy measures are required. Experiences from countries like India and Philippines show how policy and legal components can play an important role in gaining recognition by the informal sector.

4.1.1 Example from India

In India most of the waste recycling activities are performed by informal sector. Municipal Solid Waste (Handling and Management) Rules 2000 is the first set of comprehensive legislation that discusses the rules for waste segregation and recycling in great details, but does not particularly include the informal sector as such. Nevertheless, there are much national and regional legislation, committees and reports that have highlighted the roles and rights of the waste pickers to access waste and participate into the mainstream recycling (Chintan EnvironmentalResearch and Action Group 2007). Some of which are:

National Policy

At the national level, the National Action Plan for Climate Change, 2009 clearly identifies the role of informal waste sector as the backbone of recycling system. The policy states "…………..the *informal sector is the backbone of India's highly successful recycling system*, unfortunately a number of municipal regulations impede the operation of the recyclers…………"

National Environment Policy, 2006 highlights the need for formalization and integration of the IWS through a statement "…*Give legal recognition to, and strengthen the informal sector systems* of collection and recycling of various materials. In particular enhance their access to institutional finance and relevant technologies.

Regional Legislations

Many, regional legislation has also progressively recognized the importance of informal sector, and the need for their integration. Maharashtra State Legislation-the order of the Government of Maharashtra; Water Supply and Sanitation Department Government Circular No: Ghakavya 1001/Pra in 2002 states that the *unorganized rag pickers in the city should be organized* with the help of NGOs and register as a cooperative. The order of the Bhopal Municipal Corporation (BMC), dated January 4th, 2011; (433/G.O/2011) also *involves waste pickers for door to door collection* in target locations, with BMC playing a facilitating role.

Rules

India has many rules on various kinds of waste that highlights the importance of informal sector. One of which is the Plastic Waste (Management and Handling) Rules, 2011, states that the Municipality is responsible for, amongst others,…….*Engaging agencies or groups working in waste management including* *waste pickers* and ensuring that open burning of plastic waste is not permitted". Electronic Waste (Management and Handling) Rules, 2011 *include the informal sector by emphasizing that associations* can also act as collection centers, with the understanding that associations are an important form of informal sector organization that must be recognized.

Reports

The Comptroller and Auditor General of India (CAG) Audit on Municipal Solid Waste in India (December 2008) recommends that "MOEF/states should consider *providing legal recognition to rag pickers* so that recycling work becomes more organized and also ensures better working conditions for them."

National Committees

Several committees have also recognized the importance of including waste recycling sector into mainstream recycling activities.

Asim Burman Committee, March 1999 constituted by the Supreme Court as part of the Public Interest Litigation Almitra Patel versus The Union of India, made recommendations with regard to recycling and the informal sector. Recommendations included; o*rganizing waste pickers* to collect recyclable waste from shops and establishments. It also acknowledged that these *waste pickers help reduce the burden of Urban Local Bodies body* by several million rupees annually in collection, transport and disposal cost and saving of landfill space.

Bajaj Committee made specific room for the informal sector in the waste management framework. One of the recommendations included in this committee was replacing the informal sector scavenging from roadside dumps and disposal grounds by organized ward-level recycling and recovery centers that could be managed by *NGOs working with waste pickers*. It also opened an employment opportunities recommending the Municipal authorities could also *employ waste pickers* for this activity.

Despite a number of policy and new rules that emphasize the need for participation and involvement of the informal sector, the municipalities have failed to implement them (Chintan Environmental Research and Action Group 2011). The March 2007 CAG's Performance Audit of Management of Waste in India showed only 17 percent sample States recognizing the role of waste pickers. Nevertheless inclusive policies are the pathways to integration of informal sector. If there are clear policy and legal mandates, chances of overlooking the issue of IWS formalization and integration is less than having no policy recognition at all.

4.1.2 Examples from Philippines

Philippines formulated the National Framework for the Informal Sector in Solid Waste Management (NSWMC, 2009) as an initiative to *integrate the informal sector by providing them with a favorable policy environment, skills development and access to secured livelihood, employment and social services* (p. 34). It envisages the informal waste sector as an empowered and recognized partner in the promotion and implementation of the 3Rs with the end view of alleviating poverty.

Integration of informal sector in Philippines' waste management is targeted to provide secure jobs to the informal workers through formalization, and working in a centralized Material Recovery Facility (MRF). The Payatas Allaince Recycling Exchange (PARE) Multi-Purpose Cooperative, Quezon City was established through collaborative efforts of the government and NGOs through which scavengers can collectively obtain available assistance, finance or skills training, and other livelihood opportunities. Under this Quezon model, about 2,000 scavengers are organized into 13 associations (12 during daytime and 1 for night time) and assigned to designated dumping areas. They are given 20–30 min to pick, segregate, and collect garbage at the eight MRFs. This initiative was started after the closure of the controlled dump in December 31, 2010. Waste pickers are organized into clusters made up of 25 members. Three clusters are assigned to each MRF for a total of 75 workers in an MRF at one time (Atienza 2011). This Quezon model is followed in Gyor–Hungary, and in Heredia–Costa Rica, Dhaka–Bangladesh, and Lima–Peru.

Addressing integration of informal sector into the national policy and plan is a positive manifestation of governments' realization and efforts towards recognizing the significant roles of the informal waste sector as an important stakeholder in waste management. Having such policies is a measurable yardstick of inclusion of informal sector into the modern waste management systems.

4.2 Integration Through Institutionalization

Formalization of informal waste pickers into a co-operative, with facilitation from NGOs and sometimes the government authorities have been the common approach of formalization through institutionalization. Such formalization will mobilize the informal sector and put it to a different power dynamics-giving them a recognition as a legitimate stakeholder, and increasing their bargaining position to deal with LAs, formal private sector and international development and financing institutions. Institutionalization can provide an opportunity to work for private companies and LAs with an organized waste laborers. Similarly, breaking off from the middlemen brokerage and acquiring job security, better environmental and occupational health conditions comes as a package deal of formalization. Social stigmas attached to informal waste sector can also be changed with the legalization aspect, where the waste scavenging is recognized as a profession.

Institutionalization also brings the scattered informal actors under national tax system and pollution abatement by cutting off a stiff competition between formal and informal recyclers, where the former has to invest on pollution control technologies and are under tax system, while the latter enjoys tax on both. Moreover, the 'greening' of recycling industry is the added environmental benefit.

One such example of institutionalization of the informal sector is from Mumbai, India, where the waste pickers organized themselves and formed a NGO. Three organizations *Aakar, Stree Mukti Sanghatna* and Forum of Recyclers Communities and Environment (FORCE) are registered as NGO and are recognized by the Municipal Corporation of Greater Mumbai (MCGM). The MCGM issues identity cards to these waste pickers, and the NGOs have entered into contractual arrangements for waste collection with the MCGM. The trained waste pickers work with the municipality and help in sorting and storing. These organizations also adopt an approach for women empowerment through creating self-help groups and training them with skills in organic manure making, gardening, formation of saving groups, etc. Other social benefits include; education to waste pickers' children, providing micro credit facilities, health care and hygiene etc. In addition, *Stree Mukti Sanghathan* and FORCE are also provided with collection vehicles for recyclable collection and a space for running scrap shops (SNDT Women's University and Chintan Environmental Research and Action Group 2008).

The "Zero Baht Shop" in Thailand is another successful example of pro-poor approach of waste management with active participation of the informal waste sector. Under this arrangement, the waste picker community at, On Nut 14 Rai community in Prawet district has formalized themselves into a group to operate a successful community grocery shop. The Zero Baht shop is a store that allows customers to exchange recyclable wastes for consumer goods. A majority of the people in this community are waste pickers. (70 out of 140 households are engaged in waste picking as their subsistence occupation). Few enthusiasts in the community started the idea of waste exchange activity in 2001. This local initiative was further supported and strengthened by the Thailand Institute of Packaging and Recycling Management for Sustainable Environment (TIPMSE). TIMPSE renamed and launched the waste bank as "Zero Baht Shop" in July 2012. The purpose of the Zero Baht Shop is at many folds; to encourage people to separate different types of waste, convert trash (recyclables) into cash, and to help lessen the amount of garbage being dumped. The recyclables thus exchanged at the Zero Baht store is sorted, cleaned and sold to the wholesalers and some nearby recycling factories with profitable margin. Within this arrangement, the community also operates Garbage Bank/Welfare Fund that allows its members to deposit their savings (by crediting the recyclables at the Zero Baht Shop, or by depositing 2 bottles per day of glass wastes or 1 Baht/day without absence for 2 continuous months). Two percent of the income of the Zero Baht Shop is also added in this welfare fund. Thus, the collected welfare fund is utilized for medical insurance, study loan, provision of 5 kg of rice for elderly people who are 60 years and above etc. Apart from these benefits, the waste pickers in the community enjoy the identification card that legitimizes their waste picking occupation to collect recyclables from other collection points in Bangkok Metropolitan Administration areas.

4.3 Fostering Partnership Between the Informal and Formal Private Sector

Integration of informal waste sector is just not restricted to local authorities, but also expanded for partnership with formal private sector. Such partnership can promote recycling as a shared business. The shared recycling business is explained here with a case of the E-waste recovery and recycling. Extraction of valuable metals such as gold, silver, palladium, aluminum, steel and copper has been the prime attraction for E-waste recycling, and major livelihood strategy for poor people around the world. With these valuables, there are many other hazardous substances such as lead, cadmium, brominated flame retardants and PVC in E-waste. With involvement of small and medium scale informal recyclers and lack of proper recycling technologies and pollution control mechanisms in place, E-waste recycling possesses a high risk to environment and occupation hazards to the workers and local communities. In such case the partnership can be such that the informal recyclers collect E-waste using comparatively low cost and effective collection and sorting, while the partnering formal recycling industry performs recycling of the valuable materials efficiently in less polluting environment. Revenues acquired from such partnership can be invested on improving working conditions and co-financing the investment in environmental protection and improved recycling practices. Such partnership may be translated into the in-country coordination between formal and informal recycling sectors or as a regional recycling network. However, such business model may not be applicable to all sorts of recycling materials.

Linking informal waste collectors and scavengers into a formalized material recycling facility and larger waste dealers is one of the practical ways of integration of informal sector into formal private recycling businesses. Such integration is visible in Wongpanit Co. Ltd Thailand. Established in 1974, Wongpanit Garbage Recycle Separation Plant is the first and largest waste recycling separation business in Thailand. The company is ISO14001 certified and is licensed by the Ministry of Industry. Wongpanit business has spread its network to more than 400 branches in Thailand and overseas. The Wongpanit Company buys waste from local residents, other waste collectors and sells recyclable materials to recycling factories in Thailand, Burma, China, Singapore and England. It has a strong market hold and has been able to create a strong network amongst waste generators, waste pickers and buyers as in cooperative waste centers and waste banks brings informal waste scavengers, informal collectors, junk shops, small enterprises, schools and franchising partners in the region (Deutsche Gasellschaft fur Internationale Zusammenarbeit (GiZ) 2011). The concept of waste bank was coined in 1999. The aim of the waste bank was to encourage residents to segregate waste at source. The recyclables from households is purchased by the company for further processing and resale to the recycling industries. Such community waste bank was then also established at schools as “School Garbage Bank” where the school children bring recyclables from home and deposit at school collection point. The income received is then shared by the school and the student. Wongpanit is a classic example of use of market power by a formal private sector to integrate informal waste sector and the community as a whole. Such partnership with the formal private sector improves the informal sector's linkages to the industrial value chain.

5 Barriers to formalization

Formalization of informal sector is an entry point to the integration of informal sector into the formal waste management systems. Formalization offers many benefits to both the formal and especially the informal sector. But formalization is not easy in many circumstances. The benefits of formalization at times become barriers to formalization.

Legitimization of informal sector is one of the greatest benefits a formalization process can offer to the informal sector, but this in itself is taken as a risk of '*loss of identity'* by some. Resistance to get institutionalized is a strong difficulty of formalization. Institutionalization brings the informal recyclers into the closer and stricter scrutiny of the government. Need for licensing for operating waste management business (waste collection to operating recycling plants) forces the informal sector to pay tax and even invest in cleaner technologies of recycling and pollution control equipment as opposed to out of the tax and crude backyard recycling is considered as '*invasion*'. Changing government authorities' policies and priorities and bringing new non-waste sector small-and-medium scale-enterprises (SMEs) into the partnership brings an issue of '*territoriality*'.

- **Territoriality** and fierce competition over the waste economy is one of the important barriers to formalization. Informal sector does not want others to encroach upon their territory, lose their occupancy and income by sharing the space for collection, segregation of recyclables, and operating recycling plants etc. Such territorial behavior is also shown by the formal sector by prohibiting or neglecting the informal sector in solid waste management system.
- **'Invasion' of the business-tax and scrutiny for pollution activities**: Waste picking or recycling is not only a survival strategy or an occupation, but also a profitable business. Unlike formal sector, the informal sector remaining outside the taxation system and pollution control or abatement enjoys the high profitability of informal recycling. Once they are brought into a registered and licensed 'formal' system they are closely monitored, brought under national taxation system and are compelled to invest on pollution control technologies, which slices off their profitability. Fear of losing the profit and a risk of small players quitting from the business as they do not have initial investment for licensing and cleaner technologies is yet another challenge of formalization process. This close scrutiny is seen as an 'invasion' to their 'behind the door

businesses' which they otherwise would operate without paying the tax and investing on pollution control technologies.

- **Loss of identity**: Formalization process though legitimizes the informal sector as an important legal stakeholder in solid waste management, and gives a stronger bargaining position to deal with other government and formal private stakeholders. But institutionalization is also feared as the loss of independency and the possibility of forcible 'dismissal or merger' with the other government and/or formal private entrepreneurs.
- **Mistrust and lack of common grounds for formalization**: There are also the cases of mistrust on the motifs of local authorities and hence a very short-lived partnership between the formal and informal actors. Following is a case example from Africa, where the institutionalization and an authoritative partnership brought third party stakeholders to forcibly dissolve or sideline the informal sector into the new derived institutional arrangement. All these activities ultimately raised the hostility, mistrust, a short lived partnership, bitter experience and skepticism to formalization.

In 2003, the mayor of Addis Abada, Ethiopia, showed an interest to recognize informal collectors' role in household waste pre-collection services and attempted a "partnership" with informal actors in the waste sector. However, this new partnership could not flourish long, as by the end of 2003; the authorities advocated a need for further formalization of the pre-existing informal solid waste collecting enterprises. The government intervened in the sector by institutionalizing it and *introducing new actors* in the form of micro and small-scale enterprises (MSSEs). This intervention was carried out without prior consultation with the existing actors. The addition of new actors caused the rivalry, conflict and even a fierce and unhealthy competition on the collection fees, and even pushing some players out of the business. The hostility topped up with the authorities started issuing official letters signed and stamped and distributed to each household, giving an impression that the MSSEs were the only legitimate enterprises and urged the households to terminate their contract with the former collectors and to enter into a new contract with the newly institutionalized MSSEs. At times the conflicts became serious and triggered clashes. However, with time the MSSEs also faced serious challenges and failed to sustain service delivery at the newly introduced collection rates and often got dissolved after a short period of operation. This appeared as a second opportunity for the existing informal sector to re-conquer their spaces of operation. But, the earlier slashing of fees by the MSSEs has complicated the situation, as households may refuse to accept newly adjusted collection fees (Baudouin et al. 2010). Such incidents hence highlight that the formalization process has to be consultative and inclusive of the existing informal waste sector.

6 Examples of Formalization in Asia

Waste recycling in developing countries is being driven by the informal sector, which is often the outcome of poverty and other social-economic exclusions. But at the same time integration of informal sector recycling assist in poverty reduction, gender equality, education, job creation and environmental sustainability through social capital building. Social capital building is possible when the informal sector is formalized and ingrained in the large scale formal material recovery and recycling. Better working conditions, hygienic work space, secured jobs and wage, better living conditions for children, their schooling is parts of social capital building of informal sector workers. Therefore, integrated recycling not only increases the recycling rate with heavy mechanized technologies, but also uplifts the working and living conditions of informal workers.

Two experiences of formal recycling in Indonesia and Vietnam are presented below. Indonesian experience shows the possibility and positivity of social capital building through formal waste management and recycling. While the large scale MRF in Vietnam is also a welcoming feature of the formal waste economy. Both the cases provide respective approaches and lessons on formalization.

6.1 Socially Responsible Recycling Business: Banda Ache Plastic Recycling, Indonesia

This is an exemplary effort of doing socially responsible recycling business by addressing the issues of social capital building along with economic and environmental concerns. Banda Ache Plastic Recycling in Indonesia is a successful example of integration of the informal sector as the employees in the formal MRFs. Band Ache plastic recycling unit's operation is similar to any other plastic recycling business; however, the uniqueness to this is the approach of social capital building.

The Band Ache plastic recycling unit employs 17 workers (10 female and 7 male). The recycling capacity is 400 kg/day. These workers are the formally registered members to the recycling association "*Yayan Dawus Ulan Sampah* (Waste Recycling Association of Banda Aceh)". The association is supported by UNDP's Livelihood Programme, GIZ and AusCare. Most men workers are junk collectors, itinerant buyers and waste pickers in the landfill and operate the recycling machines, while female workers are engaged in cleaning, sorting activities. Figure 2 describes the generic process description of plastic recycling at the recycling unit.

In this recycling unit, waste pickers are employed and trained enough to identify category of plastic based on its packaging application performing effective segregation and sorting. As of 2011, 24 % of the waste workers have been trained technically. In case of turnover of staffs, the unit ensures training for the new

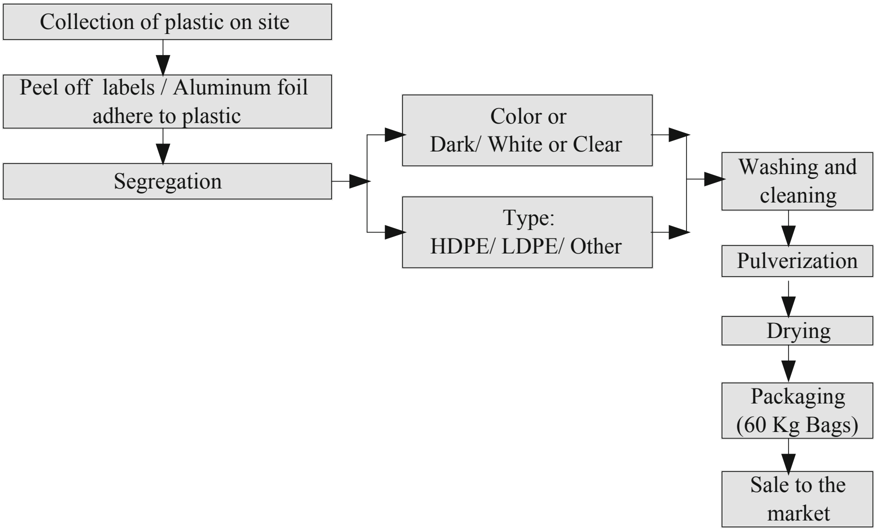

Fig. 2 Process description of Band Ache plastic recycling unit

entrants too. Waste pickers here are provided with basic facilities of clean and better environment such as toilet, temporary shed, clean drinking water, protective gears while working at the work space. Other social benefits include free elementary schools, job security, holiday entitlements, and regular and steady salary without fierce competition with fellow waste collectors, and middlemen's brokerage for the sale of recyclables. This arrangement is a win–win for both the informal sector where they are provided with employment opportunities in better conditions, and the formal recycling facility in return enjoys the dedicated and efficient labour force without any conflict with the informal sector.

6.2 Vietstar Lemna Eco Centre, Ho Chi Minh City, Vietnam

This is a typical example of formal recycling with heavy mechanized technologies and large scale recycling operation. This kind of large scale MRF is also required for increasing recycling business and overall recycling rate. However, a care must be taken to adapt this kind of formal structure by appropriately integrating the informal waste sector.

Vietstar Lemna Eco Centre is located in Phuoc Hiep village, Cu Chi district, about 38 km northwest of HCMC. This is an example of 100 % FDI from the technology provider, Lemna International, Inc., U.S.A. It has a total surface area of 77 hectares, consisting of a *windrow composting facility*, and a *plastic recycling unit*. The composting technology used here is able to utilize about 900 tonnes/day of garbage. The plastic recycling facility imported technology from Sanwa Co.

Ltd., Japan. Both the recycling units sadly suffer from incorrect waste characterization and hence are operating only at 50 % of its total design capacity (Visvanathan 2011). The company has contracted the HCMC authority for the stable supply of waste, but it doesn't involve the existing informal waste sector in the process. Since such huge amount of MSW is directly consumed by the material recovery facility (MRF), the informal waste scavengers' livelihood is affected.

One of the positive aspects of this MRF is the Vietnam government's provision of FDIs and tax benefits to encourage recycling business. Such investments from private sector shows a potential for expansion of recycling industries within Asia, however, the total exclusion of informal sector in such giant scale of operation is a matter of concern. Use of informal sector for waste input to the company by paying competitive prices can build a cooperative relationship with the informal sector than potential fierce competition and clashes. Also, training the workers and providing employment opportunities in the MRF is a win–win situation where the company enjoys cheap manual labor and the former enjoys better employment opportunities, and contributes towards waste management, environmental sustainability and poverty alleviation altogether.

7 Conclusions

Recycling in low income countries is more of a socio-economic phenomenon than an environmental concern. Presence of the informal sector recycling is the typical characteristics of recycling in these countries. However, because of its informal, unorganized nature, their contributions are often undervalued. Solutions to increase the overall recycling rate and achieving effective recycling in low-income-countries is possible through the recognition, strengthening, integration and reconciling of the informal sector recycling activity with modern integrated waste management systems. This kind of informal sector integration in Asia has opened the door for co-existence of informal and formal recycling stakeholders, but not perfected yet. Experiences show a hybrid recycling approach to be suitable in low-income countries, where recycling is neither too formally industrialized nor is completely left in the hands of informal sector.

The roadmap from formal and informal waste sector conflict to cooperation is not an easy task, and there is no one rule or one size fits models of formalization. There are various possible ways and examples of formal recycling that befits the local contexts. Rather than adopting the full-fledged gigantic MRFs and expecting to do 'wonders' in developing countries, it is wise to tailor the formalization as inter-sectoral partnership. Recognizing and partnering with existing informal sector (which needs to be organized as a group than individual competitors) and providing incentives (financial subsides, technology support and/or other capacity building support) for the informal recyclers should be the ways out for integration. It has to be understood that formalization of informal sector is not the absolute answer but certainly is a means of gaining trustworthy and a strong solidarity for sustainable recycling. Upgrading the recycling rate through international assistance (of technology, finance, and other capacity enhancement support) remains as another potential area of exploration for furthering the recycling efforts in low income countries.

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3R (Reduce, Reuse and Recycle) in Bangladesh

Tariq Bin Yousuf

1 Introduction

Rising waste volumes and increasing complexity of waste streams have become major and growing public health and environmental problems. Due to the growth of population and the changing lifestyles and consumption patterns of people; not only the quantity of waste generation is increasing, the quality and composition of waste is also changing particularly more and more hazardous and toxic waste are adding into the waste stream. To address the problem, waste has to be collected separately and more specific treatment is needed. This needs the mobilization of resources such as human, equipment and finance. It has to be viewed not only as a problem but also as an opportunity. There should be a paradigm shift in thinking about waste 'not merely as a nuisance but as a resource' and the shift of waste management 'from contain and disposal to resource management'.

In recent days, the 3Rs principle has started gaining more attention due to the depletion of natural resources and increase of pollution level in the environment. 3Rs is an approach that can promote the efficient use of resources, harmonizing both environmental and economic concerns through making efforts on waste reduction, reuse and recycling.

Figures 1 and 2 describes the changes in the flow of resources in the production to consumption and final disposal through both unsustainable pattern of economy and sustainable resource-efficient economy with 3Rs. The first diagram shows a 'one way' economy in which resource extraction, production, consumption and final disposal are open ended with little effort in resource-savings making environment at risk. The second diagram is a shift of End of Pipe to 3R a 'closed loop' of resource management in the production-consumption-disposal cycle with maximum utilization of resources and minimal waste production by reusing and recycling of by-products.

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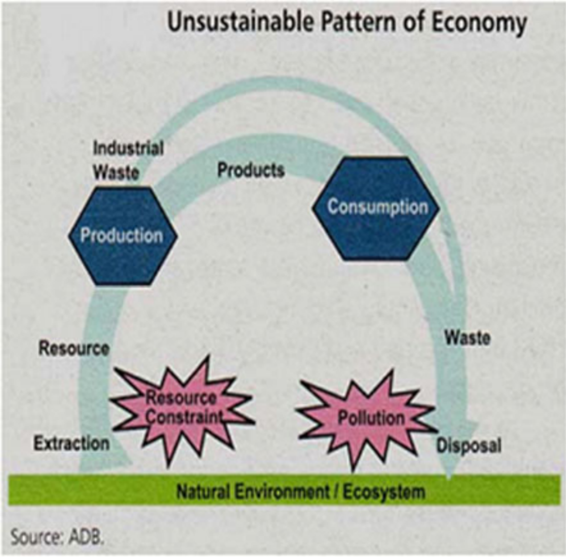

Fig. 1 Unsustainable pattern of economy

Fig. 2 Sustainable resource-efficient economy with 3Rs

2 Background of 3R Initiative

The importance of 3R is emphasized in many global agendas and action plans. Agenda 21 highlights to change consumption and production patterns for sustainable development. The Johannesburg Plan of Implementation (JPOI) adopted at the 2002 World Summit on Sustainable Development stipulated that all countries should promote sustainable consumption and production to facilitate global sustainable development. It has laid emphasis on developing waste management systems, with the highest priority placed on waste prevention and minimization, reuse and recycling and environmentally sound disposal facilities (AIT 2008). The thirtieth G8 Summit at Sea Island Georgia, US (June 2004) and the follow-up 3R Ministerial Meeting in Tokyo (April 2005) have directly or indirectly emphasized the critical need for reorienting production and consumption patterns through the effective implementation of 3R principles (Tokyo 3R Statement 2005). At the G8 summit, G8 countries agreed to launch the 3R Initiative in 2004 with the objectives of reducing barriers to the international flow of goods and materials for recycling and remanufacturing and building capacity for the 3Rs in the developing countries. The 3R Initiative towards a 'Sound Material Cycle Society' was formally launched at the 3R Ministerial meeting in Tokyo (Japan 2008). Since the late 1990s, China has been adopting 'Circular Economy Policy' with a shift of its strategies for environmental management from the end-of-pipe approach to integrated life cycle management (ISWA 2011). Activities of the 3R Initiative in Asia included a series of inter-governmental meetings and expert meeting with an outcome of adopting 'The Kobe action Plan'. The Kobe action plan has given emphasis to prioritize the 3Rs in the national development strategy (Kobe 3R Action Plan 2008). In 2009, the National 3R strategy Development Project has been implemented as a collaborative capacity development programme in six Asian countries including Bangladesh with the support of Ministry of Environment of Japan and United Nations Centre for Regional Development (UNCRD 2009).

3 Review of the National 3R (Reduce, Reuse and Recycling) Strategy for Waste Management

Department of Environment has formulated the National 3R (Reduce, Reuse and Recycle) strategy for Bangladesh having a series of national consultation meetings with the concern ministries and other potential stakeholders (UNCRD 2007). The strategy has been introduced with an intention to meet the challenges related to the continuous increase in waste generation and resource demand, intends to raise the priority of environmentally sound waste management and resource efficiency as well as increase in institutional capacity. This strategy has been ratified by the Government of Bangladesh (GOB) in 2010. The strategy sets the goal of waste reduction, reuse and recycling and minimizing waste disposal in open dumps, rivers, flood plains and landfills by 2015 and promotes recycling of waste through mandatory segregation of waste at source as well as creates a market for recycled products and provides incentives for recycling of wastes.

- It recognizes waste as a resource and advocates for segregation of waste at source.

- The strategy encourages emission reducing technology and tapping the potential of CDM provisions.
- It encourages the private sector investment.
- It promotes "polluters pay" principle as well as cleaner production and Environmental Management System (EMS).
- It supports the participation of the informal sectors who are engaged in the recycling of various materials.
- To promote 3R principles, the strategy recommends:
  - Raising public awareness,
  - Employing appropriate technology,
  - Setting up a 3R secretariat at Department of Environment (DoE),
  - Involving all stakeholder groups through Public–Private Partnership (PPP),
  - Funding through Clean Development Mechanism (CDM),
  - Segregation of waste at source and special treatment for hazardous waste.

It also defines the roles of government agencies, citizens, private sector agencies, NGOs and Media. The National 3R strategy directs the local government authorities to develop their own action plans with setting up of quantifiable targets and pursue organic waste recycling through composting, bio-gas and refused derived fuel.

4 Existing Situation of Recycling in Bangladesh

The process of recycling in Bangladesh is very much in practice informally without control of any statutory body. Recycling provides jobs for waste pickers, business for traders and commercial activities for the owners of certain mills and factories who use wastes as raw materials for producing saleable items. In many cases the recycling saves foreign exchange from importing the things that can be produced locally from wastes.

Recycling is mainly done through unorganized sector, an informal network of waste pickers (both from primary disposal points as well as intermediate/final disposal areas), door-to-door collectors, primary and secondary dealers, and finally the recycling industries. Recyclables (plastic, metal, glass, paper etc.) are mainly recycled informally by small and medium sized industries using local and inefficient technologies in an unhealthy working condition. They lack of modern affordable technology, knowhow, incentives and proper infrastructures. Solid waste management, poverty and recycling are closely linked. Recycling is mainly economics driven as it is a source of livelihood for many unemployed both man and woman. Significant number of women and children are involved in waste picking.

In Bangladesh, recovery and recycling occurs in three phases. In the first phase, the waste generators separate waste which has higher market value such as newspaper, bottles, and plastic containers and sell them to street hawkers. In the second phase, the scavengers are rummage through the wastes near the bins for collecting recyclable materials of low market value such as broken glass, cans, polythene which are discarded by households. The final phase is the collection of recyclable materials by the waste pickers from the waste vehicles immediately after unloading at dumpsites. Scavenging from an economic and social point of view, it economizes on resource use, reduces burden of waste disposal and contributes to environmental conservation. However, they work in wastes in a risky environment without due consideration to their occupational health and safety.

5 Source Segregation and 3R Project in Bangladesh

There is virtually no organized and planned source segregation in any part of Bangladesh. Segregation, if at all, is driven by economic factors except for healthcare waste in a limited scale due to regulatory requirements. Sorting is mostly done by unorganized sector (scavengers and rag pickers) and rarely done by waste generators. The efficiency of segregation is quite low as the unorganized sector tends to segregate only those waste materials which have relatively higher economic return in the recycling market. This segregation and sorting takes place in a very unsafe and hazardous condition. Despite the absence of organized segregation system, quite substantial amount of plastic, metal, paper, glass etc. are collected and recycled. A large number of people ranging from rag pickers to primary dealers, secondary dealers and recycling industries earn their living out of waste recycling.

In contrast, organic waste, which constitutes the largest portion in the waste stream, is often disposed of rather than being segregated and converted into compost, bio-gas etc. Composting is done by the private sectors from waste segregated at the plant. As no national targets have been set up to promote waste minimization, recycling and recovery, the City Corporations or municipalities have taken initiative for waste reduction through composting. However, demand and marketability of compost is found a big problem which forced to shut down of some of the composting plants.

Availability of funds to support waste segregation and recycling is a challenging issue. Municipalities are barely able to maintain the basic waste collection and disposal services, heavily subsidized by the government.

Pilot and demonstration projects could play a significant role in complementing the national 3R strategies and policies by motivating the general public, the private sector, and the other key stakeholders on the beneficial aspects and impacts of the 3Rs.

3R Pilot Project in Bangladesh

Ministry of Environment and Forest (MOEF) using the Climate Change Trust Fund initiated a demonstration project of 3R (First phase) in four communities in Dhaka and two communities in Chittagong. The main purpose of the project is to create awareness on source segregation and recycling of waste and reduction of emission of Green House Gases from waste. To address 100 tons of waste of 50,000 families, 70 thousand bins of three different color (Green = Organic, Yellow = Recyclable inorganic and Red = Hazardous) for Dhaka and 50 thousand for Chittagong has been distributed. 180 tricycle vans for Dhaka and 100 for Chittagong with three separate compartments have been made to collect three types of waste. For recycling of waste, in Dhaka a compost plant of 15 ton capacity and in Chittagong 10 ton capacity has been designed (Figs. 3, 4).

Composting Project Using Programmatic CDM

Department of Environment (DOE) is implementing composting project in four municipalities of Bangladesh in First phase under Climate Change Trust Fund using Programmatic CDM. The carbon credit under this programme will be shared between Department of Environment and the Municipalities.

Fig. 3 Source-segregation in three colored bins

Fig. 4 Three chambered waste collection vans for separate collection

6 Development of Action Plan for 3R for City Corporations

The National 3R strategy directs the relevant institutions e.g. local government bodies, industries, NGOs, trade bodies such as Chamber of Commerce and Industries to develop their own action plans for achieving National 3R goal in their respective areas. This Action Plan has been prepared for the City Corporations.

6.1 Objectives of the Action Plan

- To develop a network of stakeholders such as national, local governments, academia, scientific and research community, the private sector, media community, NGOs and the informal sectors for gradual implementation of the components of 3R strategies.
- Promote awareness among the general public including school children on the beneficial aspects of the 3Rs.
- Gradual implementation of the 3R activities such as source segregation, waste reduction and recycling activities.
- To put 3R into practice and creating a recycling oriented society.
- To address the issues of sustainable production, consumption and waste minimization through 3R approach.

6.2 Key Elements of 3R Action plan

6.2.1 Role of Relevant Stakeholders

Individual, households, community/neighborhood (clubs), Policy makers (ward councilors/officials), business community (SMEs, manufacturers), informal sectors (Waste pickers, secondary buyers), private sector, CBOs/NGOs, research and academic organizations etc. are the potential stakeholders for developing and implementing 3R action plan.

Stakeholders	Roles and responsibilities
Ministry of environment	(i) In order to promote and institutionalize effective 3R strategies/ policies, ministry of environment act as an appropriate political and economic platform in line with the needs and demands of the local community, businesses and the private sector (ii) Develop policies and guidelines with an objective to reducing waste production, reusing materials, and recycling waste for sustainable waste management (iii) Act as 3R focal point to guide the promotion and implementation of 3R strategies
Local government authorities (city corporations/ municipalities)	(i) The local government authorities can implement the national 3R strategies by initiating a range of projects and activities in collaboration with international partners and donors (ii) Arrange required infrastructure facilities/finances to implement the strategy (iii) Take initiative for the market of recyclable products (iv) Accommodate the informal sector in 3R activities
Donor communities	Bi-lateral/multi-lateral donors can provide both financial and technical resources to promote 3Rs by supporting a wide range of 3R related projects (Pilot/demonstration)
NGOs	NGOs can play an effective role in implementing 3R projects and can also act as advocates for the 3R promotion (awareness creation to secure community participation, community mobilization in the implementation of the strategy) bridge the ground-based activities such as behavioral change in source segregation, develop green purchasing habits etc.
Private sector	(i) Involvement in recycling activities (ii) Investment in 3R related projects (iii) Promotion of 3R through CSR
Local communities	The consent and participation of the local community is essential (i) Do source-segregation at household (ii) Co-operate municipalities to carry our 3R activities
Informal sector	(i) Play supportive role to promote separation and collection of waste at primary level (ii) Work in partnership with private sector, NGOs to promote 3R (iii) Improve their working condition to reduce health hazards (iv) Form co-operatives and establish rights to get justified price (v) Help to phase out children as waste pickers

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Stakeholders	Roles and responsibilities
Small and medium enterprises (SMEs)	(i) SMEs using recyclables as raw materials work closely with informal sector and create demand for recyclable materials (ii) Adopt cleaner technology and produce environment friendly products (iii) Improve health and safety of the workers
Media	(i) Coverage in print and electronic media of 3R activities (ii) Organize mass awareness raising campaign (iii) Publicity of good practices of 3R
Scientific, research and academic institutions	Research institutions both scientific and academic can conduct research programmes to develop and transfer environmentally sound technologies for the 3Rs. They can play the leading role in introducing and disseminating cleaner production technologies to industries, governments and communities through training, education programmes and other extension and outreach programmes

6.2.2 Awareness, Understanding and Involvement of 3R Activities in Society

Raising awareness of citizens is essential factor to introduce source separation and reduce amount of waste. Proper introduction of source segregation and 3R cannot be realized without citizen's support. Tools for behavioral change in source segregation of waste (Leaflets, stickers, electronic and print media support, billboards etc.), Promotion of 3R activities (TV commercial on SS, 3R songs), Environmental Education on 3R at school (Waste Bank), PR goods (Cap/T-shirt), 3R fair (Waste Market), Logo/branding etc. can be adopted.

6.2.3 3R Socialization: Partnership Building Between Stakeholders

3R is essentially multi-sectoral. Local Government, Environment, health, education, information, agriculture and other relevant ministries or agencies should work together for the promotion and implementation of 3R activities. NGOs, private sector and social organizations etc. should facilitate to bridging the work with the communities. According to 3R strategy, a 3R wing under the Ministry of Environment with subsequent Inter-ministerial committee, Technology Advisory Group and 3R secretariat has been established to guide the promotion and implementation of 3R strategy. However, to bring the 3R activities into practice in society, there should be participation from all actors and participation which could be ensured through formation of three 3R groups such as 3R promoters (official stakeholder network), 3R supporters (community based volunteer network) and 3R volunteers (young generation volunteer network). In addition, there should be establishment of 3R units in the City Corporations who will promote and

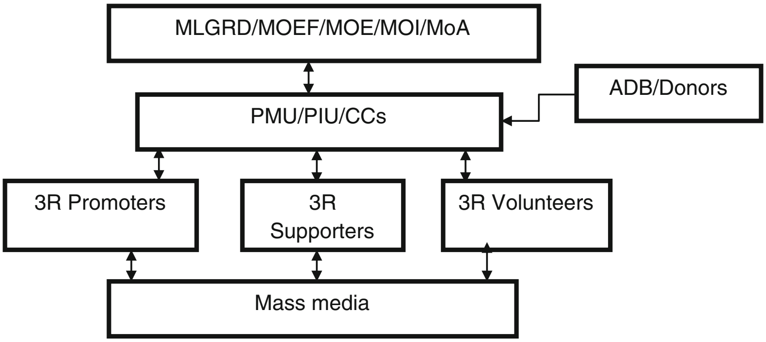

Fig. 5 3R networks of stakeholders. (3R promoters: government organizations, university and research institutions, private companies etc. 3R supporters: community groups, self-motivated citizen, women club, youth club etc. 3R volunteers: students etc.)

implement 3R activities. Mass media (Newspaper, Electronic media) should be joining on a regular basis for promoting the 3R activities. A combined 3R networks involving all stakeholders has been proposed in Fig. 5.

7 Components of 3R Action Plan

A Detailed Action plan has been prepared for the City Corporations with setting the following targets:

- Waste segregation at source: at least 1000 Households each year.
- Waste to be recycled by composting or bio-gas at least 10 % by 2013 on an incremental basis based on capacity.
- Waste to be disposed of at final disposal site is reduced at least 10 % by 2013 on an incremental basis based on capacity.

In order to achieve the targets set forth, the following actions are outlined below. The actions fall into the following categories: institutional, planning, awareness and behavior change, technical, and financial. These actions are then further divided into the following timeframe: short term (2013–2015), medium term (2016–2018) and long term (2019–2021).

Action	Timeline	Responsible organization
Short-term (2013–2015)		
Institutional		
1.0 Establishment of citizen environmental health management committee (CEHMC) in city corporation at ward level	2013	City corporations
2.0 Meeting of CEHMC involving all relevant stakeholders (twice in a year)	2013–2015	City corporations
3.0 Establish a 3R cell in city corporation	2013	City corporations
4.0 Formation of a 3R group involving the young volunteers and community people	2013	City corporations/community
5.0 Promote recycling event at school and community	2013–2015	City corporations/school authority/community
6.0 Development of material recovery facility (MRF) at secondary transfer station	2014	City corporations/small micro-enterprises (SMEs)/waste dealers
7.0 Formation of recyclers' association or co-operatives	2014	NGOs/SMEs/waste dealers/city corporations
8.0 Organize waste market (recyclable collection event) on holidays	2014	City corporations/recycler association/sponsoring company
9.0 Arrange land for integrated waste management facility including sanitary landfill for 20 year lifetime	2013–2014	City corporations
10.0 Arrange land for secondary transfer station	2013–2014	City corporations
Planning		
1.0 Prepare a survey plan for assessing the users service preferences, their ability and willingness to pay for SWM service	2013	City corporations/project management unit (PMU)
2.0 Mapping (Inventory) of solid waste generation, waste collectors (CBOs/NGOs), scavengers activity, secondary transfer/recyclable collection points, recycling centers/plants etc.	2013	City corporations/project management unit (PMU)
3.0 Integration/Institutionalization of informal sector in SWM system of City Corporation	2014	City corporations
4.0 Outsourcing of SWM service to the private sector (waste collection, integrated waste management facility etc.)	2013–2014	City corporations
5.0 Consultation with business community encouraging them to incorporate 3R activity in their CSR program	2014	City corporations/business community/corporate agencies

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Action	Timeline	Responsible organization
6.0 Inventory of E-waste situation	2013	Research organization/department of environment (DOE)/ ministry of environment and forest (MOEF)/city corporations
7.0 Preparation of E-waste management rules/guidelines	2013–2014	Research organization/DOE/ MOEF/city corporations
Awareness and behavior change		
1.0 Awareness raising on source segregation and 3R in the community		
(a) Distribution of instruction materials on source-segregation	2013–2015	City corporations/DOE/MOEF
(b) Distribution of 3R and composting/ biogas lesson material	2013–2015	City corporations/DOE/MOEF
(c)Conducting public relation activities such as community meeting, advertisement of 3R activities in local newspaper/billboard etc.	2013–2015	City corporations
(d) Promoting program on source-segregation at Goverment quarters, educational institute, apartments, hotels etc. (Bin/bag distribution, waste collection vans)	2013–2015	City corporations/DOE/MOEF/ PMU
(e) Organize a community clean and green campaign (including media campaign) (World environment day event)	2013–2015	City corporations/DOE/MOEF
2.0 Establishment of recyclable collection points (Waste bank model) and installation of composting bins at schools, community (at least 2 each year)	2013–2015	City corporations/DOE/MOEF/ ministry of education (MOE)/ community
3.0 3R Pilot project demonstration/ expansion under climate change trust fund	2013–2015	City corporations/DOE/MOEF
4.0 Conducting composting pilot projects at Government institutions and slums	2014–2015	City corporations/private sector/ public works department
5.0 Conducting training of trainers on 3R	2014–2015	DOE/MOEF/city corporations
6.0 Composting training program for households, slum dwellers, waste collectors, SMEs	2014–2015	City corporations/DOE/MOEF
7.0 Encouraging Goverment institution to use environment friendly goods/green purchasing (Jute bags, paper bags etc.)	2015	City corporations/DOE/MLGRD/ MOEF
8.0 Encouraging company to incorporate 3R programs in CSR activity	2014–2015	City corporations/MLGRD/ MOEF/business community
9.0 Awareness building on cleaner technology for industries	2014–2015	City corporations/DOE/ministry of industry/business community

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Action	Timeline	Responsible organization
10.0 Introduction of EMS (ISO 14001) in industries	2014–2015	City corporations/DOE/ministry of industries/business community/ private sector
Technical		
1.0 Construction and operation of secondary transfer station for improving collection efficiency	2013–2014	City corporations/PMU/Private sector
2.0 Design and manufacture of rickshaw vans for waste collection	2013	City corporations/PMU
3.0 Design, construction and operation of Integrated waste management facility including composting, sanitary landfill at city corporations	2013–2015	City corporations/PMU/private sector
Financial		
1.0 Development of financial management system of solid waste management (unit cost of street sweeping, waste collection, waste disposal, waste recycling etc.)	2013	City corporations/PMU
2.0 Improve city corporation revenue through		
(a) Collection of holding taxes including conservancy taxes	2013–2015	City corporations/MLGRD
(b) Collection of arrears of holding taxes including conservancy taxes	2013–2015	City corporations/MLGRD
3.0 Improve service delivery through outsourcing of solid waste management and medical waste management	2013–2014	City corporations/MLGRD/Private sector
4.0 Introduction of service charge for doorstep waste collection by CBOs/ NGOs/Private sector	2013–2015	City corporations/CBO/NGO/ community/private sector
5.0 Introduction of service charge from Healthcare establishments	2013–2015	City corporations/private contractor/health care establishments (HCEs)
6.0 Introduction of separate waste collection charge for commercial (hotel, restaurants etc.) and industrial establishments	2014–2015	City corporations/MLGRD
7.0 Introduction of waste collection charge for institutions/Government buildings	2014–2015	City corporations/MLGRD
Mid-term (2016–2018)		
Institutional		
1.0 Monitoring and evaluation of short-term program	2016	City corporations and MLGRD
2.0 Continue all the programs of short-term	2016–2018	City corporations

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Action	Timeline	Responsible organization
3.0 Establish UPEHD in local government division	2016	MLGRD
4.0 Advocacy and practice of green purchasing	2016–2018	Individual/city corporations/DOE/ business community
Planning		
1.0 Planning for regional waste management including landfill	2016	City corporations/MLGRD
2.0 Reserve land for proposed integrated waste management including landfilling	2016	City corporations/MLGRD
Financial		
1.0 Introduction of tipping fee for operation and maintenance of integrated waste management facility	2016-18	City corporations/MLGRD
2.0 Public consultation on tax increase for waste management	2016	City corporations
3.0 Introduction of pay as you throw for households	2018	City corporations/MLGRD
4.0 Introduction of polluters pay principle for industries	2016	City corporations/MLGRD/DOE/ MOEF
5.0 Introduction of incentives/ disincentives for waste management	2016	City corporations/MLGRD
Long-term (2019–2021)		
1.0 Monitoring and evaluation of mid-term program	2019	City corporations/MLGRD/DOE/ MOEF
2.0 Continue all the programs of mid-term	2019–2021	City corporations/DOE
3.0 Evaluate the achievements of 3R goal	2021	City corporations/DOE
4.0 Impact study on 3R in society	2021	City corporations/DOE/MLGRD/ MOEF
5.0 Evaluate the achievement sustainable production and consumption society	2021	City corporations/DOE/MLGRD/ MOEF

8 Conclusion

The action plan for 3R of the City Corporations has been formulated based on the guiding principles of the National 3R strategy. A realistic target has been set with gradual incremental percentage of attainment in consultation with the City Corporations based on their human and financial resources. Awareness raising, capacity building and political priority are important aspects to make the action plan workable. The ultimate goal of the action plan is to establish a recycling oriented society where sustainable production and consumption are realized with gradual implementation of the targets set in the 3R Action Plan.

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Municipal Solid Waste Management in Cambodia

Sour Sethy, Chin Sothun and Rachel Wildblood

1 Introduction

Solid waste has become an increasing concern in developing countries, particularly in urban poor areas. Cambodia is no exception to this, as a less developed country with a rapidly increasing and urbanized population. Population growth and increasing per capita consumption is leading to higher levels of waste generation, making the solid waste management system more complex. Most Cambodian waste collection, transportation and disposal in major cities and towns are provided by private companies under the supervision of local authorities and government technical line agencies. This leads to the primary concern being benefits to the private company rather than environmental and human health improvements. However, some provincial towns in Cambodia still do not have solid waste management services. Each household manages its own waste, through burning, or through illegal disposal onto vacant land or into water bodies. Generally, significant quantities of solid waste are found in public areas, on vacant land, low lying land and in wetland areas.

Solid wastes comprise all the wastes arising from human activities, including animal wastes that are discarded as useless or unwanted (Sethy 2003). The Cambodian sub-decree on Solid Waste Management was enacted in April 1999 and defines the key terms of 'solid waste' and 'garbage': "(1) Solid waste refers to hard objects, hard substances, products or refuse which are useless, disposed

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of, are intended to be disposed of, or required to be disposed of; (2) Garbage is the part of solid waste which does not contain toxin or hazardous substance, and is discarded from dwellings, public buildings, factories, markets, hotels, business buildings, restaurants, transport facilities, recreation sites, and etc."

The Ministry of Environment (MoE) (2004), classifies solid waste into three categories:

1. Domestic/household waste
2. Commercial waste (from businesses)
3. Industrial and Hazardous waste include hospital waste.

Cambodian legislation does not have a specific definition of municipal solid waste (MSW). However, based on generally accepted definitions of MSW, the main sources in Cambodia are domestic, commercial and institutional wastes. Besides coming direct from residential properties, MSW also comes from street sweepings, roadside litter (illegal disposal), landscape maintenance and tree trimmings, dead animals, dust and mud from transportation and municipal services.

2 Waste Generation and Composition

Cambodia's capital city, 23 provinces including 26 towns under provincial supervision (Census 2008), are all quickly developing their infrastructure and becoming more urbanized. Many towns within the provinces are extending their waste collection coverage, to include the increasing population. The Cambodian population is approximately 14 million people (Census 2008), generating around 6,818,000 tons/year of waste. This is based on the country's only available per capita waste figure of approximately 0.487 kg per capita per day for Phnom Penh (JICA 2005).

In general, waste management data for Cambodia are very limited. According to the MoE report (2004), solid waste generation in Phnom Penh municipality has increased from 14,500 to 240,859 tons/year from 1994 to 2003, of which approximately 62 % is collected and disposed (Table 1). A report by Phnom Penh Solid Waste Management Office shows that the waste generation has increased from 227,909 tons in 2004 to 438,000 tons in 2011. As for JICA (2005) estimates that Phnom Penh's waste generation is 340,000 tons/year (927 tons/day). In addition, an informal interview with an officer from Phnom Penh's Municipal office and the waste management company CINTRI in 2012 gave the amount of waste arising in Phnom Penh as approximately over 500,000 tons/year. These varying figures show a clear upward trend in waste generation but also show the unreliability of waste data in Cambodia in general.

Regarding waste composition, according to JICA (2005) waste in Cambodia comprises over 63 % organic kitchen waste, while plastic is about 15 % (Table 2). However the CSARO (1999) report shows that organic waste is 87 % and plastics

Table 1 Annual waste volume (tons) in Phnom Penh

Year	Volume	Year	Volume
1994	14,500	2003	240,859
1995	14,548	2004	227,909.683[a]
1996	15,264	2005	266,781.090[a]
1997	15,203	2006	324159[a]
1998	18,038	2007	343,657.38[a]
1999	20,440	2008	361,344.18[a]
2000	20,702	2009	393,044.86[a]
2001	21,050	2010	409,335.64[a]
2002	21,367	2011	438,000[a]

Source MoE 2004
[a] Waste Management Office of Phnom Penh Municipal Hall (2012). Note: waste density (400 kg/ m^3)

Table 2 Household waste composition

Composition (%)	Phnom Penh	Siem Reap[a]	Battambang[a]	Kampong Chhnang[a]
Kitchen waste	63.30	65.18	71.88	80.46
Textile	2.50	4.34	2.88	1.26
Grass and wood	6.80			
Metal	0.60	5.33	1.06	7.70
Ceramic and stone	1.50			
Paper	6.40	0.88	2.72	2.10
Plastic	15.50	8.85	8.61	3.30
Rubber and leather	0.10			
Bottle and glass	1.20	7.80	5.40	0.70
Others	2.10			

Source JICA 2005
[a] Department of Environmental Pollution Control (DoEPC), 2008

are 6 % (Fig. 1). This shows the variability in waste composition data for solid waste in Cambodia, showing that data reliability is a key challenge for MSW planning.

3 Current Solid Waste Management System

3.1 Collection and Transportation

Awareness of solid waste issues in Cambodia is poor. As a result, little attention is paid to proper waste management. Not all towns in Cambodia have an official waste collection system. Solid waste collection, transportation and disposal are properly undertaken only in Phnom Penh municipality, Preah Sihanouk, Siem

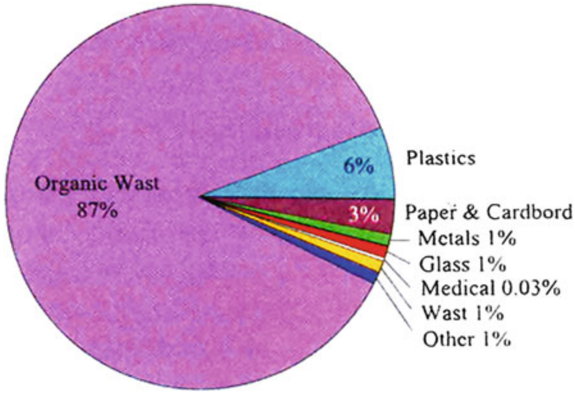

Fig. 1 Composition of solid waste in Phnom Penh. *Source* CSARO (1999)

Reap and Battambang towns, which are the major population centers. In some towns waste is only collected from markets. Therefore it is not possible to collect exact data on the solid waste generation in all the urban areas. However, based on MoE's report (2011) Table 3 shows that the proportion of waste collection and disposed in a provincial dumpsite is very variable. More touristy cities, e.g. Siem Reap have good waste management service coverage, but more remote provinces e.g. Preah Vihear, having a very low percentage of MSW collected.

Based on annual report made by Department of Environmental Pollution Control (DoEPC) in 2011, the amount of waste collected and transported to landfill in Phnom Penh was 20,702 tons in 2000, increasing to 409,335 tons in 2010 (Fig. 2) that resulted by increasing waste collection coverage areas and also city's extension.

The DoEPC also reported that waste collected and transported to dump sites in urban areas across the country is also increasing, indicating that waste collection coverage is improving (Fig. 3).

Several combined systems are used for waste collection and transportation in Cambodia. The curbside waste collection has been implemented only in a few cities including Phnom Penh. The waste trucks are generally open, resulting in odor and litter issues. Street sweeping is also implemented in only a few towns which are tourist focused (Phnom Penh, Siem Reap and Preah Sihanouk). In addition, where service providers are contracted, waste is collected from a number of waste containers in public areas.

3.2 Treatment and Disposal

Waste treatment is limited in Cambodia. Apart from small amounts of recyclable materials sorted out by the waste pickers and a few local NGOs, wastes are dumped at open dumpsites without any treatment.

Table 3 Waste generation and disposal into dump sites by towns

Name of towns and province	Waste generation (ton/day)	% of waste disposed into landfill/dump site
Takhmao, Kandal Province	116.0	34
Prey Veng, Prey Veng Province	17.2	32
Siem Reap, Siem Reap Province	130.0	85
Svay Rieng, Svay Rieng Province	2.1	75
Sihanouk, Sihanouk Province	110.0	73
Kampong Cham, Kampong Cham Province	35.0	71
Chbamon, Kampong Speu Province	19.7	67
Battambang, Battambang Province	80.0	63
Senmonorom, Mondulkiri Province	6.5	62
Kep, Kep Province	8.7	57
Steung Sen, Kampong Thom Province	31.8	36
Samrong, Odormeanchey Province	6.0	33
Kratie, Kratie Province	20.0	28
Kampong Chhnang, Kampong Chhnang Province	27.0	26
Khemarak Phoumin, Koh Kong Province	15.0	20
Daunkeo, Takeo Province	13.0	15
Pursat, Pursat Province	35.6	14
Kampot, Kampot Province	28.0	7
Serey Sophorn, Banteay Meanchey Province	168.0	6
Preah Vihear, Preah Vihear Province	9.6	6
Pailin, Pailin Province	8.0	0

Source Department of Environmental Pollution Control (MoE), 2011

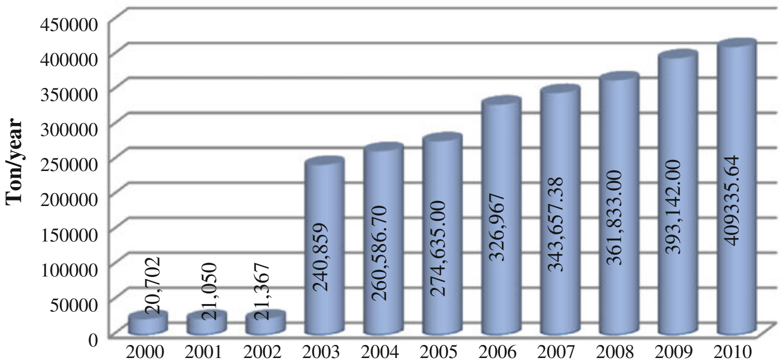

Fig. 2 Amount of solid waste disposed at Steung Mean Chey and Dangkor landfill. *Source* Department of Environmental Pollution Control (DoEPC), 2011

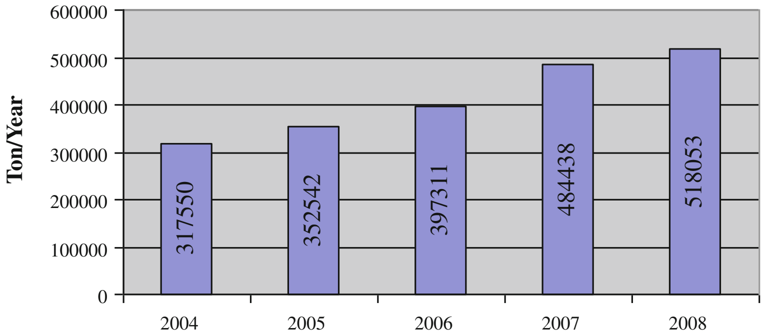

Fig. 3 Waste collection, transportation and disposal in Cambodia. *Source* DoEPC (2008)

There are no sanitary landfills, incinerators or other treatment facilities for industrial or municipal wastes. Therefore, municipal wastes are disposed of in open dumpsites except in Phnom Penh municipality where MSW waste goes to an engineered landfill.

DoEPC of Ministry of Environment (2011) states that the total number of dump sites in the whole country is approximately 72. The sites are generally open dumps, without fencing, covering or any management or control. This leads to environmental and human health impacts. Dump sites generate many flies and insects and other disease vectors as well as a bad odors which nearby residents or workers endure.

Some solid wastes are also illegally dumped on vacant land, public roads and waterways. JICA (2004) states that the percentages of waste illegally dumped in Phnom Penh is approximately 2.5 % in the centre and 15 % in the outskirts while percentage of burning is 15 % in the centre and 50 % in sub-urban areas. This demonstrates a general lack of control over MSW in Cambodia, and a lack of treatment and disposal facilities.

4 Legal Framework

4.1 Reduce, Reuse and Recycle: 3Rs

The practice of 3R's is active only in the major urban areas while in rural areas only practical material reuse is implemented. In rural and urban areas, informal waste recycling is undertaken by private recyclers and some NGOs but on a limited scale. Cambodia's recyclables collectors are generally either poorer people who collect recyclables from waste bins or illegal dumps, or collectors with a vehicle collecting metals and plastics from households and businesses (Wildblood 2008).

JICA 2004 states that 86 tons per day of material is recycled in Cambodia; CSARO states a figure of 1.5–2.0 tons/month. This demonstrates further data issues in Cambodia. However the informal recycling sector is very active in the collection and separation of value materials for recycling. In Phnom Penh the collected recyclables are estimated to reach 39.7 tons/day, or 4.3 % of the total waste generated in the Phnom Penh municipality (JICA 2004). The majority of recyclables are exported to Vietnam and Thailand, with little or no processing in Cambodia.

Waste composition analyses (Table 2) show household waste to have a high organic content, with market wastes likely to have even larger organic fractions. Therefore composting is a feasible alternative to disposal. However, composting is not widely practiced. According to a survey of 39 villagers in Sihanouk Ville only one respondent composts waste (Sethy 2008).

In order to improve waste management and to extend the implementation of the 3Rs the MoE developed a 3Rs national strategy in 2009, for the management of municipal and industrial waste. The purpose of the 3Rs is to ensure progress in recycling is environmentally sound, legally compliant and in line with technological developments.

The 3Rs strategies include plans to:

1. Develop 3R policy and regulations for effective waste management;
2. Develop awareness and promote the technical capacity of responsible officers including institutional strengthening to deal with the application of 3R initiatives;
3. Develop appropriate pilot projects focusing on urban household waste management; and
4. Disseminate the 3R policy and regulations in the public and private sectors.

Until now, the 3R policy implementation is still poor. Only few NGOs have carried out the waste recycles in the country while huge amount of the recyclable materials have exported to neighboring countries including Vietnam and Thailand.

4.2 Current MSW Policy and Future Developments

The 1999 sub-decree on Solid Waste Management established the legal basis for solid waste management together including MSW and hazardous wastes. The main purpose of the sub-decree is to regulate the solid waste management in order to protect human health and the conservation of bio-diversity. This sub-decree applies to all activities related to disposal, storage, collection, transportation, recycling, dumping of garbage and hazardous waste MoE (1999).

The crucial roles and responsibilities defined in the sub-decree (Article 4) state that the Ministry of Environment shall establish guidelines on disposal, collection, transport, storage, recycling, minimizing, and dumping of household waste in provinces and cities in order to ensure the management of household waste safely. The authorities of the provinces and cities shall establish a waste management plan in their provinces and cities.

Article 6 states that the Ministry shall also be responsible for monitoring the management of household waste, including disposal, collection, transport, storage, recycling. The enforcement of the sub-decree is not thorough; Article 7 states that waste disposal in public areas or any unauthorized site is prohibited. However it is clear from the number of illegal disposal sites that as yet, this Article is not yet fully enforced. The sub-decree also manages the import and export of household waste from Cambodia in Articles 9 and 10, as the issue of trans-frontier shipments of waste can cause health and environmental impacts, particularly in developing economies.

In addition, in order to support this sub-decree the Ministry of Interior and the Ministry of Environment established an inter-declaration together on solid waste management. This aims to support the local authorities and related agencies for effective implementation of solid waste management in their provinces or cities. The declaration is to ensure human health and improve, environmental quality and aesthetics and protection of biodiversity. In support of this aim the declaration introduced penalties of between $2.5 and $25 USD for beach of the sub-decree (MoI and MoE 2003).

5 Impacts of MSW on Climate Change

As a low income country, Cambodia produces less than 1 % of the world's carbon dioxide emissions, and is ranked at 181st out of 212 countries (CDIAC 2006). For Cambodia is it clear that the key issue is vulnerability to climate change, rather than its greenhouse gas emissions. However, although Cambodia is vulnerable to climate change, it is clear that a contribution to reducing the global impacts of climate change from emissions can be made by sound waste management. The focus of this can be on waste prevention at source and waste reduction through recycling. Particular attention should be paid to the organic waste stream which can degrade to produce methane, a potent greenhouse gas.

6 Local Case Study

Post-Implementation Survey on Community-Based Solid Waste Management[1]—A Pilot Project Extension, Sihanouk Ville, Cambodia, August 2008. Funded by: International Marine Organization (IMO)

[1] Technical adviser and the report preparation by Mr. Sour Sethy (Consultant), Department of Environmental Science, Royal University of Phnom Penh.

6.1 Introduction

A pilot project of community solid waste management and awareness raising was undertaken in Villages 1–5 in Sangkat 4, Preah Sihanouk. The project involved the private sector waste management company CINTRI, which agreed that the project could undertake a community waste pilot in Village 1 only; therefore in the remaining villages (2–5) the project was only able to offer awareness raising. Nevertheless, the post survey interview process includes the residents of all five villages.

This case study describes the post-implementation survey results which had the following Objectives:

Objective 1: Evaluate the performance of the solid waste management situation in the villages after the pilot project was introduced.
Objective 2: Identify shortfalls and constraints that need to be further addressed in order to improve and maintain the functionality of the current waste management system.

6.2 Methodology and Data Processing

The sample population for interview was randomly selected being comprised of 20 villagers from village 1 (group 17–29), five villagers each from villages 2–4, and four villagers from village 5 (Fig. 1).

A structured questionnaire was developed to obtain information on aspects of environmental issues, waste storage, transportation, and the willingness to pay. In addition primary data was obtained by direct observation, serving to confirm them of the responses given by residents. Short-term data collectors were trained to carry out the interviews.

The data obtained from the questionnaires was processed by computer using the SPSS statistical package. The software was used to generate standard tables, simple descriptive statistics, and perform quantitative analysis.

6.3 Current Waste Management System in the Community

6.3.1 Institutional Arrangements

The current waste management system in the study area involves the private waste management contract (CINTRI), the Preah Sihanouk Municipality, and the community itself.

During the pilot, the Municipality served as the project facilitator and coordinator. It initiated and successfully led the community in clean-up activities and has been providing necessary information relevant to waste management issues through training. The Municipality was responsible for monitoring the waste collection service by the private company by visiting the project site every 3 days to inspect the performance of the waste collection service.

The Community (residents) established a community waste management committees in each village. Each committee had between 6 and 12 members, all of whom received trainings in solid waste management provided by a technical assistance consultant. In turn the committee members played an important role in training other local people in the communities.

CINTRI supported and participated in the activities of cleaning up large volumes of uncollected waste in the communities. Before the project started the waste collection and the accompanying service fee charged by the private waste collection agency covered only a small part of the study areas. However, since the project, CINTRI extended its waste collection service.

6.4 Waste Collection Service

Following project implementation, the survey revealed that 67 % of respondents received the waste collection service while the remaining 33 % did not. Among those receiving the service the high percentage 90 % (18 respondents) from village 1 and only 42 % (eight respondents) in villages 2–5 said that the waste collection service was acceptable. According to data from the community of village 1, out of the total of 285 households in village 1,250 households (88 %) have received a waste collection service while only few percentage of residents in village 2–5, who lives along the main road only, have also received a waste collection service from CINTRI.

6.5 Household Waste Management

In Village 1, according to the results of the survey, all respondents said that since the project started they have never disposed of their waste into the street and 95 % of the interviews stated that they have never disposed of waste in the local stream or their backyard. The respondents confirmed that 65 % dispose of all their wastes into the garbage truck and public bins, 15 % dispose of ‘most’ of their waste this way, and 10 % dispose of ‘some’ of their waste through these methods. However 10 % of respondents still practice the burning and disposal of their waste into the open areas of the community.

The data indicate that the majority of the people in the communities understood the problems of solid waste and participated in the community solid waste management program. In reference to the state of the community environment, 90 % of the respondents stated that the communities are environmentally cleaner after project implementation, with less litter visible. The remaining 10 % feel the same situation exists as before the project. However, all respondents agreed that the community-based solid waste management is the best choice and an appropriate solution for their communities.

6.6 Waste Disposal In Villages 2–5

In these villages the project only offered training for the committee members and environmental public awareness building to the communities, because they, especially village 3, were already being serviced by the private company (CINTRI). Therefore these villages were included in the post-implementation survey.

The results of the training and public awareness building are seen as positive steps in engaging public participation in the solid waste collection and payment activities. According to the survey only 42 % (eight respondents) who receive waste collection service dispose all of their wastes into the garbage truck and public bins. The remaining residents still practice burning and disposing of waste in open areas and their back yard. However all respondents confirmed that community-based solid waste management is the best choice and the appropriate solution for their communities.

6.7 Waste Storage Points and Storage Bins

According to the survey it was revealed that household waste management is seen as the responsibility of the wife (about 54 %), the husband (23 %), and female adult (20 %). The remaining respondents stated that it is the responsibility of male adults and male children. It was important that the waste storage points were accessible by those responsible for household waste management, primarily women.

Field observations confirmed that the bins were placed at suitable locations as storage points, in regard to the distance from households that were supposed to bring and place their waste to the storage bins. However, the housekeeping of these storage areas was not ideal as was seen scattered near and around the bins.

Basket bins were used for temporary storage of the household waste in areas where the waste collection vehicles cannot access. A basket bin has the capacity to store at least 75 kg and is reserved for waste storage from nearby households for only 1 day. In total, 170 basket bins were produced under the project and used for the waste storage in the target areas which included 100 baskets bins for 4 participating schools.

6.8 Solid Waste Collection

Primary waste collection handled by the community in village 1, and CINTRI in the remaining villages 2–5. The Committees established in each village by the municipal facilitators assisted in building environmental awareness and training programs. Workers involved in the primary waste collection were selected by these committees to collect waste from the storage points and door to door of some households every day for secondary waste collection made by CINTRI.

Due to the difficult geographic location of the project area, CINTRI's waste collection trucks were able to access only to some parts of the area. In some places in the project area to which the collection vehicles of the company cannot access, temporary storage bins were placed at specific points; each household in the area brings their waste and dumps it into the bins. Each bin is reserved for waste from nearby households. Push carts are used to bring the waste from each bin to the collection points where vehicles can reach. The type of push cart was selected according to the geography and access conditions. A higher capacity push cart was too big and heavy for workers in hilly areas.

6.9 Recycling and Composting Activities

The interviews disclosed for some people in the community, it is a common practice (87 % of residents) to separate waste especially the recyclable and reusable materials. A high percentage (32 respondents) stated that the reason for waste separation is for additional income generation. The remaining respondents stated that they separate the wastes in order to reduce the amount of waste needing disposal, for environmental reasons and also because it has always been part of their behavior.

The results of the baseline survey showed that the organic component of the wastes in the project area is high. As a result, composting was recommended in the baseline study. However, the survey found that only one respondent composts waste although organic waste was commonly separated for animal feed. Village 1 is hilly with a small amount of land available, which makes it difficult to promote composting. However it is more applicable for villages 2–5 where land is available and the growing of vegetables takes place.

6.10 Willingness to Pay and Customer Service Satisfaction

A questionnaire checklist was used to understand the communitys' willingness to pay for waste collection service. Data analysis showed that about 15 % of surveyed households paid a monthly fee of more than 5,000 Riel (over $1.25 USD),

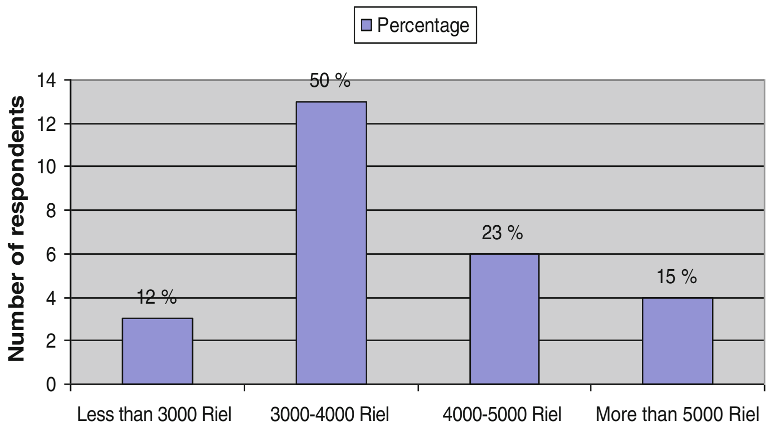

Fig. 4 Waste service fee (willingness to pay) by number and percentage for post-implementation survey 2008

23 % are willing to pay between 4,000 and 5,000 Riel ($1–1.25), and 50 % accepted to pay between 3,000 and 4,000 Riel ($0.75–1). Only 12 % responded to pay fee of less than $0.75 for the monthly collection service (Fig. 4).

Comparative analysis of the post-implementation survey and the baseline survey found that the willingness to pay for waste management post-implementation was higher than the baseline survey. The willingness to pay more than 5,000 Riel increased from 5.75 % in the baseline survey to 15 % in the post-implementation survey. This means that the environmental awareness and training in the communities proved effective for encouraging public participation.

The level of the satisfaction of the waste collection service was also surveyed. The questionnaire provided four categories for respondents in respect to their satisfaction with the service provider. The results are presented in Fig. 5.

Fig. 5 Satisfaction of the waste collection service

The main criticisms of the service providers related to the following issues: (1) the service is not reliable; (2) the frequency of the waste collection is too long; (3) the waste collectors/workers are rude in their behavior and, (4) a lack of the cleaning around the waste bins.

6.11 Fee Collection

Two service fee collectors were selected from the committees in the community collecting door to door. However, during the survey, they complained that some clients do not pay for the service. The committees in the community try to encourage payment by explaining to the public that payment for waste collection services pays for the workers, repairing push carts, the transportation fee by CINTRI, and some administrative expenditure.

6.12 Comparative Analysis of the Community Environment

In reference to analysis of the community environment three categories were provided in the questionnaire: (1) better than before, (2) the same and (3) worse than before. It was found that 35 respondents (90 %) stated that the environment was better than before the project was implemented, and four respondents (10 %) said it was the same. None of the respondents stated that the environment was worse than before.

Linked to environmental quality, residents were also surveyed about their health status. A high percentage of the respondents (92 %) stated that their health status was better than before; 8 % said the situation was the same as before. This may indicate that the environmental training and public awareness building, especially in respect to the collection system, has been appropriate and successful for these communities. None of the respondents stated that the health status was worse than before.

6.13 Case Study Findings and Discussion

In general the waste situation in the extension project areas improved through cooperation with CINTRI, the communitys' participation, and with the coordination from the Preah Sihanouk authority. In the places where previously piles of waste would be found, the areas were found to be clean. Many people were seen to change from disposing of waste in the local stream, the open road, and burning. Instead now that waste collection service is provided, waste is put into waste bins near residents' homes and some bring it to public containers. Even though the waste and environmental situation in the project areas have improved, the performance of the waste management system itself still needs much improvement.

Twenty-three percent (23 %) of the people receiving the waste collection service said that they are not satisfied. In general, complaints centered on the irregular service of the waste collection, as well as the behavior of collection staff. During the survey, the chief of the committee in the village 1 also complained that when a waste collector was asked to stop working, finding a replacement was difficult because the low salary offered.

For storage points, at the onset of the implementation of the pilot projects, many home owners accepted that storage points could be near their homes. However, based on the results of the survey, these householders changed their minds, wanting the bins placed further from their homes. They complained about the bad odor of the waste and the piles of waste at the storage points near their home. They blamed the irregular service of the waste collection for this problem.

The waste collection system coverage is still not available to all the communities, as currently service can only be offered on the main road, especially in villages 2–5 by the CINTRI. As a result, there are complaints from the people living in the communities about the lack of total service coverage. However, these complaints were considered beyond the responsibility of the project, as CINTRI only permitted the project to offer the public awareness building and training programs in the areas it services. Additionally, in some projects areas there were no roads at all, meaning waste collection is very difficult without a road network.

Regarding the willingness to pay, the survey found that the willingness to pay increased from the time of the baseline survey. This means that the people in the communities are interested in participating in waste management. However, some of the people living in the communities still do not accept the waste collection service because they do not want to pay. Some of them complained that as the service is not reliable and does not extend to all areas yet, payment for this level of service is not acceptable. Hence, an appropriate design for extending the coverage area and regular waste collection is the key issue in terms of increasing the public willingness to pay for the collection service.

Regarding the waste collection system, the majority of the complaints centered on the timing and low, irregular frequency of waste collection. Members of the community stated that waste is uncollected at times for 5 days, thus generating foul odors and attracting flies around the bins. These are key issues that need to be addressed. A suggestion from many people is that the waste collector should clean around the bins and collect the waste from the public container regularly and dispose it into the collection trucks. It was noted that during the survey only one waste collector was working as his collection partner had stopped therefore the Committee should find another worker. These issues of the waste collection frequency, transportation, and cleaning around the waste bins need be considered in the future development and improvement of the waste collection system.

Regarding disposal behaviors, at the time of the baseline survey almost all people living in the communities disposed of their waste illegally e.g. in the local stream. As a result environmental problems were significant. However, the survey shows communities have responded positively and as a result the environment has improved and is much cleaner meaning behavioral change regarding waste disposal is evident. Thus the public awareness and environmental training given by the project have produced successful changes in knowledge, attitudes, and behavior. Additional training on the management of waste in the community would continue to build awareness and appropriate behaviors towards a responsible and effective community waste management system.

Regarding fee collection system, key issues to be considered are: (1) the continuing collaboration of the local authorities in explanation and dialogue with the communities on the reasoning and logic of service fees, (2) continuing to build public awareness of the needs not only of the community, but also the service providers, (3) providing regular waste collection and transportation, (4) improve the cleaning around the waste bins and containers (5) educating the workers as to the proper way to behave in the community, so as to eliminate issues of their behavior.

6.14 Conclusion and Recommendation

Despite the short duration of the pilot project, a marked improvement in the environmental situation in the communities was observed. All of the respondents have stated that the environmental and health conditions in their communities are better than before and they are very pleased with these improvements. In order to establish a sustainable system of waste management in the communities, some recommendations were provided as a result of the post-implementation survey:

- The waste from the storage points should be regularly collected as scheduled.
- Training should continue to increase public awareness as not all residents were able to receive training during the pilot.
- Necessary funds should be allocated to the community waste management committee so that it can perform its tasks more effectively. This could be linked with an improved and effective fee collection system.
- The performance of the waste management system would operate much more effectively with an integrated approach where the financial, technical, and social elements are taken into consideration. The social aspect is vital, especially regarding altering people's behavior.
- All respondents agreed that the community-based waste management is an appropriate tool for solving environmental issues in their communities.

7 Conclusion

The waste management systems in Cambodia are varied. Curbside waste collection has been implemented only in a few cities such as Phnom Penh and other key population centers. Data on waste collection is poor which is likely to reflect the lack on importance placed on municipal waste management. Although the country has a comprehensive sub-decree on solid waste management, its enforcement is limited.

Available waste data do show that there is a clear trend upwards with more waste being generated each year, particularly in urban areas as the growing population becomes increasingly urbanized. Also the increase in resource use and consumerism is likely to be a factor in higher levels of waste generation.

The facilities for the treatment and disposal of municipal waste do not increase correspondingly to the volumes of waste generated. The country has approximately 71 dump sites and one engineered landfill. The dumps are home to many disease vectors, generating bad odors and impacting on the local environment.

The Government's 3R strategies were formulated for the effective management of municipal and industrial waste. However, the 3R strategies are not implemented widely yet. However, regardless of government led strategies, the informal recycling sector plays very important role in solid waste management in rural and urban areas. Collectors, pickers and scavengers all collect the valuable recyclable materials which are largely sent outside the country for processing, following limited treatment in Cambodia.

Finally it is concluded that municipal solid waste management in the country has improved, when compared to the last 10 years or so, with at least one engineered landfill and slowly increasing waste collection service coverage. The Government is showing it understands the need for improved waste management however it is still very poor in sub-urban and rural areas, with plenty of room for improvement.

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Municipal Solid Waste Management in China

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1 Introduction

China is one of the largest nations in the world, encompassing a vast area, with diversified nationalities and cultures, and a very large population. It is also the largest developing country and which has relatively poor infrastructures and an underdeveloped industry. China has been undergoing a rapid urbanization, resulting in the enormous generation of municipal solid waste (MSW). In terms of municipal solid waste management, no country has ever experienced such a rapid increase or such large in MSW quantities that China is now facing. Along with this rapidly growing waste stream, MSW treatment technology has been improved, environmental legal framework has been established and developed, and public environmental awareness has also been promoted in the past three decades, although the MSW management in China still facing many challenges.

2 Waste Generation and Composition

This chapter defines municipal solid waste, also known as garbage or refuse, as the waste originating in urban areas from residential, commercial, institutional, and municipal services sources. This definition of municipal solid waste does not include industrial (non-hazardous), agricultural, hazardous waste or sewage sludge. The common categories of MSW in China include kitchen waste, paper,

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plastic, fabric, metal, glass, pottery, brick and stones, batteries, and discarded household appliances, etc.

The characterization of MSW is not always consistent from different cities in China. Indeed, China might be divided geographically into at least two subparts, roughly the north and the south, according to the different MSW composition, with an approximate boundary along the Yangtze River. In the north of China, the weather is dry and cold for most seasons of year, with a fragile ecological environment and a vast area of desert and high plateau. By contrast, it is humid and hot for nearly the whole year in the south of China, especially in the provinces along the East China Sea and South China Sea. There are differences in their living and eating habits as well. While in the south, many kinds of soups are consumed because the weather is always hot; the food in the north is relatively dry.

As a result, the MSW in the north and south differ in terms of moisture, composites, odor, etc. The moisture in MSW in the north is around 30–50 %, compared with that in the south, which is around 40–60 %. The moisture of MSW in the north disappears rapidly because of the dry weather, without strong odor and severe corruption. By contrast, the MSW in the south may degrade and corrupt very quickly, producing strong odor and leachate. In the north, a great deal of coal is used for heat generation in the winter. Consequently, the proportion of coal ash in the MSW can be as high as 70 %. Currently, the number of cities using natural gas or coal gas as fuel is increasing in the north (also in the southern cities), and the coal ash content is decreasing as a consequence.

At present, about one half of the Chinese population lives in the 656 cities and over 23,000 towns. The population of these cities varies from 0.1 to 23 million. It should be pointed out that, especially in the small cities, the service area for organized MSW collection by the relevant authorities usually covers only a small central part of the cities. The MSW generated in the suburbs and small towns is often not collected at all.

The treatment and disposal of MSW in China started in the 1980s. Before 1990, the treatment and disposal rate of MSW in China was less than 2 %. Since the 1990s, the MSW management in China has been greatly improved. Over the last few years, the MSW generation has increased at an annual rate of 5.7 %. Especially during the years 2000–2005, the amount of MSW collected and transported increased by more than 35 million tons (Fig. 1). According to statistics, the amount of MSW collected and transported in the 656 municipalities reached 158 million tons by the end of 2010, with the harmless treatment rate of 77.9 %.

Table 1 shows the average composites of MSW in typical cities in China. As mentioned above, the situation may vary greatly from one city to another. Generally speaking, the contents of plastics and paper are gradually increasing, while those of coal ash decreasing. The construction and demolition wastes have increased in recent years as the rising of urbanization level. Food and ash wastes contents in Tibet and Nanjing are much higher than other cities.

The contents of recyclable wastes such as paper, plastics, metals, etc., are low. In fact, most of these wastes are collected and recovered by scavengers. The composite of MSW is determined in situ in landfills or dumping sites, not in the

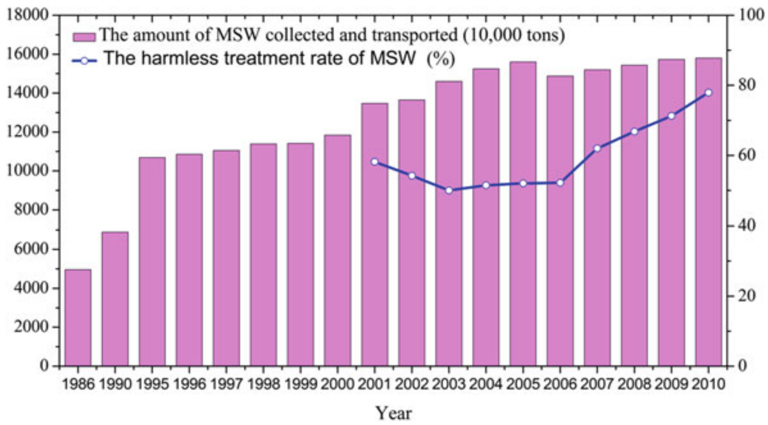


Fig. 1 The collected and transported MSW in China from 1986 to 2010

Table 1 Average MSW composition in typical cities in China present in landfills (wt %)

Cities (Year)	Organic garbage	Paper	Glass	Metals	Plastics	Textiles	Wood/timber	Ash
Beijing (2010)	63.40	11.10	1.60	0.30	12.70	2.50	1.80	6.60
Shanghai (2009)	66.70	4.46	2.72	0.27	19.98	1.80	1.21	2.77
Hangzhou (2009)	57.0	15.0	8.0	3.0	3.0	2.0	2.0	4.0
Yangzhou (2009)	57.81	10.49	3.05	0.45	16.08	3.78	2.10	6.84
Tibet (2009)	72.0	6.0	–	1.0	12.0	7.0	–	–
Shenzhen (2008)	51.10	8.40	3.00	1.10	14.70	6.90	5.90	8.90
Nanjin (2008)	70.59	8.32	1.45	0.08	14.18	3.05	1.04	1.29

generation sites of the MSW. In large cities such as Shanghai, Beijing and Guangzhou, the recyclable wastes are well recovered, including cans, cardboard, big pieces of wood, TV sets, nearly all kinds of plastics and glass bottles. However, used batteries, lamps, thermometers, etc., have not been collected separately but mixed with MSW, ultimately entering the landfills or dumping sites. In addition, the moisture in the MSW may vary from 30 to 65 % of the total weight, depending on the seasons and locations. In the rainy seasons, in the south of China, the moisture content is so high (over 65 %) that landfill operations become unacceptable.

The MSW yield per capita in China is shown in Table 2. Obviously, the average values are relatively low for urban areas, as only 0.61–1.15 kg per day/person is generated. Lower yield in Nanjing, situated in the Yangtze River Delta and with a population of 7.7 million, may be due to better recycling and reuse of the recyclable wastes including organic, electrical, glass, plastics and

Table 2 MSW yield per capita per day in large cities in China based on household waste

City	Yield (kg/day/person)	Year
Beijing	1.10	2009
Guangzhou	1.15	2009
Nanjing	0.61	2007
Shanghai	1.03	2009
Wuhan	0.73	2008

paper. The highest yield is found in Guangzhou, which is the political and cultural capital of the southern Chinese province of Guangdong.

3 Overview of Environmental Laws and Regulations

From the end of 1950s when China focused on development of heavy industry, environmental deterioration appeared. At that time, environmental considerations were not included in economic and industrialization plans. Superficial numbers or speed of economic development was of main concern. Low efficiency, waste of resources, and factitious arrangements of the industrial structure brought on environmental impacts which gradually showed their significance for many years, even to the present. The situation became serious during the period of the Cultural Revolution (1966–1976), when the country was politically unstable, and economics and social life were undergoing change. After the Cultural Revolution, there was a sudden bloom in industry and economy, in the early 1980s. Although the higher levels of the administration began to notice the significance of environmental issues, environmental awareness was far from necessary for the whole country. In many areas, only direct benefits were emphasized. Lacking proper planning, regulation and technology, environmental pollution and ecological damage markedly worsened.

After the late 1970s, China adapted the reform policy and opened itself to the outside world. When China stepped onto the rapid development track, as what happened in the developed countries, environmental deterioration also began. The China Government utilized the experience of the western world. A delegation was sent to attend the 1972 Stockholm Conference on Human and Environment. The First National Meeting on Environmental Protection was held in August 1973, and the first legal document was issued by the State Council based on the proposal of the meeting: Certain Regulations on Environmental Protection and Improvement. The Provisional Environmental Protection Law of the People's Republic of China was promulgated in 1979. Articles on environmental protection were added to the 1982 National Constitution of PR China. These formed the foundation for the environmental protection practices in China. Also at this initial stage, the regulations on "Three Wastes Control" (industrial wastes in three phases: solid, liquid, and gaseous) and "Three Simultaneities" (environmental facilities must be designed, constructed and operated along with the engineering project involved) which were first brought out played important roles for many years. "Three Simultaneities" with EIA (Environmental Impact Assessment) is now one of the noticeable features of China's environmental management.

In December 1983, at the Second National Meeting on Environmental Protection, it was officially announced that environmental protection be made one of the states "fundamental policies". The strategy was to plan, implement, and develop simultaneously, economic growth, urban and countryside construction, and environmental protection; so as to realize the continuing benefits of economic, environmental and social development. At the Third National Meeting on Environmental Protection held at the beginning of 1989, it was decided to enforce the following eight regulations: "Environmental Impact Assessment", "Three Simultaneities", "Discharge Fee for Industrial Pollutants", "Objective Responsibility", "Quantitative Evaluation on Integrated Management for Urban Environment", "Emission Permit", "Centralized Pollution Control", and "Timed Pollution Control".

Based on the experiences of industrial pollution control, the importance of Cleaner Production was recognized from the early 1990s. The emphasis of environmental protection began to turn from "End of Pipe Control" to control throughout the whole production process, from (discharge) "Concentration Regulation" to "Emission Total Control" (mass loading control), from separate pollution source control to centralized control. These symbolized the change in the direction of policy to guide industrial pollution control. In the same period, several official documents were formulated: "Ten Countermeasures for Environment and Development", "The Twenty-First Century Agenda", and "Environmental Protection Action Plan of China", etc., illustrating the adoption of the strategy of a sustainable development.

With respect to the challenges brought by the rapid economic development from 1990s, legislation and regulations in China have been enhanced quickly over the past ten years. For example, the existing Air Pollution Prevention and Control Law were enacted in 1995, and its revised new law was already announced at the end of 2000. The key points in the newly established laws include: a Mass Loading Control policy for key pollutants, an emission permit system, specified discharge fees regulations, more stringent violation punishments, and broadening of pollutants to include domestic heating boilers and straw burning in rural areas. Furthermore, new legislation recently published includes an Environmental Impact Assessment Law, a Cleaner Production Law, a Circular Economy Promotion Law, a Desertification Prevention Law, and a Nuclear Pollution Law. In terms of municipal solid waste management, Law on the Prevention and Control of Environmental Pollution by Solid Waste was implemented as of April 1, 2005.

4 Legislative Framework

4.1 Laws and Regulations

The legislative system on environmental protection in China is composed of the Constitution of the People's Republic of China, international conventions and pacts, the basic laws on environmental protection, laws for natural resource protection, environmental standards, and management regulations. From the 1979 Provisional Environmental Protection Law of PR China to the present, six environmental laws, nine natural resource conservation laws, over 990 environmental regulations have been promulgated. Meanwhile, China has signed and/or participated in 37 international environmental conventions. In the 1997 amended Criminal Law, an article on natural resource and environmental damaging sin was promulgated, which is an important step to promote environmental legislation.

4.2 Standards

As part of the legislative establishments, the environmental standards system of China was also initiated and developed since 1970s. In August 1973, the Provisional Standard for Industrial "Three Wastes" Discharge (GB J4-73), a result of the First National Meeting on Environmental Protection, was the first environmental standard in China. The respective items had been kept and put into effect when specific standards were issued.

After the Environmental Protection Law of the PR China was enacted, the environmental standards have gradually developed to form a comprehensive system. The structure of this system is best described in the issued Regulation on Environmental Standards Management in May 1999 by the State Environmental Protection Administration—SEPA. The standards are categorized into national (state) and local levels, as well as standards of SEPA. The State and SEPA standards apply to the whole country. Local standards apply to the respective regions, but when there is a state standard available, a local standard should be more strictly ruled out if applicable. When there is a need for a joint technique but lacks a state standard, a standard by SEPA should be issued.

At the state level, the environmental standards comprise mainly ambient quality standards and pollutant discharge (or control) standards. For implementation, there are also three technical standards: performance standards, sampling standards, and base standards. Performance standards are set to unify the procedure and analysis of monitoring, and calculation. Sampling standards are set for standardizing samples. Base standards include environment-specific terms, phrases, symbols, codes, icons, as well as guidelines. In addition, a number of ministerial standards have been established for special purposes. At provincial levels, environmental standards consist of the local ambient quality standards and pollutant discharge

Table 3 Major technical standard for MSW treatment and disposal in China

Composting	Sanitary Standard for the Innocent Treatment of Faecal (GB7959-1987)
	Control Standards for Municipal Solid Waste for Agricultural Use (GB8172-1987)
	Technical Specification for Static Aerobic Municipal Solid Waste Composting (CJ/T52-93)
	Technical Specification for Operation, Maintenance and Safety of Municipal Solid Waste Composting Plant (CJ/T 86-2000)
	Construction Standard for Municipal Solid Waste Composting Project (CJ 141-2010)
Landfill	Technical Code for Municipal Solid Waste Sanitary Landfill (CJJ17-2004)
	Standard for Pollution Control on the Landfill Site of Municipal Solid Waste (GB16889-2008)
	Technical Specification for Operation and Maintenance of Municipal Solid Waste Sanitary Landfill (CJJ93-2011)
	Construction Standard for Municipal Solid Waste Sanitary Landfill Project (CJ 124-2009)
	Standard of Assessment on Municipal Solid Waste Landfill (CJJ/T 107-2005)
	Technical Requirements for Site Utilization after Stabilization in Municipal Solid Waste Landfill (GB/T 25179-2010)
	Technical Code for Liner System of Municipal Solid Waste Landfill (CJJ 113-2007)
	Technical Requirement for Environmental Monitor on Sanitary Landfill Site of Domestic Refuse (GB/T 18772-2008)
Incineration	Technical code for Projects of Municipal Solid Waste Incineration (CJJ 90-2009)
	Standard for Pollution Control on the Municipal Solid Waste Incineration (GB 18485-2001)
	Municipal Solid Waste Incinerator (CJ/T 118-2000)
	Municipal Solid Waste Incineration Bottom Ash Aggregate (GB/T 25032-2010)
	Municipal Solid Waste Incineration Boiler (GB/T 18750-2002)
	Technical Specification for Operation Maintenance and Safety of Municipal Solid Waste Incineration Plant (CJJ 128-2009)
	Construction Standard for Municipal Solid Waste Incineration Project (CJ142-2010)

(or control) standards. Table 3 lists the major technical standards for MSW treatment and disposal in China.

4.3 Environmental Policy

"Three Wastes" policy illustrated the experiences gained from the resource wasting during the late 1950s development, and attention initially paid to industrial pollution and the emphasis on the benefits from waste-recycling and waste-reuse rather than on pollution prevention. In 1970s, the policy on "Three Wastes" evolved to environmental protection, which led to Provisional Standard for Industrial Three Wastes Discharge (1973) and Regulations on Industrial Three Wastes Treatment and Synthetic Utilization (1977).

Though the importance of environmental protection awakened China's top authorities since the 1972 Stockholm Conference on Human and Environment, however, environmental awareness followed in proper sequence from the lower level governments and the public. In 1980s, there was a sudden boom in industry and economy. Many small-scale enterprises, including numerous township enterprises engaged in the production of paper, chemical materials such as sulfur, dyes, textiles, etc., spread all over the country without the necessary environmental considerations. This period was probably the worst for the deterioration of China's natural resources and environment. Therefore, much stricter laws and regulations were enacted at the end of 1980s. A mass loading control policy was enacted for water and air pollution control. The production process control, mass loading control, and centralized control were widely promoted.

Ecological deterioration has also become rather severe in China, especially in the northern territory, where precipitation is limited and the land is over-grazed and over-developed. Soil erosion, shrinkage of biological diversity, poverty, deforestation, etc., has challenged the economic and social development.

5 Environmental Protection in Shanghai

Shanghai is the largest industrial and commercial city in China, with a total population of over 23 million and an area of 6,340 km^2. Because of its industrial and economic importance, the localization of environmental laws and regulations is most often practiced in Shanghai. Under the State Laws on environmental protection, scientific research and public participation, in the form of on-site surveying and expertise consultation with experts, standards and regulations were formulated to suit the local conditions. For example, after the 1973 state discharge standards (GB J4-73) for industrial "Three Wastes", two research projects which were carried out and completed in 1975, were the basis for the two provisional discharge standards (1975) for industrial waste waters and waste gases. Most control items in these two standards were stricter than the corresponding state standards. Similarly, Shanghai promulgated a number of environmental regulations and management methods, including the Regulation on Environmental Protection of Shanghai (1993, 1997).

6 Current Status of Municipal Solid Waste Management

Up to 1984, MSW being transferred and used as organic fertilizer in the agricultural field around the city has been the main MSW treatment method. However, the farmers rejected the organic fertilizer from MSW as the quantity of non-biodegradable matters such as plastics and construction demolition tailings increased. Hence, more and more MSW has been dumped in the suburbs since

1985 and over 20,000 dumping sites could be traced across China and over 200 sites in Shanghai Municipality in the Year 2000.

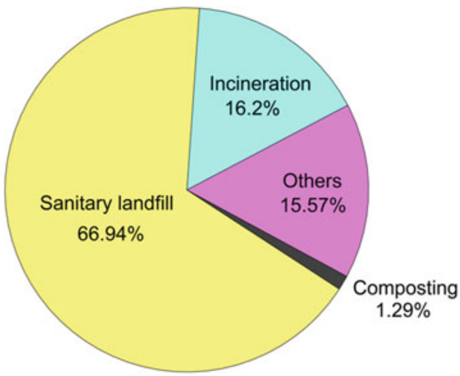
Meanwhile, the collected MSW quantity increase fast, as the urbanization rate accelerated and the urban population expanded exponentially. Around 5 million tons of MSW were collected in the Chinese cities in 1984, which increased dramatically to 100 million tons in 2000 and 158 million tons in 2010. The dramatic increase of heating values of the MSW mainly because of the high content of plastics and papers, while those of coal ash decreased, as the use of coal in the cities decreased considerately, though the moisture was up to over 65 % in the summer when a huge quantity of fruit, such as water melon, was consumed.

The classification and separated collection of wastes are poorly practiced. Although that, as there are a lot of poor people, it is estimated that at least 1/3 of the waste is scavenged and separated from the transfer stations and collection facilities by scavengers. The materials scavenged include newspapers, cardboards, packaging materials, plastic, beer bottles, cans, electric and electronic devices.

Currently, sanitary landfills and incineration are still the main treatment approaches in China, followed by composting and dumping sites (Fig. 2). In 2010, around 158 million tons of MSW were collected in the cities, the MSW treatment and disposal capacity in the 656 municipalities reached 143 million tons by the end of 2010, with the harmless treatment rate of 77.9 %. Among the wastes collected, around 66.94 % was sanitary-landfilled, 16.20 % was incinerated, 1.29 % was composted, and the balance is dumped at random.

By the year 2010, 498 sanitary landfill sites have been constructed in China, and the MSW quantity disposed at sanitary landfills increased from 180,000 tons/day in 2001 to 290,000 tons/day in 2010 gradually (Fig. 3). Many new landfills constructed in recent years employ high-density polyethylene membrane (HDPE) liner to improve anti-leakage capability. Some large-scale landfills use landfill compaction machines to improve landfill operation efficiency. Some landfill sites in Hangzhou, Guangzhou, Nanjing, Shenzhen, Beijing, etc. have started to collect and recycle landfill gasses. In October 1998, the first landfill gas power plant was built in Hangzhou Tianziling Landfill Site. All these practices have provided a solid foundation for the normalized construction of sanitary landfill sites.

Fig. 2 MSW management methods used in China 2010



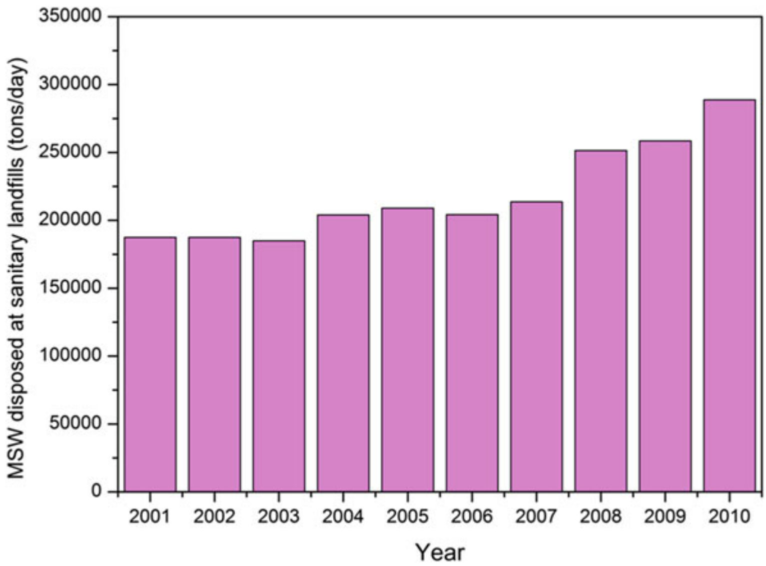


Fig. 3 MSW disposed at sanitary landfills in China from 2001 to 2010

Refuse in landfills becomes stabilized or aged as referred to in this chapter, as organic matter in the refuse gradually degrades and as the soluble inorganic substances dissolve during their long-term stabilization process. The mineralization extents of the aged refuse is certainly dependent on the age of refuse placed in landfills. In this chapter, this process is referred to as mineralization process and the resultant stabilized or essentially stabilized refuse is referred to as "aged refuse". The aged refuse contains a wide spectrum and a large quantity of microorganisms, which have a strong decomposition capability for refractory organic matter present in some wastewaters, such as leachate. In a study, aged refuse excavated from 2 to 10 year old closed landfill compartments in Shanghai Refuse Landfill is characterized in terms of particulate distribution by screening, and a biofilter consisting of 10 year old aged refuse was then used for biofiltration of leachate sampled from the landfill. Typically, 400 kg of screened aged refuse with a limiting diameter of less than 15 mm was used as biofiltration materials in a round shape biofilter with 80 cm of inner diameter and 80 cm of height. Leachate with initial COD, BOD, and NH_3–N concentrations of 3,000–7,000 mg/L, 540–1,500 mg/L, and 500–800 mg/L, respectively, was passed through the biofilter. As a result, the corresponding concentrations in the effluent were reduced to lower than 100–350 mg/L, 10–200 mg/L, 10–25 mg/L, respectively, 90–99 % removal for these parameters at a hydraulic load of 80–200 L/m^3 refuse/day. The color of the effluent was slight grey, in comparison with the heavy brown in the influent.

The treatment efficiencies heavily depend on hydraulic load, BOD/COD ratios in leachate and preliminary treatment of aged refuse. A variety of leachate with various BOD/COD ratios was tested. It is found that effluent will deteriorate when BOD/COD ratios are lower than 0.1–0.2. Increase of hydraulic load results to decrease of removal efficiencies. Removal of stone, plastics, glass etc., from the aged refuse will improve the treatment. A pilot test was conducted at Shanghai Refuse Landfill and the experimental results obtained at the laboratory were verified. The capital and operational costs are estimated to be around 20–30 % those of traditional processes such as activated sludge method, upper anaerobic sludge bed, sequence biological reactor, etc., and their combinations. Currently, over 15 aged-refuse-bioreactors were operated for the effective treatment of leachate and all work very well, with a scale of 70–1,400 ton leachate/day.

Solid waste incineration has made a substantial progress since it was introduced. In 1985, Shenzhen City imported the first and second units of waste incinerators with a capacity of 150 tons per day each from Mitsubishi Heavy Industries and built the first modern waste incineration plant and a third incinerator started work at the end of 1994. The equipment localization level of the third project reached over 80 %, and the technical performance of the equipment also reached OEM level. In 2000, Wenzhou City constructed an incineration power plant with independent intellectual property rights and complete localization of manufacture. All these achievements have forged solid foundation for localization of large-scale incineration equipment in China. Meanwhile, the incineration power plants built in some cities such as Shanghai, Ningbo, Shenzhen, Wenzhou have been put into operation. Most of these incineration power plants use the latest grate incineration technologies, which were constructed with the aid of foreign funds, key technologies or equipment.

All the incineration plants are in accordance with more stringent pollution control standards. In the past 10 years, a growing number of cities, both in coastal region and western region (e.g., Chongqing), are switching to incineration as the preferable option in MSW treatment, as shown in Fig. 4. By the year 2010, 120 MSW incinerating plants have been completed, and the total incineration capacity reached 71,200 ton/day, about 25 times that of 2000. It is expected that the proportion of China urban waste that is incinerated will reach a rate of 30 % by 2020, and thus incineration would play an increasingly important role in MSW management in China in the coming decade.

Fly ash and bottom ash are the main by-products in the incineration process and have been studied extensively. Fly ash has been classified as a hazardous waste due to the presence of leachable heavy metals Zn, Cu, Hg, Cd, Cr, As, Ni and dioxins, which need to be disposed of carefully. SEM, EDS, XRD, IR, ICP, DTA-TGA, soil tests, laser-size analysis were used to characterize the fly ash and glazed tile thus obtained using the fly ash, both microscopically and macroscopically. It is found that the main contaminative heavy metals and the sequence of their leachability are determined to be Cd, Hg, Zn and Pb, and the corresponding volatility sequence of volatile heavy metals is found to be Hg, As, Pb, Cd, and Zn, with Cr, Ni and Cu registering the minimum volatility. When the fly ash was treated alone at a high temperature, below 1,150 °C, Cr could change into a more active form and leachability of Zn and Pb could exceed the China National

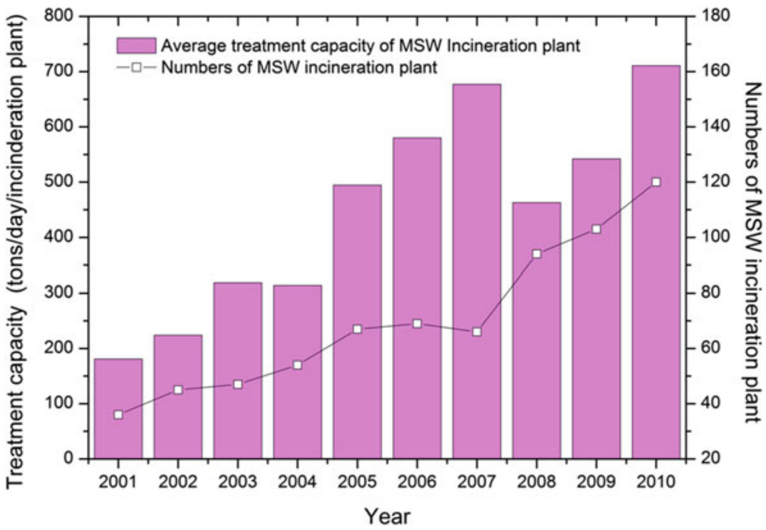


Fig. 4 Number of MSW incineration plant and its average treatment capacity in China from 2001 to 2010

Standard. Hence, fly ash was used as one of materials for yellow glazed tile making (named as Y-series hereinafter). It is observed that fly ash plays a key role in the sintering of the Y-series glazed tile, with the optimum mixture ratios of 20 % ash, 60 % cream-colored argil, 10 % ripe sand, and 10 % feldspar.

It was found that the bottom ash comprised mainly of glass, synthetic ceramics, metals, minerals such as silicates, phosphates, sulfates or carbonates, and some unburned organic matters. Over 60 % of the bottom ash was >4 mm in size. The chemical composition of the bottom ash was analyzed by X-ray fluorescence (XRF) method. The results indicated that the bottom ashes were mainly composed of SiO_2 (35.3–42.3 %), CaO (19–27.2 %), Al_2O_3 (7.4–7.8 %) and Fe_2O_3 (3.9–5.1 %). The contents of CaO, P_2O_5, MgO, TiO_2 increased and SiO_2, Al_2O_3, Fe_2O_3, Na_2O, K_2O decreased, as the particle size of the bottom ash decreased. Moreover, the concentrations of heavy metals also increased as the particle size of bottom ashes decreased. It may be considered that the coarser particles may originate from the wastes incinerated and the smaller ones are formed during the incineration process. The contents of heavy metals in both the bottom ash and fly ash were found to be inter-related and depended on the volatilization of the heavy metals involved. The heavy metals with low volatilization mainly remained in the bottom ash. The heavy metals in bottom ash were mainly present as carbonates and in residual forms with high stabilization. The leachability of heavy metals in the bottom ashes were lower than the leachability toxicity limit of wastes according to the China leaching standard and USA TCLP and could be treated as a non-hazardous waste for use as building materials, etc.

Composting, as one of the earliest solid waste treatment technology, has been widely used from the early stage of MSW management in China. The low cost composting system such as the open static pile composting system is widely used in the majority of waste composting plants in China. During 1980s, research on dynamic composting technology with a high degree of mechanization has been conducted extensively in China, and substantial results have been achieved. In the middle of 1990s, China established a series of demonstration projects of dynamic composting application, including the Changzhou Comprehensive Environment and Sanitation Plant, Beijing Nangong Composting Plant and Shanghai Pudong Composting Plant. Unfortunately, the compost product had limited outcome and even had to be landfilled. Therefore, the numbers of MSW composting facility and its treatment capacity were decreased dramatically in the past decade in China (Fig. 5), in which the number of MSW composting facility decreased from 134 to 11, and the total treatment capacity decreased from 25,461 to 5,480 tons/day. The uses of the compost for non-fertilizer use, such as for the remediation of PCB/PAHs polluted soil, need to be developed.

The China Government is making a great effort to improve the urban living garbage harmless treatment level. According to the '12th Five-Year' national urban life garbage treatment facilities construction plan, issued by China State Council recently, a total of more than 2,200 MSW treatment facilities would be constructed in the cities and towns in China from 2012 to 2015. Specifically, 264 MSW incinerating plants with the treatment capacity of 223,000 ton/day, 1875 MSW sanitary landfills with the treatment capacity of 323,000 ton/day, and 112 other treatment facilities with the treatment capacity of 35,000 ton/day would be

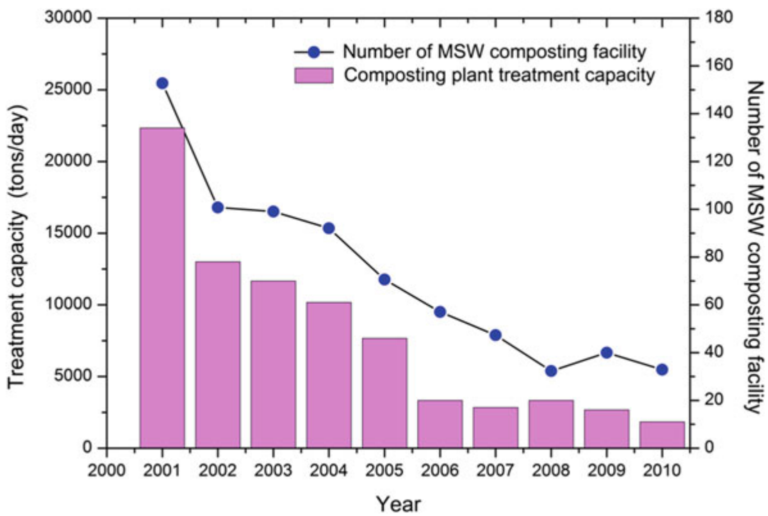


Fig. 5 Number of MSW composting facility and its total treatment capacity in China from 2001 to 2010

accomplished by 2015. In order to implement this plan, a special fund of totaled 260 billion Yuan was allocated by China Government.

There needs to be awareness that, with the rapid development of the economy, urban construction and the rapid increase in population, MSW will bring about a serious challenge to urban areas. The MSW management in China is still in its early stage of development, where the investment in waste treatment projects is rather insufficient compared with the actual demand. The MSW management remains at a very low level, with large amounts of solid waste being disposed of in open dumps. The uncontrolled dumping of solid waste and secondary pollution in waste treatment facilities not only occupy valuable land resource, but also bring about problems to the surrounding environment, thus compromising the living standard of people and affecting the sustainable development of the society. The statistics for 2010 show that 67 % of MSW is treated in sanitary landfills, 16 % incinerated, 1.3 % composted and the balance simply dumped.

China is a developing country not only in its economy but also in science and technology. However, for solid waste management in China, technology does not seem to be the key limiting factor obstructing the development of solid waste management although it needs to be improved in the future. In past years, great deals of feasible and cost-effective technologies have been developed, and some of them have been applied in the completed and ongoing projects.

Nearly all of solid waste management expenditure, including capital investment and operational costs, come from the finances of local governments, which is largely different from industrialized countries. Such a situation has made the advancement of MSW treatment lag behind the economic development. Moreover, many Chinese still think that solid waste management is the duty of the government. Action for in situ sorting and separation for MSW at home is also difficult to practice, though local governments and the NGOs have made a great effort for this merit. Hence, responsibility of the public towards the environment needs to be awakened.

Recently, the central government and local governments have issued policies encouraging the private investors to invest the MSW treatment engineering project, including sanitary landfills and incineration for power generation (waste to energy). China opened its MSW management market to the private, especially to the foreign owners, since 1990s'. It is estimated that around 30–40 % MSW projects are owned by the private or the joint venture co-owned by the private and the public. The stakeholders include internationally-recognized companies from France, Japan, Germany, and USA.

The main forces for the MSW management in China are still the state-owned companies, small or large, with a staff of from a dozen to several thousands, depending the scale of cities and the quantity of MSW collected. Nearly all the MSW is collected and transferred by the state-owned companies of the local governments. Several large scale state-owned companies have grown in the recent years and can act in compliance with the rapid increase of MSW quantity.

7 Greenhouse Gas Mitigation from Municipal Solid Waste Landfills

Methane is a main greenhouse gas, 12 % of which may come from municipal solid waste (MSW) landfills, and above 80 % of refuse is landfilled currently in China. Meanwhile, around 70 % landfill gas is estimated to enter into the air directly, even a few efficient collection system is installed. The mitigation measures for the landfill gases have been extensively studied.

The methane oxidation capacity of the original and modified aged refuse (the mixture of aged refuse with aged sludge (AS)/fresh sludge (FS)/nitrate minimal salt (NMS)) was investigated as biocover for methane mitigation from landfills. 79–92 % of methane can be biologically converted to CO_2 by the original aged refuse. Methanotrophic DNA and PCR analysis exhibited a greater active community in the aged refuse belonging to type I group, and the amounts of bacteria in aged refuse showed the advantage of biological diversity in contrast to aged sludge and soil. It is recommended to use aged refuse as the cover for landfills so that the methane emitted can be biologically oxidized.

Moreover, the combination process "wind-heat-bacteria", which consisted of the cowl at the exit of exhaust pipeline and aged refuse around the pipeline, was further studied. The process takes advantage of the enhancement of natural ventilation and capacity of oxidation bacteria. Methane concentration could maintain below 10 % with cowl driven by "wind and heat", and Scatter Matrix studies indicated that methane, carbon dioxide, and oxygen concentration were interacted each other. Methane oxidation rate can be up to 97 % in this combination process of "wind-heat-bacteria". Over all of the factors, thickness of filled aged refuse and NMS were the main factors influencing the bio-oxidation capacity of aged refuse.

The inhibition capacity of chlorinated methane, anthraquinone and acetylene on methanogenesis in the anaerobic digestion process of biodegradable solid wastes were also investigated. Both chloroform and acetylene could effectively inhibit methanogens. Acetylene inhibited the activity of methanogens, while chloroform inhibited metabolic process of methanogenesis. Acetylene promoted the inhibition efficiency more effectively than chloroform. Methanogens can be inhibited effectively in the presence of chlorinated methane, anthraquinone or acetylene, while the stabilization process of solid wastes can still work well.

8 Challenges and R&D on MSW Management

Leachate from landfills and incineration plants, around 15–30 % of the MSW to be daily treated, is still a great challenge for MSW management in China. The pollutants concentrations in leachate are very high, with COD 5,000–65,000 mg/L, NH_3–N 200–3,000 mg/L, and a required discharge standard of COD < 60 mg/L and NH_3-N < 15 mg/L and TN < 40 mg/L, respectively. The most popular treatment process for leachate include holding tank with 90 days retention time and a COD reduction of over 50 %, followed by SBR or MBR for further reduction of COD and NH_3–N and TN, polished by NF and RO so that the COD and NH_3–N and TN in the end effluent can reach the discharge standards. In this process, the most challenging issue is the way-out of the resultant high-strength concentrated liquid from RO system, about 20–30 % of the fresh leachate filtered by the RO. No cost-effective treatment for the liquid has been developed or can be reasonably selected, among choices of the re-circulation into the landfill mass or evaporation, as the former leading to the accumulation of salts and conductivity and the latter leading to the unacceptable operation costs and heavy corrosion of the equipment.

Fly ash generated from incineration plants, about 2–5 % of the wastes to be incinerated, has not been well treated. It is required that the fly ash be stabilized using chemical binders and then landfilled in a MSW sanitary landfill, when the stabilized fly ash reaches the toxicity leachability level set by the regulations mainly focused on the heavy metals release characteristics. Technology for molting and uses as cement material, have remained unsolved, as the ash contains quite a great proportion of insoluble chlorine and salts, and a unacceptable cost. It is difficult to remove these components from the ash using the available techniques.

There were nearly no research activities on MSW treatment in China before 1984, as the wastes were dumped or transferred to the surrounding countryside. In 1984, then China Ministry of Urban and Countryside Construction funded the first research project on the composting of organic wastes and an engineering project on a scale of 100 ton/day composting. Several composting plants have been established since then.

At the end of 1984, the China Government founded the National Natural Science Foundation and a few basic research projects were supported, such as the stabilization process of MSW landfill, composting process, remediation of dumping sites, leachate pollution, etc. The sanitary landfill process was studied in 1995 and the first sanitary landfill construction guideline was issued in 1998, in which high density polyethylene (HDPE) was used as the lining system. The vertical lining system of clay materials which were used between 1990 and 2003, are currently prohibited as the vertical lining system would collect all the runoff in the landfill and lead to the generation of a huge quantity of leachate.

Since 2003, the China Government supported over 200 projects of MSW treatment, including landfills, incineration plants, composting, collection and transportation, mechanical separation, policy making, etc., together with many demonstration projects which were constructed and operated. The research results were rapidly disseminated across China. Currently, all the MSW treatment facilities can be designed, constructed and operated independently, except for the automatic control system for incineration plants.

So far, over 10 national level and 20 provincial level research and development centers or laboratories have been established, with around 200–300 staff members working there for R&D of MSW. A total of 268 universities and colleges have

Environmental Engineering subjects and Solid Wastes Management and Treatment Technologies are listed in the curriculum. Around 130 books and thousands of papers have been published, including several solid wastes textbooks.

9 Conclusions

The MSW management mechanism in China is basically centralized, in which local governments are responsible for MSW collection, transportation, treatment, facilities investment and construction, recruitment of all staff, who are productive and without heavy bureaucracy. The investment for MSW facilities construction is very constrained, as the central and local governments are still the main investors, although the private investors have been encouraged to invest in the MSW management field, especially the incineration plants. Refuse tax may be levied in the future. Considering the advantages and disadvantages of the individual technologies, such as incineration, composting, landfill, 'Integrated Treatment' concept may be adopted, which attempts to combine all the available technologies together to an optimum mode, in order to solve the difficulty of site selection and to facilitate recycling of resources. The MSW management in Shanghai in fact involves a series of complex issues, e.g., adoption of centralized or decentralized systems, trading of facilities, maturing and developing of competitive and qualified companies and workers, etc. A significant amount of investment is required to create new facilities and upgrade the existing ones. As many cities have not yet possessed any environmentally-friendly treatment facilities for MSW, according to the experiences gained in the past years, landfilling seems to be the priority alternative for a rapid improvement of the city sanitation situation, as the duration of construction of landfill is usually relatively short and the investment and operational costs are relatively lower, if qualified liners can be installed and leachate can be properly treated and landfill gas can be well collected. Nevertheless, the remediation of closed and existing dumping sites should gain more attention from the public, in general, and from the local governments in particular, as the adverse long-term impacts of the dumping sites on human health and the environment have been firmly proven. Meanwhile, incineration is rapidly practiced, though the proper disposal of fly ash is still a serious problem which remains unsolved. In contrast, the composting practices are being shrunk quickly due to the heterogeneities of the wastes.

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Municipal Solid Waste Management in India

Kurian Joseph

1 Introduction

The Municipal Solid Wastes (Management and Handling) Rules (MoEF 2000) in India, defines 'municipal solid waste (MSW)' as 'commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but includes treated bio-medical wastes.' It includes household garbage and rubbish, street sweeping, construction and demolition debris, sanitation residues, non hazardous industrial refuse and treated bio-medical solid wastes. MSW has been treated as 'public nuisance' affecting the public health and safety as improper management of MSW can cause

- blockage of drains leading to overflows and water stagnation leading to breeding of mosquitoes that transmit many diseases like malaria and yellow fever
- breeding of flies that spread diseases like diarrhea, dysentery, typhoid, hepatitis, and cholera
- breeding of rats that carry a variety of diseases including plague and flea born fever
- dust in the air at dumpsites causing breathing problems as well as skin and eye infections
- resource depletion, land, water and air pollution due to leachate, methane emissions and open burning.

In particular, biodegradable waste poses a serious threat, since they ferment, creating unfavorable conditions such as odour.

Municipal Solid Waste Management (MSWM) deals with the control of generation, collection, storage, transfer and transport, processing and disposal of solid wastes in accordance with the best principles of public health, economics,

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engineering, conservation, aesthetics and other environmental considerations (CPHEEO 2000). MSWM service is by far the largest employer of labour and user of transport which spends the largest proportion of the revenue budget of a city. MSWM is inherently a complex issue, in terms of the multiple science areas involved and also the social and economic interactions comprising of not only the environmental aspects of the waste hierarchy or the technical aspects of the conventional approach, but also incorporating economic, legal, institutional, political, cultural as well as social issues.

The modern MSWM demands effective institutional arrangements with rules and regulatory instruments, which define the obligatory administrative, technical and financial standards complemented by a high technical, logistic and hygienic know-how to operate an efficient waste collection and disposal system. Environmental protection, economic feasibility and public acceptability of the system are the priorities. Public apathy towards waste management, institutional weakness, and improper choice of technology and lack of financial resources are attributed to be the reasons for poor MSWM services.

The physical, climatic, geographic, ecological, social, cultural and linguistic diversity of India adds to the complexity of MSWM in India. Sketching briefly the waste generation, collection, and disposal scenario across urban India along with the regulatory and institutional frame work, this Chapter highlights the interventions required for sustainable solid waste management in Indian cities. It advocates a phased and integrated approach with the involvement of the private and public taking into account the operational hurdles in the capacity building of local bodies.

2 Waste Generation and Composition

India's population, increased from 342 millions in 1947 to 1210 million, as per 2011 Census, generates about 36,000 truckloads of MSW every day (Sethuraman 2007). According to the Central Pollution Control Board (CPCB), there are about 4,400 Local bodies in India, the population distribution of which is categorized in Table 1. The per capita generation of MSW in India, vary from 200 to 700 g per day depending on the socio-economic status and cultural habits, climate, location, urban structure, density of population and extent of non-residential activities (CPCB 2006). For the purpose of project identification and planning, the following MSW generation rates have been recommended (CPHEEO 2000).

Residential refuse : 0.3–0.6 kg/capita/day
Commercial refuse : 0.1–0.2 kg/capita/day
Street sweepings : 0.05–0.2 kg/capita/day

Due to increasing per capita waste generation at the rate of about 1.3 % per year, and growth of urban population between 3 and 3.5 % per annum, yearly

Table 1 Classification of Indian cities based on population

Population	Class	Number of cities
>1,000,000 and above (metro only)	–	35
>100,000 and above	Class I	393
50,000–99,999	Class II	401
20,000–49,999	Class III	1,115
10,000–19,999	Class IV	1,344
5,000–9,999	Class V	888
>5000	Class VI	191
Unclassified	–	10
Total		4,377

Source CPCB (2006)

increase in the overall quantity of solid waste in the Indian cities is estimated to be about 5 %.

A survey by CPCB with the assistance of National Environmental Engineering Research Institute (NEERI) conducted in 59 cities (35 metro cities and 24 state capitals) in the year 2004–2005, reveals that the Composition of MSW (Table 2) varies with size of city and income group (Kumar et al. 2009). The compostable (biodegradable) fraction of waste in Indian cities varies in the range of 31–70 %. About 20–45 % of the waste is inert matter and 5–15 % recyclables. A direct consequence of the combination of hot climate, limited storage space in living premises and a high putrescible content of the refuse in Indian cities is that the collection frequency for municipal solid waste in densely populated areas has to be every day, whereas in many industrialised countries frequencies of one or two times a week are considered adequate to control odours and public health risks.

The high inert content of MSW due to the mixing of street sweepings, drain silt, and construction and demolition debris increases the density, which is between 330 and 560 kg/m^3. This means that the vehicles and systems that operate well with low-density wastes in industrialised countries may not be suitable or reliable for Indian cities. Urban solid waste from Indian cities, in general, has low calorific value and high moisture content with high percentage of non-combustible materials, making it unsuitable for thermal technologies.

However, it is interesting to note from Table 2 that very high calorific values have been reported from certain cities (e.g. Itanagar, Imphal, Kohima etc.) while it is too low in some other cities (e.g. Agra and Kochy). This could be indicative of the drastic variation in the heat content of the wastes or the errors in the representative sampling or the use of different in the basis (e.g. some expressing it on "kg of wastes as discarded" and others on "kg of dry wastes") for expressing the calorific values. Such anomalies reported in the waste characteristics calls for more attention in the representative sampling of wastes and standardization of protocols for characterization of wastes.

The recyclable wastes continues to be low (Table 3) as evident from a recent study (CES 2008). On an average, the recyclables in the MSW from residential

Table 2 Typical composition of municipal solid waste from Indian cities

S.No	Name of city	Compostables (%)	Recyclables (%)	C/N ratio	HCV* (kcal/kg)	Moisture (%)
1	Kavarati	46.01	27.20	18.04	2,242	25
2	Gangtok	46.52	16.48	25.61	1,234	44
3	Itanagar	52.02	20.57	17.68	3,414	50
4	Daman	29.60	22.02	22.34	2,588	53
5	Silvassa	71.67	13.97	35.24	1,281	42
6	Panjim	61.75	17.44	23.77	2,211	47
7	Kohima	57.48	22.67	30.87	2,844	65
8	Port Blair	48.25	27.66	35.88	1,474	63
9	Shillong	62.54	17.27	28.86	2,736	63
10	Simla	43.02	36.64	23.76	2,572	60
11	Agartala	58.57	13.68	30.02	2,427	60
12	Gandhinagar	34.30	13.20	36.05	698	24
13	Dhanbad	46.93	16.16	18.22	591	50
14	Pondicherry	49.96	24.29	36.86	1,846	54
15	Imphal	60.00	18.51	22.34	3,766	40
16	Aizwal	54.24	20.97	27.45	3,766	43
17	Jammu	51.51	21.08	26.79	1,782	40
18	Dehradun	51.37	19.58	25.90	2,445	60
19	Asansol	50.33	14.21	14.08	1,156	54
20	Kochi	57.34	19.36	18.22	591	50
21	Raipur	51.40	16.31	22.35	1,273	29
22	Bhubaneswar	49.81	12.69	20.57	742	59
23	Tiruvananthapuram	72.96	14.36	35.19	2,378	60
24	Chandigarh	57.18	10.91	20.52	1,408	64
25	Guwahati	53.69	23.28	17.71	1,519	61
26	Ranchi	51.49	9.86	20.23	1,060	49
27	Vijaywada	59.43	17.40	33.90	1,910	46
28	Srinagar	6177	17.76	22.46	1,264	61
29	Madurai	55.32	17.25	32.69	1,813	46
30	Coimbatore	50.06	15.52	45.83	2,381	54
31	Jabalpur	58.07	16.61	28.22	2,051	35
32	Amritsar	65.02	13.94	30.69	1,836	61
33	Rajkot	41.50	11.20	52.56	687	17
34	Allahabad	35.49	19.22	19.00	1,180	18
35	Visakhapatnam	45.96	24.20	41.70	1,602	53
36	Faridabad	42.06	23.31	18.58	1,319	34
37	Meerut	54.54	10.96	19.24	1,089	32
38	Nasik	39.52	25.11	37.20	2,762	62
39	Varanasi	45.18	17.23	19.40	804	44
40	Jamshedpur	43.36	15.69	19.69	1,009	48
41	Agra	46.38	15.79	21.56	520	28
42	Vadodara	47.43	14.50	40.34	1,781	25
43	Patna	51.96	12.57	18.62	819	36
44	Ludhiana	49.80	19.32	52.17	2,559	65

(continued)

Table 2 (continued)

S.No	Name of city	Compostables (%)	Recyclables (%)	C/N ratio	HCV* (kcal/kg)	Moisture (%)
45	Bhopal	52.44	22.33	21.58	1,421	43
46	Indore	48.97	12.57	29.30	1,437	31
47	Nagpur	47.41	15.53	26.37	2,632	41
48	Lucknow	47.41	15.53	21.41	1,557	60
49	Jaipur	45.50	12.10	43.29	834	21
50	Surat	56.87	11.21	42.16	990	51
51	Pune	62.44	16.66	35.54	2,531	63
52	Kanpur	47.52	11.93	27.64	1,571	46
53	Ahemdabad	40.81	11.65	29.64	1,180	32
54	Hyderabad	54.20	21.60	25.90	1,969	46
55	Bangalore	51.84	22.43	35.12	2,386	55
56	Chennai	41.34	16.34	29.25	2,594	47
57	Kolkata	50.56	11.48	31.81	1,201	46
58	Delhi	54.42	15.52	34.87	1,802	49
59	Gr. Mumbai	62.44	16.66	39.04	1,786	54

Source CPCB (2006)

areas consist of plastic bags (3.1–4.8 %), soiled news paper (1.7–3.9 %), corrugated boxes (1.4–2.5 %), textiles (1.3–2.6 %), plastic containers and milk bags (0.8–1.9 %). Glass, metal, rubber and leather components in the waste are very low in the range of 0.1–0.9 %.

3 Collection and Transportation

Waste generated at households is generally accumulated in small containers (often plastic buckets/bags) until it is disposed into community bins built by the Civic bodies. Containers used for household storage of solid wastes are of many shapes and sizes, fabricated from a variety of materials depending on the economic status of the waste generator. The wide variety of types and shapes commonly encountered within a community creates difficulty in establishing and operating an efficient solid waste collection system.

MSW is collected through methods like community bin collection and house-to-house collection on regular pre-informed timings and scheduling by using musical bell of the vehicle. Commercial wastes are also collected along with the household wastes except in a rare number of commercial complexes where they pay a negotiated fee to the municipality for collecting waste from their premises. Wastes from slaughterhouses, meat and fish markets, fruits and vegetable markets, which are biodegradable in nature, are also collected along with other wastes.

Table 3 Recyclables in municipal solid waste from an Indian metro city

S.No	Components	Composition ± SD (%)				Mean ± SD (%)
		HIG	MIG	Mixed	LIG	
1	News paper	3.9 ± 1.6	1.7 ± 1.1	2.2 ± 1.3	1.8 ± 1.1	2.5 ± 1.3
2	Corrugated boxes	1.4 ± 0.7	1.5 ± 0.6	2.5 ± 1.8	1.4 ± 0.6	1.9 ± 1.0
3	Plastic–containers and milk bags	1.1 ± 0.4	0.8 ± 0.4	1.7 ± 1.3	1.3 ± 0.6	1.4 ± 0.7
4	Plastic–bags	3.1 ± 1.5	3.5 ± 1.3	3.9 ± 0.9	3.6 ± 1.5	3.9 ± 1.3
5	Glass–plain	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.3	0.1 ± 0.1	0.3 ± 0.3
6	Glass–colored	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
7	Textiles	1.9 ± 1.5	1.8 ± 1.0	1.9 ± 1.2	2.6 ± 2.3	1.9 ± 1.3
8	Rubber	0.2 ± 0.3	0.4 ± 0.7	0 ± 0.1	0.2 ± 0.2	0.3 ± 0.5
9	Leather	0.1 ± 0.1	0.2 ± 0.2	0.2 ± 0.3	0.4 ± 0.7	0.2 ± 0.3
10	Metal–containers	0.1 ± 0.1	0.1 ± 0.1	–	–	0.1 ± 0.1
11	Wooden materials	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.2	0 ± 0.1	0.1 ± 0.1
12	Total recyclables	12.0 ± 6.5	10.4 ± 5.8	13.0 ± 7.5	11.5 ± 7.3	13.0 ± 6.7
13	Unsegregated waste	88.0 ± 3.3	89.7 ± 3.3	87.3 ± 4.8	88.5 ± 5.1	87.0 ± 4.1

Source CES (2008)

Note HIG/MIG/Mixed/LIG—High/Middle/Mixed/Low Income Group

Source segregation of biodegradable and recyclable wastes at household level is seldom practiced and the door to door collection practiced in some cities and the community collections bins used in most cities are not well designed to have separate compartments for recyclable and organic wastes. Though, the MSW Rules (MoEF 2000) requires that the bins for storage of bio-degradable wastes shall be painted green, those for storage of recyclable wastes shall be painted white and those for storage of other wastes shall be painted black, it is seldom practised. An analysis of the community bins and street sweepers in some of the cities in India in the Supreme Court Committee Report (1999) indicates lack of standardisation of work norms and prevalence of Ad hoc-ism.

The major problems related to MSW collection systems are that (i) most households do not deposit their wastes into the community bins which result in wastes being thrown on roadside (ii) many community bins are at most of the times overflowing causing unhygienic conditions and (iii) rag pickers poaching on the community bins for retrieving recyclable wastes are spilling wastes around the bins. Such wastes left mostly on the street until the next day's collection, means that the streets are mostly littered, even if there is regular collection services. Poor civic discipline and inadequate community storage arrangements make the householders to often throw their wastes onto the roadsides for clearance by street sweeping crews, which adds to the inert content of wastes.

The labour intensive waste collection methods commonly practiced in Indian cities have several drawbacks including:

- wide variations in the collection vehicles ranging from bullock cart to lorries.
- time consuming and unhygienic manual handling of wastes, which involves multiple handling of wastes and reduces the productivity of manpower and vehicles.
- poor synchronization of waste vehicles with the types of waste bins provided.
- potential health hazard for the workers as all type of waste are disposed off in the common waste bin.
- inadequate number of vehicles with large percentage of vehicles remaining off the road due to poor preventive maintenance practices.

The slums and squatters in cities also create in sanitary conditions. Open defecation and disposal of sewage and garbage from such settlements need proper attention. Similarly, operation of dairy related activities in residential areas cause nuisance. Cow-dung and other waste are not properly managed. Vendors selling eatables, vegetables, fruits etc. also throw their wastes recklessly, which need to be regulated.

The waste is transported mostly by municipal vehicles; though, in some large towns, private vehicles are also hired to augment the fleet size. General-purpose open body trucks of 5–8 tones capacity are in common use for waste transport in main cities. Bullock carts, tractor trailers, power tillers, tricycles etc. are mainly used for the transportation of waste in smaller (Rural) towns. The recent trend is to use compactor trucks, container-carriers and dumper placers where the containers of the vehicle themselves are used as community bins.

Transfer of waste from smaller vehicles to larger size vehicles is carried out at the transfer stations, which need extensive modifications to ensure their sanitary operation. Due to the higher density of waste in Indian cities, use of compaction trucks which achieve a final density of about 400 kg/m^3 and a compaction ratio of 4:1 in industrialised countries, commonly could achieve only a compaction ratio of 1.5:1 or less. In a number of cities, compaction vehicles appear to be used primarily because of the low loading height of the hopper rather than because of the need for compaction. The conventional side loading vehicles have the bodies mounted at a high level, so that the typical refuse collector is attempting to discharge container at a higher than head height. Appropriate workshop facilities for routine servicing, and the management structure to ensure that the vehicles can be repaired rapidly, are essential for success of MSW collection. MSW storage facilities set up by municipal authorities are to be so designed that wastes stored are not exposed to open atmosphere and shall be aesthetically acceptable and user-friendly. Such facilities or 'bins' shall have 'easy to operate' design for handling, transfer and transportation of waste.

Private sector involvement has been tried in primary collection, street sweeping, transportation and disposal of solid waste in the cities (Hanrahan et al. 2006). Municipal Corporation of Hyderabad (MCH) has privatised SWM in 58 areas of the city, catering to over 1 million population. The city of Chennai has the experience of operating privatized waste collection services for almost a decade. The private agency could offer the service at about 70 % of the cost that would have incurred by the local body otherwise. Navi Mumbai Municipal Corporation has engaged private contractors in 82 zones using two approaches. One is the use of sanitation contractors, who sweep roads and footpaths, and collect and transfer garbage to street containers. The second is transport contractors who then transport the garbage, using NMMC vehicles, from containers to disposal sites. Private sector participation have helped to upgrade technical and managerial expertise, increase efficiency in operation and maintenance, improve customer services, apart from bringing in the capital to support the government in its efforts at waste management.

4 Treatment and Disposal

Source separation of biodegradable waste, construction and demolition waste as well as household hazardous waste is rarely done; consequently most of the waste collected is a mixture of these components. Such mixed waste is rarely suitable for biological/ processing or thermal processing as it has high content of inert material, low calorific value and indeterminate mixing of hazardous elements. An April 2004 study of 128 cities by Mr. P. U. Asnani showed that 50 % compliance for Waste Processing in only 8 % of 128 cities (Hanrahan et al. 2006). Out of the total municipal waste collected, about 94 % is disposed by open dumping and the rest is composted (Visvanathan et al. 2004). It very often produces unpleasant and hazardous smoke from slow burning fires. The common priority of all ULBs should be to improve conditions of existing landfills parallel to adoption of alternative means of municipal waste management. Decomposed municipal waste at dumpsites may be sieved and used as cover material at dumpsites (Scheu and Battacharyya 1995).

The larger proportion of biodegradable matter in MSW indicates the desirability of biological processing (Composting or Biomethanation) of waste. Biological processing of mixed municipal waste yields low quality compost which may have contaminants in excess of permissible limits. Several large scale mechanical compost plants in India have failed on account of the high sophistication of the plant, leading to difficulties with operation and maintenance and prohibitive costs. Such plants have produced poor quality compost due to use of mixed municipal wastes as feedstock. A few large-to-medium plants are still operating with simpler technology, and with government subsidies, e.g. the autonomous Karnataka Compost Development Corporation plant in Bangalore. Encouraged by the move for public–private partnerships in solid waste management, the interest of private companies in composting is reviving. The units are often set up by agro-chemical companies that receive assistance from municipalities in the form of access to free municipal wastes, and a rent-free site, as is the case with the Excel Industries plant in Bombay and some of the company's franchises (Bhoyar et al. 1996). The proliferation of thin plastic bags and mix up of household hazardous wastes such as batteries is a threat to any types of composting in Indian cities.

Neighbourhood scale compost plants, promoted by NGOs or CBOs, with assistance (such as access to land) from municipal councils, are of limited relevance for the solid waste reduction of larger cities. This community-based approach would require the coordination of city and regional authorities, prior research into existing practices, pilot studies, safety tests of the compost being produced by the farmers, monitoring, and so on (Furedy 1995). This amounts to quite complicated environmental and economic planning and the institutional set-up which restricts a city official from taking such initiatives.

Producing compost acceptable in quality and price to buyers, on the scale that can significantly reduce urban organic solid waste, would seem to require large-scale ‘separation at source’ and a mechanism to separately collect such wastes by households and bulk generators (food processing plants, wholesale market terminals, green markets, large hotels, large restaurants, large institutions, parks). It is important to note that in addition to waste-generator cooperation, the separate collection of residential organics on a large scale requires radical changes in existing solid waste management systems. An approach that does not demand complete waste generator compliance with separation is doorstep sorting by waste collectors. It is being currently applied in many Indian cities. Attempts to link composting with urban food production, or with plant nurseries and parks’ improvement deserves to be seriously examined as part of a waste management strategy to ensure sustainability of compost plants.

The biodegradable organic fraction separated from MSW could also be used as a feedstock for anaerobic digestion to produce biogas and compost. The Ministry of Non-conventional Energy Sources (MNES), Government of India is looking forward to Biomethanation Technology as a secondary source of energy by utilizing industrial, agricultural and municipal wastes. The local availability of the anaerobic technology in India is limited to smaller capacities applied to vegetable and slaughter wastes.

The first large scale biomethanation plant to generate 5 MW power utilizing 300 t/day of MSW at Lucknow, at a cost of Rs. 760 million commissioned in 2005 could not function to its design capacity due to the poor quality (very high content of inerts) of input materials. The Plant had a number of state-of-art technologies (screening, hand sorting, magnetic separation, size reduction, ballistic separation, pulping and grit removal, etc.) to segregate wastes as per requirements for functioning of the anaerobic digesters. A bio-methanation plant to generate electricity from 30 tons of vegetable waste setup at Koyambedu Wholesale Market Complex in Chennai at a total cost of Rs. 50 million could generate electricity to the tune of 230 kW per day and compost of 10 tonnes per day. This Plant is also facing difficulties in sustaining its operation, mainly due to poor quality of inputs. The homogeneity of the feed material is an important parameter from the efficiency point of view. The solid waste management system needs to be modified and improved to make source separation and separate collection of solid waste. Or else the applicability of biomethanation will be limited to highly organic and homogenous waste streams like Market wastes.

Waste to Energy (WTE) by thermal or biological route is in a nascent stage in India and most WTE initiatives are heavily dependent on subsidies being provided by various government agencies, primary the MNES. Thermal processing of waste becomes viable only if sufficient high calorific value components (such as paper, plastic) are present in the waste. Thermal processing technologies such as Mass burn incineration is not a realistic option in India for technical and financial reasons since Indian MSW have low calorific value, high moisture content and high inorganic matter leading to high economic and environmental costs. Though Refuse Derived Fuel (RDF) based plants have been reported to be technically feasible (Dhussa and Tiwari 2000), the details needs to be carefully considered with reference to the volumes and nature of the wastes accepted and the quantity and mode of disposal of the rejects including the emission controls. The cost economics of WTE plants are such that these can be considered as an option for disposal of MSW, only as part of integrated waste management largely in metro cities of India.

The challenges of medium or small municipalities related to finding land for waste disposal, getting enough funds for its construction and operation, finding the technical personnel to operate the heavy machinery, and fighting the opposition from the neighborhoods can be handled easily if a group of neighboring municipalities creates a common landfill facility on a cost-sharing basis on a large parcel of land at a suitable location away from the cities. The operation and management may be handled through a professional agency, the cost of which is shared by the participating municipalities in the form of tipping fees proportional with the waste delivered to the landfill site for disposal. Municipalities considering such regionalized waste disposal facilities should recognize that the costs and benefits, although shared, will not necessarily be identical for all communities. For example, a community that sends its waste to a facility shared with another municipality benefits from not having to site and manage the landfill within its jurisdiction. However, it will probably be subject to fees levied by the community in which the waste management site is located. Regionalization sometimes can require that waste be transported over long distances and through neighboring areas and communities. Municipalities should explore these and other potential barriers thoroughly and consider the tradeoffs of sharing common facilities.

5 Reduce, Reuse and Recycle: 3 R's

The popular concept of waste reduction, reuse and recycle, often referred to as "3R" are often well established in Indian cities. This is evident from the low levels of recyclables in Indian MSW as well as low per capita generation of wastes. The promotion of compost-making from municipal wastes is also a clear endorsement of the principle of resource recovery. The Municipal Solid Wastes (Management Handling) Rules (MoEF 2000) stipulates source segregation as a necessary activity, and promotes recycling of 'recoverable resources' based on segregation.

The socio-economic structure of the Indian society not only makes per capita generation of waste much less compared to that of the western societies, it has also brought in a system of waste recycling and reusing not common in developed societies, though these systems are fast losing ground. A substantial amount of MSW is recycled and reused through the primary intervention of ragpickers and second-hand markets, though there are problems like the health hazard to the ragpickers and the degradation and devaluation of the recyclables.

Waste recycling is done in a very labour-intensive way. Newspaper, cardboard and metals are collected from door to door or community bins. The waste collectors spend perhaps 30–50 % of their time sorting saleable materials from the refuse. Communities of 200–500 families live on each of the dump sites, depending for their livelihood on scavenging. All of these people sell to middle men who often perform some simple sorting and cleaning of the recycled materials. The middlemen sell to wholesalers and hence back to primary industries. Some key factors that affect the potential for resource recovery are the market for the separated material, its purity, its quantity and its location. The costs of storage and transport are major factors that decide the economic potential for resource recovery (Baud and Schenk 1996).

The common view of scavengers held by public and municipal officials is that they are nuisances and even threats to public health. They are seen as interfering with waste collection operations. Local authorities may make good use of them effectively allowing their activities to be included in the overall MSWM system by contracting to small-scale waste collection enterprises of waste pickers and itinerant collectors. Such facilitation to develop the rag pickers as micro entrepreneurs to offer waste collection services will be beneficial to the municipality in the form of efficient waste collection at less cost and absence of ragpicker interference at waste processing/disposal facilities. This will also improve the working conditions and earning capacity of the ragpickers. Recycling industry needs technological upgradation to improve the quality of the product, reduce cost and minimize potential health hazards.

An NGO in Chennai, called Exnora (EXcellent, NOvel and RAdical Ideas) are practicing such a system of waste management through the Civic Exnoras, entirely based on people's co-operation and participation. They employ trained rag pickers (named as 'Street Beautifiers') to undertake door-to-door collection of waste and transport them to community bins. 'Street Beautifiers', are paid a monthly salary, which is subscribed by the community. The City Beautifier is also able to augment his salary by selling recyclable wastes segregated from the garbage.

6 Local Case Studies

Some of the local bodies in India have taken initiatives to improve SWM practices as summarised in Table 4. Such efforts are restricted to either a few wards/area or for the entire town (Kirti Devi and Satayanarayana 2001).

Table 4 Case studies on waste management from Indian cities

Project name	Project description
Compost plant in Vijayawada	Vijayawada with a population of 0.7 million generates about 560 tons of solid waste per day. Excel Industries, based on their earlier experience in different Indian cities implemented the Composting facility in 1997, on 'build-own-operate' basis, at a cost of Rs. 14.9 million (1996 prices). The facility is designed for an initial capacity of at 150 tons per day (tpd) and an ultimate design capacity of 300 tpd. Operating the facility at initial capacity produces about 40 metric tons of organic manure per day. Excel Industries' financial obligations towards VMC included: Rent of Rs. 1 per square meter per year for 3.36 hectares of land leased for 30 years; A lump sum of Rs. 0.225 million per year as compensation for using existing buildings, equipment, machinery, etc.; Royalty of 2.5 % on net ex-factory sales or Rs. 35 per metric ton of organic manure produced, whichever is higher Similar facilities are in operational in few other cities like Delhi and Thiruvanathapuram in Kerala
Private sector participation in MSW collection and transport	The Municipal Corporation of Hyderabad (MCH) introduced a voluntary garbage collection scheme in 1994. The scheme provided a full subsidy to voluntary agencies and resident associations to undertake house-to-house collection of garbage. The association submits a signed list of households it will serve. The subsidy covers a tricycle for every 100–150 households. The association is responsible for appointing and supervising staff. The tricycle puller must be paid at least Rs. 750 per month with every household contributing at least Rs. 10. About 600 localities, representing about 20 % of the population, have been covered, mainly from middle-income areas In 1998 MCH introduced a new unit-based system for private sector participation that integrated road cleaning at night and sweeping, collection, and transportation by day. The city has been divided into 266-day units and 50 night units. About 40 % of the day units have been reserved for the MCH staff and the rest given out to private contractors. One hundred contractors have been awarded day units and 20–30 contractors night units. A provision has been made for monitoring performance through community action. Five men and five women constitute an informal community in each unit; their daily certification is mandatory for the payment to the contractor

(continued)

Table 4 (continued)

Project name	Project description
Biomethanation plant in Lucknow	The city of Lucknow in Uttar Pradesh producing around 1,500 tons of solid waste every day partnered with Enkem India Ltd, a promoter, through a Special Purpose Vehicle called Asia Bio Energy (India) Ltd to build a power generation-cum-bio-fertilizer plant on a Build-Own-Operate (BOO) basis. The project was designed to generate 5.1 MW of electric power per day (after captive consumption of 0.5 MW) and about 75 tons per day of organic manure by treating 300 TPD of waste. The total project cost was about Rs. 760 million (2,001 prices). The Ministry of Non-conventional Energy Sources approved the project as a demonstration project under the National Programme on Energy Recovery from Urban, Municipal and Industrial Waste. The plant construction was completed in August 2003, but could not deliver the design outputs due to poor quality of garbage. The lessons to be learnt from this project are that (i) detailed waste characterization is very important while project planning (ii) Biomethanation is not a practical solution for mixed municipal solid wastes and its application needs to be restricted to highly biodegradable and homogenous waste such as those from slaughter houses, hotels, vegetable/fish markets
Pelletisation plant—Hyderabad	A Waste to Energy (WTE) plant to process 1,000 TPD of MSW to manufacture about 200–250 TPD of fuel pellets was setup by Selco International started in 1999 based on Refuse Derrived Fuel (RDF) technology. The plant located next to the Ganghamguda municipal dumpsite of the Municipal Corporation of Hyderabad (MCH) is currently in operation using a mixture of sorted MSW (Fluff) and Biomass (Rice husk). The sustainability of the plant is still under debate since the facility is capable of processing only a part of the wastes and its viability is attributed to financial support in the form of subsidies. Such plants may have a role only in integrated waste processing of larger cities
International private sector participation in MSW collection and transport	Chennai, with the highest per capita solid waste generation rate in India, is the first city in India to contract out MSWM services to a foreign private agency—ONYX, a Singapore based company in the year 2000. The scope of privatization included activities such as sweeping, collection, storing, transporting of MSW and creating public awareness in three municipal zones. Similar Contract with another international consortium (Neel Metal Fenalca), is in operation currently. This project clearly demonstrated the benefits of privatization in terms of significant reduction in the waste collection cost and increased efficiency. It is important to note that the privatization restricted to part of the city whereby the municipal employees from there area were utilized to improve the waste collection system efficiency of non privatized area

7 Legal Framework

MSWM in India is the primary responsibility of the municipal authorities. State legislation and the local acts that govern municipal authorities include special provisions for collection, transport, and disposal of waste. They assign the responsibility for provision of services to the chief executive of the municipal authority. A public interest litigation was filed in the Supreme Court in 1996 (Special Civil Application No. 888 of 1996) against the government of India, state governments, and municipal authorities for their failure to perform their duty of managing MSW adequately. The Apex Court forced the government and local bodies to improve the situation. The Supreme Court then appointed an expert committee to look into all aspects of SWM and to make recommendations to improve the situation. After consulting around 300 municipal authorities, as well as other stakeholders, the committee submitted a final report to the Supreme Court in March 1999. (Almitra 1999) The report included detailed recommendations regarding the actions to be taken by class 1 cities, by the state governments, and by the central government to address all the issues of MSWM effectively.

On the basis of the report, the Supreme Court directed the government of India, state governments, and municipal authorities to take the necessary actions. The Ministry of Environment and Forests was directed to expeditiously issue rules regarding MSW management and handling. Such rules were already under development and had been under consideration for quite some time. Thus, in September 2000, the ministry issued the Municipal Solid Waste (Management and Handling) Rules 2000 under the Environment Protection Act 1986. The Rules (MoEF 2000), mandate the following:

- Prohibiting littering of street that in turn requires the storage of wastes at source and promotion of waste segregation
- Organizing house to house waste collection
- Conducting awareness programmes to disseminate information to public
- Providing adequate community storage facilities, daily sweeping of streets and abolition of open storage
- Transport of wastes in covered vehicles
- Processing of wastes by adopting an appropriate combination of composting, anaerobic digestion, thermal processing etc
- Upgradation of the existing dump sites
- Disposal of inert wastes and residues in sanitary landfills.

The MSW Rules makes every ‘municipal authority’ responsible to implement those rules and ‘for any infrastructure development for collection, storage, segregation, transportation, processing and disposal of municipal solid waste.’ It also requires that the municipal authority or an operator will have to seek permission for setting up waste processing and disposal facility including landfills from the State Pollution Board or the committee constituted for the purpose. The over-all responsibility for the enforcement of the provisions of these rules in metropolitan cities have been given to the Secretary-incharge of the Department of Urban Development of the State/Union Territory. Further, the District Magistrate/Deputy Commissioner of the concerned district shall have the overall responsibility for the enforcement of these rules within their area of jurisdiction. Monitoring of the compliance of the standards regarding ground water, ambient air quality and compost quality including incineration standards as per the Rules shall be done by the State Pollution Boards/Committee.

The Courts of India, on various occasions have declared in unequivocal terms that maintenance of health and preservation of sanitation falls within the purview of Article 21 of the Constitution as it adversely affects the life of the citizen, if not checked. The courts have also declared that it is a primary, mandatory and obligatory duty of the municipal corporations/councils to remove rubbish, filth, night soil or any noxious or offensive matter. The Supreme Court of India in *Dr. B. L. Wadehra versus Union of India*, emphatically pronouncement that the '*resident of Delhi have a statutory right to live in a clean city*.' Therefore, the Municipal Corporation and Municipal Council are under a *statutory obligation* to scavenge and clean the city and 'it is mandatory for these authorities to collect and dispose of the garbage/waste generated from various sources in the city.' It was further observed that 'non-availability of funds inadequacy or inefficiency of the staff, insufficiency of machinery etc. cannot be pleaded as ground for non-performance of their statutory obligations.'

7.1 Financing System

The state laws governing municipal authorities establish their powers to levy taxes, charges, fees, and the like for raising money to meet their statutory obligations. Some municipalities also levy monthly user fees or charges for water, drainage, and sanitation to meet the necessary operating and maintenance cost of the service. By and large, however, municipal authorities suffer a major deficit of funds to meet their obligations. Municipalities can obtain grants such as

- State Finance Commission grants
- 12th Finance Commission grants
- Jawaharlal Nehru National Urban Renewal Mission (JNNURM) grants
- Urban Infrastructure Development for Small and Medium Towns scheme grants.

Started in the year 2005, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) cover 63 selected towns and the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) cover 5,098 urban towns for providing infrastructure facilities including solid waste management in a 7 year Mission period. The 12th Finance Commission had taken a very considered view for improving urban infrastructure and allotted Rs. 5,000 crores for supplementing the resources of the ULBs in the country during 2005–2010. Out of this amount, 50 % was earmarked for improving SWM Services.

The Ministry of Urban Development have created a Community Participation Fund (CPF) under which a community can conceive a project on municipal solid waste and submit it through the local Municipality to the Union Government. Funds to the tune of Rs. 9.5 lakh can be granted with community contributing 5 % in case of slums and 10 % in case of others. The Ministry of Agriculture (MOA) and the Ministry of Environment and Forests (MOEF) have been actively promoting waste composting, while the Ministry of New and Renewable Energy has designed schemes to promote waste-to-energy projects. In addition to financial and technical support from central and state governments, the following incentives are available for financing solid waste infrastructure in urban areas.

- Tax Exemption of Certain Bonds Issued by Local Authorities
- Tax Holiday for the Project Entity for Solid Waste Management
- Tax Exemption for Income of Infrastructure Capital Funds and Companies
- Availability of Funds by Sale of Carbon Credits
- Sectorial Lending by Financial Institutions and Multilateral Donors.

It has been estimated that the ULBs spend about Rs. 500–1,500 per ton on solid waste collection, transportation, treatment and disposal. About 60–70 % of this amount is spent on street sweeping, 20–30 % on transportation, and less than 5 % on final disposal of waste, which shows that hardly any attention is given to scientific disposal of waste. The role of the private sector in financing resource recovery (composting, waste-to-energy) facilities is growing in India, particularly for door-to door collection of solid waste, street sweeping, transportation and for treatment and disposal of waste. Cities which have pioneered in public private partnerships (PPPs) in SWM include Bangalore, Chennai, Hyderabad, Ahmadabad, Surat, Guwahati, Mumbai and Jaipur. The irony is that Municipal decision makers do not give adequate priority to SWM and even most of the budget for SWM is consumed in salaries of sanitation workers and transport of waste. Very little or none is set apart for actual treatment and disposal of waste. The municipal authorities need to seriously consider introducing a sanitation or SWM cess to meet the cost of service. User charges can be an equitable means of funding SWM services if properly administered. Waste recycling, composting, and waste-to-energy operations may generate operating revenues or at least reduce the cost of waste treatment.

As the present capacity of municipalities in India to manage the privatization process is quite limited, there is need for developing in-house financial and managerial capability to award contracts to private sector and monitoring services provided by the private operator since the onus of ensuring proper service delivery and compliance of standards lies with the local bodies.

8 Current Issues and Future Perspectives

Management of MSW is a major problem for most of the urban areas in India due to the growing urban population and per capita waste generation rate, inadequate public participation and the deplorable organizational and financial capacities of urban local bodies (Ali and Cotton 1999). The contemporary approach to MSWM, with the primary objective being merely the collection and disposal of the wastes for reasons of public health and hygiene, is increasingly proving to be ineffective and inappropriate (Singhal and Pandey 2001). Several attempts are underway to improve better management of MSW. The Ministry of Urban Affairs and Employment (MoUAE) engaged the NEERI, Nagpur for formulation of a strategy paper on municipal waste management and prepared a manual on solid waste management (CPHEEO 2000). These documents highlight various critical issues (Table 5) relating to management of solid wastes and have offered number of suggestions for improving the management practices.

Table 5 Summary of waste management issues

S.No.	Element of waste management	Issues
1	Waste segregation	Poor public support ULBs are not having segregated waste collection (two bin) system Lack of waste processing facilities
2	Primary collection	Poor public support for storage of waste at source Lack of Door-to-Door (D2D) collection system Poor waste collection in slums Low user fee collection (20–40 %) Poor Enforcement of Law against defaulters and poor support of elected representatives for user fee collection
3	Secondary collection & transportation	Frequent shifting of storage containers Manual handling of waste without safety measures Littering of storage points and during transport Poor monitoring system by ULBs
4	Treatment and disposal	Public litigation and difficulty in facility siting Lack of Technical Capacity with ULBs Political interference Lack of monitoring
5	Administration & planning	Lack of vision and planning for creating awareness Lack of seriousness of issue among the local bodies, elected representatives and community Lack of integrated action plan Poor consultation with community/public Institutional weakness and human resources Poor commitment of Waste Managers Mix of Bio-Medical & industrial wastes with municipal solid waste Poor efforts to channelize funding opportunities

A high-powered committee on urban waste constituted by Government of India during 1975, in its report made 76 recommendations, covering eight important areas of waste management. Another high-powered committee constituted in 1995, under the chairmanship of Prof. J. S. Bajaj, Member, Planning Commission, Government of India had given a number of recommendations.

Some of the key recommendations include

- Segregation of waste at household level should be encouraged and promoted.
- Primary level of collection should be ensured from each household.
- Private agencies/NGOs may be involved in primary collection.
- Monthly charging for door-to-door collection based on income groups may be implemented.
- The vehicles for transporting solid waste from the transfer point to the disposal site should be of appropriate design, suiting the waste characteristics.
- Along with land filling, composting of municipal solid wastes should be the next appropriate option.
- Private participation in setting up pilot plants using appropriate technologies for urban solid waste management should be encouraged.

The sustainability of SWM programs in Indian cities hinges on the structural and functional integration of education and community participation, policy and regulatory intervention, waste reduction, reuse and recycling, healthcare, electronics and household hazardous waste, landfill management, dumpsite rehabilitation, composting, waste to energy and financing, economic analysis and public private partnership (Kurian et al. 2007). Some of the major measures required in this regard will include

- Development of cities based on master plans, inclusion of land for waste management in city Master plans and maintenance of Buffer Zones around such sites. This requires clear awareness of its need and strong commitment of the planners and the political leadership to resist the pressures of the developer lobbies for short term gains
- Setting up of common or regional waste processing and disposal facilities for adjoining municipalities and compensating Local neighborhoods hosting such SWM facilities
- Establishment of Technology/process parks related to SWM in the context of local conditions
- Demonstration of model facilities to be used as driver to get the acceptance of community to allow the establishment of MSW management facilities at its backyard
- Ensuring the participation of school children and college students in educating the public on SWM
- Setting up of a National and State level Waste Management Missions and creation of Resource Centres for MSWM to augment professional training and to support capacity building

- Separate collection and disposal of the construction and demolition as well as inert waste from road sweeping and de-silting operations of drains
- Development and updating of Database on waste characteristics
- Policy intervention to make the "Manufacturers" responsible for management of household hazardous wastes such as used batteries and e-wastes
- Encouraging source separation and door to door collections
- Use of appropriate equipment for collection, transport and processing and their preventive maintenance
- Development and use of appropriate waste processing methods such as composting, community vermi-composting, biomethanation etc
- Coordinated action among local bodies, State and Central Departments of Agriculture, Department of Fertilizers, Fertilizer Association of India and other related agencies in the farm sector to ensure effective marketing of the compost
- Encouraging co-incineration of urban waste derived fuel in cement plants where necessary infrastructure is already in place
- Rehabilitation of the open dumps to sustainable landfills
- Sensitization of stakeholders and Single agency coordination
- Improved service conditions of workers and informal sectors
- Professional training and incentives for ULB staff
- Introduction of Service Performance Indicators and effective monitoring system
- Institution of tipping fee at waste treatment sites to make waste treatment and disposal project financially viable and attractive to entrepreneurs
- Fixation of rational tariff and efficient recovery of tariff for waste management
- Development of waste management as a profession
- Promotion of private sector participation to overcome constraints imposed by lack of funds and professional experience
- Tapping of CDM benefits for both fresh waste processing and disposal and for remediation of open dumps.

A fundamental issue in SWM is "how to translate these recommendations on the ground" by gradual transformation of practices according to scientific principles and standards via official policy and administrative reforms. The weaknesses in existing institutional systems such as untrained Staff, lack of incentives to do a good job, inadequate supervision of workers and inadequate maintenance of facilities act as barriers (Kumar and Gaikwad 2004). The concern for efficiency, for "making an impact" still tend to favour high technology approaches in preference to the slower, more uncertain, more socially demanding, "appropriate technology" (Shekdar1999).

The task of resolving this problem requires an integrated approach that involves not only the leadership of the government, but it also demands active participation of all other stakeholders, most importantly, the public. The role of the government is to formulate and enforce rules and regulations concerning waste management so as to protect health and safety of the people and environment.

What all cities and towns need first is a change in orientation to waste matters so that the psychological barriers to general public interest, concern and co-operation are reduced. Public awareness and attitudes to waste can affect the readiness to carry waste to a shared container, the willingness to accept the proximity of a shared container, the willingness to segregate waste to assist recycling, the frequency at which wastes should be collected, the amount of litter and animal excreta that are left on the street, the willingness to pay for waste management services, the opposition to the siting of waste treatment and disposal facilities, gender issues with regard to waste recycling and collection activities, and the social groups from which waste management staff can be drawn. The people can participate by generating less waste and providing feedback during major decision making processes regarding waste management.

To improve the status of solid waste management in the cities, CPCB with the assistance of NEERI, Nagpur, has undertaken a study for development of criteria for selection of site for sanitary landfill. CPCB has undertaken a study on Assessment of Impact of Existing and Completed Municipal Landfill Sites at Kanpur, with assistance from National Productivity Council. Pursuant to the Hon'ble Supreme Court's directives, CPCB interacted with State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) to get the action plans prepared for management of MSW in 35 metro cities and 24 State capitals. It has been observed that many cities have taken initiatives to organize proper Collection, Segregation, Storage and Transportation of waste. Steps have also been taken for setting up of Waste Processing and Disposal facilities.

To demonstrate implementation of the provisions of MSW rules, the CPCB undertook pilot projects at North Dum–Dum and New Barrackpore municipalities in West Bengal, Chandigarh and at Udumalpet in Tamil Nadu. The purpose of these projects is to undertake collection, segregation, storage, transportation, processing and disposal of waste in accordance with MSW rules. The demo-project is on cost sharing basis where the respective local bodies have agreed to share 50 % of the total cost of the project. MoEF and CPCB need to continue this on-going scheme of Demo-Projects for at least one to two towns in each State.

A Task Force on integrated plant nutrient management using city compost, constituted by the Ministry of Urban Development on 26th March, 2003, submitted its report in 2005 that dwells on length the general/technical and financial requirement for setting-up of compost plants as a viable option for promoting integrated plant nutrient management using city compost.

In pursuance of an order of the Hon'ble Supreme Court on a writ petition regarding solid waste management in Class-I cities, an Expert Committee constituted by MNES (now MNRE) submitted a Report addressing issues relating to composting and energy generation and will help State Governments/Local Bodies while taking decision for setting up of waste processing plants and particularly with reference to Waste to Energy Project.

There is currently considerable interest in introducing the private sector to SWM services for cost saving. The contracting system needs to be improved by measures such as pre-qualification procedures to eliminate companies without the resources or experience, improving the quality of contract documentation, with particular reference to the specification of the services, penalty clauses and bills of quantity. The pitfall to avoid is that of accepting the lowest bids irrespective of the standard of service to be provided. Extending the contract period from two to five or seven years, and requiring that the contractor purchases purpose-built refuse vehicles along with increasing the responsibility of local district officers in supervising contractors are some measures to be seriously considered.

NGOs can play an important role in bringing up the awareness and consciousness for good sanitation. They can help in:

- ensuring public participation in segregation of recyclable material and storage of waste at source;
- ensuring public participation in community based primary collection system;
- organizing ragpickers for collection of recyclable material at the community level;
- providing health education to the ragpickers and suggesting tools for safety;
- providing employment through organizing door to door collection of waste; and

encouraging minimization of waste through in-house backyard composting, vermiculture and biogas generation etc.

The principle of polluter pays, which requires the person or organization generating waste to bear the full cost of waste management needs to be put into practice, so that the polluter will have the incentive to minimise the cost and amount of waste generated. The application of the principle involves establishing a fee collection system that represents the true costs of waste management and charged in proportion to the amount of waste generated. It is also important to identify who is the polluter, which in the case of MSW will be the individuals and commercial suppliers. Following the principle of 'Polluter Pays', the Municipal Corporation of Ahmedabad & Surat have passed a resolution vide which they levy cleaning charges on the spot for littering.

Upgrading the equipment and technology for waste management requires significant financing that can either be achieved through private sector participation/ investment or by strengthening the financial capacity of the Municipalities. The Twelfth Finance Commission has recommended devolution of grants for Urban Local Bodies to the tune of Rs. 50,000 million for the period 2005–2010 of which 50 % have to be devolved upon local bodies exclusively for setting-up of solid waste management systems in Urban areas to ensure management of MSW in accordance with MSW Rules. The establishment of a dedicated fund for waste management should be considered.

The research network as part of the Asian Regional Research Programme on Environmental Technologies, funded by Swedish International Development Co-operation Agency (SIDA) recommends that all changes introduced should represent a progressive improvement with the basic elements of the approach as depicted in Fig. 1 (Kurian et al. 2007). The steps may vary depending on local circumstances. The simplest thing that can be achieved in the short term without much additional investment to significantly improve the open dumps and reduce its adverse impacts and associated nuisance is to move to controlled tipping. This can be followed up with gradual and obvious adoption of source segregation on the upstream and

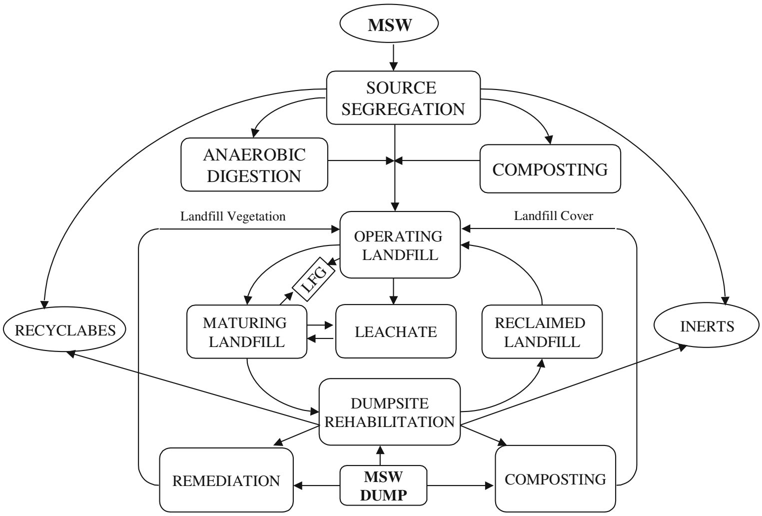

Fig. 1 Elements of sustainable solid waste management in Indian cities

engineering techniques to improve the dumpsites on the downstream. Movement from the controlled dumping to engineered landfills may be a long-term goal depending on the availability of physical and financial resources. The waste degradation in landfills can be accelerated by operating it in the bioreactor mode.

Regional approaches to MSW management is gaining momentum in India as it can be a practical and cost-effective way to discharge common tasks, share resources, and take advantage of the economies of scale. The options include

- Creation of regional solid waste management authorities or entities empowered by law to undertake waste management activities over a region or state;
- Creation of solid waste management 'regions'; and
- Municipalities jointly constituting a company, or common authority, to implement a regional waste management project.

A guidance note to support such initiatives has already been prepared by MoEF.

9 Institutional Development and Capacity Building

For improving the solid waste management services it is essential to adopt modern methods of waste management having a proper choice of technology which can work in the given area successfully. Simultaneously, measures must be taken for institutional strengthening and internal capacity building, so that the efforts made can be sustained over a period of time and the system put in place can be well managed.

Institutional strengthening can be done by adequately decentralizing the administration, delegating adequate powers at the decentralized level, inducting professionals into the administration and providing adequate training to the existing staff. It is also necessary to fix work norms for the work force as well as for supervisory staff and the output expected from the vehicles and machinery utilized. Non-Governmental Organisations/private sector participation also needs to be encouraged to make the service competitive and efficient. Training, motivation, incentives for outstanding service and disincentives for those who fail to perform are essential for human resources development.

It is also necessary that the elected members of the Local Bodies such as the Mayors/Presidents of the Corporations/Municipalities and other important office bearers of the local bodies are given appropriate orientation towards the need of modernization of solid waste management practices in the urban areas and the importance of the same in terms of health and sanitation in the cities/towns. With a view to avoid the problems of lack of coordination and passing of the responsibility on others, it is necessary to have one person exclusively in charge of SWM in the city with responsibility and authority to control collection, transportation, processing and disposal of all waste, including workshop facilities. It should also be responsible for the cleaning of open drains, collection of silt, construction waste and debris and vehicle deployment and maintenance.

NGOs may fully involved in creating public awareness and encouraging public participation in SWM planning and practice. The local body may also encourage NGOs or co-operative of rag pickers to enter this field and organize rag pickers in doorstep collection of waste and provide them an opportunity to improve their working conditions and income.

10 Green House Gas Emission Potential

The impact of solid waste management on the greenhouse gas emissions comes mostly from CH_4 released as biodegradable wastes decay under the anaerobic conditions in landfills. Urban India produces about 42 million tonnes of municipal solid waste annually out of which 72.5 % is generated and disposed in 423 class-I cities. In order to assess the landfill gas yield of a particular waste stream or combination of waste streams, it is important to understand the composition of the waste stream: in particular the distribution of cellulose and hemi-cellulose (the primary gas generating components of waste) and their degradability.

Among the available methods, the simplest one for the estimation of methane emissions from landfills is based on mass balance approach, used in the IPCC (1996) guidelines as the default methodology for estimating methane emissions from solid waste disposal sites. The national level methane emission from solid waste disposal sites estimated by Kumar et al. (2004) using the default methodology varies from 263 Gg in year 1980 to 502 Gg in year 1999 and the methane emissions using triangular pattern of gas generation indicates that the methane emissions vary between 119 in 1980 and 400 Gg in 1999. An estimate of methane generation, based on the waste composition, waste age and the amount of total MSW dumped and applying the first order decay model varies in the range of 500–1,500 Gg per year.

Source segregation of MSW followed by recycling (for paper, metals, textiles and plastics) and composting/anaerobic digestion (for putrescible wastes) gives the lowest net flux of greenhouse gases, compared with other options for the treatment of mixed MSW. The largest contribution to this effect is the avoidance of emissions from landfills as a result of recycling these materials. Further, segregation of material for recycling at the point at which it is produced (i.e. at households) provides the highest degree of clean, contaminant-free material for recycling.

11 Conclusion

The main driver for domestic waste is the rapid urbanization that is slated to change India from a largely rural to a majority urban country in the next decade. The total waste quantity generated by the year 2047 is estimated to be about 260 million tons per year. It is estimated that if the waste is not disposed off in a more systematic manner, more than 1,400 km^2 of land, equivalent to the size of city of Delhi, would be required in the country by the year 2047 for its disposal. Though sustainable management of waste is the possibility for sustainable use of natural resources and reduction of negative impacts on the human health and the natural environment, the low priority, institutional weaknesses, improper choice of technology and public apathy towards waste has made the prevalent system of waste management far from satisfactory, with the practice of uncontrolled dumping of waste on the outskirts of towns and cities creating serious environmental and public health problems.

Despite all the issues discussed, the good news is that there is currently increased official as well as civil society consciousness about the importance of waste management which was not there a decade ago. There are few Indian cities, e.g. Suryapet in Andhra Pradesh (population 103,000) and Namakkal in Tamil Nadu (population 53,000), which are both dustbin-free “zero-garbage” towns (Good Governance India 2004). Their highly motivated city managers and elected members, working in unison with dedication and focus with public participation could achieve this. The Decision makers in the Municipality who had been exposed to alternative strategies for SWM services and who were aware of widespread public discontent over the status of SWM services were effectively able to translate public discontent into public cooperation and also built up political support for the program. The Namakkal town has followed a 10 point charter which included extending the scheme of door to door collection with segregation to entire town and make the streets and roads garbage free, introducing night sweeping at bus stand and important roads etc., extending the scheme of door-to-door collection and sweeping on Holidays and Sundays and making the town clean on all days by continuous sweeping, making the parks and burial grounds beautiful and attractive through NGOs and voluntary agencies, removing encroachments on all roads and streets, levying service charges on hotels, Kalyanamandapams, commercial complexes and garbage generating industries, manufacturing of Vermi-compost from organic waste through voluntary organization/private agencies on B.O.T. basis, selling the inorganic recyclable garbage and converting the compost yard into a garden etc. Sanitary inspectors have been appointed to impose spot fines upon those who resort to littering. This experiment has been successful due to a holistic approach with all agencies including the district administration, the municipality, consortium of NGOs, women self-help groups, schools, market associations, industrial associations and ragpickers cooperating together under the leadership of the District Collector.

Yet another success story is from Kerala under which women from the financially backward families who are the members of the Community Based Organizations (CBOs) of “Kudumbashree” are engaged in door to door household waste collection and transportation to the transit points fixed by the Urban Local Bodies. The initiative provides a means of livelihood to the urban poor especially women, apart from better waste management and reduction in pollution. For collecting waste from the households, the entrepreneurs charge Rs. 30/-per month from each household. The women entrepreneurs engaged in solid waste collection are earning Rs. 3,000–5,000 per month. Now 155 Kudumbashree solid waste management groups are in operation in 18 urban local bodies in the State.

All these means that the future of municipal waste management in India depends on the effectiveness of local government—the operator of public services, attitude of citizens, private sector participation and on the key role of NGOs and CBOs to shape and develop community participation. An essential prerequisite for any successful programme to improve solid waste management is to establish it as a political priority. The pressure for change should come from the “top” of administrative systems. The exposure of decision-makers and professionals to issues and practical examples would be instrumental for the spread of new ideas. Solid waste management is much more than a technological issue—it usually involves managing a large workforce and working together closely with the public. Political support is often crucial for obtaining financing and ensuring that the program gets the resources needed to construct facilities and operate them efficiently. Specific earmarked allocation of land for landfill sites as well as composting and other processing facilities should be a part of town planning and must be made a mandatory prerequisite for approval of new urban settlements.

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Municipal Solid Waste Management in Indonesia

Enri Damanhuri, Widhi Handoko and Tri Padmi

Abbreviations

ANS	Agency for national standard
FD	Final disposal
ITB	Institut teknologi bandung
JICA	Japan international cooperation agency
MPW	Ministry of public works of Indonesia
MSW	Municipal solid waste
NGO	Non-govermental organization
SNI	Standar nasional Indonesia (Indonesia national standard)
3Rs	Reduce, reuse and recycle
SME	State ministry of environment of Indonesia
TS	Transfer station

1 Introduction

Solid Waste Management Act 18/2008 defines municipal solid waste (MSW) as the residues of human daily activities and/or residues of natural processes in solid forms. Wastes specified under this law are: (a) domestic waste; (b) domestic waste equivalents; and (c) specific wastes:

- Domestic wastes are generated by daily activities performed within households, but does not include feces and specific wastes;

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- Domestic waste equivalents are generated from commercial zones, industrial estates, special zones, social facilities, public facilities and any other facility;
- Specific wastes are wastes that require special management due to their properties, concentrations and/or volumes, in forms of hazardous materials contained wastes, hazardous wastes, wastes generated by disasters, demolition wastes, unprocessable wastes due to availability of technology and non-periodical generated wastes.

Indonesia is a country located in South East Asia, which comprises of more than 13,000 big and small islands with a total population of 224,904,900 in 2007. Administratively, the country is divided into 33 Provinces and more than 465 municipalities which consist of 14 metropolitans (one million population or more), 15 big cities (500,000 up to one million population), 56 medium cities (100,000 up to 500,000 populations), and 380 small cities (20,000 up to 100,000 populations).

Municipal solid waste management in Indonesia is the responsibility of the municipality (local government). There is a city/district cleanliness division within the municipality organization. Most of them carry out cleansing service by themselves; while some other big cities contract out part of the services to third parties. In fact, most of the municipalities still give low priority to solid waste services. It can be seen in their low allocation in their annual budget which is mainly used for covering operational costs with a very small allocation for maintenance and investment.

At the national level, the solid waste sector is handled by the Ministry of Public Works (MPW) for its infrastructure planning and implementation, the State Ministry of Environment (SME) for its control and monitoring and some other related Ministry or Board of the Central Government. Although their responsibility is to provide guidance and supervision, they still provide an allocation for the initial investment as well as technical assistance. At the local government level, the Province Government is responsible for coordinating cities/districts in the case of centralized final treatment/disposal in their regions. The Province Government can also provide a 'participatory' budget for the investment of those centralized facilities.

Municipal solid waste problem in Indonesia, particularly in big cities, is one of the most challenging urban problems for city administrators. Population growth and ever increasing activities in major cities entails the increase of waste generation and all of the inherent consequences. It was estimated, that of the entire wastes generated in 2006, at most only around 60–70 % could be transported to final disposal by the institutions responsible in handling wastes and cleanliness, such as City/District Cleanliness Divisions. The rest is handled by the community through their self-effort or unsystematically disposed all over the city.

The general method currently observed in MSW managements all over Indonesia is collect-transport-dispose. The authorities of urban municipalities transport the MSW from designated collection points to a location for its final dumping. Most of the local authorities practice crude open dumping, creating a despondent situation at the landfill sites.

2 Data for MSW Management

The availability of data associated with MSW handling all over Indonesia is currently limited in nature. Generally speaking, municipalities and districts have no adequate data except general data such as number of trucks, number of personnel and the like. There is no systematic data collection on the volume of waste unable to be transported, due to the current practices of measurement based on truck travel frequencies to final disposals. Any waste being handled by the community through self-effort or unsystematically disposed off into improper sites is not systematically calculated.

Although each City/District Cleanliness Division should be responsible for data recording of solid waste measurements in their respective areas, these data are rarely found. Measurement is usually conducted to support certain study activities. Related data are submitted to the Ministry of Public Works or to the State Ministry of Environment as part of Annual Solid Waste Management Performance Questionnaire. Some data are put in Municipal/City Annual Statistics. Many programs and development of solid waste management are mostly based on an estimated quantity of solid waste. Data requiring periodical updates such as wastes generation, wastes composition/characteristics, source composition and the like are generally lacking or incomplete. This would create difficulties in evaluating the conditions or the performances of the existing waste managements, and contribute to further difficulties in setting future development plans. Availability of these data will be necessary to assess factors such as waste quantity and quality projection for the future, specific design of facilities, costs and budgeting, cooperation with third parties.

3 Waste Generation and Composition

Indonesia is located at the equator, and it has two seasons every year (dry and rainy seasons) and because of the monsoon rains, each season lasts 6 months. The rainy season is also the fruit season and fruits like the durian produce an enormous amount of waste in the city.

The principal generation source of MSW in Indonesia is households. They generate about 50–60 % (wet-weight) of the total quantity of MSW per day. This waste consists mainly of food scraps, yard waste, and wrapping materials. It is a mixture of all kinds of waste, organic and non-organic, recyclable and non-recyclable waste, even hazardous and non-hazardous materials. The other sources are traditional markets, commercial activities/areas, industries (non-hazardous categories), public gardens and streets.

Some cities provide their generation data by conducting surveys and sampling but many other cities usually estimate their waste volume by using the estimated generation rate as 2.5–3.0 l/capita/day based on standard national of MSW generation (SNI S 04-1993-03) established in 1993 (ANS, 1994). Therefore, the accuracy of solid waste generation figures is questionable. Table 1 shows the MSW generation from some main cities in Indonesia based on those approaches. Based on questionnaire survey conducted by JICA and ITB in 2007. it was estimated that MSW generation of all municipalities in Indonesia in 2006 was 38.5 million tonne as presented in Table 2.

Some big cities in Indonesia, such as Jakarta and Bandung, are one step ahead of other cities in Indonesia in terms of MSW quantity measurements. Some studies conducted in Jakarta indicate the waste quantity (Table 3) and the waste composition (Table 4).

The amount of MSW is normally dominated by the organic compositions (more than 55 %-by weight) that mainly come from food scraps type of waste. This amount contributes to about 65 % of the water content of MSW. Plastic and paper forms are the two next major items. They are mainly composed of packaging/wrapping materials and food, beverage etc. Wood and textiles are the next two important components. Based on a survey in 2007 in Bandung metropolitan areas, the average amount of organic MSW taken at Transfer Stations was around 60 % (by weight) as presented in Table 5.

The amount of inorganic wastes was around 40 % (by weight), while about 6 % (by weight) was classified as recyclable inorganic components. Table 5 and 6 present the characteristics of MSW at Bandung Metropolitan areas in 2007.

Table 1 MSW generated in main cities, 2005

Cities	Population (inhabitant)	Waste generation (M^3/day)	Generation rate (L/cap/day)
Surabaya	2,599,796	6,700.0	2.58
East Jakarta	2,385,121	5,442.0	2.28
Bandung	2,141,837	6,473.7	3.02
Medan	2,068,400	4,382.0	2.12
South Jakarta	1,708,269	5,223.0	3.06
Tangerang	1,700.000	4,225.0	2.49
West Jakarta	1,565,406	5,500.0	3.51
Palembang	1,500,872	4,698.0	3.13
Semarang	1,424,000	4,274.0	3.00
North Jakarta	1,176,307	4,180.0	3.55
Makassar	1,160,011	3,580.2	3.09
Central Jakarta	897,789	4,651.0	5.18
Bogor	820,707	1,996.0	2.43
Denpasar	585,150	2,320.0	3.96
Yogyakarta	512,464	1,571.0	3.07

Source Handoko and Sulistysdi (2008)

Table 2 MSW generated in main cities, 2006

Islands	MSW generation (thousands tonnes)
Sumatera	8.7
Java	21.2
Bali and Nusa Tenggara Islands	1.3
Kalimantan	2.3
Sulawesi, Maluku and Papua	5.0
Total	38.5

Source SME 2008

Table 3 MSW generation in Jakarta

Sources	1997[a]	2000[b]		2005[c]	
	(%)	(Tonne/day)	(%)	(Tonne/day)	(%)
Households	65	4,169	65	3,067	51
Markets	–	–	–	280	5
Schools	–	–	–	308	5
Commercial	15	963	15	1,583	26
Industry/institution	10	641	10	516	9
Others/roads, drainage	10	640	10	246	4
Total	100	6,413	100	6,000	100

Sources Handoko and Sulistysdi (2008) quoted from:
[a] Jakarta cleansing bureau, 1997
[b] Feasibility study of SWM improvement, 2000
[c] SWM for jakarta master plan review, 2005

Table 4 Solid waste composition in Jakarta

Components	1981[a]	1986/1987[b]	1987[c]	1996/1997[d]	2001[e]	2005[f]
Garbage, leaves	79.7	74.7	72.0	65.1	52.7	55.4
Paper	7.8	8.3	8.3	10.1	20.1	20.6
Plastics/Styrofoam	3.7	5.4	5.4	11.1	14.5	13.3
Wood	3.7	3.8	3.2	3.1	2.6	0.1
Textiles	2.4	3.2	3.2	2.5	2.6	0.6
Rubber/leather	0.5	0.6	3.2	0.6	0.9	0.2
Metals	1.4	1.4	2.1	1.9	1.1	1.1
Glass	0.5	1.8	1.8	1.6	1.2	1.9
Construction waste	-	-	-	-	-	0.8
Hazardous waste	-	-	-	-	-	1.5
Others	0.5	1.0	1.0	4.1	4.4	4.7

Sources Handoko and Sulistysdi (2008) quoted from:
[a] Board for assessment and application of technology, 1981
[b] Jakarta cleansing bureau, 1986/1987
[c] JICA, jakarta solid waste management master plan, 1987
[d] Jakarta cleansing bureau, 1996/1997
[e] JCI survey, 2001
[f] SWM for jakarta master plan review, 2005

Table 5 Composition of MSW at 2 transfer station (TS) at Bandung (July 2007)

Item		% Wet-weight	
		TS-1	TS-2
Recyclable components	Hard-papers	0.92	0.95
	Archives (white) Papers	0.14	0.34
	Bottle-glass	1.77	0.50
	Drinking bottle-plastic	0.29	0.19
	Drinking glass-plastic	0.17	0.34
	Can	0.22	0.32
	PE-plastic	0.03	0.42
	Divers-plastic	1.63	0.47
	Aluminum	0.06	0.05
	Cartoon/cardboard	0.33	0.31
	Newspapers	0.13	0.16
	Metals		0.03
Total of recyclable components		5.69	4.08
Organic Component	Food waste	33.90	58.04
	Leaves etc.	12.32	2.21
	Tissue-papers	11.02	1.78
	Textile	0.89	0.90
	Wood	1.98	0.70
Total of organic components		60.10	63.62
Others: an-organic non-recyclable		34.21	32.30

Source Damanhuri and Padmi (2009)

Table 6 Some characteristics of MSW at transfer points in Bandung, 2007

Components	Water contents (% wet-weight)	Volatile matters (% dry-weight)	Ash contents (% dry-weight)
Food waste	88.33	88.09	11.91
Tissue-papers	5.03	99.69	0.31
Leaf etc.	34.62	96.92	3.08
Bottle-glass	1.30	0.52	99.48
Plastic bottles, cups	2.57	88.48	11.52
Hard paper (board)	6.57	94.45	5.55
White papers	50.65	80.00	20.00
Textiles	3.41	86.32	13.68
Divers plastics	68.45	98.21	1.79
Cans	0.13	2.62	97.38

Source Damanhuri and Padmi (2009)

4 Reduce, Reuse and Recycle (3Rs) Approach

A positive impact derived from the current SWM systems in developing countries and economies in transition is the high level of recycling of the inorganic component of MSW. Although the methods employed for sorting and separation of MSW in these countries are considered inappropriate for solid waste management systems as defined by developed countries, these existing methods not only provide an income stream to the hundreds of thousand of people involved in this informal sector but also ensure a far greater amount of MSW generated is recycled.

Most Indonesian people of all economic levels have a different terminology in perceiving the end-of-life of goods, including consumer goods. In developed countries, some goods like used newspapers, old magazines/books, old clothes, old electronic–electrical equipments etc. are considered to be waste and tend to generate problems. In Indonesia. plastics, glass, paper, and metals are well collected by either the informal sector or municipalities, and these materials are recycled. These wastes would be perceived as used objects that still have an economic value, to the extent that they rarely would be found in municipal waste management chains, for the very reason that these items are actually saleable, or could be donated to others of lower income.

> Like other major cities in developing countries, the informal sector plays an important role in any recovery effort over the usable materials of waste. The recycling activity engages this sector, to include housewives, waste workers (from the cleansing division), vendors of used articles, and waste pickers. Middlemen or intermediary traders are found in all corners of Indonesian cities to buy used articles directly door-to-door. Dry waste (inorganic waste) is the most easily found for waste recycling in large cities in Indonesia.

Some of the recyclable wastes are collected by wastes pickers who sell these wastes to the collectors. The latter separate and classify the wastes into several groups of items depending on the types, then sell them to the wholesalers. These wholesalers will then trade these wastes with recycling factories. Some parts of these wastes are recycled within the cities that produce them, or they sell these wastes to other cities, or even export them aboard.

It is known that the recyclable-material is reduced en route to the transfer points and to the final disposal. Many stakeholders are involved in the reduction process, e.g. sorting at the solid waste sources, scavenging. It is not only done by the scavengers but also the waste handling crew. These waste recovery activities that have been practiced in many cities in Indonesia are mostly done by the informal sectors, consists of handcarts crews, mobile scavengers, transfer depot scavengers, final disposal scavengers, waste traders, recycling business people, and composing units at several points over a city. In so far, the role of informal sectors in wastes recovering activities is not well organized.

Waste pickers often throw the contents of garbage bags or bins to take anything of value. In many cases, they take the plastic bag as part of waste recovered for being sold, so will be increasing the difficulty of waste crew collector to collect waste. Waste recovery by waste pickers often is considered as a problem. Unorganized waste picking can have an adverse impact on neighborhoods and cities. However, municipal authorities do not ban their activity but do not also support them.

Surabaya Best Practice: Empowerment of Citizen in Waste Handling

To enhance the community participation in waste reduction efforts at the source through the 3R program, the Ministry for Environment and the Ministry of Public Works, especially after the enactation of the Solid Waste Management Act 18/2008, created similar programs annually in cities in Indonesia, including pilot programs involving NGOs and local communities. The main problem faced is how to maintain the sustainability of this system, and how to keep the community for continually willing to involve in the program.

Government of Surabaya City in cooperation with Unilever Care Foundation Indonesia since 2001 introduced a yearly program namely *Surabaya Green and Clean* (SGC program). The primary aim is to make settlements in Surabaya green and free from garbage by educating people to manage their waste with the 3Rs concept (http://rileksmedia.com).

Surabaya is the second largest metropolitan city in Indonesia after Jakarta. The population of Surabaya in 2006 was 3,221,119 in the night and up to twice during the day, and generated MSW approximately 8,700 m^3/day waste (http://www.silaban.net). Surabaya is also working with city of Kitakyushu (Japan) since 2001 in the sister city program. One result from this cooperation was the introduction of composting model for household scale, known as Takakura composter (inovated by Mr. Koji Takakura), which is widely used in Indonesia.

The SGC program is consistent with the main program of waste management in the city of Surabaya, namely (a) empowerment of citizens to handle their waste, (b) street sweeping and transportation of waste, (c) proper waste handling at transfers station and landfill site, and (d) planning and construction of new landfill. The targets are not only segregating the organic and inorganic waste, processing the organic waste into compost, recovering the valuable inorganic component, but also is empowering the communities to reduce waste at its source (www.silaban.net).

The SGC program in Surabaya (and other cities in Indonesia) is similar to that conducted by the Ministry for Environment through the Adipura Program (Damanhuri and Padmi 2009). The approach is to develop citizen participation in handling their waste by way of empowering them, to provide them with the environmental knowledge, particularly in waste handling. The second approach is the selection of cadres, which are selected among the citizens in each neighborhood level. These cadres serve continuously in each neighborhood to persuade and to invite the respective community to participate in the program.

The assessment criteria for the neighborhood winner include the innovation on waste management, greening the settlement, local leader participation, citizen enthusiasm in participating in this program. The local leaders from the neighborhood which win this competition will be awarded as '*environmental cadre*'. They are considered successful in getting citizens to participate in this program. When an environmental cadre in the next year re-elected, then the corresponding status is upgraded to become '*environmental facilitator*', and when the next year he/she wins again as the best facilitator, then the corresponding status will be upgraded again to become an '*environmental motivato*r', who shall serve to motivate citizens more broadly not only in his/her respective neighbourhood.

Each year, the neighbourhood that followed the program increases. For example in 2006, there were 968 neighbourhoods from 163 villages (kampong) which were participating, and 20 neighborhoods were elected as the winner. At the same time, about 350 environmental cadres have been selected which won in this competition. The rewards are performed by the Mayor of the city in the event such a citizen party. In 2006 the program was enhanced, by involving more private companies that wish to participate, with the theme *Let's Independence from the Garbage* (http://www.silaban.net). In 2008, the number of the environmental cadres has reached 5,684 people who came from some 1,200 neighbourhoods (http://www.unilever.co.id).

Another important activities undertaken by the Surabaya city is to coordinate the activities of scavengers in the area, by forming a kind of association between them. The first step is to record the scavengers in the city of Surabaya.

The positive outcome of this program among others is the increasing of motivation and desire of citizens to participate in waste segregation, while creating opportunities for income from the sale of valuable waste. One of the waste recovery mechanism is the formation of garbage-savings-selling mechanism, that is widely known in Indonesia as "banks of garbage", which is managed by residents in the form of cooperative. This institution will accept valuable dry waste deposited from citizens, then it will be sold to the waste collector coming to the cooperative. This kind of business form (banks of garbage) is widely found in Indonesia, mostly in the form of cooperative (a business that is owned and run jointly by its members, who share the profits). Money from the sale of such material will be recorded in the 'account' of citizens who deposit their waste in the cooperative. Some profits from this transaction will be an additional cash income for the neighborhood.

5 Waste Collection and Transportation

The handling of the MSW is the responsibility of the local government. Usually the cleanliness division is in charge to carry out this task, particularly for transporting the waste from transfer point to final disposal. The waste collection from house-to-house to transfer point is organized and handled by the neighborhood community, which is consist of sub-neighbourhoods and neighbourhoods. The structure of neighborhood community in Indonesia is as follows:

- Sub-neighbourhoods (*RT* = *rukun tetangga*) are the smallest social units within the community structures, led by the community leader who is elected by the members of each sub-neighbourhood; one sub-neighbourhood comprises of 30–35 households;

- Neighbourhood (*RW* = *rukun warga*) comprises of 10–15 sub-neighbourhoods, led by neighbourhood leader who is elected by neighbourhood members;
- Villages or kampong (*kelurahan/desa*) are the lowest formal governmental units within the governmental structures of Indonesia, comprise of several neighbourhoods and led by *Lurah*;
- Sub-district (*kecamatan*) is the next hierarchy of formal governmental unit, led by *Camat*. *Lurahs* and *Camats* are civil servants of the local government on municipal or city level; and
- City, municipality or district comprises of several sub-districts, led by *Walikota* (Mayor) or district leader, called *Bupati.* Several cities and districts form provincial territory or provinces, led by Governor. *Walikota*, *Bupati* and Governor are political positions elected by their respective peoples through direct general elections.

As generally practiced in urban areas all over Indonesia, there are two different services in MSW handling:

- The collection-transportation of waste from households to a transfer-point, mostly done by manual handcart carriages, is normally organized by the respective neighborhoods. The system is being handled and funded by the *RT/RW* communities, who could afford the expenses associated with the activities. This community employs a person who is known his residence address, which usually live near the settlement. Generally these people are those who do not have a permanent job. They are not scavengers and this activity is considered legal, however the waste crew is categorized as an informal sector. Almost all these waste crews perform valuable waste segregation. In many cases, the waste collected is already sorted by the generator and given to these waste crews.
- All of wastes in the transfer-depot, along with non-residential wastes, would be subsequently transported by trucks to landfills by city cleansing division crews.

Like any other collection system in developing countries, where the municipal waste from household sources is commonly collected through labor-intensive (Cointreau 1982; Joseph 2010), in urban area in Indonesia their waste is collected mostly using handcarts drawn by 1–2 crews. Typically, waste generated at households is generally accumulated in small containers, and then is placed on the ground directly, thus requiring being shoveled by hand; or it is left in plastic bag, open carton or basket to be picked up by hand. These waste crew collection workers have significantly direct contact with solid waste, so they are more likely to encounter potentially toxic and hazardous materials. Containers used for household storage of solid wastes are of many shapes and sizes, fabricated from a variety of materials depending on the economic status of the waste generator. The wide variety of types and shapes commonly encountered within a community creates difficulty in establishing and operating an efficient solid waste collection system (Joseph 2010).

In 2001, it was estimated that the existing city waste management could only serve around 32 % of the population in 384 cities all over Indonesia (Table 7). Of this percentage, only 40 % of the entire wastes generated by the city population could be transported to processing sites (Table 8). The transportation of MSW in most cities are conducted by the city cleanliness division of the municipalities. Some big and medium cities have been contracting out part of the collection and transportation to private firms.

Collection of waste is conducted in several methods, namely:

- Communal collection: where the community bring their waste by themselves to the transfer collection point located in certain places from where the transportation is carried out by using trucks. n certain places, the community brings their waste to vehicles which move along their routes while playing a traditional song.
- Individual indirect collection: where collection of waste is conducted by small vehicles or carts' from door-to-door, and brought to the transfer depot from where the waste is transferred onto trucks and transported to disposal/treatment sites.
- Individual direct collection: where garbage is collected door-to-door by using trucks and directly transported to disposal/treatment sites. This type of

Table 7 Population served by city waste management in 2001

Region	Total city		Population		% Population
	City	(%)	Population	(%)	Served
Sumatera	100	6.04	17,884,336	16.35	46.0
Java and Bali	148	8.54	75,049,732	68.59	28.4
Kalimantan	45	1.72	5,259,688	4.81	34.4
Sulawesi	62	6.15	6,103,336	5.58	36.5
Others	29	0.55	5,115,469	4.68	30.9
Total indonesia	384	00.00	109,412,561	100.00	32.1
West Indonesia	248	4.58	92,934,068	84.94	31.8
East Indonesia	136	5.42	16,478,493	15.06	34.1

Source Sujono (2003)

Table 8 Population served by municipalities in Indonesia, 2006

Islands	Population (million inhabit)	Population served (million inhabit)	% Population served
Sumatera	49.3	23.5	48
Java	137.2	80.8	59
Bali and Nusa Tenggara Islands	12.6	6.0	47
Kalimantan	12.9	6.0	46
Sulawesi, Maluku and Papua	20.8	14.2	68
Total	232.7	130.3	56

Source SME (2008)

collection is conducted in the high income area or commercial areas where a large amount of waste is generated.

Transportation of waste is carried out via several other methods in conjunction with the earlier mentioned collection methods:

- Temporary collection or load haul method: it is applied in conjunction with communal and/or individual indirect collection. Dump trucks and/or arm roll trucks are used to carry out this transportation work;
- Direct transportation: it is applied in conjunction with individual direct collection by using dump trucks or compactor trucks to collect and transport the waste from each source in the serviced area;
- Transfer station: to bring big amount of waste by using about 20 tonne container/trailer trucks especially when the distance to disposal site is more than 25 km. This method is used in Jakarta City, where the disposal site is located more than 40 km from the city center.

6 Treatment and Disposal of Waste

So far, most of the existing MSW management systems in Indonesian municipalities rely on the existence of landfills. The excess has been handled by the community through various ways, such as burning, burying, composting, and other ways such as recycling or disposing at improper sites, including ducts or drainage channels. Based on a questionnaire survey conducted by JICA and ITB in 2007 in 154 cities in Indonesia, the mode of handling of MSW in Indonesia in 2006 is shown in Fig. 1.

Most wastes transported to final disposal sites left in open dumps, and it is estimated that only about 10 % of it was handled through better systems such as using controlled landfills. In many sites, these facilities are nothing more than uncontrolled open dumping sites. Lack of serious attention over these final

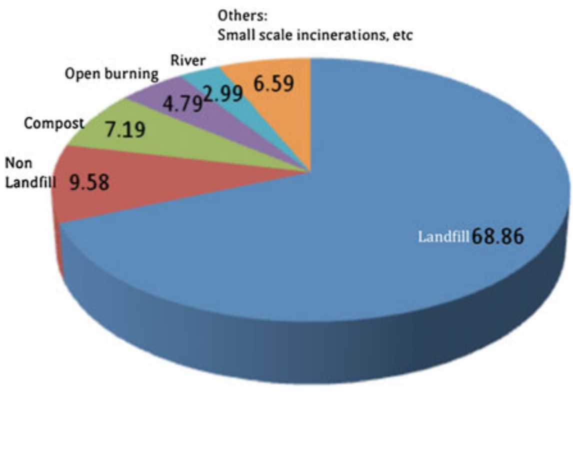

Fig. 1 Percentage of MSW handling in Indonesia in 2006 (*Source* SME, 2008)

disposals tends to be a general practice on the part of city administrators in Indonesia. In many cases, it was found that waste from industry and also pathogenic waste from hospitals were brought to the same dumpsites as the non-hazardous municipal waste, although since 1995 the government of Indonesia has regulated hazardous waste landfill criteria.

Another method of treating MSW in some cities in Indonesia is incineration. There are several small-scale incinerators in operation in different cities, each with a capacity of about 100–200 kg/h operating 8 h per-day. Therefore, the system is only able to handle a small percentage of the total MSW generated. Composting of organic waste has also been introduced as part of waste treatment. They are located, mostly, in final disposal sites. In principle, the composting system comprises a centralized sorting and shredding system, and thereafter composting of the organic matter is by a simple composting method.

Most municipal authorities have no other alternative if their existing landfill are in a troubled state, and have no experience in other better and more efficient way of handling waste. In so far as the existing landfills are not adequately prepared and are not professionally operated the troubled landfill cases would always appear. On the other hand, the consciousness on the part of the surrounding communities of their right to enjoy better environmental quality in their lives is ever increasing.

Landsliding of Leuwigajah Landfill

Since 2000, failures of landfill operations all over Indonesia began to show themselves, the most interesting of them are Bantar Gebang landfill in Jakarta, Keputih landfill in Surabaya and the latest Leuwigajah landfill in Bandung. The most remarkable failure of a landfill is the case of the landslide at Leuwigajah landfill in 2005. The Leuwigajah landfill landslide caused the termination of the landfill service to receive more wastes from three local governments, namely, City of Bandung, City of Cimahi and the District of Bandung. Wastes that could be transported to landfills were very limited in volumes, resulting in stacks of garbage on the sides of streets and roads. The City of Bandung turned to the Jelekong landfill, 20 km to the south of Bandung, to handle its waste problems. The Jelekong landfill was facing similar conditions of exposed to environmental factors and also protects from its surrounding communities.

Bandung is the capital of the West Java Province in Indonesia. The population of the Bandung Metropolitan area in 2005 accounts for approximately six million. The landfill site was operated by three different authorities, the City and the District of Bandung, as well as the City of Cimahi.

The Leuwigajah landfill, about 12 km from the center of Bandung City and located at City of Cimahi, was one of principal facilities in waste handling at the Bandung Metropolitan area, particularly for Bandung City and Cimahi City. From ±23.5 Ha of the site, 17Ha (72.3 %) of it is owned by Bandung City. The contribution of Bandung City to the inflow of waste to Leuwigajah was ±3.000 m^3/day, while Cimahi City contributed up to 400 m^3/day, and residential areas of Bandung District on the vicinity contributed about 750 m^3/day.

The dumpsite was established in a narrow valley on the outskirts of Leuwigaja. From a hydrogeological point of view, the valley is a suitable site. The subsoil consists of rock covered by a thin layer of 1 m of silt or clay material, performing as a natural barrier. Before the waste disposal started, small water streams were running through the valley in the wet season carrying the surface runs off. Precipitation in the region is high (between 1,500 and 2,000 mm per year) while rain distribution is significantly non-uniform. Heavy rainfall and thunderstorms are common during the wet season.

Officially, sanitary landfills had already been adopted for final disposal since the middle 1990s. However, due to financial constraints, the cleansing agency could not afford it, so open dumping became a general procedure for waste disposal for nearly all landfill sites in Indonesia. Dumping activities started from the top of the valley by just dropping the waste over the edge. The natural landscape of the valley showed a gentle slope of approximately 5–10 % at the bottom of the valley and a slightly higher slope at the upper end. Before the failure happened, the maximum height of the dumpsite rose to 60–70 m. The front slope facing the open valley showed a slope angle between 30° and 45°.

The landslide happened on February 21st, 2005 at 2.00 a.m. After 3 days of heavy rain, about 2.04 million cubic meters of waste started sliding down the valley. The waste covered a 200–250 m wide stripe on a length of 900 m. Witnesses reported a roll of thunder similar to an explosion. Regarding the speed, observations indicate that the waste came like an avalanche. Rescue teams' uncovered 147 dead bodies out of the waste. Rescue activities were carried out only in the area close to the two settlements.

Observations and researches done, particularly in 2003/2004 by ITB, concluded that the condition of the Leuwigajah site was very unhygienic and had a very high exposure to environmental problem, due mainly to open dump filling which could result in landslides. The operation of the dump itself had created environmental problems. Uncontrollable leachate polluted the water body over its downstream. The smoke, bad smell and flies continuously affected the environment around the landfill. Before the last landslide, which resulted in death and casualties, there were at least two slides of waste stacks which occurred during the preceding.

After the closing of the Leuwigajah site, the only dumping site available was Jelekong, located in the district of Bandung, 20 km South of Bandung, which had a limited capacity. The Cicabe dumping site that closed in 1985 and the Babakan dumping site owned by the District of Bandung, operated as emergency sites until April 2005. After that, Jelekong became the only site that operated, but it was closed because of objections from the community in December 2005. Cicabe was re-opened and this time the surrounding community only consented to its operation until April 15, 2006.

The state of solid waste management one year after the Leuwigajah site landslide disaster was the worst in Bandung history. By April 15, 2006 the city of Bandung did not have a dumping site to dispose their waste. The heaped waste in

Bandung city since April 15, 2006 to June 21, 2006 reached 105.000 m^3. This situation drew the attention of the President of Indonesia who through the Minister of Environment obligated the Governor of West Java to overcome the problem.

The termination of the Leuwigajah landfill operation has direct impacts on the Bandung metropolitan area until now. The currently available alternative for Bandung is temporary Sarimukti dumping site, 45 km west of Bandung. Being in a emergency state, the local governments of Bandung area were forced to find alternative landfills, including re-opening long-terminated landfills. After the disaster, the West Java Government took the lead in appointing emergency dumping sites so as to be able to handle administrative "cross-border" issues (Damanhuri 2006).

7 Current MSW Policy and Future Development

The MSW management in Indonesia had reached a relatively sound performance level during 1990–1995, where many cities were motivated to improve their cleanliness/sanitation due to, inter alia, the existence of the Adipura Award program which was granted to any city that was successful. Since the multidimensional crises in Indonesia and the reforms entailing such crises in 1998, the turning point in MSW management in Indonesia began. The era was significantly marked by fundamental changes in political and governmental aspects, such as decentralization and local autonomy (Damanhuri 2008).

In line with the implementation of the local autonomy policy, municipal/district governments took over the full authority and responsibility of waste management from the central/province government. Many of these local governments adjusted the related policies, even drastically, especially in its institutional aspects. The MSW management which formerly tended towards independent divisional establishment was contracted to sections or even sub-sections. These have directly affected unfavorably the priority of handling wastes in many cities, especially in budgetary allocations. Another significant impact is the appearance of locality egocentrism which in turn posed difficulties to municipal governments to operate their respective landfills that are generally situated in sites outside their own jurisdiction.

In 2005, the Government Regulation 16/2005 was announced. It regulated the final disposal of MSW in relation to water resources protection for water supply. In 2006, the Ministry of Public Works through Ministry Regulation 21/PRT/2006 outlined the policy and national strategy for MSW management. This regulation defined the target of MSW recycling for the subsequent 10 years (MPW 2007). The last formal regulation issued by the Indonesian Government was the Solid Waste Management Act 18/2008. This act is expected to bring major changes and new challenges in waste management, which will serve as the umbrella for sound MSW managements in Indonesia.

The basic approach of this new law is waste reduction through 3Rs as the first priority, and the next priority is waste handling. This concept is considered as a new paradigm to replace the collect-transport-dispose concept, which is usually adopted in most Indonesian cities. All of the involved parties agreed that the concept is the best available measure to reduce wastes, and active involvement on the part of the community and other waste generators to reduce waste volumes are the key to the success of any waste management systems.

According to this law, waste processing and dumping technologies that are safe and healthy, and conform to Indonesian circumstances would serve as Indonesia's principal method of MSW processing in the years ahead. There needs to be, however, a common intention among the parties concerned, that the volume of waste to be transported and dumped should be progressively decreased, particularly through reduction and recycling-based waste management, or any other processes such as composting and so on. In the long run, the existence of landfill as a facility should be seen as one component of the more fundamental strategy of reduction and recycling waste management, which would require determination and commitment on the part of city managers to carry out the process consistently.

One of the most strategic governmental programs, through the Ministry of Environment associated with wastes issue is the Adipura Program, which has been revived since June, 2002. The program of award granting reached its highest position as the most important program during the era prior to multidimensional crises as discussed earlier in this paper. The main objective of this program is to motivate local governments to apply good environmental principles in managing the urban environment, so as to realize a clean and green city (SME 2004).

The development of a better final disposal such as the sanitary landfill, based on a regional approach in some metropolitan areas is in progress. The government is committed to close open dumping sites and rehabilitate them to sanitary landfills or controlled landfills. A target has been set to develop 240 new landfills site by the year 2014. This program has been conducted since 2006 in 187 landfill locations across Indonesia in 2012. Some of this development is connected to the CDM project. Indonesia has promising potential for development of landfill gas facilities. With many large urban areas including 18 cities with a population over 500,000 and 10 cities with a population over 1,000,000, Indonesia produces large quantities of MSW. It is estimated that the major urban centers in Indonesia generate enough waste to provide just less than 80 MW of electricity through landfill gas (Damanhuri 2008).

The first CDM project in Indonesia is proposed by the landfill of Suwung (Metropolitan of Denpasar, Bali). Other big city, Pontianak, Bekasi, Palembang, Makassar, Semarang, Bandung and Jakarta are currently interested in undertaking a landfill gas project under the CDM project. This project aims to improve environment both at global and local scales through the capture and treatment of landfill gases, which would not only make significant impacts on global warming but also great negative effects on neighborhoods around the waste disposal sites. In addition, the project aims to contribute to sustainable development of the respective municipalities as economic profits will be achieved and waste management will be improved.

An integrated and a centralized (regional) landfill would significantly reduce potential problems. The landfill would serve wastes from the surrounding areas regardless of their administrative boundaries or local governments transporting them. The local government where the landfill lies could serve only as a monitoring agent to the extent that the functioning of the landfill creates no harm to the population and environment within its administrative authority. The prerequisite is the existence of a single institution to operate it (MPW 2008). The regional landfills that are currently being reviewed extensively are landfills in the metropolitan area of Denpasar (Bali Province), metropolitan area of Yogyakarta, metropolitan area of Bandung (West Java Province), and metropolitan area of Makassar (South Sulawesi Province), and metropolitan of Banda Aceh (Aceh Province).

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Municipal Solid Waste Management in Japan

Masaru Tanaka

1 Introduction

The municipal solid waste (MSW) management in Japan was initiated upon the promulgation of the "Dirt Removal Law" in 1900. Enacted after an epidemic of dysentery, pest and other infectious diseases, this law was aimed at overcoming sanitary problems in cities. In 1954, the "Public Cleansing Law" was introduced to secure a hygienically sound living environment. Following rapid economic growth, "Waste Management and Public Cleansing Law" (hereinafter "The Waste Management Law") was enacted in 1970, was passed by the Diet during its "Pollution Session" along with other environmental restraint laws. This law constitutes the main framework of the present waste management legislation and has a widened regulatory coverage extending from MSW to waste including "industrial wastes" generated from business activities.

In the last 43 years from the enactment of the Waste Management Law, the Japanese people's lifestyle and economic structure have undergone drastic changes with their economic affluence as the background, with resultant quantitative growth and diversity in the nature of wastes. Mass-production and mass-consumption by human beings have resulted in pollution; depletion of forests, mineral and other natural resources, global warming and other forms of degradation of environmental quality. It has been realized that waste management holds the key to "sustainable society" and the target of solid waste management has been shifted to 3R (reduce, reuse and recycle) (Tanaka 1999). Issues such as compliance with the law, typically illegal dumping, responsibility of manufacturers, huge cost of management and concern about emission of toxic substances have also been raised.

Responding to these changes and situations, the policy on MSW management has shifted the target from proper treatment and disposal to establishing a Sound

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Material-Cycle society (herein after 3R society). Policy measures are changed to: (1) developing a legal system for recycling with extended producer responsibility (EPR), (2) setting a national target for MSW reduction, (3) strengthening enforcement, especially by strengthening the compliance system and responsibility of the waste discharger and (4) developing high-tech treatment facilities with subsidies from the central government for establishing a 3R society. The national subsidy policy changed its basic target to the creation of a 3R society in 2005.

Reflecting this move, the "Fundamental Law for Establishing a Sound Material-Cycle (3R) Society" was enacted in 2001 and specific recycling laws were enacted together with amendments to the Waste Management Law to further reinforce the regulatory measures.

1.1 Basic Principles

As for responsibilities of the stakeholder prescribed in the Waste Management Law, citizens shall cooperate with the central government and local governments in their activities for waste reduction. The businesses shall appropriately manage the waste left as a result of their business activities and endeavor to reduce the amount of waste. The businesses shall also assess the handling or processing difficulty of the waste generated when the products, their containers or whatever they manufacture are discarded. They shall develop such products, containers or the like which are unlikely to present handling or processing difficulty, provide information on appropriate management of the waste generated when the products, their containers or the like are discarded, or take some other actions to ensure appropriate management of the said products, containers or the like without difficulty. Municipalities shall endeavor to perform waste management work efficiently by improving the ability of the management personnel, consolidating disposal facilities and developing operation techniques.

As for measures on waste reduction and other proper waste management, first, waste generation shall be restrained as much as possible, then waste that is generated shall be utilized as much as possible in the order of reuse, recycle and heat recovery while taking into account the prevention of improper management as well as reduction of the load on the environment by decreasing the quantity of their disposal. Restraint of waste generation and the proper recycling shall be thoroughly carried out, and it is fundamental that the proper disposal shall be ensured for those which still cannot be recycled (Ministry of the Environment 2001).

1.2 Definition and Waste Classification

According to the Waste Management Law, waste is defined as, "refuse, bulky refuse, ashes, sludge, excreta, waste oil, waste acid and alkali, carcasses and other

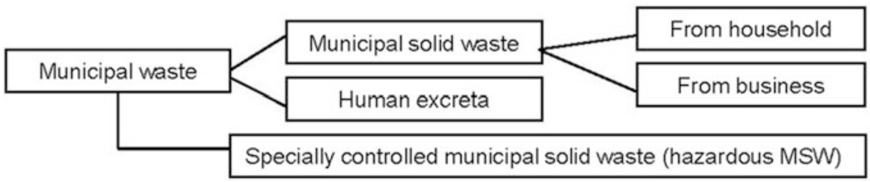

Fig. 1 Classification of MSW

filthy and unnecessary matter, which are in solid or liquid state (excluding radioactive waste and waste polluted by radioactivity)." Waste is divided into municipal waste and industrial waste. Municipal waste refers to waste other than industrial waste, while industrial waste refers to waste generated in the course of business activities classified according to the type of substance and generation source as follows: (1) ashes, sludge, waste oil, waste acid, waste alkali, waste plastics and others specified by a Cabinet Order and (2) imported waste. Wastes which are explosive, toxic, and infectious or of a nature otherwise harmful to human health or the living environment are defined as "specially controlled municipal waste" or "specially controlled industrial waste."

Municipal waste is classified as follows. In this chapter, in principle, the term "municipal solid waste" refers to municipal waste which is in the form of a solid and does not include human excreta (Fig. 1).

2 Waste Generation and Composition

Total quantity of MSW generated in Japan was 46.3 million tons in FY2010 and the quantities of waste collected or disposed of by municipalities add up to approximately 42.6 million tons. That is about 0.98 kg of waste capita per day. The 71 % of MSW is generated by households and the rest by businesses. From the total MSW generated, 93 % went though intermediate treatments, mainly incineration in 2010. Material recovery by voluntary groups in local communities was 2.7 million tons. Promotion of intermediate processing led to a decrease in the quantity of waste disposed of at landfill sites to 4.8 million tons (Ministry of the Environment 2012) (Figs. 2 and 3).

3 Collection and Transportation

Method of MSW collection depends on the respective municipalities. Collection service usually covers all urbanized areas. The waste collection vehicle with a compactor is the most popular in Japan and has a compression device to automatically push waste into the container.

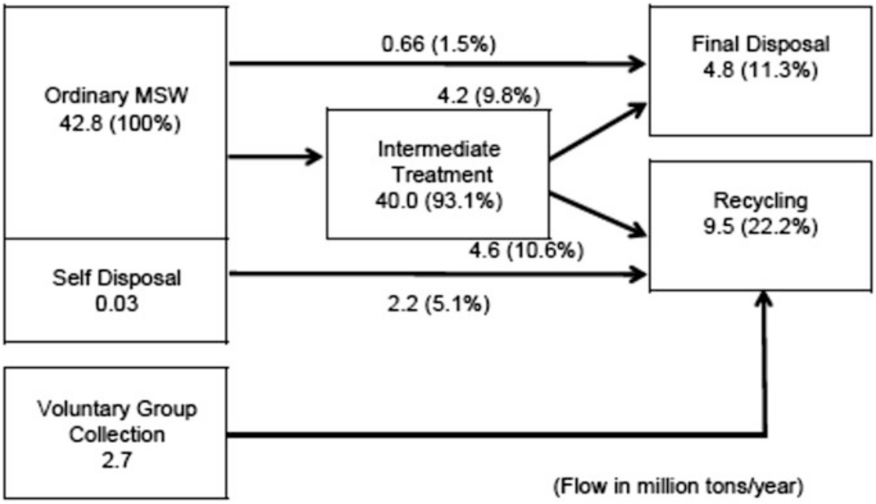

Fig. 2 Flow of MSW in Japan (FY2010). *Source* Ministry of the environment 2012

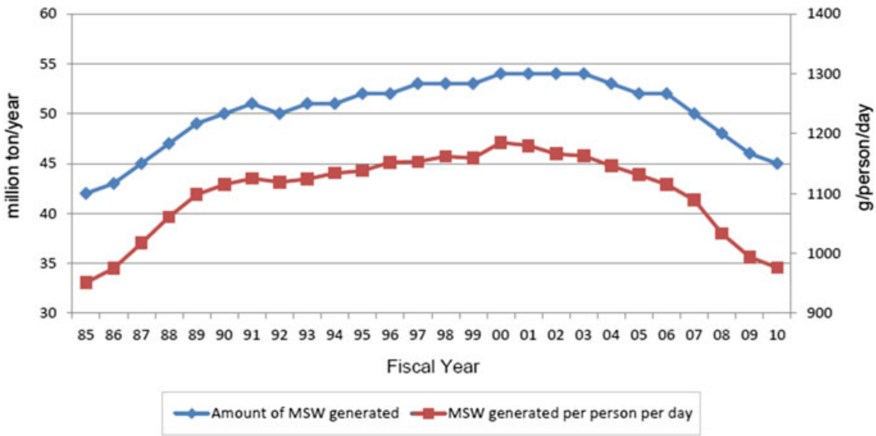

Fig. 3 Trend of MSW generation in Japan. *Source* Ministry of the environment (2012)

Separation of waste into several items at source is very popular, while ways of separation depends on municipalities. More than half municipality requests a generator for separating their waste into more than 10 kinds of items [Ministry of the Environment 2008]. Municipalities collect waste typically separated into combustibles, non-combustibles and recyclable items such as paper, glass bottles, metal, PET bottle, etc. Part of such waste is further sorted at recycling facilities.

In addition, part of MSW from businesses is also brought to intermediate treatment and recycling facilities run by municipal authorities.

4 Treatment and Disposal

4.1 Situation of Treatment and Disposal

Japan is quite a densely populated country in comparison with other countries in the world, and its industries and population are concentrated in urban areas. In large cities, waste generation density is high, but space is very scarce and there is a "not in my backyard" attitude against waste management facilities. Acquisition of suitable site for waste treatment or disposal becomes a challenge each year. It is more severe for final disposal sites which demand a larger space. In order to prolong service lives of landfill sites, extra efforts have been made to reduce landfilled waste by various pre-treatments. Incineration, which can reduce the volume of waste and make waste hygienic enough to prevent biological hazards, is utilized extensively as an intermediate treatment process.

Consequently, incineration is very popular and 79 % of generated MSW went through incineration in FY2010. The number of incineration plants was 1,221 in FY2010 and 306 of them recovered energy from MSW for power generation. Other popular methods of intermediate treatment are crushing of bulky waste and turning waste to refuse derived fuel (RDF) (Ministry of the Environment 2012).

The amount of final disposal (sum of direct disposal and residue after intermediate treatment) was 4.8 million tons in FY2010 and has been decreasing year by year. The number of landfill sites was 1,775 in FY2010 (Ministry of the Environment 2012).

4.2 Incinerators and Dioxin

Emission of dioxins due to waste incineration and other source has been drawing keen attention of society since the late 1983. This has called for the formation of a new legal framework necessary to take measures to control dioxins. The law for special measures against dioxins was promulgated in 1999 and enforced in 2000 (Tanaka 1999). This law calls for the establishment of the tolerable daily intake (TDI) and the environmental quality standards for dioxins. The facilities which may generate dioxins, including the MSW incinerators are designated by a cabinet order and the emission standards for exhaust and effluents were set for various types of facilities. The TDI of dioxins was determined to be 4 pg-TEQ/kg-body/day, and environmental standards in air, water and soil were set at 0.6 pg-TEQ/m^3, 1 pg-TEQ/L and 1,000 pg-TEQ/g, respectively. For waste incinerators, the strictest emission standard is 0.1 ng-TEQ/m^3, which is applied to newly constructed waste incinerators having a capacity of 4 tons/hour or more (Fig. 4).

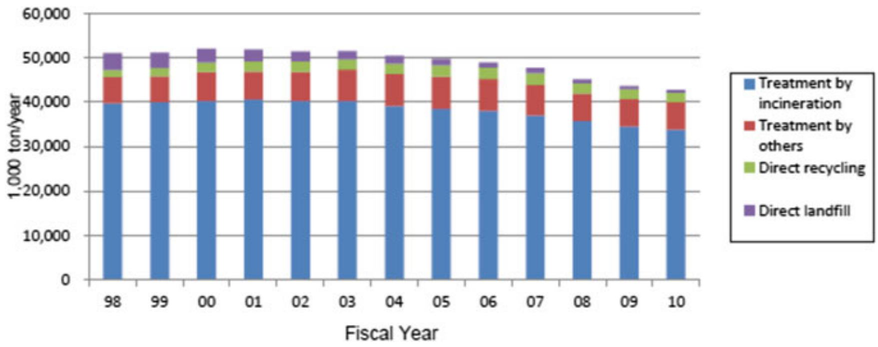

Fig. 4 Trend of treatment and disposal in Japan. *Note* "Treatment by others" includes recycling through sorting, treatment of bulky waste, composting and waste to fuel. *Source* Ministry of the environment (2012)

4.3 Illegal Dumping

Huge accumulation of illegally dumped waste was discovered in several sites in Japan and this became a topic for heated debate in the late twentieth century. Most of the cases were that of industrial waste. Who should take responsibility for cleaning up the waste when illegal dumpers cannot be identified or cannot pay for? The illegal dumping problem exposed the fact that business activities in industrial waste management were conducted in a disorganized manner and bad money (contractors) drove out the good ones.

There was a very serious problem on Teshima Island in Kagawa prefecture in the western part of Japan. More than half a million tons of industrial waste had been dumped illegally on the island and it caused serious conflict with the residents who brought the case to the court. Originally, the waste management company stated that the dumped items were recyclable and that almost all of them could be recovered, but actually those were more likely hazardous waste. Owners of the company were convicted, but they did not have the ability to clean up all the waste. The Governor of Kagawa prefecture agreed to take responsibility for the clean up program, which has now been implemented with the support of the central government.

To respond to illegal dumping, several measures are taken: (1) strengthening regulations and enforcement power by amending the law, (2) introducing responsibility to a waste discharger for illegal dumping, (3) strengthening monitoring and (4) governmental support to clean up illegal dumping sites and improper disposal sites.

5 Reduce, Reuse and Recycle—3R

Based on the "Fundamental Law for Establishing a Sound Material-Cycle Society," the first phase of the Fundamental Plan for Establishing a Sound Material-Cycle Society approved by the Cabinet in 2003, three targets on resource productivity, cyclical use rate and final disposal amount were set. The Waste Management Law was also amended for the reinforcement of measures for recycling.

By applying the concept of extended producer's responsibility (EPR), recycling laws for specific products or waste type were enacted as follows and the legislative framework is shown in Fig. 5.

- Containers and Packaging Recycling Law (1995): for PET bottles, glass bottles, and plastic or paper containers and packaging.
- Home Appliance Recycling Law (1998): for TV Sets, air conditioners, refrigerators, freezers and washing machines (flat-screen TV sets and home driers are added in 2009).
- Construction Material Recycling Law (2000): for waste materials from designated construction and civil works.
- Food Recycling Law (2000): for food waste from manufacturers, wholesalers, retailers, and restaurants.
- End of Life Vehicles Recycling Law (2002): for end of life vehicle (Fig. 6).

Resource recovery by the local communities and municipalities amounted to 9.4 million tons and was 21 % of the amount of treated, disposed and voluntarily collected waste in FY2010. These figures increased from year to year (Ministry of the Environment 2012).

Fig. 5 Legislative framework to establish a sound material-cycle society. *Source* Ministry of the environment 2012

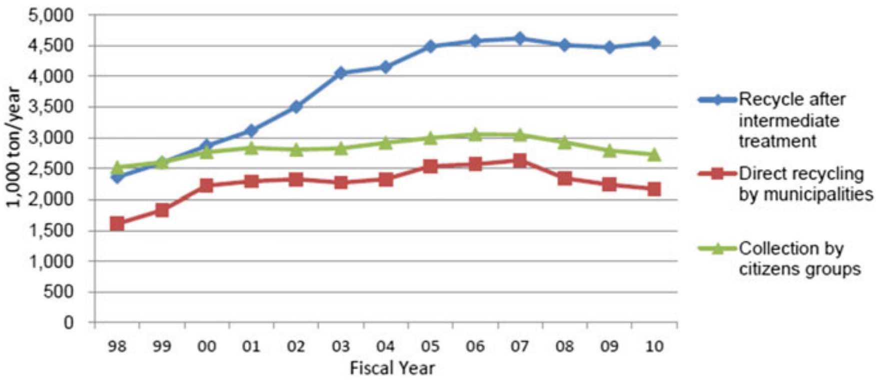

Fig. 6 Trend of resource recovery from MSW. *Source* Ministry of the environment (2012)

6 Current MSW Policy and Future Development

6.1 Current Management System

The Waste Management Law mainly sets the overall waste management system. Table 1 shows regulatory framework on MSW by Waste Management Law. Figure 7 shows the structure of the Waste Management Law including the definition, responsibility, planning, licensing, standards and penalty.

6.2 Establishing a 3R Society

MSW policy has shifted from proper treatment and disposal of MSW by developing MSW facilities to establishing a 3R society. The background of this movement is: (1) increase in the amount of solid waste, (2) difficulty in siting of final disposal (development of treatment by incineration), (3) limited capacity of remaining landfill site, (4) frequent illegal dumping of waste and (5) public attention to toxic substances such as dioxins arising in the course of waste management. The policy shift brought such moves as (1) bringing valuable goods in waste to managed material flow, (2) pursuing waste discharger responsibility, (3) applying extended producer's responsibility on recycling measures and (4) collaboration of the central and local governments to involve stakeholders.

In order to establish a 3R Society, the Government of Japan intends, among other initiatives, to further develop laws and regulations for waste management and recycling; to promote a 'slower', less consumption-oriented lifestyle by enhancing environmental education and learning and providing adequate information; and to accelerate the production of environmentally friendly goods and

Table 1 Regulatory framework on MSW by waste management law

Activity	Regulation
(Discharger)	
Consignment of treatment/disposal	Consignment standard
(Contractor)	
Status of contractor	Municipality's permit to those meeting conditions on capability of the applicant and the needs of the municipality
(Collection and transportation)	
Collection and transportation by contractor	Standards on collection and transportation
(Treatment/disposal facilities)	
Installation or change of facilities	Permit to those meeting conditions on environmental impact study, technical standards and capability of the applicant Information disclosure
Operation of facilities	Technical standard Information disclosure Closure of landfill site
(Export)	
Export of MSW	Confirmation by the Minister whether the exporter meets conditions

services through the incorporation of Design for the Environment (and systems for the lease or rental of items).

As a result, resource productivity and cyclical use rate in the Fundamental Plan for Establishing a Sound Material-Cycle Society has gradually risen and the final disposal amount has greatly dropped. But the reduction of waste generation has not progressed. Although there is a high public consensus about the need to reduce waste generation, there is a discrepancy between this awareness and actual behavior by citizens. The national and local governments, businesses, and the public should continue to coordinate their efforts to establish a Sound Material-Cycle Society. Also, there is an economic risk in the recycling system, as commodity prices fluctuate, sometimes double or and at other times half the price, all within a short period.

Apart from municipalities' separate collection of recyclables, resources retrieval groups in local communities and other voluntary measures play an important role in recycling. To establish an optimum recycling need in the society, it is essential to fully recognize the deficiencies and drawbacks of existing methods. A more efficient system must be worked out through close cooperation among the administrative authorities, citizens and producers, each with a definite assigned responsibility (Tanaka 1999).

Also, as solid waste and recyclables circulate beyond national borders, the Japanese government have called for 3R Initiatives at the international and regional fora (see Sect. 1.2).

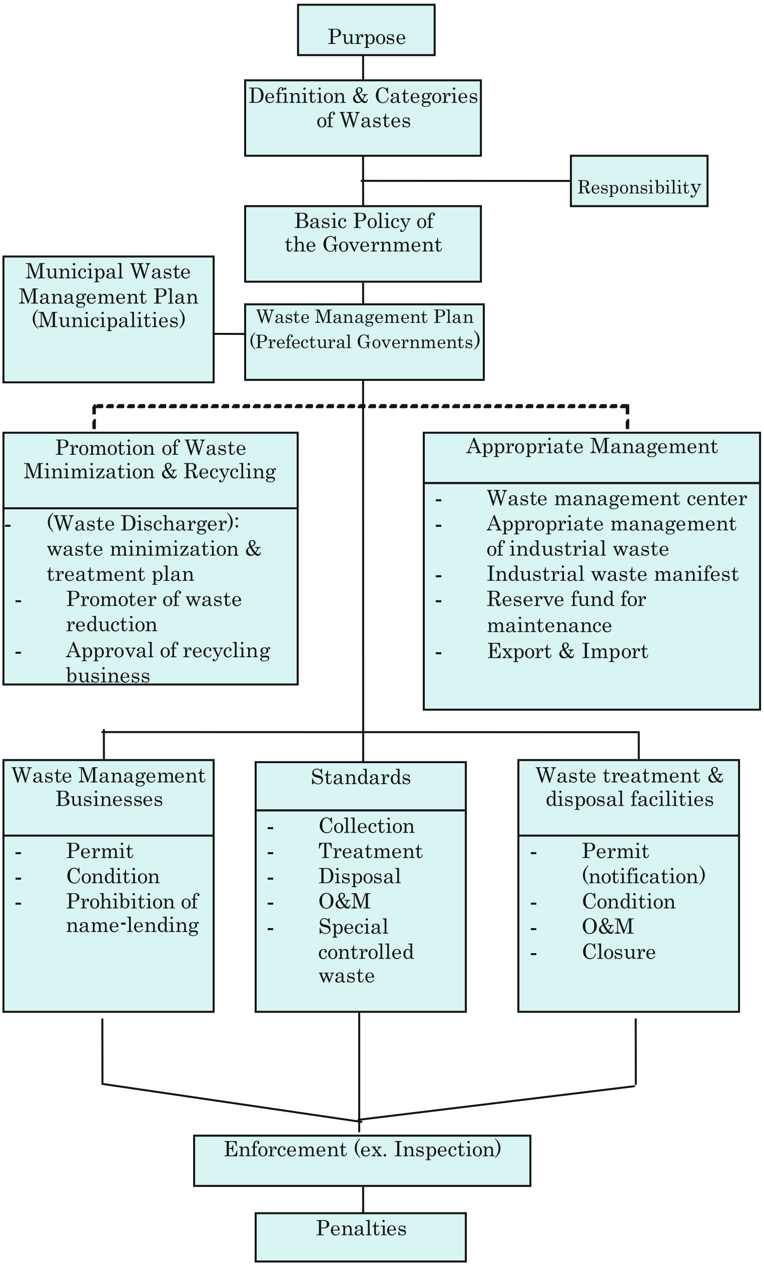

Fig. 7 Structure of waste management law

6.3 EPR Approach

New public policy called "Extended Producer Responsibility" (EPR) was studied at OECD as a major means for constructing a successful life-cycle waste management system. EPR entails still wider responsibility including liability for the management of a product after consumption. EPR is based on a new strategy for promoting the internalization of all environmental and other "external" costs related to the entire life-cycle of a product.

Firstly, Japan introduced the EPR policy on waste management with the promulgation of the Containers and Packaging Recycling Law in 1995. The aim of this law is to introduce a recycling system under which, specified business entities (manufacturers, retailers, wholesalers and importers) have a responsibility to recycle containers and packaging, while municipalities have the responsibility for the sorted collection of those items. A government-designated organization provides actual recycling operation on behalf of specified business entities which pay recycling fees to the organization.

Home Appliance Recycling Law promulgated in 1998 provides a collection and recycling system. Home appliance retailers take charge of collecting used home appliances and home appliance manufacturers take charge of recycling used appliances. Consumers who discharge home appliances shall pay for the recycling cost. Association for Electric Home Appliances operates the home appliance recycling coupon system, which is convenient for paying and collecting recycling fees. Recycling fees may be paid and collected via retailers or by postal transfer [Ministry of Economy, Trade and Industry 2008].

6.4 Cost of MSW Management

Total expenditure on MSW management by municipalities was 1,863 billion Yen and 14,600 Yen/capita in FY2006. The total cost of municipalities started decreasing after FY2001 [Ministry of the Environment 2008]. Because solid waste management cost shares a substantial portion of the budget for municipalities, reducing cost with keeping service level is a big challenge especially for local governments. Municipalities have reduced solid waste management cost by reducing construction and reform cost of their facilities. Also, municipalities try to keep operation and maintenance cost by commissioning these works to the private sector in order to reduce personnel expenses. Finance in many municipalities is very tight and most municipalities need further reduction of their expenditure. Waste reduction is also necessary from this viewpoint.

Recycling also incurs expenditure. According estimates for 2003, as a result of The Containers and Packaging Recycling Law, the net increase of expenditure in all municipalities was 38 billion Yen. That is, cost reduction in incineration and landfilling was subtracted from 300 billion Yen of additional collection and

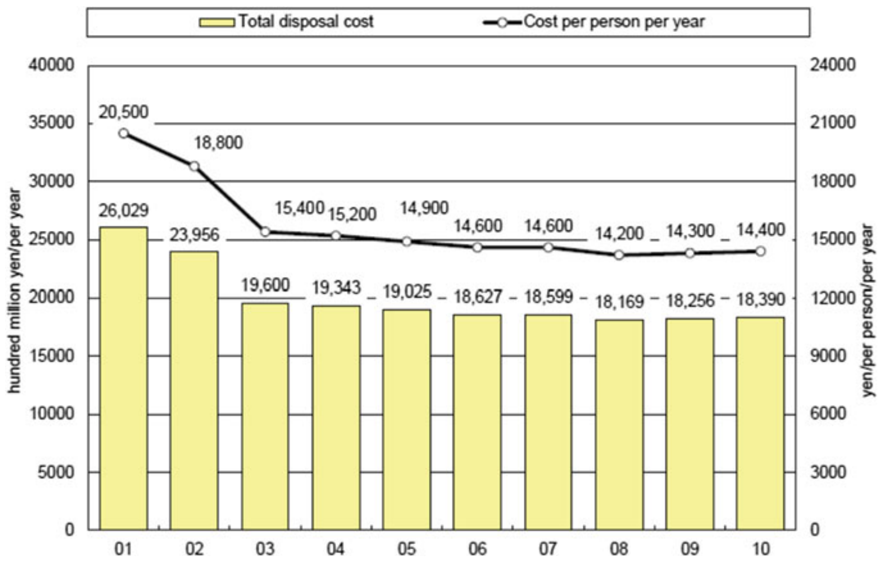

Fig. 8 Total disposal cost and cost per person per year for MSW. *Source* Ministry of the environment (2012)

storage cost for recycling. On the other hand, business entities of containers and packaging bore the cost of 40 billion Yen in FY2003, 48 billion Yen in FY2006 and 38 billion Yen in FY2011 for the recycling of merchandise (Ministry of the Environment 2008). The Japan Containers and Packaging Recycling Association, 2012, http://www.jcpra.or.jp/archive/cycledata/total_fee_detail.html (Fig. 8).

7 Case Study-Management of Disaster Waste Generated by Great East Japan Earthquake

On March 11, 2011, Iwate and Miyagi Prefectures suffered badly from the Great East Japan Earthquake, and large quantity of disaster waste was generated by the earthquake and tsunami. Japanese government decided to conduct wide area disposal of disaster waste, and ask for cooperation of the local governments in non-disaster area. The radiation level of disaster waste is very low, but some people express concern about radioactive contamination and it causes a delay of wide area disposal plan (Table 2).

The total waste generated by the Great East Japan Earthquake in Iwate, Miyagi and Fukushima Prefectures is estimated at about 25 million tons (as of April 5, 2011) Ministry of the Environment (2001). Although proper disposal of disaster waste is essential to restore disaster-stricken areas, the amount far exceeds the processing capacities of existing and specially built emergency waste disposal facilities.

Table 2 Total quantity of disaster waste generated by earthquake and tsunami in Iwate and Miyagi Prefectures, and its portions which washed out to the sea and needs to be disposed of in land (4)

Classification of the waste	Concrete waste (x1, 000 t)	Combustible waste (x1, 000 t)	Total (x1, 000 t)
Iwate prefecture (Total waste generated)	3,746	2,236	5,982
(Washed out to the sea)	1,124	671	1,795
(Needs to be disposed of)	2,622	1,565	4,187
Miyagi prefecture (Total waste generated)	11,963	3,980	15,943
(Washed out to the sea)	837	279	1,116
(Needs to be disposed of)	11,126	3,701	14,827
Total of 2 prefecture (Total waste generated)	15,709	6,216	21,925
(Washed out to the sea)	1,961	950	2,911
(Needs to be disposed of)	13,748	5,266	19,014

Thus, the national government of Japan is seeking the cooperation of local governments nationwide to receive, process and dispose of disaster waste. (Processing and disposal of surplus waste in non-disaster areas due to insufficient waste processing/disposal capacity in the disaster area is called "wide area disposal.") Waste subject to wide area disposal is the portion of disaster waste generated in Iwate and Miyagi Prefectures for which the local municipalities seek cooperation for wide area disposal. This portion of waste consists of combustible materials (e.g., wood waste) and non-combustible materials (e.g., concrete waste). Local governments nationwide have incineration facilities to process combustible waste, which have been built with government subsidies. Many local governments have managed to reduce waste by promoting "3Rs (Reduce, Reuse, Recycle)" in recent years, hence their waste processing facilities are believed to have surplus capacities. However, even local governments that were willing to accept disaster waste when the national government began requesting their cooperation for wide area disposal have taken virtually no action to do so. Although local governments wish to cooperate to restore disaster areas, they have been unable to accept disaster waste, mainly due to concern over radioactive contamination expressed by some residents.

7.1 Quantities and Physical Composition of Disaster Waste

The estimated amount of disaster waste generated in the three disaster-stricken prefectures in the Tohoku region is approximately 21 million tons, which excludes approximately 4.1 million tons of the waste that was washed out to sea. Since it has been decided that 1.7 million tons of disaster waste generated in Fukushima Prefecture would be processed and disposed of in the same prefecture, the remaining 19 million tons or so are subject to wide area disposal. Of this waste, around

14 million tons is concrete waste, plus 5 million tons of combustible materials e.g. wood. Most of this waste has been moved to temporary storage sites, but is still awaiting processing and disposal. Only 6–7 % had been disposed of as of March 2012 (Ministry of the Environment 2012).

Concrete waste is supposed to be crushed and reused as a building material for reconstruction purposes. Conversely, combustible materials e.g. remnants of destroyed houses are fire hazards, which can also decay and produce unpleasant odors. Therefore, they should be incinerated as soon as possible for public health. Better still, the heat produced from incinerating such waste should be exploited for power generation if possible. However, local waste processing facilities have capacity limits. It will not be easy to obtain public understanding to construct waste processing facilities for short-term use. Of the 4.2 million tons of waste in Iwate Prefecture, the local government seeks cooperation for the wide area disposal of 1.2 million tons. Of the 15 million tons of waste in Miyagi Prefecture, the local government is requesting the wide area disposal of 1.27 million tons generated in the Ishinomaki district.

7.2 *Master Plan for Disaster Waste*

In May 2011, the national government announced the guidelines (master plan) for disaster waste management (Tanaka 1999). This master plan targets the complete transfer of disaster waste to temporary storage sites by around the end of March 2012, and calls for the completion of intermediate processing and final disposal of waste two years later, by the end of March 2014. In Iwate and Miyagi, a total of 31 temporary incinerators were constructed (Photo 1) (Ministry of Enviroment Homepage 2013). The master plan sets forth the following basic rules for waste processing and disposal: (1) Waste shall be sorted and separated as much as possible at the disaster areas. (2) Recyclable materials shall be recycled and reused as much as possible. (3) Non-recyclable combustible materials shall be incinerated, and the ashes subject to landfill disposal. (4) Non-combustible materials that cannot be recycled or reused subject to landfill disposal.

7.3 *Risk Management of Radioactive Material in Disaster Waste*

Only disaster waste with no or low-level radioactive cesium is eligible for wide area disposal. In the case of combustible waste, this includes materials with a radioactive cesium level under 240–480 Bq/kg. This standard was set to ensure that the radioactive cesium level in incinerated ashes remains below 8,000 Bq/kg and that the radiation exposure to landfill workers, who are most affected by

Photo1 Disposal facility for disaster waste (Ishinomaki-city, Miyagi prefecture)

radioactive contamination during landfill disposal work, is lower than 1 mSv per year. Also, it is evaluated that influence among residents living near the disposal site is lower than 0.01 mSv per year with the worst-case scenario.

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Management of Municipal Solid Waste in Korea

Dal-Ki Min and Seung-Whee Rhee

1 Overview of the Republic of Korea

The Republic of Korea (ROK) has small land area and high population. ROK has diverse natural habitats and abundant biodiversity because ROK is located in the Korean Peninsula with four distinct seasons and 65.4 % of land is covered with forests and trees. The total land size of ROK extends to 223,343 km^2 and the territory of the Republic of Korea is 100,210 km^2 excluding the area in the Demilitarized Zone (DMZ). The population of ROK in 2010 is about 50 million and the population density is 499/km^2, which is equivalent to 0.002 km^2 per capita (world's 3rd smallest). The capital city of ROK is Seoul and about 46 % of population occupies Seoul metropolitan area which is only 11.8 % of total land area. And the number of foreign residents, which is about 1.2 million, has sharply increased in recent years.

Korean economy is characterized by the service-centered industrial structure (Service 73 %, Mining/Manufacturing 19 %, Agriculture/Forestry 8 %) and heavy industries are regarded as main source of economic growth. Rapid industrialization of Korea had been achieved with high rate of economic growth by export-driven heavy industry. In 2010, Gross Domestic Productv (GDP) of Korea is 29,791 USD per capita which is the 25th in the world. This economic growth resulted in an aggravated environmental load and caused recording the heaviest pollution per unit space among Organization of Economic Cooperation and Development (OECD) countries. In particular, it had a significant impact on the environment of most

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industrial complexes. Household wastes generation per capita is pretty stable in spite of increased income and consumption while commercial waste shows a rapid increase in its volume due to increased business activities and expansion of economy. Recently, the amount of construction waste is drastically being increased due to a lot of reconstruction projects implemented throughout the nation.

2 Current Status

2.1 Definition and Classification of Wastes

Under the Wastes Control Act in Korea, the term "wastes" means such materials as garbage, ash, sludge, waste oil, waste acid and alkali, and carcasses of animals, which have become no longer useful for human life or business activities. In Korea, wastes are divided into household wastes and commercial wastes by source and volume of generation as shown in Fig. 1. Commercial wastes also are classified into construction waste, general waste, and controlled waste. Controlled waste means the commercial wastes specifically enumerated by Presidential

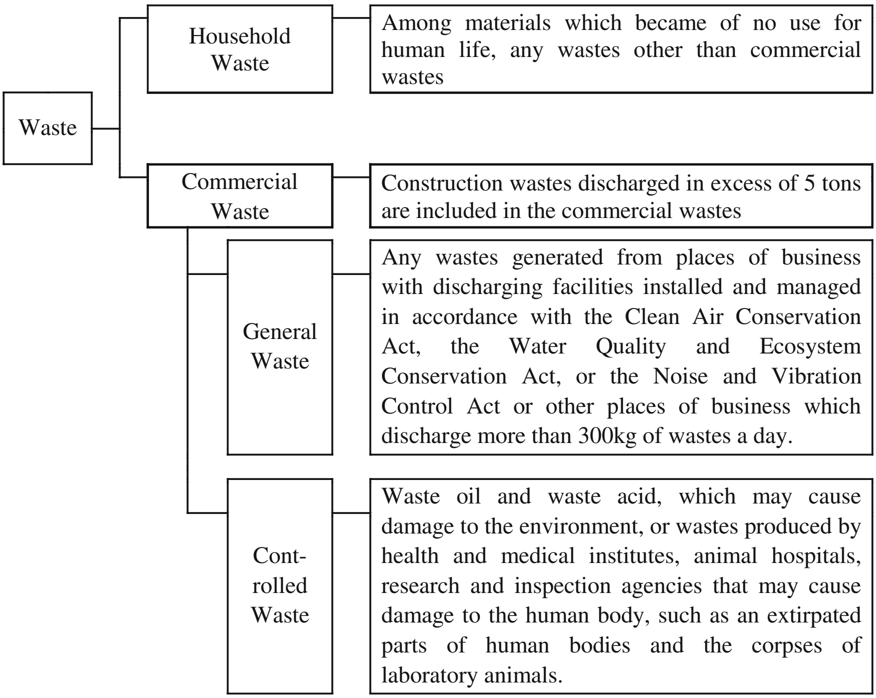

Fig. 1 Classification of waste in Korea (ROK)

Decree as harmful substances such as waste oil and waste acid, which may contaminate environments or medical refuse, which may cause harm to human bodies.

Management of waste in Korea is operated by a dual system. The local government is responsible for the management of household waste and the discharger in industrial sectors is responsible for the management of commercial waste.

2.2 Current Status of Waste Generation

Total waste generation has steadily increased from 1993 and the average annual increase is 4.6 % for the past 5 years (2003–2007). But total waste generation in 2010 was 374,700 tons per day and the average annual increase in 2010 is about 2.1 % compared to the previous year. Waste is composed of household wastes (13.1 %), commercial wastes (36.8 %) and construction wastes (47.5 %), which accounts for the largest portion of waste generated. This ratio indicates that construction waste drastically increased as a result of a rise in construction and reconstruction. Also, the reporting system for the management of a construction waste may overestimate the generation of construction waste.

Household wastes were anticipated to steadily rise due to an increase in population and economic growth. But policies for controlling waste generation (e.g., regulations on disposable goods and a Volume-Based Rate System) have led to a gradual reduction in the amount of waste generated.

Commercial wastes have increased by an annual average of 5.5 % over the past 5 years (2003–2007) because of a rise in industrial activities, the expansion of economic activities, and energy-intensive industrial/economic structures. In 2010, commercial wastes reached a record of 325,500 tons per day and the average annual increase is 3.0 % compared to the previous year.

2.3 Current Status of Waste Treatment

In order to manage of household wastes effectively, it is important to reduce waste generation and recycle waste as much as possible. In the case of household wastes, the implementation of the "Volume-Based Waste Fee System", a Pay As You Throw (PAYT) system, has promoted waste separation and significantly increased recycling, and the rate of incineration also omit been. The recycling rate has shown a steady increase to 60.5 % in 2010 because Korean government has been focusing on establishing Extended Producer Responsibility (EPR) system to improve recycling rate, expanding recycling facilities suitable to regional conditions developing advanced technologies and encouraging the use of recycled products. The rate of incineration has also increased to 21.6 % in 2010 from 11.7 % in 2000, whereas landfilling has continued to decline to 17.9 % in 2010 (Tables 1, 2).

Table 1 Trends in waste generation (unit: 1,000 ton/day)

Year	Household wastes	Commercial wastes				Total	MSW (kg/cap/day)
		General waste	Construction wastes	Controlled wastes	Sub-total		
2000	46.4	101.5	78.7	7.6	187.8	234.2	0.98
2001	48.5	95.9	108.5	7.8	212.2	260.7	1.01
2002	49.9	99.5	120.1	8.0	227.6	277.5	1.04
2003	50.7	98.9	145.4	8.0	252.3	303.0	1.05
2004	50.0	105.0	158.5	8.2	271.7	321.7	1.03
2005	48.4	112.4	134.9	8.6	255.9	304.3	0.99
2006	48.8	101.1	169.0	10.0	280.1	328.9	0.99
2007	50.3	114.8	172.0	9.5	296.3	346.6	1.02
2008	52.1	130.8	176.4	9.6	316.8	368.9	1.04
2009	50.9	123.6	183.4	9.1	316.1	367.0	1.02
2010	49.2	137.9	178.1	9.5	325.5	374.7	0.96
2011	48.9	138.0	186.4	10.0	334.4	383.3	0.95

Ministry of Environment, Korea, 2012

Table 2 Status in municipal waste treatment (unit: ton/day)

	Landfilling	Incineration	Recycling	Total
2000	21,831	5,440	19,167	46,438
2001	21,000	6,577	20,922	48,499
2002	20,724	7,229	21,949	49,929
2003	20,450	7,348	22,938	50,736
2004	18,195	7,224	24,588	50,007
2005	13,402	7,753	27,243	49,398
2006	12,601	8,321	27,922	48,844
2007	11,882	9,348	29,116	50,346
2008	10,585	10,349	31,138	52,072
2009	9,471	10,309	31,126	50,906
2010	8,797	10,609	29,753	49,159
2011	8,391	11,604	28,939	48,934

Ministry of Environment, Korea, 2012

The separation of food wastes from other wastes has been in place since direct landfilling of food waste was banned in January 2005. For this reason, while food waste generation has been on the rise, the rate of recycling food waste such as livestock feed and compost is at 92 % as of 2007.

The rate of recycling commercial wastes has been on the rise. As of 2010, of commercial wastes, 86.9 % were recycled, 8.1 % went to landfills, 2.8 % were incinerated and 2.2 % were dumped at sea, etc. (Table 3).

In the case of commercial wastes and construction waste, their recycling rates are very high at 72.3 and 98.2 %, respectively, because they are mostly single material items that can be recycled with ease. But they show low incineration rates of 5.8 and 0.5 %, respectively.

Table 3 Status in commercial waste treatment (unit: ton/day)

	General wastes					Construction wastes				
	L.F[a]	Inc.[b]	3R's	Others	Total	L.F	Inc.	3R's	Others	Total
2000	18,962	8,034	67,514	–	101,453	10,021	2,071	66,685	–	78,777
2001	18,493	7,875	61,727	7,813	95,908	12,943	2,424	93,153	–	108,520
2002	15,455	7,094	67,451	9,505	99,505	17,462	2,462	100,209	8	120,141
2003	14,240	7,735	66,723	10,193	98,891	13,715	2,233	129,462	10	145,420
2004	13,616	7,044	73,189	11,139	105,108	10,976	2,949	134,557	7	148,489
2005	16,604	7,326	76,957	11,532	112,419	3,491	871	130,451	93	134,096
2006	8,897	7,709	74,761	9,732	101,099	3,935	1,179	163,871	–	168,985
2007	22,503	7,478	76,740	8,086	114,807	3,169	1,131	167,705	–	172,005
2008	24,285	6,937	92,615	6,940	130,777	2,914	1,423	172,110	–	176,447
2009	27,531	6,926	82,155	6,992	123,604	2,792	1,283	179,276	–	183,351
2010	23,309	7,983	99,627	6,956	137,875	2,200	919	175,001	–	178,120
2011	23,037	8,307	100,750	5,867	137,961	2,598	987	182,832	–	186,417

[a] L.F: Landfilling
[b] Inc.: Incineration
Ministry of Environment, Korea, 2012

3 Policies on Waste Reduction

3.1 Restriction on Disposable Products

(1) Restriction on the Use of Disposable Products

Though disposable products are widely used to improve the standard of living as a result of economic development, they are considered to be a wasteful use of resources and are considered to have a negative effect on the natural environment. As such, the government has been implementing policies that save resources and reduce waste by inducing the public to use returnable products rather than disposable products in order to establish a healthier consumer culture.

(2) Items Restricted from Use

A "disposable product" is a product that is designed to be used only once. Restrictions outlined in the 'Act on the Promotion of Saving and Recycling of Resources' on the use of disposable products were first implemented in March 1994, and were applied to disposable plates and disposable chopsticks. From 1994, the government has been expanding the items for industrial fields subject to the Act, and has been carrying out policies to prevent the use of disposable products, such as a restriction on 18 items including disposable plastic bags and shopping bags, and a restriction in 20 industrial fields on the use of disposable products including paper cups and toothpicks, as well as a restriction on the free distribution of disposable items, including plastic bags and paper shopping bags.

(3) Method for the Implementation of Policies

The government discriminatively restricts disposable products for each industrial field which uses large amounts of disposable items. The relevant regulations entrust the management of disposable products used in industries to local governments, and inspections to determine whether the restriction system on disposable products is being conducted properly shall be undertaken at least once a year. In the event that the restriction system is not being carried out, a fine of 3,000,000 Korean won (equivalent to about 3,000 USD) shall be imposed. In the initial stage of implementation of this policy, it was hard to firmly establish the system due to a serious lack of officers to inspect company compared to the number of company (1,200,000). Therefore, the government signed a voluntary agreement with company for the reduction of disposable products. This agreement focused on restaurants and catering company, encouraged the use of returnable products, and promoted a reduction in the usage of disposable products. It also implemented a reward system for reporting the unlawful use of disposable products, to establish the restriction system quickly through the participation of citizens.

(4) Results of Carrying Out Restriction Policies

Thanks to carrying out restriction policies on disposable products, the wasteful use of disposable products such as wooden chopsticks, styrofoam plates, disposable razors, toothbrushes, disposable shampoos and conditioners in the restaurant and hospitality industries has been significantly reduced.

3.2 Control on Packing Waste

Due to the diversity of products, the reduction of product life cycles, and changes of lifestyles, packaging waste, which currently accounts for 32 % of total household wastes based on weight and for 50 % based on volume, has been constantly increasing. Consequently, the government has been conducting preventive policies since 1993 to reduce the environmental impact caused by overpackaging and the use of non-biodegradable packaging materials (synthetic resins) [Lee 2009].

(1) Restriction Measure

"Packaging Materials" are defined as materials or containers that are used for the purpose of protecting the value or state of a product or preserving the quality of a product in the process of transportation, storage, disposal, and use. In order to reduce the overuse of packaging materials as well as to promote the use of recyclable and reusable packaging materials, the following restrictive measures are currently in force.

①Restrictions on packaging materials

②Restrictions on packaging methods

③Recommendation for manufacturing refill products and avoiding the re-packaging of goods

(2) Management Measures

The relevant regulations prescribe that the management for restraining the manufacturer, importer or dealer of a product from producing packaging waste is entrusted to the competent local government. Regulations also prescribe that the inspection of the manufacturer, importer or dealer of a product shall be conducted at least once per year. In particular, to inspect in order to determine whether the manufacturer conforms to the prescribed packaging methods, the inspection officer shall give the manufacturer an administrative order to submit the inspection results taken by a professional institution. If the manufacturer does not conform to the prescribed packaging methods, a fine of 3,000,000 Korean won (equivalent to about 3,000 USD) shall be imposed upon the manufacturer.

(3) Results of Carrying Out Restriction Policies

Thanks to carrying out restriction policies on disposable products, the wasteful use of disposable products such as wooden chopsticks, styrofoam plates, disposable razors, toothbrushes, disposable shampoos and conditioners in the restaurant and hospitality industries has been significantly reduced.

3.3 Waste Charge System

The waste charge system is a system that charges the manufacturer and importer of the product part of the cost involved in the disposal of a product that contains hazardous materials or that is not easy to be recycled.

(1) Purpose of Waste Charge System

The waste charge system is intended to reduce the production of waste from the manufacturing stage and promote the efficient disposal of waste in consideration of the environmental impacts of a product.

(2) Items to Which Waste Charges are Applied

For the purpose of preventing the use and production, waste charges are imposed on 7 items such as containers of insecticides and toxic chemicals, antifreeze, chewing gum, disposable diapers, cigarettes, plastic products, and packaging materials.

(3) Use of Waste Charges

Waste charges are used for the research and development of technology to reduce the amount of waste and recycle waste, the installation of waste disposal facilities, carrying out waste recycling projects, financial support for local governments to collect and recycle waste, and the purchase and storage of recyclable resources.

3.4 Volume-Based Rate System

The volume-based waste fee system is a system that was enforced in January 1995 to achieve a significant role in reducing the amount of waste generated. The system introduces the concept of imposing a charge for waste to the general population by applying the "Producer Pays" Principle, which forces the person who discharges waste to pay the treatment cost according to the quantity of wastes.

(1) Meaning of Volume-Based Rate System

This system is intended to establish a frugal lifestyle and change patterns of consumption and disposal so as to reduce waste from the stage of its production by charging fees according to the quantity of waste produced. In order to motivate people to reduce waste, the volume-based waste fee system is not applied to recyclable wastes to recycle as much waste as possible.

(2) Principles for the Application of the Volume-Based Rate System

- Polluter Pays Principle (3P's): Principle that requires that the costs of pollution be borne by those who cause it
- User Pay Principle: Principle that requires those who benefit from the use of a resource to pay costs associated with the loss of the resource, and the full costs for use of the resource and the services associated with it
- Prevention Principle: Principle that prevention takes precedence over disposal, which shifts the direction of waste policy from supply-oriented to a demand-control approach
- Economic Incentive Principle: Principle by which waste discharging dues, fees, and taxes are charged based on the quantity and quality of waste discharged into the environment

(3) Operation of Volume-Based Rate System

In order to apply the Producer Pays principle, the costs involved in collecting, transporting, and disposing of waste are included in the price of the standard plastic garbage bag. The standard plastic garbage bag is manufactured according to the standards that are appropriate for waste discharge such as size, capacity, and quality requirements. In addition, in the case of over-sized waste (such as furniture, electric home appliances), discharge stickers must be purchased and attached to the waste when throwing them out.

(4) Results of Volume-Based Rate System

With the efforts and cooperation of citizens, the amount of waste by the implementation of the volume-based rate system has been reduced to a level equivalent to the developed world, and the amount of recyclable waste collected has doubled. The amount of waste produced per person was reduced from 1.33 kg per day in 1994 to 0.96 kg per day in 2010. The recycling amount has also significantly increased to 29,753 tons per day in 2010 from 8,927 tons per day in 1994.

(5) Development of the Waste Recycling Industry and its Technology

As the collection of recyclable wastes such as paper, cans, and plastics has increased, the supply of recycled materials has been increased abundantly. Hence, the number of companies that use recycled materials has increased and numerous technologies for the recycling of materials have been developed. Manufacturing and distribution industries have also changed their production and sales systems in order to reduce waste by avoiding over-packaging. And packaging technology is developed to enable the recycling of packaging materials.

(6) Development of an Environmental Conscience

Green consumption patterns have become ingrained among the general publics to prefer products that produce less waste such as refillable products and also prefer to use personal shopping bags with disposable paper or plastic bags. Also, recycling centers have been established in a number of places to exchange of used products and electronic products and furniture. A frugal lifestyle has been generally accepted in society.

4 Policies on Waste Recycling

4.1 Extended Producer Responsibility [EPR]

Extended Producer Responsibility is introduced to place responsibility of recycling on producers determining structures and materials, and choosing packaging materials. For the recycling of wastes from products or packaging materials on the manufacturer of the products, EPR imposed a quota on the manufacturer of products that use the packaging materials. If the quota is not complied with, a fine that is greater than the cost of implementing proper recycling shall be imposed upon the manufacturer [Park 2009].

(1) Items Subject to EPR

EPR is basically applied to existing items such as cotton pack, glass bottles, tires, etc. under a deposit system, and new items including air conditioner, TVs, refrigerators, etc. began to be added to EPR starting in 2003. In 2004, film-type packaging materials and fluorescent lamps were added, and audio products and mobile communication devices were added in 2005. Printers, copiers, and facsimile machines were added in 2006, and cosmetics were added in 2007. In 2008, manganese batteries, alkaline manganese batteries, and Ni–MH batteries were added, so EPR is currently being applied to a total of 24 items. Also, electric and electronic products among EPR items have become subject to the Act on the Resource Circulation of Electric and Electronic Equipment and Vehicles following the enforcement of the Act since 2008. Preventive management, such as restrictions on the use of hazardous materials, have been strengthened.

(2) Roles of EPR Stakeholders

As the EPR system is based on the Shared Producer Responsibility (SPR) system, the government's and the consumers' responsibilities as well as the producers' responsibilities are extended. In the past, the government takes the responsibility for the disposal of non-recycled wastes and the overall responsibility to collect recyclable wastes. In EPR system, contributing to wastes collected easily by separating and sorting wastes, the consumer eventually bears part of the recycling costs that producers pay because the recycling costs are reflected in the price of products.

(3) Major Achievements of EPR System

From the introduction of the EPR system in 2003, recycling product has been continuously increased. 6,069,000 tons of waste resources have been recycled over a 5-year period, from 2003 to 2007. With respect to the output of EPR items, the amount of the items recycled in 2007 increased by 32.3 % compared to the period before the EPR system was implemented. Also, it is estimated that 1 trillion 700 billion Korean won (equivalent to about 1 billion 700 million USD) of economic benefits and 3,200 new jobs have been created in the 4 years (2003–2006) by the implementation of the EPR system in 2003.

4.2 Eco-assurance System

Countries in the developed world, such as the EU, have shifted to an Integrated Product Policy (IPP) approach, which enables the environmental impact to be reduced over the entire life cycle of a product, from the stage of design to the stage of disposal. In particular, these countries have been enhancing a recycling policy with regard to electronic products and automobiles which people consume in significant numbers and which contains hazardous materials such as heavy metals.

In Korea, the government has made preliminary management regulations such as restrictions on the use of hazardous materials in electronic products and automobiles, and after-care management regulations on electronic products through the EPR system until 2007, but no specific recycling system had been carried out in the auto industry [Lee 2009].

Thus, the Act on the Resource Circulation of Electric and Electronic Equipment and Vehicles was legislated on July 24, 2007, and enforced as of January 1, 2008. The idea of Eco-assurance System is to promote recycling, save resources, protect the environment, and respond to the tightening of international environmental regulations by establishing a law that makes recycling easier by requiring its consideration in the product design stage of electronics and automobiles, restricts the use of hazardous materials, and manages the entire life cycle of a product so as to be properly recycled.

Producers should make self-declaration of compliance with the concentration limits of the hazardous substances and provide recycling information and take improvement proposals. Producers should provide information on composition materials and dismantling and recycling method on the request by waste recycling associations or through recycling information net work. Producers should review feasibility of the proposal by recycling associations for the improvement of materials and structure and should determine the adoption of the proposal. Producers should carry out recycling of their waste in accordance with the recycling methods and standards product categories as prescribed by the Ministry of Environment ordinance. Producers can collect and recycle individually or join the mutual recycling aid association. Mandatory recycling rate and amount is stipulated and announced by the Ministry of Environment.

As a result of introducing the system, it is expected that hazardous materials from electric and electronic products and vehicles will be reduced, recycling conditions will be improved, and the environment can be protected, as the import of environmentally hazardous materials from developing countries will be restricted. In addition, it is estimated that the competitiveness of Korean products in the domestic market will increase, the installation of recycling facilities will also increase to promote recycling in the era of high oil prices, and a system that boosts the development of recycling technology will be established, while 376 billion Korean won (equivalent to about 376 million USD) in economic effects will be achieved annually to the reduction of the outlay for hazardous material disposal, an increase in the recycling rate, a reduction in expenses for the recollection and disposal of freon gas, and lower landfill costs. More than 85 % (2009–2014) or 95 % (after 2015) of the waste should be recovered by material recycling or energy recovery.

4.3 Food Waste Recycling

(1) Overview

It is essential to reduce the food waste generation itself for minimizing economic loss and environment pollution.

Therefore, the Ministry of Environment has implemented food waste management policies centering on reducing its generation. At the same time, the Ministry of Environment has promoted recycling food waste as an organic resource. According to the results of several researches, food waste is sufficient to be used as livestock feed and compost with proper organics and nutrition.

Considering the fact that 95 % of grain and materials for livestock feed is imported, the government intends to make the best use of food waste as useful resources and build a resource-recirculating society. As a part of efforts to promote food waste-to-energy policy, the government required developers of building lots and tourist spots to install food waste-to-energy facilities by revising the Enforcement Decree of the Promotion of Installation of Waste Disposal Facilities and Assistance Act in December 1997. In September 1998, under the food waste to energy master plans, the following measures were taken: reducing discharge of food waste by more than 10 % and recycling of discharged food waste as resources by more than 60 % until 2002. As a result of medium- and long-term measures including comprehensive measures of food wastes in 2004, 92.2 % of food wastes generated (14,452 tons/day) were recycled as livestock feed and compost as of 2007. In addition, the ocean dumping of recycled food wastewater will be converted to land-based disposal by 2012.

Under the revised Control of Live Stock and Fish Feed Act (March 28, 2001) by the Ministry of Food, Agriculture, Forestry and Fisheries, registration as a feed manufacturer became essential to produce and provide livestock feed whether it was for free or not. Also, criteria for heating temperature and time were introduced to enhance the safety of the livestock feed. In addition, registration as a fertilizer manufacturer became essential to produce and distribute free of charge by-product fertilizers using food waste under the revised Fertilizer Control Act (March 19, 2003).

(2) Installation, Operation, and Management Intensification of Food Waste-to-Energy Facilities

With a view to promoting food waste-to-energy systems, 144.8 billion Korean won (equivalent to about 144.8 million USD) was provided to 248 places to install food waste-to-energy facilities and purchasing automobiles at the end of 2008. In addition, among recycling industry promotion fund, 731 billion Korean won (equivalent to about 731 million USD) had been offered to 2,013 places for developing waste-to-energy technology and installing facilities.

With the revision of Enforcement Decree of Wastes Control Act in 2004, it became a rule to report the use of food waste-to-energy facilities and have regular inspection for maintaining the performance of the facilities. Also, the criteria of installation of the facilities became to be enhanced in order to improve the quality of the products.

4.4 Waste-to-Energy Policy

(1) Background [Choi 2009]

With the rapid increase in energy and resources consumption from the advancement of free trade, globalization and economic activities from emerging economies like Brazil, Russia, India and China, the world is facing a double crisis—a resource crisis such as an oil price rising and an environmental crisis that is often described as climate change. In particular, although the international oil prices have begun to fall lately, the prices have rapidly risen since the second half of 2007 and surged over one hundred dollars per barrel in 2008.

Korea is the world's 10th largest energy consumer, and imports 97 % of its energy. In this regard, it is essential to reduce its energy dependency by producing and widely distributing new and renewable energies that can replace fossil fuels such as oil and coal. As of 2006, the ratio of new and renewable energy to primary energy amounted to just 2.24 %. However, with the goal of materializing "Low Carbon, Green Growth" as its core vision, the government plans to expand the ratio of new and renewable energies by 20 % by 2050. What is noteworthy is that currently more than 76 % of new and renewable energy is generated from wastes, and the manufacturing cost of the renewable energy from wastes is only about 10 % of that of solar energy and 66 % of that of wind energy. Given that, energy production from waste is emerging as the most cost-effective method to realize new and renewable energy.

In addition, the waste-to-energy policy is an effective method to respond to climate change arising from the global warming potential (GWP) of methane, which has a heat-trapping effect in the atmosphere that is 21 times stronger than that of carbon dioxide, because it replaces fossil fuels and reduces the generation of methane gas. Recently, countries around the globe are striving to reduce greenhouse effects by using refuse-derived fuel (RDF) made from combustible solid wastes to produce energy. In particular, the EU has set the goal of reducing 320 million tons of CO_2 through the waste to energy program by 2010, and has implemented the measure. Meanwhile, Korea's greenhouse gas emissions stood at 591 million tons of CO_2, rising by 4.7 % annually from 1990, which is the highest rate among OECD members. For this reason, Korea is under pressure to be included in the group of countries with mandatory emission control.

In addition, there is the growing demand for intensified regulations on waste dumping in the oceans from the international community, in line with 1996 Protocol to the Convention (London Protocol), which took effect in March, 2006. As for Korea, 53.8 % of food wastewater which is generated in the process of food waste reuse, 68.5 % of sewage sludge, and 4.1 % of livestock manure have been disposed of through the ocean dumping method as of the end of 2007.

However, the government has decided to ban ocean dumping of sewage sludge and livestock manure among organic waste starting from January 2012 and also the disposal of food wastewater starting from January 2013 in order to protect the ocean environment and marine creatures. With regard to these measures, the development of alternatives for on land disposal of ocean dumping are urgently required. However, a number of problems could arise including the security of landfill and foul odors from the landfills. Incineration brings the problems of the enormous costs of dealing with carbon dioxide and other sources of air pollution. Thus, it should be established alternatives for land-based disposal of ocean dumping through biogas technology from organic wastes, instead of pursuing landfill or incineration methods, and take this conversion as an opportunity for producing new and renewable energy and reducing greenhouse gas in an effective manner.

(2) Domestic Waste to Energy Status

The total amount of new and renewable energy generated in 2006, was 5.23 million Ton of Oil Equivalent (TOE), of which waste-to-energy including waste gas accounted for about 4 million TOE. The amount of renewable energy from waste excluding waste gas was 2.44 million TOE, accounting for 1 % of primary energy and 61 % of new and renewable energy. This amount mostly comes from collecting residual heat generated from household waste incinerators or collecting waste landfill gas, but this is hard to consider as results of the government's aggressive waste to energy policy.

Therefore, in order to more actively implement the waste to energy policy, it is necessary to expand manufacturing RDF using combustible solid wastes and exclusive power generation, electricity generation and purification projects using biogasification of organic waste, as advanced countries do. However, in the waste solid fuel field as of 2007, Korea has only one RDF manufacturing facility (in Wonju in Gangwon province) and 34 RDF manufacturing facilities led by private sector companies. Although Biogasification using food waste, sewage sludge and livestock manure has been partly processed in the livestock wastewater disposal facility in Paju Gyeonggi province, the Saenggok landfill site in Busan, and sewage disposal facilities in Dongrae-gu in Busan and Nam-gu in Ulsan.

From Korea's waste-to-energy technology development perspectives, manufacturing technology of the RDF from combustible wastes is in practical use, but the biogasification technology of organic waste is still considered to have a long way to go, compared to that of advanced countries.

(3) Waste to Energy Facility Expansion and System Enhancement

In October 2008, as a part of the method to achieve the national vision of "Low Carbon, Green Growth," the ministry of environment announced "Waste Resources and Biomass Energy Utilization Initiatives", and has strived to establish a wide range of measures with the publication of the implemented road map in

July 2009. As of 2007, the amounts of combustible wastes and organic wastes accounted for about 3.84 and 7.85 million tons per year, respectively. However, only 1.5 % (58,000 tons/year) of combustible waste, and 2 % (160,000 tons/year) of organic waste were utilized as energy resources. In an effort to facilitate waste to energy policy, the ministry aims to achieve energy utilization of combustible waste (by 47 % or 1.82 million tons/year) and of organic waste (by 26 % or 2.04 million tons/year). In addition, it plans to increase energy collecting rates for residual thermal from middle and large-scale incinerators and for landfill gas from waste landfill sites.

Since 2007, the ministry has gradually increased the government subsidies for waste to energy facility establishment and provided about 33 billion Korean won (equivalent to about 33 million USD) of national budget for establishment of such facilities in local governments. It is expected the ministry will offer more government subsidies to increase the waste to energy distribution rate by 2010. As the results of its effort to expand power generation facilities from waste, it is scheduled to complete the construction work of an RDF manufacturing facility capable of producing 200 tons of RDF a year in the metropolitan areas in 2009, a biogasification facility capable of producing 98 tons of biogas per day in Dongdaemun-gu in Seoul, a sewage sludge drying facility capable of processing 450 tons per day in Suwon, and landfill gas facilities in Gumi and Masan. In addition, RDF manufacturing facilities and exclusive RDF boilers in 12 cities including Naju, and biogasification facilities and sewage sludge drying facilities in 8 landfill sites in the metropolitan areas are under construction or in the planning stage.

In the expansion of waste to energy facilities through expansion and centralization of facilities, the ministry plans to establish environmental and energy towns equipped with waste to energy facilities by provincial region, so as to resolve the side effects resulting from excess equipment operated by local governments or private companies and to achieve the economy of scale. In particular, it plans to set up an “Environment and Energy Town” pilot complex in the landfill site in the metropolitan areas as part of its plan to spread environment and energy towns nationwide. The landfill site in the metropolitan areas covers an area of about 20 million m^2 and boasts the world’s largest landfill capacity of 18,000 tons of waste per day produced from the metropolitan areas. At the prospective landfill site of about 4.55 million m^2 in the landfill site, the ministry plans to create a waste resource energy town, bio-energy town and other environmental and cultural complex including an RDF manufacturing facility and its exclusive boiler, food wastewater biogasification facility, sewage sludge to energy facility, landfill gas power generation facility, with an aim of turning it into an international environmental tourist attraction. The waste resource energy town that will be established in the landfill site is expected to achieve the 40 % of waste to energy utilization goal by 2013. In addition to the metropolitan landfill site, the ministry plans to set up 13 environmental and energy towns in 8 local regions, in consideration of geological, economic, social and cultural conditions. It is expected to achieve 43 % of energy utilization of waste resources through these towns. As of 2009, the ministry is conducting the feasibility study of establishment of 6 environmental and energy complexes in Gangwon and North Chungcheong province (Wonju), Jeju province (Jeju Special Self-Governing Province), Daejeon and South Chungcheong province (Daejeon), Daegu and North Gyeongsang province (Daegu), and Gwangju and North Jeolla province (Gwangju).

In addition, it plans to establish independent facilities and expand facilities by local and municipal governments based on regional and facility characteristics, and promote economic efficiency by utilizing RDF and biogas produced from local facilities in the regional environmental and energy towns. Through the facility expansion, it is estimated to process 17 % of waste reclamation for energy by 2013.

(4) Low Carbon, Green Growth City Establishment

Agricultural, fishery areas and small cities have large potential for waste-to-energy generation using, for example, combustible and organic waste, forest resources and farming by-products, but energy utilization for those resources is very low since the resources are scattered by region or the amount of generated waste is limited. Advanced countries such as Germany and Japan have created independent bio-energy towns utilizing sewage sludge, food waste, livestock manure and forest, agricultural by-product. Thus, the Korean government should also make efforts to maximize resource utilization and promote the local economy through the establishment of small-scale energy independent towns. In line with this, the Ministry of Environment, the Ministry of Food, Agriculture, Forestry and Fisheries, Korea Forest Service, and the Ministry of Public Administration and Security established an consulting council and plans to create 600 low carbon, green growth cities by 2020. In order to achieve successful outcomes from this plan, each ministry will develop standard model types of city areas, agricultural areas, combined city and rural areas, mountain village areas, and fishing village areas, and promote a pilot project starting in 2010.

(5) Waste to Energy Technology Development and Human Resources Development

Korea's waste to energy technology level is at about 60 % of that of developed countries, and thus its fundamental technology and commercialization is limited. Although the ministry is promoting the Eco-Star Project (2007–2014) as part of the next-generation environmental technology development project, the project alone is not sufficient to take the upper hand in the relevant industry and develop as an export facilitation strategy. In order to raise the domestic technological level in waste to energy development to 90–95 % level of that of advanced countries by 2020, and nurture as the world class state-of-the-art technology to lead the global market, the ministry plans to promote the waste to energy research and development program. As its fist step, the practical study and commercialization of the obtained technology will be provided through the Eco-Star project. In the second step, technologies to secure new growth engines will be developed. The third step will focus on finding and developing state-of-the-art technology to lead the global market. To that end, by 2013, the ministry plans to offer 203.4 billion Korean won (equivalent to about 203.4 million USD) of government subsidies to the relevant research and development.

Each year, about 7,000 of the domestic undergraduate students graduate from environment-related colleges and universities. However, the ratio of those with master and doctoral degrees, compared with bachelors degree holders, accounts for just 12.6 %. This means that there is a great shortage of skilled human resources specializing in green growth industries. In particular, given that the waste to energy field is a relatively new industrial field. It should be urgently nurtured manpower that can adapt from the conventional waste disposal to energy conversion and develop waste to energy technology. In order to establish fundamental research and develop education for energy generation from wastes, the ministry, in 2009, is operating special research centers for three specialized fields, such as combustible wastes, organic wastes, and biomass, and plans to gradually increase the number of research centers to produce 900 talented people in the waste to energy industry by 2013. In addition, with the expansion of waste to energy facilities, the ministry is providing 30–50 environment-related college graduates with the on-site training at the Korea Institute of Environmental Science and Technology annually in order to nurture them as skilled manpower. Through these measures, about 540 specialized industrial human resources are expected to be produced by 2013.

(6) Facility Investment and Expected Effects

The government and private sector expect to spend a total 5.63 trillion Korean won (equivalent to about 5.63 billion USD) to expand a variety of waste to energy facilities by 2013, of which about 2.77 trillion Korean won (equivalent to about 2.77 billion USD) will be provided by the government subsidies. By 2012, when the construction of most waste to energy facilities will be complete, it is estimated that through the construction and management of waste to energy facilities, and technology development about 46,000 new jobs as well as 1.2 trillion Korean won (equivalent to about 1.2 billion USD) of economic values from saving waste disposal costs, reducing the importation of crude oil, and reducing greenhouse gas will be created.

Moreover, waste to energy program is expected to contribute to resolving current international environmental issues, such as climate change and restrictions on the discharge of wastes into the sea.

5 Safe Waste Treatment

5.1 Allbaro System

(1) Waste Manifest System in Korea

The current "waste disposal verification system", which was designed to track the entire disposal process of waste, takes excess time, human resources and costs to verify the process since all the paper work involving the process such as transfer, authorization, and final administrative report should be manually reported, and thus failed to achieve its original purpose.

In this regard, the newly introduced Waste Manifest System is an electronic information system that computerizes the whole process of waste disposal from generation through transportation to final disposal on the web. It was developed and established by the Ministry of Information and Communication as an information assistance project in September 2001, and has been used to monitor businesses that produce more than a certain amount of controlled wastes and their waste collection and disposal businesses since September 2002.

The "Waste Manifest System" allows waste generators, transporters, and managers to deal with hand-over statements through electronic information on the web, so as to help them monitor the whole process of waste disposal, from generation to disposal. Through this method, the administrative organizations can check the process of waste in a transparent way in real time and effectively prevent illegal waste disposal (Fig. 2).

Since September 2002 when the system was put in place, 1,094,674 electronic handover statements (monthly average of 91,223 units) were issued in 2007 and 22.21 million tons of designated wastes are managed (monthly average of 185 tons) by the electronic information.

Until 2004, most of the system users were company that produce designated or general waste, but producers of construction waste were included as users since September 2005. 'Waste Manifest System" was completed in 2006, and most of

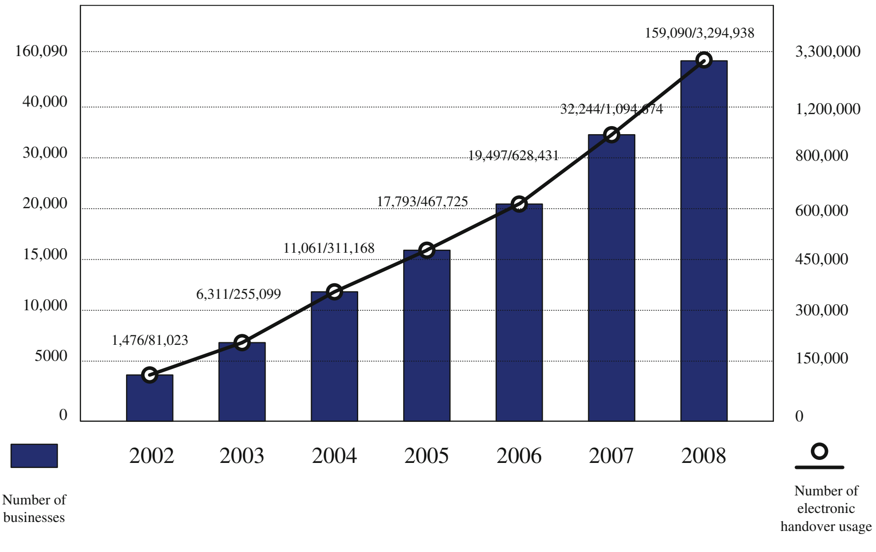

Fig. 2 System user businesses and electronic hand-over usage status by year (as of 2008)

generation, transportation and disposal process of commercial wastes are analyzed in the system to be applied to waste management policy. Collected data are effectively utilized for development of the waste management industry and system enhancement. Meanwhile, in accordance with the revision of the Wastes Control Act in August, 2007, preparing electronic hand-over statements in case of waste generation, transport, and disposal has become mandatory since August 4, 2008, and has become a user-friendly system through intensified monitoring systems and consistent system upgrades [Korea Legislation Research Institute 2007a].

5.2 Waste Import and Export Management

The approval system for the import and export of 86 types of hazardous wastes has been in operation in Korea since 1994, in order to comply with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. In addition, the report system for the import and export of general wastes to which the approval system does not apply is scheduled to come into effect in August 2008.

As the environmental pollution resulting from the improper disposal of hazardous waste in underdeveloped countries by company based in developed countries for the purpose of evading strict regulations on the disposal of hazardous waste in their own countries has emerged as an international issue, the necessity of international cooperation for the protection of the natural environment in underdeveloped countries and, by extension, the global environment has also increased. To address this, a convention on the control of transboundary movements of hazardous wastes was concluded in Basel, Switzerland in 1989, and came into effect on May 5th, 1992 [Korea Legislation Research Institute 2007b].

(1) Approval System for the Import and Export of Waste

According to Article 2 of the Act on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal, the import or export of waste that is on the "list of wastes subject to the Act on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal (Notification of the Ministry of Environment, No. 2007-188)" is possible only after acquiring approval from the competent authority, the regional offices of Ministry of Environment.

(2) Reporting System for the Import and Export of Waste

According to Article 24-2 of the Wastes Control Act, the import or export of waste that is on the "list of wastes of which import and export must be reported (Notification of the Ministry of Environment, No. 2008-105)" is only possible after reporting the import or export to the competent authority, the regional offices of Ministry of Environment.

5.3 Sudokwon Landfill Site Management Corporation

The Sudokwon Landfill Site Management Corporation (SLC) founded in July 2000 as a corporation affiliated with the Ministry of Environment. SLC has been working towards not only treating wastes from metropolitan regions in an eco-friendly way and converting them into useful resources, but also creating a pleasant environment park in the surrounding areas.

The landfill site, which is under the control of SLC and located 40 min away by car from Seoul, was built with environmentally friendly methods. Its size is 20 million m^2 (equivalent to the size of 2,800 soccer fields) making it the landfill of the largest scale in the world. The site takes and sanitarily processes processing waste influxes from 24 million people living in Seoul, Incheon, and Gyeonggi province. The quantity of general wastes from households, construction sites, and industrial site transported to the landfill site amount to 18,000 ton per day. High strength leachate and gas from the landfill site is safely treated with cutting-edge technological capacities.

The facility's systematic management is rated as a very outstanding example in the world. The OECD's Environmental Performance Review of Korea once mentioned, "The landfill site in Korea is the biggest in the world, serving as a good model for the international society." The basic foundation facility consists of an underground water draining layer, a solidification water shutting layer, and a leachate drainage layer, forming an infrastructure with a total size of 165 cm used to prevent pollution caused by leachate. In order to bury and manage wastes in a sanitary manner, landfill gas collection and treatment facilities are installed to prevent waste layers from sinking; other major facilities include leachate draining and treatment facilities, internal transportation roads, outer banks, and environmental pollution reduction facilities. Dream Park Golf Course and 50 MW Landfill Gas Power Plant were constructed and cleanliness of the site's management system was completed. In order to apply a more stable processing method for leachate with fluctuating qualities and quantities, SLC has taken numerous steps towards the continuous improvement of landfill procedures and the effective management of the facility as it contributes to the improvement of water quality. The leachate treatment facility is able to discharge 6,700 m^3 of water per day. Leachate goes through the processes of anaerobic digestion, denitrification and nitrification, first chemical coagulation, and oxidation-coagulation before it is discharged. The economic and efficient automated process is successfully built into the structure, triggering beneficial effects such as reduced processing costs and technology transfers to areas abroad.

Abiding by its motto 'Wastes are also Resources', the corporation has introduced a sustainable resource circulation system that focuses on waste minimization through the improvement of the environmental efficiency of waste management and studies the development of alternative energy sources. For example, a 50 MW Landfill Gas Power Plant, which is the biggest in the world, makes practical use of landfill gases generated from the landfill site. Through the use of this power plant, the corporation generates 40 billion Korean won (equivalent to about 40 million USD) worth of electricity annually and secures 850,000 tons of carbon emission credits. In particular, the government is currently promoting the construction of the 'Sudokwon Environment Energy Complex (an area consisting of a waste resource energy town, natural energy town, bio-energy town, and environment and culture town)'as a pilot project for waste resource and biomass energy. If completed in 2020, it will generate 2.61 million Gcal of energy annually, leading to the substitution of crude oil, which amounts to 1.92 million barrels, and the diminishment of CO_2 by 1.2 million tons every year.

Used landfills are being converted into an environmental ecology park called 'Dream Park', where 10 million trees are to be planted, for citizens of the municipal areas and community residents. In order to accommodate diverse leisure activities while promoting healthier lifestyles among urban citizens, a variety of facilities have been established, ranging from sports parks to green bio complexes with ecological ponds and wild flower gardens.

SLC will continue to make business more efficient through business activities and the creation of creative and flexible organizations with the aim of placing the Sudokwon Landfill Site in the center of the new renewable energy industry, making it the standard of environmental facilities. Furthermore, SLC is planning to host several sports games during the '2014 Incheon Asian Games, including golf, swimming, and horseback riding'.

6 Conclusion and Tasks for the Future

Korea has succeeded in achieving an environmentally sustainable structure in which waste reduction and recycling are prevailed. The significance of the waste issues is well understood by the all Korean people and the policy and management of waste are focused on waste minimization and recirculation. Through segregated discharge of waste, separation of recyclable wastes, reprocessing of the collected wastes, paying recycling cost, and etc., all the waste policies and programs prove our success in the sense that benefit exceeds cost.

However, there must be more room for further improvement even though the generation of household waste is very low. It is the time to pay our attention to the information statistics of waste generation and recycling rate that shows the trend of waste management. Despite of very high recycling rate of waste, the disposal waste in landfill is not dramatically decreased. What does this imply? It means recycling pathways of waste may be not reported correctly. Hence, it should be take care of basic information of waste generation, waste tracking, the pathways of recirculation, and final disposal.

As economy grows, production and consumption increase, and this increase causes increased commercial waste amount. Since the portion of commercial waste in Korea is more than 80 %, it should be focused on the management of commercial waste. In order to management of waste properly, it should be realized that the pattern of generation of waste can be changed because the average lifetimes of goods are getting shortened, resulting in massive creation of waste.

The future focuses in waste management in Korea are as followings. First, integrated waste management should be activated for the waste minimization in the whole life-cycle of production, consumption and disposal. Also, material flow analysis (MFA) can be introduced to find the pathways of waste stream to minimize waste amount and to obtain resources from waste. Secondly, statistic information of waste should be examined to improve the management of waste. In order to examine the statistics of waste information, enhancing administrative transparency is crucial work. Thirdly, recycling technology should be developed for the advanced waste management. It is very important to secure the original technology to recovery valuable metals from electric and electronic wastes and other wastes. Finally, international cooperations in waste management should be promoted. Transboundary movement of waste will be more important because the waste amount for import and export will be increased to obtain the resources economically.

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MSW Management in Malaysia-Changes for Sustainability

Agamuthu Pariatamby

1 Introduction

Municipal Solid Waste is solid, other than emission or effluent, and is regarded as inevitable, valueless by-product due to human activities, and is generated at a rate and discarded after use when no longer needed by the generator. Waste consists of materials that are no longer considered valuable and subsequently disposed off (Tchobanaglous et al. 1993).

In Malaysia, urban waste generation increased 3 % annually due to urban migration, affluence and rapid development (Agamuthu 2001). In 2008, approximately 31,000 tonnes of waste were disposed off into 260 landfills in Malaysia (Agamuthu et al. 2009a, b). Municipal solid waste (MSW) problems have been gaining prominence in Malaysia due to the ever increasing waste generation and the ineffectiveness of the existing mechanism to tackle the problem holistically (Agamuthu and Fauziah 2006). Early management of solid waste involved very little effort since waste was generated at a manageable level and generally consists of organic materials such as food waste, paper, wood and others (Fauziah et al. 2007). This began to change with the increase in the human population and advancement in living standards. Quantity of waste generated increased together with the complexity of waste where plastic and other mixed waste became a significant portion in the waste stream. This called for an appropriate waste management system to avoid the proliferation of disease and the deterioration of environmental quality through pollution.

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2 Changes in Waste Generation

The production of MSW has doubled or tripled in some industrial countries over the last two decades. Developing and transitory countries, which are becoming industrial nations, are also producing MSW at an alarming rate, particularly due to the rapid development of urban areas, the rural–urban migration and the increase in per capita income, as well as, the changes in consumption patterns brought by the development (Agamuthu and Fauziah 2006; Agamuthu and Khan 1997). Consistent data on rates of solid waste generation in Malaysia are lacking due to the absence of established activity in the MSW field. Urban population, which contributes more than 65 % of the total population, is the main waste generator. Table 1 shows the trends of waste generation in major urban areas in Peninsular Malaysia from 1970 to 2010.

The increase in urban population in Peninsular Malaysia from 6.05 million in 1988 to more than 16.5 million in 2007 resulted in the acceleration of waste generation in urban areas. The refuse generation rate has increased from 241 to 438 kg/capita/year. Kuala Lumpur, the capital city of Malaysia, showed increasing trends of waste generation since 1970. The initial generation of 98.9 tonnes/day in 1970 increased by approximately 300 % in 1980. To date, the waste generation in Kuala Lumpur had increased tenfold since 1990s from approximately 590–3,000 tonnes/day. Similar increasing trends were observed throughout 1996–2006 in most states in the country as indicated in Table 2. Increase in waste generation from 2000–2006 was 60 %, giving an average of 10 % increment annually for the past 6 years. In 1997, the total solid waste generated in Peninsular Malaysia was 5.6 million tonnes or 14,000 tonnes/day and of this 80 % was domestic waste, while the remaining 20 % was commercial waste.

By the year 2000, production of domestic and commercial waste reached 8.0 million tonnes/year, where one quarter of the total solid waste was generated in the Klang Valley. The total refuse tonnage was found to have increased two-fold to

Table 1 Generation of MSW in major urban areas in Peninsular Malaysia (1970–2012)

Urban centre	Solid waste generated (tonnes/day)							
	1970	1980	1990	2002	2006*	2009*	2010*	2012*
Kuala Lumpur	99	311	587	2,754	3,100	3,387	3,489	3,701
Johor Bharu (Johor)	41	100	175	215	242	264	272	289
Ipoh (Perak)	23	83	162	208	234	256	264	280
Georgetown (P. Pinang)	53	83	137	221	249	272	280	297
Klang (Selangor)	18	65	123	478	538	588	606	643
Kuala Terengganu (Terengganu)	9	62	121	137	154	168	173	184
Kota Bharu (Kelantan)	9	57	103	130	146	160	165	175
Kuantan (Pahang)	7	45	85	174	196	214	220	233
Seremban (N. Sembilan)	13	45	85	165	186	203	209	222
Melaka	14	29	47	562	632	691	712	755

* Estimated figure

Table 2 Generation of MSW in Peninsular Malaysia according to states (1996–2006)

States	Solid waste generated (tonnes/day)					
	1996	1998	2000	2002	2004*	2006*
Johor	1,612.9	1,785.35	1,914.95	2,093.17	2,255.27	2,429.93
Kedah	1,114.53	1,215.42	1,323.67	1,446.86	1,558.91	1,679.64
Kelantan	870.84	949.67	1,034.25	1,130.51	1,213.37	1,302.31
Melaka	433.26	799.97	514.56	562.45	604.84	650.43
Negeri Sembilan	637.4	695.1	757.01	827.46	889.82	956.89
Pahang	805.88	878.83	957.1	1,046.18	1,125.03	1,209.82
Perak	1,285.81	1,402.2	1,527.09	1,669.22	1,795.03	1,930.32
Perlis	164.61	179.51	195.5	213.7	229.81	247.13
Pulau Pinang	915.72	998.61	1,087.55	1,188.77	1,278.37	1,374.72
Selangor	2,379.89	2,595.33	2,826.47	3,089.53	3,322.38	3,572.79
Terengganu	743.21	810.49	882.67	964.82	1,037.54	1,115.74
Kuala Lumpur	2,105.43	2,305.29	2,520	2,754.54	3,025.32	3,322.72
WP Labuan	NA	NA	46	70	74.26	81.15
Sabah	NA	NA	NA	2,490	2,641.64	2,886.59
Sarawak	NA	NA	NA	1,905	2,021.01	2,208.42
Total	*13,069.48*	*14,588.77*	*15,586.82*	*21,452.21*	*23,072.60*	*24,968.58*

http://www.kpkt.gov.my/statistik/perangkaan2002
NA Not available
* Estimated figure

2.448 million tonnes/year in 1995 or an increase of 169,670 tonnes/year, which works out to about 13.5 % increase per year. For Kuala Lumpur alone, the waste production exceeded 2,800 tonnes/day in 1997, reached a generation of 3,000 tonnes in 2001 and is expected to be about 3,200 tonnes in 2017. In Selangor, the waste generated in 1997 was over 3,000 tonnes/day, and will reach 5,700 tonnes/day in the year 2017(Sekarajasekaran and Lum 1982). The generation of MSW in Malaysia currently has reached more than 31,000 tonnes/day with the highest generator being Selangor, where industrial activities are mainly concentrated. Selangor contributed approximately 14, 15 and 17 % of the country's total waste generation in 2002, 2004 and 2006, respectively. Labuan being the youngest developed town had the lowest solid waste generation of only 46 tonnes/day in 2002 and eventually increased to 82 tonnes/day in 2006. The MSW generated was 6.0 million tonnes in 1998 at an average per capita generation of 0.5–0.8 kg/day (Fig. 1).

Level of per capita solid waste generation changed accordingly with urbanization of more areas, as well as with the improvement to the people's quality of life in the country. The rate in the 1980s was 0.5 kg/day and had increased to 1.3 kg/day in 2006. Current rate ranged at 1.5–2.0 kg/day in most cities. This increasing trend could be due to the changes in consumption habits, as well as, the increasing affordability to consume more goods. The economic status of individuals has a direct impact on the waste generation and waste characteristics (Table 3).

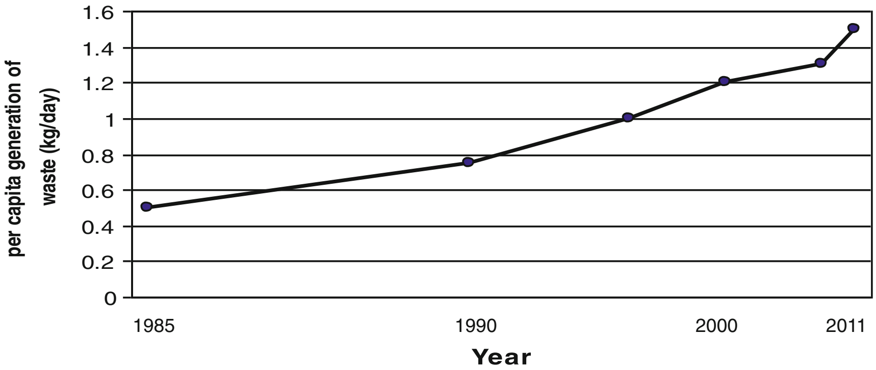

Fig. 1 Increasing trend in per capita generation from 1985 to 2011 (Agamuthu and Fauziah 2012)

Table 3 MSW generated from different economic households

Composition (%)	Socio-economic status		
	High	Middle	Low
Paper products	19.79	15.73	13.04
Plastic and rubber	21.05	18.61	13.01
Glass and ceramics	14.99	9.42	7.57
Food waste	24.13	29.77	31.86
Metals	8.80	12.75	9.15
Textiles	1.57	3.87	3.08
Garden waste	5.50	6.95	15.56
Wood	3.45	2.90	6.72
Total	*100.00*	*100.00*	*100.00*

3 Changes in Waste Composition

Waste stream consists of approximately 46 % organic waste followed by 14 % paper and 15 % plastic. Figure 2 illustrates the average composition of Malaysian waste.

The availability of comprehensive data on solid waste composition on a national scale is limited. A study conducted by the Ministry of Housing and Local Government (MHLG) reported that the solid waste composition in Malaysia was dominated by organic waste, followed by paper in the total waste stream (Hoorwerg and Thomas 1999). Similar trend was observed in 2003 indicating high percentage of organic waste present in the MSW composition as shown in Table 4.

Waste composition in Malaysia is dominated by organic waste comprising approximately 50 % of the total waste stream. Current waste composition indicates a very high percentage of putrescible waste, which mainly consisted of processed kitchen waste and food waste. Figure 3 indicates the average

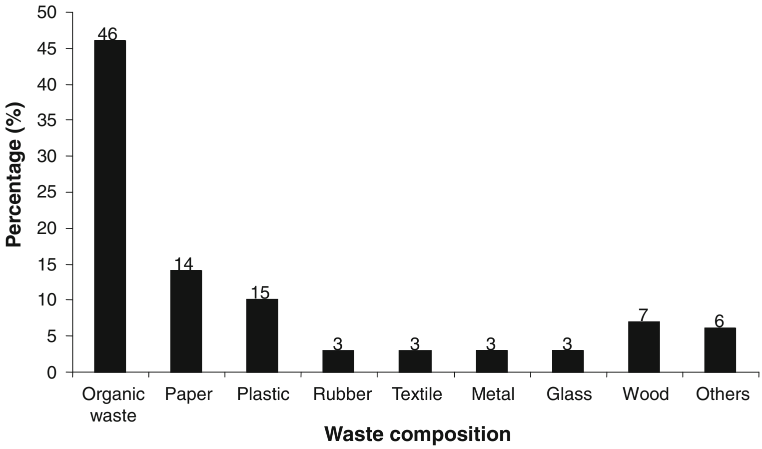

Fig. 2 Average waste composition received by Malaysian landfills

Table 4 Waste composition in Malaysia throughout 1975–2011

Waste composition	1975	1980	1985	1990	1995	2000	2003	2011
Organic	63.7	54.4	48.3	48.4	45.7	43.2	46.4	58
Paper	7.0	8.0	23.6	8.9	9.0	23.7	14.4	7
Plastic	2.5	0.4	9.4	3.0	3.9	11.2	15.0	12
Glass	2.5	0.4	4.0	3.0	3.9	3.2	3.0	3
Metal	6.4	2.2	5.9	4.6	5.1	4.2	3.3	6
Textile	1.3	2.2	NA	NA	2.1	1.5	2.8	3
Wood	6.5	1.8	NA	NA	NA	0.7	6.7	1
Others	0.9	0.3	8.8	32.1	4.3	12.3	8.4	10

http://www.kpkt.gov.my/statistik/perangkaan2002
Fauziah and Agamuthu (2003), Agamuthu and Fauziah (2011)

composition of waste received by the landfills in Malaysia. It is a worrying trend that the unconsumed food disposed ranged from 3–5 % which indicates the affluence of the Malaysian public.

Putrescible waste contributes approximately 46 % of the total waste received by landfills in Malaysia, followed by 14 % of paper waste and 15 % of plastics based waste (Table 4). The trends in MSW composition in Malaysia indicates that food, paper and plastic are the main components which form the solid waste generated in most places. The findings indicated that highest percentage was food waste at 41 % followed by 8 % plastic film and 6 % rigid plastic. The 7,200 tonnes of food wastes theoretically allowed the diversion of these fractions for biological treatment. The possibility to incorporate composting programs would also utilize the 6 % garden waste which would reduce approximately 45 % of the total MSW stream from being disposed off into landfills. The quality of the compost can be monitored and various additives available in the market offer

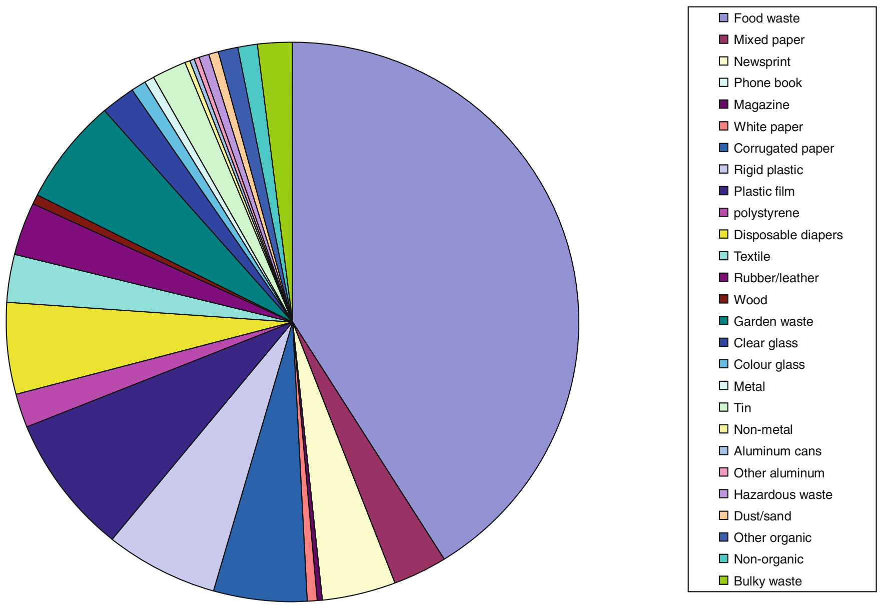

Fig. 3 Average composition of waste received by landfills in Malaysia

quality improvement of the compost from MSW, to generate a net profit of RM5.32 (US$1.51) million daily.

Besides composting, the putrescible components can also be converted into biogas. Biogas generation had gained importance worldwide where organic wastes are treated in anaerobic digestion chambers which convert landfills into bioreactors. However, due to lack of expertise and insufficient technology, the biogas conversion generally is not a convenient effort to manage the waste.

Other material recovery options include the recovery of paper, plastic, glass, and metals. A total of 40 % of the daily waste received by the landfills consists of recyclable components including 14 % paper, 15 % plastic, 3 % metal and 3 % glass.

Since Malaysian waste consists of non-degradable plastic, diversion of these plastic components is very crucial. Plastic composition has increased from 15 % in 2004 to 24 % in 2005 which means there is approximately 4,550 tonnes of plastic wastes in the 19,000 tonnes MSW generated (Kamariah 1998) (Fig. 4).

The waste composition also depends on the location of the landfill and the area served. Putrescible waste is highest in rural landfill (Table 5) and the composition is affected by the occupational activities within the area of service.

Similarly the landfill leachate characteristic is also influenced by the waste composition in these landfills.

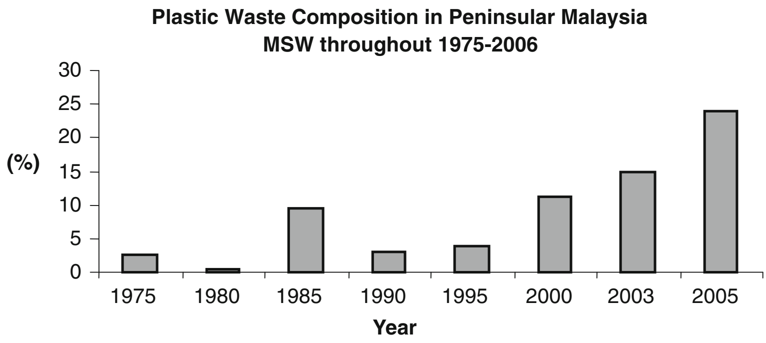

Fig. 4 Plastic waste composition in Peninsular Malaysia (Kamariah 1998; Kuman and Abdullah 2002; Yani and Rahman 2000)

Table 5 Municipal waste composition (% FW) in rural, sub-urban and urban landfills

Component	Rural landfill (Panchang Bedena)	Sub-urban landfill (Sungai Sedu)	Urban landfill (Kundang)
Age of landfill	9 years	13 years	12 years
Putrescible waste	58.67 ± 20.89	51.60 ± 11.89	42.02 ± 9.67
Paper	10.55 ± 2.52	10.90 ± 10.63	12.90 ± 5.32
Plastic	15.86 ± 1.89	18.60 ± 2.06	24.74 ± 4.11
Rubber	1.24 ± 1.07	3.00 ± 0.88	2.45 ± 1.27
Textile	3.59 ± 1.04	2.50 ± 1.39	2.48 ± 1.76
Metal	3.21 ± 0.33	3.90 ± 1.38	5.30 ± 3.18
Glass	2.18 ± 0.76	2.90 ± 1.0	1.84 ± 1.06
Wood	0.54 ± 0.36	2.00 ± 0.60	5.74 ± 0.64
Others, such as disposable diapers	4.16 ± 3.53	4.60 ± 0.70	2.53 ± 1.92

4 Changes in Management

Development of solid waste management programmes in Malaysia has taken place in phases. Up till the end of 1970s, the municipal solid waste management was quite primitive. Local district health offices were only to clean the streets and to haul away household wastes to municipal disposal sites assigned as authorized dumping ground.

Local Authorities (LA) were the main bodies responsible for the operation and management of solid waste on the ground. The LAs are mainly empowered through Provisions under the Streets, Drainage and Building Act 1974, Local Government Act 1976 and the Town and Country Planning Act 1976. The three types of LA in Malaysia comprise of City Halls, Municipal Councils and District Councils. Solid waste management in the LAs is handled by the Department of Urban Services. However, the privatization of solid waste management in the LAs, has delegated this function of solid waste management from some of the LAs to the private waste managers.

Therefore, the existing role of the LAs in terms of solid waste is evolving towards the enforcement of solid waste management rather than in providing solid waste management services. The LAs also act as the liaison between the public and the private waste managers in areas where the waste managers have taken over through the indirect billing system. In these areas, the public pays the LAs for the solid waste management services in their annual assessment, which the LAs then reimburse to waste consortiums. The LAs also monitor the private waste managers to ensure that they meet the required standard and quality of service.

Privatization in Malaysia was initiated as a national policy in 1983, to transfer responsibility and functions from the public sector to the private sector (Zainal 1997). The aim of privatization is:

- to relieve the financial and administrative responsibility of the government
- to improve efficiency and productivity
- to facilitate economic growth
- to reduce the presence of the public sector in the economy, and
- to assist the country in meeting its' national development policy goals.

The objective of privatization was to provide an integrated, effective, efficient, and technologically advanced solid waste management system. It is also expected to resolve the problems in solid waste management faced by the LAs such as finance, lack of expertise, illegal dumping, open burning and lack of proper solid waste disposal sites. Therefore, four private waste managing consortiums were appointed for the whole country, which are:

- Alam Flora Sdn. Bhd., which is responsible for the central and eastern regions (the Federal Territory of Kuala Lumpur, Selangor, Pahang, Terengganu and Kelantan). Their involvement in the latter three states is somewhat limited or totally nil.
- Northern Waste Industries Sdn. Bhd., which is responsible for the northern region (Perlis, Kedah, Penang and Perak). This consortium is non-functional and has been replaced.
- Southern Waste Management Sdn. Bhd., which is responsible for the southern region (Negeri Sembilan, Melaka and Johor) and
- Eastern Waste Management Sdn. Bhd., which is responsible for East Malaysia (Sarawak, Sabah and Federal Territory of Labuan).

At present, the privatization of solid waste management is carried out as an interim management agreement between the LA and the concessionaires concerned, where during the period, the level of services provided should not be less than that given by the LA. Generally the process of privatization shifted the burden from the LA to the waste consortia. Nevertheless the level of waste management services has been significantly improved with modern transporting vehicles and sanitary disposal sites.

5 Changes in Disposal Technology

In Malaysia, waste management trend has not experienced much change. In 1970s, MSW were mainly collected by the LAs to be dumped into the assigned disposal sites, which were operating as a typical open dumping ground. However, with changes in environmental consciousness in the 1980s and 1990s, and with the stipulation of various acts and regulations, waste disposal into the dumping ground was monitored to prevent accidents like fire and landslide. Regulations which concern solid waste disposal vary from one country to another (Lu et al. 2006; Gidarakos et al. 2006; Hui et al. 2006; Harison and Richard 1992).

In Malaysia the concern was more on pollution control. It was only in recent years that more attention was focused on the solid waste management issues, when the impact of improper management was considered a highly potential risk of pollution, that alternatives for waste disposal were suggested. Among the most controversial issue was the construction of incinerator plants to cater the ever increasing rate of waste generation. The ever increasing waste generation shortens the span of a landfill that more and more new area has to be converted into disposal sites.

With the population expansion experienced throughout the globe, scarcity of land had caused price of land to increase constantly. With less and less land available for development, other alternative options were seriously looked into. This includes the land-reclamation option. Land use subjected to reclamation includes ex-mining land, wetland, ex-landfill and coastal area (Misgav et al. 2001). Reclamation of land has been practiced in many places including London (Greenwich/Plumstead), Boston, Macau and Hong Kong (Karakiewicz and Kvan 1997). Malaysia had reclaimed approximately 1,214 ha of land in the coastal region in order to provide more space for urbanization (Karakiewicz and Kvan 1997). Variety of materials can be used to reclaim land. Among the most commonly used are the construction and demolition wastes which generally consisted of inert materials such as brick, cement and others. In developing nations, filling up 'unwanted' area for reclamation purpose is sometimes conducted with the dumping of municipal solid waste. However problems arise later such as H_2S emission or As and Hg contamination of soil. These will be discussed later in the case studies.

The problem of MSW disposal is likely to become more acute with the land available for landfills becoming scarce. In addition, landfill sites must be environmentally and socially acceptable so as to avoid any untoward problems and must be sufficiently buffered from human settlements to prevent odor, health risks and groundwater contamination.

In 1990, there were about 230 waste disposal sites in Malaysia with an average area of 15 ha (Table 6). More than 80 % of these sites had a remaining operating lifetime of less than 2 years.

The management and operation practices at most of these sites were relatively poor. About 60 % of these sites were open dumps and thus did not have

Table 6 Number of landfill sites in Malaysia throughout 1990–2009

Years	1990	1998	2003	2009
Total	230	177	144	270

*including illegal dump

appropriate studies, lack of cover materials, inadequate facilities like weighbridges and fencing, and lack of pollution control measures including leachate and gas emissions piping systems. Lorries and trucks collected waste and transported them directly to the disposal sites with no waste recovery system. Thus, the currently practiced system has caused recovery of reusable material impractical and would shorten the life span of the existing landfills (Fauziah and Agamuthu 2003).

There are many challenges and issues faced by Malaysian MSW managers particularly in dealing with the disposal sites. The traditional waste management system practised by local governments and the municipalities was inefficient and was very unsustainable when Malaysian waste generation per capita increased to 0.5 kg in the late 1980s and to more than 1.3 kg of waste in 2009 (Agamuthu et al. 2009a, b; EPU 2007). In certain cities like Kuala Lumpur and Petaling Jaya, the generation increased to 1.5–2.5 kg per capita (Agamuthu et al. 2009a, b). To date, annual waste generation in Malaysia has reached 11 millon tonnes with more complex and heterogeneous compositions mainly with putrescible waste (557 %), paper (13 %) and plastic (19 %) (Fauziah and Agamuthu 2009a, b). The smaller portion of the waste contained wood, rubber, metal, glass, textile and miscellaneous with the contributions of 7, 2, 4, 3, 3 and 0.5 %, respectively (Fauziah and Agamuthu 2004).

World Bank (1999) reported that waste management is one of the three major environmental problems faced by most municipalities including those in Malaysia which is closely related to the unsustainable landfilling practices. In 1998 alone, 228 licensed dumping sites were reported to the Ministry of Science Technology and Environment of Malaysia, and these caused contamination to the surrounding areas (Haznews 1998). This was due to the fact that project developers and local authorities failed to adhere to the guidelines stipulated for the development of a disposal site. Various factors influenced the management of a landfill. Among others is human factor which include attitude problems and public participation.

Human factor plays an important role in establishing an appropriate management of a landfill. This is due to the fact that human activities are the main generators of waste that requires proper treatment system. In more environmentally-concerned nations, positive attitude leads to high public participation in matters concerning the environment. Therefore, implementing strategies that involved the public, such as source separation, can be achieved in due time. As a result, wastes can be managed efficiently and landfills are more sustainable, with longer life-span and operating period.

Although Malaysia is a country with rapid economic development, public participation in environmental issues is very low. Though various campaigns such as recycling adverts have been launched to instil the awareness among Malaysians, it failed to mould the community to respond positively. The concern and awareness among the public in Malaysia are not parallel with the living standards that their participation towards sustainable waste management such as 3Rs is severely lacking. Currently, official recycling was only at 5 % (though estimates indicate up to 15 %). Studies indicate that more than 70 % of Malaysians are aware of recycling concept but less than 25 % are actually participating in 3R activities (Irra 1999; Fauziah et al. 2009). More than 70 % Malaysians implied that they refuse to recycle since the recycling facilities provided is insufficient while 65 % indicated that recycling is an inconvenient practice for them (Fauziah et al. 2009). As a result, more than 80 % of the recyclables in the waste stream are disposed off into landfills. This caused the volume of MSW to increase at 3 % per year rather than decrease with efficient recycling practices.

In addition to that, illegal dumping has become a serious matter to be tackled by waste managers (Agamuthu and Fauziah 2011). In 2003, 500 drums of paint sludge and glue were dumped illegally at a ravine in an isolated disused land that more than RM12 million (US$3.4 million) was spent for the cleaning-up (The Star 2002). In the Klang Valley alone, more than 52 illegal dump sites or ‘hotspots’ were reported to accumulate more than 933 tonnes of waste. The wastes cleared from these illegal dumping sites are sent to landfills that consequently landfill space will be exhausted earlier than anticipated. As a result, it hinders the practice of sustainable landfilling as wastes collected did not undergo any pre-treatment prior to disposal. This un-planned activity will increase the management cost of the landfills that existing practice is no-longer sustainable. The occurrence of illegal dumping is generally due to the ‘not bothered’ attitude among the waste collectors whose main concern is to profit from their illegal action.

Also, the NIMBY (Not In My Backyard), LULU (Locally Unacceptable Land Use) and NOTE (Not Over There Either) syndromes are very intense among Malaysians that siting of landfill on appropriate site becomes extremely difficult. Similarly with the construction of pre-treatment facilities such as compactor stations and transfer stations, it was always sturdily opposed by the public and non-governmental agencies (NGOs) (Agamuthu et al. 2009a, b) The strong resistance from the public towards new waste management or disposal facilities had caused the siting of a landfill to move further away from city center that developing the area incurred higher cost for the construction of non-existing infrastructures.

Even though Malaysia is a developing country with progressive economy, economic constraints are among the issues to be tackled in establishing sustainable landfilling practices. From the economic point, the challenges arise from lack of funding and the increase in the price of land.

The lack of financial assistance from the government for waste management in Malaysia had prompted in well-established and multinational company to bid for tender in providing waste treatment and disposal facilities. As a result, sanitary landfills in Malaysia are only owned by companies such as Worldwide Landfill Sdn. Bhd., Alam Flora Sdn. Bhd. and KUB Berjaya Environ Sdn. Bhd which belong to established companies namely Worldwide Holdings Bhd., DRB-Hicom Holdings Bhd, and Berjaya Corp Bhd., respectively. The waste management in the country seems to be monopolized by these companies when the actual issue of concern for other waste companies is the unavailability of financial aid to bid. To make matters worse, the existing National Policy on waste management in the country discourages financial institutions such as banks to invest in waste management projects. Therefore, waste managers with small capital are impeded from improving their disposal sites. Loans from banks are unavailable that smaller waste management companies will have no opportunities to venture into the establishment of sustainable landfills. As a result, most waste managers normally aimed for "just enough" to comply with the regulations instead of "self-sustained landfills". In addition to that, the increase in the price of land has resulted with new landfills being located at areas with very minimal infrastructure or none at all in order to minimize the capital cost of the landfill.

The fact that landfills are seen as a mere burden and not as a commodity in Malaysia is another aspect that impedes establishment of sustainable landfills. This is because landfills are mere disposal sites for waste that once a landfill is closed, it retains no further economic value. Typically this resulted from the fact that the revenue from tipping fees is no longer available for the landfill managers once the landfill ceased its operation. The absence of gas harvesting system resulted with landfill not being able to generate revenues from methane conversion. Collection of landfill gas to be converted into electricity is not feasible and non-economical since most landfills in Malaysia are less than 60 ha in size. In addition, most of the landfills in Malaysia are non-sanitary landfills that rely mainly on natural clay lining as the landfill liners. The establishment of these disposal sites were mainly based on the traditional concern of getting rid of waste. These landfills are not designed with the intention to generate resources such as methane to profit the landfill managers. Therefore, existing non-sanitary landfills in Malaysia only practice passive release of landfill gas where the installation of gas pipes are done as the waste cells are receiving waste.

Only the newly established landfills are designed with appropriate landfill liners to prevent leachate migration to the groundwater system and suitable gas collection system to harvest the gas. Air Hitam Sanitary Landfill, the first sanitary in Malaysia produced 2 MW of electricity from the conversion of methane. Similarly, newer sanitary landfills are capturing landfill gas for the purpose of energy conversion. However, the national policy on energy practiced by the country fails to enhance this green approach. This is due to the low price of electricity in the country where the electricity tariff for Malaysia ranges from RM0.15 (US$0.05) to RM0.43 (US$0.13) per kWh (MIDA 2012). It is at a low end due to government subsidies. As a result, the electricity tariff deprived the market potential of electricity produced via the conversion of landfill gas.

Aside from economy, the existing policies in the country also make sustainable landfilling difficult to achieve. This institutional factor also becomes a major issue of concern. Institutional factor hampers the practice of sustainable landfilling in the country due to the lack of proper waste management policy. The absence of an appropriate policy hinders the implementation of an integrated waste management system in Malaysia. As a result, 3Rs is not mandatory and waste separation is totally absent. Though the MSW stream contains significant amount of retrievable materials, non-existence of source segregation makes resource recovery very costly. In addition, the waste disposed into landfills in Malaysia is highly commingled with wet and putrescible components that moisture content of the waste may reach 70–80 %. This indiscriminate practice of non-separated MSW disposal into landfill is highly un-sustainable. It translates to the loss of valuable resources such as metal components, paper and plastics, and the degradation of the environment with increased environmental pollution from leachate and landfill gas. Aside from that, the un-sustainable practice also resulted with the shortening of landfill life-span where waste cells which can be optimized with only garbage also catering the recyclable items. As a result, a sustainable landfilling practice is not achievable.

Besides the lack of appropriate policy, waste management is also highly political. Competitions among the ruling parties in the countries are jeopardizing the waste management system. Since waste management is a very sensitive issue, it is usually used to fish votes among the people during election. Together with the indifferent attitude among the public, environmental concern including issues on appropriate waste management are impossible to experience improvement. Even the newly passed Solid Waste and Public Cleansing Management Act 2007 are ridiculed by opposing parties with the claim that the Act deprives public rights. This has resulted with the federal government 'playing safe' in passing statement regarding this issue as to avoid loss of voters in the coming elections. It is seen as the lack of political will of the ruling government to improve current waste management system. Thus, no voluntary effort was taken by most waste managers to improve the current state of their landfills. As a result, 90 % disposal sites in Malaysia remains as non-sanitary landfills which lack pollution prevention features such as bottom lining, leachate treatment and gas collection system. As most developing countries, more than 15 % of 187 million tonnes of Malaysian carbon emissions were contributed by landfill gases emission.

On the other hands, landfills often cause concern and fear among the community residents. Water pollution, both surface and ground water, gas explosion and odor are some of the common impacts caused by presence of landfills. Generation of landfill leachate remains an inevitable consequence of the practice of waste disposal in landfills. Leachate often contains high concentration of organic matter and inorganic ions including heavy metals and therefore highly contaminating. The subsequent migration of leachate away from landfill boundaries and the release to the adjacent environment for example water bodies is a serious environmental pollution concern and a threat to public health and safety.

The composition of landfill leachate exhibits spatial and temporal variations depending upon site operations and management practices, refuse characteristics, internal landfill processes as well as age factor (Hoeks and Harmsen 1980). Research shows that the concentration of many constituents in landfill leachate decreases with refuse age (Table 7). Leachate concentration peaks when landfill life is within 2–3 years of refuse placement and gradually declines in ensuing years.

Table 7 Characteristics of raw landfill leachate

Parameter	Jeram sanitary landfill	Bukit Tagar sanitary landfill	Panchang Bedena disposal site (rural)	EQA 1974 standard 2009
BOD_5 (mg/l)	27,000	26,379	348	20
COD (mg/l)	51,200	36,413	5,056	400
pH	7.35	6.6	8.1	6.0-9.0
TSS (mg/l)	NA	14	1.6	50
Cd (ppm)	NA	7	ND	0.01
Cu (ppm)	NA	7	1.0	0.20
Pb (ppm)	NA	13	41.7	0.10
Zn (ppm)	827.7	31	675.7	2.0
Mg (ppm)	32	59	36,533.3	NA
K (ppm)	1,130	923	NA	0.05
Ammoniacal-N (mg/l)	0.085	4,329	NA	5
Hg (ppm)	0.05	NA	NA	0.005
Fe (ppm)	97.76	74.0	NA	5.0

NA Data not available, *ND* Elements not detected

Landfill leachate, in many cases, is highly contaminating and can degrade surface and ground water resources. In Malaysia, the traditional source of drinking water had been surface water. It is therefore very important that municipal landfill is properly sited, designed, managed and maintained so that the sources of water are protected from leachate pollution.

6 Changes in Awareness

The concern over waste management and disposal parallels an increased appreciation of the concept that people, as the custodians of the environment with waste production being increasingly regarded as an antisocial activity rather than as the necessary and inevitable consequence of the demands of a consumer society. Public has the main task in creating an efficient waste management system since they are the main stakeholders that generate volumes of waste. Their participation and awareness regarding environmental issues is very crucial to ensure the success of proper waste management systems. Urbanization improves the standard of living and the transformed population consumed goods and services at a more rapid rate, which increases the rate of waste generation as well. In Asian cities, waste generation is projected to escalate to more than 1.8 million tonnes per day in 2025 when more areas are urbanized.

Even the best waste management system would not succeed without the participation of the public. Obviously, the public plays an important role in improving the environmental state of a nation due to the fact that public is the main stakeholder in this issue. The level of environmental awareness of the society would determine the effectiveness in public participation towards environmental matter. Studies based on questionnaires and interviews were conducted at nine landfill areas throughout Selangor, the fastest developing state in Malaysia, to establish the level of environmental responsiveness among the public regarding MSW related issues.

Approximately 84 % of the respondents from all levels of urbanization knew the meaning of recycling, however, the practice of recycling was quite low with the respondents from sub-urban areas being less responsive than those from urban and rural areas (Suite101.com 2003). The high percentage of the knowledge among the respondents probably was contributed by the effectiveness of campaigns launched by the ministry, the local government and the NGOs. Among the sub-urbanites, there was high level of environmental awareness but their participation in environmental programs is very minimal. This possibly was contributed by the fact that most of them 'do not walk their talk'. 56 % of the respondents from both rural and urban areas participate in recycling activities, generally more encouraging than the sub-urban population. The presence of more recycling centers in urban areas and recycling personnel among the rural community would probably enhance recycling rate.

Majority of the respondents agreed with the suggestion to establish more recycling centers in order to encourage recycling activities. Willingness to separate waste for recycling purposes was high, with rural respondents giving highest percentage (68 %) as they would have more time to spare for the activity. This is followed by the urban respondents particularly when recycling is convenient with the establishment of recycling center and it gives good monetary returns. Generally, more than 50 % of the respondents from all areas are willing to pay more for environmental friendly products possibly because most of them possess some knowledge on environmental issues and somewhat aware of the serious environmental degradation. A percentage of 98 % are willing to follow the regulations imposed by the government, if the implementation would improve the environmental quality in Malaysia.

This indicates the importance of environmental policy implementations to improve the environmental state as majority of the respondents felt that they need to oblige with the government's ruling. In conclusion, it can be stated that awareness related to MSW issues existed, however more steps should be taken to increase the participation of the public to seriously improve the quality of the environment.

In 1970s, with very low generation of MSW, the issue was not considered critical that very minimum attention was focused on creating awareness among the public. However, as the generation increased steadily over the years, the government had realized the solidness and seriousness of MSW problems in the country that more campaign were launched to establish awareness and to create environmental consciousness among the general public. During the 1980s, the government had launched various campaigns including the introduction of the Action Plan for A Beautiful and Clean Malaysia in 1988 and recycling campaign in the consecutive years. However, due to a very minimal response from the general public, the campaigns failed, though the awareness among the public increased slightly.

A survey carried out in 1999 showed that, 59 % of the respondents are moderately aware, where, they have some basic knowledge and are mildly aware of solid waste issues. While this is relatively satisfactory, 10 % of the respondents have no knowledge and are unaware of MSW such issues. Result on "willingness to co-operate and/or participate in recycling programs" survey shows that, only 55 % of the respondents stated their willingness as opposed to 45 % who are were unwilling.

Over the years, Malaysian awareness especially in recycling campaigns is increasing. A survey showed that 93 % of Malaysian are aware of recycling program (Fauziah and Agamuthu 2004). However, from the 93 %, only 28 % Malaysian practiced it through source-reduction. The survey indicated that, the most preferable method Malaysian recyclers do recycling are by selling the recycle materials to door-to-door itinerant buyers (72 %). Above survey also showed that, only 20 % of Malaysians were aware about waste minimization campaigns, which is comparatively low with recycling campaigns (93 %).

On the other hand, average of 58 % Malaysian practiced home-based reuse activities such as; repair old materials, donate to others to reuse it, sells as recyclable items and use disposable items different from initial purpose (e.g. use milk tins to store dry food products). It's believed that, awareness in waste minimization campaigns will increase with more waste minimization facilities provided to public and more waste minimization activities implemented.

7 Changes in Recycling Activity

Recycling and resource recovery from MSW occurs at a minimal level, where the national rate of recycling is estimated at 1–2 % of the total waste stream. It is mainly conducted by scavengers and municipal waste collector crews. Currently, recycling is initiated by LAs and NGOs. In 1993, the MHLG launched the first National Recycling Program involving 23 LAs with the main aim to reduce waste disposal and promote resource recovery concept (Kamariah 1998). However, the performance was very poor with only 10 LAs succeeding that a second National Recycling Program was initiated in November 2001 (Kuman and Abdullah 2002).

Currently it is estimated in Petaling Jaya, more than half of the collection crews are involved in retrieving recyclable items reaching approximately 24.5 tonnes/day or 5.2 % of the total waste disposed. Meanwhile, dumpsite scavengers in Petaling Jaya recycle about 3.9 tonnes of waste per day or almost 1 % of the total waste disposed. Consequently, the total resource recovery from the waste stream is about 28.4 tonnes of waste per day or about 6 % of the total waste stream. Reports also indicated that for the period of June 1999 to November 1999, as much as 50,660 kg of recyclable materials was recovered, valued at approximately RM4000.

Table 8 Recyclable wastes collected from year 1993–1998 in Malaysia

Years	Recyclable materials collected (kg)			
	Paper	Metals	Glass	Plastic
1993	446,713	79,169	55,803	48,584
1994	1,703,431	552,574	293,408	162,794
1995	338,699	78,389	1,865	18,771
1996	940,121	567,451	185,020	186,549
1997	260,667	13,600	0	4,010
1998	70,130	51	0	0

Source http://www.kpkt.gov.my/statistik/perangkaan2002

In Kuala Lumpur, approximately 672.3 tonnes or 22 % of the total waste stream were recyclable items, with paper contributing 41 % of the total recyclable items of about 3,000 tonnes/day. If properly recycled, the recovered resource would yield as much as RM55, 260.00 daily.

Based on the figures for Kuala Lumpur and Petaling Jaya, it is anticipated that the potential for maximum resource recovery through recycling is approximately 22 % while potential for recourse recovery through scavenging reached 6 % indicating that recovery through recycling is a growing industry and is profitable.

Realizing the market for recyclable materials, the draft Concession Agreement between the private managers and the Government set targets for waste diversion and recourse recovery. The interim targets aim to achieve a 3 % recycling rate in 2003 and consequently a 1 % increment annually to achieve a 22 % recycling rate in 2020. Table 8 shows that there were no trends in recycling activities and the amount of recyclable materials collected were high in the beginning but decreased over the following years and some reached zero.

8 Changes in Economics of Waste Management

Table 9 shows the National Waste Treatment Goal. Malaysia currently only depends on landfill method for waste disposal. Average disposal cost is RM30 per tonne of MSW while an estimated RM400 million was spent to landfill 7.8 million

Table 9 National waste treatment goal and current scenario in Malaysia for the year 2002

Treatment	Malaysia	National goal		
	2002	2001	2005	2020
Recycling	5.0	3.0	7.0	22.0
Composting	0.0	0.0	4.0	8.0
Incineration	0.0	0.0	11.9	16.8
Inert landfill	0.0	0.0	9.2	9.1
Sanitary landfill	95.0	97.0	67.9	44.1
Total	100.0	100.0	100.0	100.0

tonnes of MSW in 2003. The disposal cost will increase since MSW generation is increasing annually at the rate 2–3 %.

Once thermal treatment plant (incinerator) in Kuala Lumpur is ready for operation, it is expected to manage 11.9 % of MSW in 2005 and 16.8 % of MSW in 2020. Number of landfills will reduce when the incinerator is in operation.

Waste-to-Energy technology like Refuse-Derived-Fuel (RDF) is now in pilot-scale research phase in Kajang, Selangor. It is expected to convert about 30 % of the MSW to RDF fuel pellets with the market price of RM50 per tonne.

Based on National Waste Treatment Goal (Table 9), increase in recycling and composting activities will generate more revenue from recycled materials and compost. Recycling and composting industries would create more jobs and investment opportunities too.

Positive change has also been seen in the energy sector as the Malaysian government is promoting the utilization of renewable energy. This is possible with the high potential of biomass from agricultural wastes (estimated at 665 MW) and domestic waste for energy conversion. Table 10 details the current energy dependency according to sources.

With the implementation of the Renewable Energy Policy in 2010, wastes have been identified as a potential source for renewable energy as detailed in Table 11.

Nevertheless, there are various issues and challenges in the utilization of waste and biomass as energy sources. Table 12 details these major issues in Malaysia.

However, it is hoped that the newly proposed policy under the Renewable Energy/Malaysia Building Integrated Photovoltaic (MBPIV) of Ministry of Energy, Green Technology and Water would pave better future for waste and biomass utilization as renewable energy sources.

Table 10 Sources of energy supply in Malaysia

Energy sources	Reserves	Duration of production (years)	Production capacity
Oil	400 Mt	10	Decrease (35 Mt against 39 Mt in 2003)
Gas	2,500 Gm^3	50	Increasing rapidly and reached 61.5 Gm^3 in 2006
Coal	1 Gt	–	–

Table 11 Cumulative quota on renewable energy capacity (MW)

Year	Biomass	Biogas	Mini-hydro	Solar PV	Solid waste	Total
2011	110	20	60	9	20	219
2015	330	100	290	65	200	985
2020	800	240	490	190	360	2,080
2025	1,190	350	490	455	380	2,865
2030	1,340	140	490	1,370	390	4,000
2040	1,340	410	490	7,450	410	10,100
2050	1,340	410	490	18,700	430	21,370

Table 12 Issues arising from the utilization of biomass and waste as energy sources in Malaysia

Factors	Issues
Policy barriers	Limited incentives on biomass utilization
Supply and demand	No reliable data on actual potential of biomass slow implementation of 5th Fuel Policy (RE, including biomass) Limited effort to regulate and enforce biomass programs
Environment	Current technologies are inefficient and polluting
Financial and technical	High initial investment Limited local technologies and equipment Poor financial support, no record on biomass industry
Institutional barrier	Limited coordination among the local agencies Unwillingness of the industry to change and to be proactive

9 Policy and Regulations for MSW

9.1 Solid Waste Management and Public Cleansing Management Act

The 88 pages Solid Waste and Public Cleansing Management (SWPCM) Act were under review for more than 10 years before it was finally approved in July 2007. The main objective of the Act is to improve and ensure high quality services in managing solid waste. The Act which is adapted from Best Management Practices in solid waste management i.e. from Japan, Denmark, Switzerland, Germany and United States, focused mainly on public cleanliness management. The main strategies are to tackle the 3R issues namely reduce, reuse and recycling of solid waste, interim treatment and final disposal of solid waste. It includes amenities from roads and toilets to drains, food courts and grasses by the roadsides. Main features of SWPCM Act:

- With the passing of the Act, the authority over solid waste and public cleansing is shifted from states and local authorities to the federal government.
- The cost of waste management will be shared between the federal government and the local authorities where this will allow the local authorities to be rid of waste management cost by directing funds to a federal corporation.
- The functions of the appointed Federal Corporation cover the whole aspect which is deemed necessary in ensuring the implementation and the success of an effective solid waste management.
- The Act covers solid waste from commercial centers, public sites, construction sites, households, industrial zones and institutions, as well as, imported solid wastes.

9.2 Funding

In order to cope with expenditure in waste management cost, a fund has been administered. The Solid Waste and Public Cleansing Management Corporation Fund consist of:

- income of the Corporation from investments
- allocations provided by the Parliament for the purpose of the management of solid waste and public cleansing
- income sourced from property of the Corporation
- consultancy fees from services provided by the Corporation
- other sources
- loan money by the Corporation
- money earned from operation of projects
- donations and contributions received from any sources
- other money lawfully obtained by the Corporation.

The financial issues are to be tackled in a very sensitive manner so as to ensure that this issue will not become the major drawback of an effective waste management system. This is very crucial as the privatization of the solid waste management system from 1980s to early 2007 failed due to lack of budget and the inability among some of the concessionaires to generate income to cover their expenditure. The interim agreement with the concessionaires prevented the companies from expanding investment and obtaining bank financing (Tan 2007).The inclusion of the financial section in the Act is hoped to overcome this problem thoroughly.

9.3 Payment

Punitive measures are provided in the Act to tackle problem of consumers who refuse to pay the waste disposal fees. The failure of a person to settle the collection fees will allow the licensed concessionaire to take the case to the Tribunal for Solid Waste Management. A fine up to RM5,000 (US$1,316) and RM50 (US$13) for each day of the continuation of the offence is proposed.

9.4 Responsibilities of Waste Generators

The Act also listed the responsibility of the waste generator to conduct waste separation in order to promote recycling and retrieving valuable components from the waste stream. Under clause 74 of the Bill, it is an offence if a person fails to separate the waste generated by the premises. By committing the offence and upon conviction the person is liable to a fine not exceeding RM1000 (US$263).

9.5 Enforcement

In terms of enforcement, it is also improved with the enforcement provision clause in Part IX of the Solid Waste and Public Cleansing Management Bill. According to the clause, an authorized officer may:call for, examine, make copies or extract any book, document, instrument or record which is in custody or control of any person pertaining to any matter under the Act;

- visit, enter, inspect and examine with or without previous notice any solid waste management facilities;
- investigate to ensure proper maintenance and sanitation, matters related to safety and health, the effects of any operation or practice, presence and accumulation of noxious gas, in any solid waste management facilities, land or other premises;
- take samples of any material found at the solid waste management facilities on land, water or air.

Upon failure to comply with the regulations stated in the Act, the convicted solid waste management facilities can be ordered by the court to cease its operation. The authorized officers are also empowered to stop, search and seize vehicles suspected of carrying anything prohibited by the regulations. This is meant to curb the increasing rate of illegal dumping faced by the local authorities. A stricter penalty can be imposed on a person upon conviction of this offence, which includes RM10, 000 (US$2,632) or less than 6 months imprisonment or both. With continuous offence, offender is liable to a fine not exceeding RM1000 (US$263) for everyday or a part of a day during which the offence continues after conviction.

9.6 3R

The implementation and enforcement of 3R are also listed in the Bill under Part X where solid waste generators are required to reduce the generation of solid waste, to use environmental friendly materials, limit the generation, import, use, discharge or dispose specified products, implement coding and labeling on products to promote recycling, and utilize any method to reduce adverse impact of MSW on the environment and to reduce, reuse and recycle MSW. Failure to comply will subject the offender liable to a fine not exceeding RM10,000 (USD2,632) or imprisonment not exceeding 6 months or both.

With the source separation, the authority targets to reduce 40 % MSW sent to the landfill. Aside from material recycling program, other waste management technologies have been identified. Among others are anaerobic digestion, composting and thermal treatment. The diversion of MSW from landfilling is very crucial as the generation of pollution from disposal sites is inevitable and the risk increase significantly when disposal sites lack of appropriate pollution confining measures such as landfill liners and leachate treatment system.

Various campaigns have been organized since 2000 to promote 3R activities among Malaysians. However, the recycling rate in particular has been very low and was not able to significantly reduce the volume of waste sent to landfills for disposal. Nevertheless, unofficial recycling was found to be more than 15 % of the total waste generated. Yet, the refusal of the unregistered recyclers to participate in the data collection has disabled the capability of the authority to capture the actual recycling rate in the country. Thus, extensive campaigns have been launched since September 2011 to promote proper recycling activities. This campaign involved various mass media including advertisement in television, radio and websites. The recycling target for 2020 is 22 %.

Additionally, a range of incentives have been introduced to encourage the public to participate in the 3R activities. Promotions of these activities were carried out in schools and learning institutions, in government offices and residential areas, and in public places such as hypermarkets and shopping complexes. The promotion of the 3R activities also involves the participation of voluntary bodies including the non-governmental agencies (NGOs) and residential associations. Apart from recycling and the 3R activities, the authority also strategized the possibility of converting waste to value added products. In order to formulate the strategies

Among the options taken into consideration by the authority to divert the MSW by 2015 are biological treatments of organic waste and thermal treatments. A major discussion was organized by authority recently from end of March 2012 to mid April 2012 which indicated their seriousness in finding most appropriate technologies to solve the MSW issues in Malaysia. The discussion involved more than 150 stakeholders including relevant government agencies, research institutions, industrial sectors and private entities in waste management, NGOs, media and others. The outcomes of the discussion include the identification of several strategies to be implemented by the government to enable the reduction of 40 % MSW sent to landfill and the reduction of greenhouse gases by 38 %. Results obtained from the 3 weeks discussion were disseminated to the public via the authority Open-day Events. The events were held at four main cities in Malaysia.

Composting and anaerobic digestion are found feasible due to the fact that the technologies are rather simple and the resources are available. As for the capital investment, though composting plant incurs smaller capital than anaerobic digestion plant, the latter has bigger market potential. This is so as biogas is more marketable in Malaysia than MSW compost. This is due to the recent government policy that promote the generation of renewable energy including energy from waste. Yet, both options were thoroughly analyzed and the implementation of these technologies would be dependent on its suitability to the regions. The most recent progress in diverting organic component from the waste stream is the introduction of the co-composting of putrescible waste with the sewage sludge in the communal sewage treatment facilities in urban areas.

The diversion of organic components from the MSW stream was found viable through several feasible studies conducted throughout the country. However, the strategy to promote material recycling namely paper, plastic and metals was still being studied. Nevertheless, regulations stipulated under the Act is seen somewhat promising. This is so as the Act also introduced the take back and deposit refund systems. This applies to the manufacturer, assembler, importer or dealer to take back specified products for the purpose of recycling or disposal. Deposit refund system can be implemented in order to help the efficiency of the take back system. Upon failure to comply, a fine of up to RM10, 000 (US$2,632) or imprisonment up to six months or both can be imposed. Under the control of waste generation clause, unauthorized person are not allow to deposit, transport, separate or store MSW, or allow the escape of solid waste from their possession. A fine between RM10, 000 (US$2,632) and RM100, 000 (US$26,320) or jail term of up to 5 years can be imposed on any offender. This clause had removed the role of scavengers in increasing the rate of recycling in the country. Positively, this would prevent the adverse impacts related to sanitation to the scavengers and curb the larceny of valuable materials such as aluminum and iron-based components, which are frequently committed by irresponsible personnel.

Currently, there are eight regulations which have been enacted under the SWM Act 2007 though more are still in the draft stage and as such are still confidential. The eight existing regulations are as follows:

1. Solid Waste and Public Cleansing Management (Manner of Appeal) Regulations 2011
2. Solid Waste and Public Cleansing Management (Prescribed Solid Waste Management Facilities and Approval for Construction, Alteration and Closure of Facilities) Regulations 2011
3. Solid Waste and Public Cleansing Management (Compounding of Offences) Regulations 2011
4. Solid Waste and Public Cleansing Management (Licensing) (Management and Operation of Prescribed Solid Waste Management Facilities) Regulations 2011
5. Solid Waste and Public Cleansing Management (Licensing) (Undertaking or Provision of Collection Services for Household Solid Waste, Public Solid Waste, Public Institutional Solid Waste and Solid Waste Similar to Household Solid Waste) Regulations 2011
6. Solid Waste and Public Cleansing Management (Licensing) (Undertaking or Provision of Transportation Services by Long Haulage) Regulations 2011
7. Solid Waste and Public Cleansing Management (Licensing) (Undertaking or Provision of Public Cleansing Management Services) Regulations 2011
8. Solid Waste and Public Cleansing Management (Scheme for Household Solid Waste and Solid Waste Similar to Household Solid Waste) Regulations 2011.

The eventual implementation of these regulations will undoubtedly enhance waste management in Malaysia.

9.7 Policy Recommendation for Integrated Solid Waste Management in Malaysia

Policy Recommendation 1.

A National Integrated Solid Waste Management Strategy for Malaysia shall be formulated which will contain the mechanisms, goals and priority areas for action.

Policy Recommendation 2.

Legislation shall be developed to address Key Issues in Solid Waste Management.

Policy Recommendation 3.

Incorporation of Integration shall be done in the Solid Waste Management Process.

Policy Recommendation 4.

Utilization of Economic Instruments shall be emphasized to Reduce Solid Waste Generation and Increase Solid Waste Resource Recovery.

Policy Recommendation 5.

Development and Support of Market for Solid Waste Recovered Materials shall be intensified.

Policy Recommendation 6.

Communication of Information on Solid Waste Management shall be emphasized to all relevant stakeholders.

Policy Recommendation 7.

Promotion and Funding for Research and Development in Solid Waste Data and Solid Waste Management shall be emphasized.

10 Local Case Studies

10.1 Ampang Landfill (Closed Landfill)

Ampang landfill is located within Bukit Seputeh Forest Area, under the jurisdiction of Majlis Perbandaran Ampang Jaya (MPAJ). It is approximately 2 km from Hulu Langat town. Solid waste from Ampang and Hulu Langat areas had been disposed at this landfill since 1980s. In 1995, the average amount of solid waste dumped in this area was 287 tonnes/day. This landfill was merely an open dump and lacked proper leachate and gas collection system. In 1998, two major incidents involving landslide and fire took place and due to safety reasons this landfill was later closed. Table 13 presents the characteristics of the landfill leachate during its active stage and after it was closed.

In general and as expected, the pollution strength of the leachate reduced after the landfill was closed and this enhances the leachate quality, ranging between 1.9 and 91.4 %. BOD reduced 91.4 % reduction from 1,025.8 mg/l during landfill operation to 87.8 mg/l after the landfill was closed while COD was reduced

Table 13 Characteristics of Ampang landfill leachate before and after closure

Parameter	Before closure	After 5 years of closure	DOE standard		Percentage of reduction
			A	B	
BOD5 (mg/l)	1,025.8	87.8	20	50	+91.44
COD (mg/l)	3,087.5	1071.5	50	100	+65.2
pH	7.85	7.7	6–9	5.5–9.0	+1.9
Turbidity (NTU)	224	125.5	–	–	+43.97
TSS (mg/l)	618.0	194.0	50	100	+68.6
Hardness (CaCO3) (ppm)	680	510	–	–	+25.0
Sodium (ppm)	687	315	–	–	+54.1
Chloride (ppm)	2,500	1200	1.0	2.0	+52.0
Kalium (ppm)	785	350	–	–	+55.4
Magnesium (ppm)	35	9.1	–	–	+74.0
Plumbum (ppm)	0.030	0.027	0.10	0.5	+10.0
Ferum (ppm)	45	22	1.0	5.0	+51.1
Manganese (ppm)	0.187	0.041	0.20	1.0	+78.1

65.2 %. The quantities of Fe were found to be generally high compared to other municipal landfills. This is probably because of large amount of scrap metals disposed in this landfill.

Other parameters for example pH was found to be neutral in the leachate collected from the closed landfill, whereas during its active life, the leachate was found to be slightly acidic. This is probably due to high production of acids from aerobic and anaerobic degradation by indigenous microbes.

The heavy metals content in the leachate were above the standard stipulated in the EQA 1974. Mg concentration in the leachate was 35 ppm before closure and 9.1 ppm, after closure, while the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 sets its limit as 0.2 ppm for Standard A. However, the concentration of heavy metals reduced 50 % after closure except for Pb. The consecutive sections discuss the issues related to the closure and post-closure of the four case studies in detail.

10.2 Air Hitam Sanitary Landfill

Air Hitam Sanitary Landfill was to accommodate the disposal of waste from Klang Valley with an annual capacity of 550,000 tonnes of MSW. It began its operation in 1995 and was originally planned for closure in 2007. However, the landfill space was exhausted in 2005 due to the 3 % annual increase of MSW with approximately 6 million tonnes of waste deposited. In addition, the encroachment of residential areas to the fringe of the landfill made it unsuitable to operate actively. Even though the raw leachate contained very high concentration of pollutants, the on-site leachate treatment facilities managed to remove and reduce the pollutant to the limit allowed. The quality of leachate discharged from this landfill adheres to the Malaysia EQA 1985.

The landfill gas system is also properly regulated and managed. It involved an active system where landfill gases were extracted from vertical wells. Approximately 30–40 % of the gases generated are CO_2 while 50–60 % are CH_4. Two landfill gas power generation plants utilized the extracted CH_4 from the landfill to generate 1 MW power each where it had been sold at RM0.30 (US$0.08) per kilowatt hour and 5 % royalty under a 15-year Renewable Energy Power Purchase Agreement. The landfill has become the blueprint of energy conversion technology with a capability of 2 MW. The closure of this landfill was conducted according to plan followed by post-closure procedures. The closure of the landfill involved the capping of waste cell with non-permeable liner which primarily containing PVC to reduce intrusion of precipitation, and the appropriate gas venting system to ensure a proper extraction of landfill gas. Post-closure procedures for the landfill include the layering of biocover and rehabilitation of the area with suitable plants.

10.3 Closure of an Open-Dumping Site

While Air Hitam landfill is a sanitary landfill, Kundang landfill was a mere open-dumping ground covering approximately 80 acres of land which has been operating since late 1996. This disposal site received approximately 300 tonnes MSW daily until 2005. The landfill area is lined with natural clay liner that a few ponds formed from depression of the geographical landscape and collects leachate. As a result, less importance was given to the management of the leachate. The landfill had no leachate treatment system and the leachate accumulated in the ponds was left unattended. Eventually, the leachate were mixed and diluted with surface water and flushed into the adjacent river, Kundang River. The characteristic of the leachate is indicated in Table 14.

Leachate analysis results indicated that approximately 280,440.00 g/day of COD were released into the river. Table 15 illustrates the amount of pollutant released daily.

Fortunately, due to the presence of the natural clay layer, the leachate was only contained in the ponds. Since leachate did not seep through, the groundwater system was left unharmed.

In October 2006, Kundang landfill was identified to be one of the contributors towards the incident of drinking water contamination in Klang Valley resulting in its immediate closure by the government. Immediate action taken by the landfill manager was to cap the waste cells with suitable covering material to prevent penetration of precipitation, followed by the capping of the whole area with geomembrane to further reduce leachate generation. Even though approximately 40 % leachate was reduced, leachate still contaminates the river adjacent to the landfill with minimal changes in the pollutants intensity.

Table 14 Characteristics of leachate from Kundang landfill

Parameter	Kundang landfill (urban)	EQA 1974	
		Standard A	Standard B
BOD5 (mg/l)	27.5 ± 0.7	20	50
COD (mg/l)	6232 ± 1824	50	100
pH	7.43 ± 0.04	6–9	5.5–9
TSS (mg/l)	0.06 ± 0.01	50	100
Hardness (CaCO3) (mg/l)	429 ± 240	–	–
Cd (mg/l)	Not detected	0.01	0.02
Cr (mg/l)	0.19 ± 0.02	–	0.05
Cu (mg/l)	0.003 ± 0.002	0.2	1.0
Pb (mg/l)	0.03 ± 0.01	0.1	0.5
Zn (mg/l)	0.06 ± 0.04	0.2	1.0
Mg (mg/l)	4.25 ± 0.42	–	–

Table 15 Impact on river pollution caused by leachate contamination

Parameter (g/day)	River adjacent to Kundang landfill
BOD5	1 238
COD	280 440
TSS	2.7
Hardness ($CaCO_3$)	19 320
Cd	Not detected
Cr	8.7
Cu	0.14
Pb	1.22
Zn	2.7
Mg	191

In addition to the lack of leachate treatment facility, this landfill also does not have a proper gas venting system. The only regulative measure taken by the landfill's management was installing vertical gas pipes. Approximately 7 m high, perforated PVC pipes with 25 cm diameter were erected throughout the landfill to allow passive release of the landfill gas into the atmosphere. The monitoring of the landfill gas throughout the landfill area indicated that these gases, particularly CH_4, ranged at a low level (0.05–2.0 ppm). The gases were released without any treatment.

Even though Kundang landfill is closed, it is still contaminating the environment. It is mainly due to improper planning of the dumping site at the initial stage that no precautionary measures were taken into consideration. At the current stage, grasses particularly *Bromus hordeaceus* were planted to avoid soil erosion. The area is left without any development plan since the issue of leachate is not solved. The closure of the landfill did not achieve the target to isolate the pollutants from contaminating the surrounding environment. This scenario is common throughout the country since most of the landfills which operated from 1980s were mere open-dumps. The reclamation of landfills for other types of land use can be made possible with proper post-closure procedures. The redevelopment of the ex-landfill is one example of reclamation for other land-use.

10.4 Ex-Landfill Used for Development

The ex- landfill which is located in Kelana Jaya district in Selangor was closed in 2000. It covers approximately 138 acres. More than 1.57 million m3 of MSW had been deposited of which contained 40 % organic materials. The area was a former tin mining pool that was used as a landfill since 1981 and currently, it is being developed into residential and commercial land. To complicate the matter, the area accommodates 70 % completed terrace houses, high rise apartments, and commercial buildings. No record of post closure assessment is available that the site is assumed not properly closed. Prior to the development of the area, most developers excavated and removed the deposited waste where only a small portion of the waste remained.

Leachate samples analyzed indicated that BOD5 averaged at 78 mg/l while COD at 230 mg/l exceeded the EQA Standard B limit (50 and 100 mg/l, respectively). However, it only concentrated at one main sampling point which is due to the presence of waste within the area. Groundwater analysis from the same area also indicated high TOC (460 mg/l) while pollutions at other groundwater sites were insignificant. There is a possibility of groundwater contamination with leachate that seeps from the remaining waste.

The surrounding soil was heavily contaminated with metal elements which exceeded the Dutch Intervention Value. Table 16 shows the results of surface and deep soil analysis.

The highest value among the elements in surface soil is arsenic (64.4 mg/kg). The elevated as level is probably due to the disposal batteries and industrial waste. Hg on the other hand was 11.5 mg/kg. This again could have originated from disposed batteries or fluorescent bulbs. The toxic nature of these elements warrants immediate remediation to prevent long-term effects on the occupants of the area. Although wastes have been removed from most of the development area, the residues from the wastes have migrated into the soil and contaminated the soil surface. As and Hg are of particular concern due to its highly toxic nature. Furthermore, contaminated surface soil may result in pollution of surface and ground water via run-off.

Gas analysis indicated that H_2S and CH_4 were below the detection limit with an exception at the site with waste. The exceptional site recorded 5 % LEL (equivalent to 0.25 % CH_4). The concentration of gas at the area is low and its emission was intermittent. The study indicated that pollution sourced from the area where waste has not been excavated yet. Therefore, rehabilitation and redevelopment of this area requires the wastes to be removed from the site. Also, the area can be justified as safe for residential and commercial purpose if contact to surface and deep soil can be prevented.

Table 16 Average concentration of metal and non-metal elements in surface and deep soil from the ex- landfill

Parameter	Unit	Surface soil (5 cm from ground surface)	Deep soil (5 m below the ground surface)	Dutch intervention standard
Phosphate	mg/kg	2.5–5.5	0–13.6	–
Flouride	mg/kg	2.4– 7.0	0.5–0.9	–
Sulfate	mg/kg	30.2–946.3	4.2–10.2	–
pH	na	5.8–9.9	7.3–8.2	–
Chloride	mg/kg	6.3–238.3	2.1–8.1	–
Nitrate	mg/kg	4.7–83.3	0.5–5.0	–
Nitrite	mg/kg	1.1–2.9	Not detected	–
Zn	mg/kg	7.7–129.8	Not detected	720
Sb	mg/kg	0–3.0	Not detected	15
Cd	mg/kg	0–0.6	Not detected	12
Cr	mg/kg	0.5–14.1	Not detected	380
Cu	mg/kg	2.3–17.3	Not detected	190
Pb	mg/kg	2.7–148.0	Not detected	530
Ni	mg/kg	0.3–5.0	0–9.0	210
Ag	mg/kg	0–1.2	Not detected	15
Tl	mg/kg	0–58.0	Not detected	15
As	mg/kg	8.8–64.5	0.3–2.7	55
Hg	mg/kg	0–1.4	8.5–11.5	10

While redevelopment of the ex- landfill is possible with appropriate measures, it is not yet occupied and preventive measures can be implemented to avoid exposure to toxic substances. However in the study area of the ex-mining land where people had been staying for the past few years, the improper reclamation causes detrimental effects to the resident.

10.5 *Ex-Mining Area Used as MSW Dumpsite*

The ex-mining area is located at the southern part of Petaling Jaya. Petaling Jaya is one of the fastest developing city that land price is excruciatingly high. Therefore, the city council had conducted an extensive reclamation activity on approximately 114 acres of the ex-mining pond. The objective of the reclamation was to allow the area to be more economically viable. Since the 1980s, the reclamation was carried out by filling the ponds with domestic, industrial, and construction debris. The absence of any enforcement had resulted with indiscriminate disposal of toxic and hazardous wastes too. As a result, tremendous amounts of H_2S are emitted to the surrounding area. The surrounding area was already developed and occupied that the release of this gas had caused a lot of problem to the residents. From the study, H_2S was recorded as high as 200 ppm. Figure 5 depicts the trend in H_2S emission over the past 3 years.

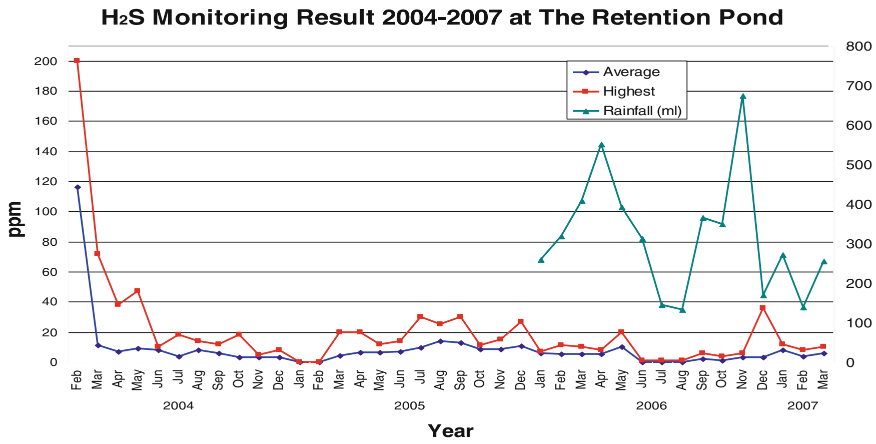

Fig. 5 H_2S emission from February 2004 to March 2007

Due to the improper regulation on the rehabilitation of the area, contamination to surface water by gypsum caused the release of H_2S to the surrounding area. The high concentration of the gas in the surrounding atmosphere also had caused very bad corrosion problem due to the H_2S conversion from gas form to sulphuric acid. Leachate contamination was also serious where some of the pollutants exceed the standard allowed by Malaysian EQA 1985. Table 17 indicates the concentration of the pollutants in leachate at four sampling points.

Table 17 Leachate analysis from four sampling points in the study area

Parameter	Unit	Range	Average	Standard B
BOD	mg/l	23.5–42.0	33.0	50
COD	mg/l	51.5–128.0	82.9	100
pH	–	4.7–7.1	6.5	5.5-9.0
Sulphide	mg/l	0.9–10.4	3.8	0.5
Ammoniacal-N	mg/l	13.4–17.8	16.1	Not available
Phosphate	mg/l	1.6–315.6	80.2	Not available
Sulfate	mg/l	55.0–132.5	101.6	Not available
Chloride	mg/l	22.1–37.8	27.3	Not available
Nitrate	mg/l	0–2,687.1	671.8	Not available
Cd	mg/l	Not detected	0.0	0.02
Cr	mg/l	Not detected	0.0	0.05
Pb	mg/l	Not detected	0.0	0.5
Fe	mg/l	0.1–16.3	4.4	5
Ag	mg/l	0–0.6	0.2	Not available
As	mg/l	0–0.3	0.2	0.1
Hg	mg/l	Not detected	0.0	0.05
Se	mg/l	Not detected	0.0	Not available
Ba	mg/l	0.2–0.3	0.2	Not available

Sulphide level was seven times more than the limit allowed. This has called for the need for proper monitoring of waste disposal activity within the area and stricter enforcement. The study has indicated that the water body was heavily contaminated with various pollutants that reclamation should only be conducted using inert materials. In order to stop the problem of H_2S release to the surrounding environment, drastic actions should be taken which include covering of existing drains, diverting the surface water channel from the ponds, and installing gas venting system. This is to ensure that the level of H_2S in the atmosphere can be brought down to a less hazardous level. The case study in this area proved that improper planning of the closure and post-closure of a dumping site can be very detrimental to the environment, particularly to the inhabitants of the respective area.

10.6 Landfill Cover Strategy for Leachate Management

In 2009, Malaysians generated more than 10 million tonnes of solid waste which were disposed off into 190 landfills/dumps throughout the country (Agamuthu and Fauziah 2010). Due to leachate contamination in the Klang valley water catchment in 2007, immediate ruling was ordered by the Federal government of Malaysia which saw the closure of many non-sanitary landfills adjacent to river and upgrading of operating landfills. These upgraded open dumps were installed with appropriate facilities to enable control tipping, and daily compaction and soil cover. However, the foundations of landfills are the same without lining system which allowed leachate and landfill gas to migrate to the groundwater system and the surface water.

The production of leachate is mainly due to infiltration of precipitation and groundwater intrusion (Bagchi 1994). Malaysian MSW landfill produced 150–200 l/tonne of leachate or approximately 2.1×10^7 l/day (Agamuthu et al. 2010). The leachate generation is enhanced due to the high moisture content of Malaysian waste at approximately 70 % (Agamuthu and Fauziah 2010). Additionally, Malaysia also received heavy rainfall of 3,000 mm annually. With more than 90 % of Malaysian landfills lacking engineering waste containment system, (e.g. compacted clay liner, geomembrane or geosynthetic clay liners) it allows precipitation to infiltrate into the waste cells to produce leachate. Therefore, it is crucial that landfills were covered appropriately with an effective landfill final-cover system, in order to reduce the infiltration of precipitation into the waste cells, and thus control the leachate generation. An evaluation to determine the effectiveness and the efficiency of different combinations of landfill final-cover systems in preventing water infiltration was conducted, based on water balance components (WBCs) which include surface runoff, evapotranspiration, lateral drainage, and leachate generated. Thus, the quantity of leachate generated reflects the performance of landfill besides other quantity of WBCs.

To determine leachate mitigation, a specific program namely Visual Hydrologic Evaluation of Landfill Performance (VHELP) was utilized. The program was designed to perform water balance analysis of landfill cover systems and the waste cells. The output included the rapid estimation of the amount of excess water or overflow, evapotranspiration, liner leakage, drainage and leachate collection that can be generated from the operation based on the water balances, while the input data (Petaling Jaya, Selangor) includes climate including growing season, average relative humidity, mean monthly temperatures, maximum leaf area index, evaporative zone depth and latitude, and landfill design (includes slope surface, maximum drainage distance, layer thickness and subsurface materials characteristics). Additionally, data for precipitation, air temperature and solar radiation were also included into five models as shown in Fig. 6.

10.7 Influence of Cover System Designs on Surface Runoff

T-2 cover system showed maximum quantity of surface runoff with a depth of 557.05 mm while T-1, T-3, T-4, and T-5 has 168.93 mm, 269.07 mm, 244.49 mm and 189.47 mm respectively. For T-2 cover system, the topsoil became saturated during rainfall due to the presence of geomembrane barrier of low hydraulic conductivity and overlaid soil barrier layer. This resulted with higher quantity of surface runoff. On the other hand, T-3, T-4, and T-5 cover systems which incorporate lateral drainage materials underlying the topsoil allow lateral drainage of rain water resulting with an unsaturated condition of the topsoil and less surface runoff. The additional or contributing layers assisted in minimizing the downward passage of surface water into the refuse (Oweis 1994).

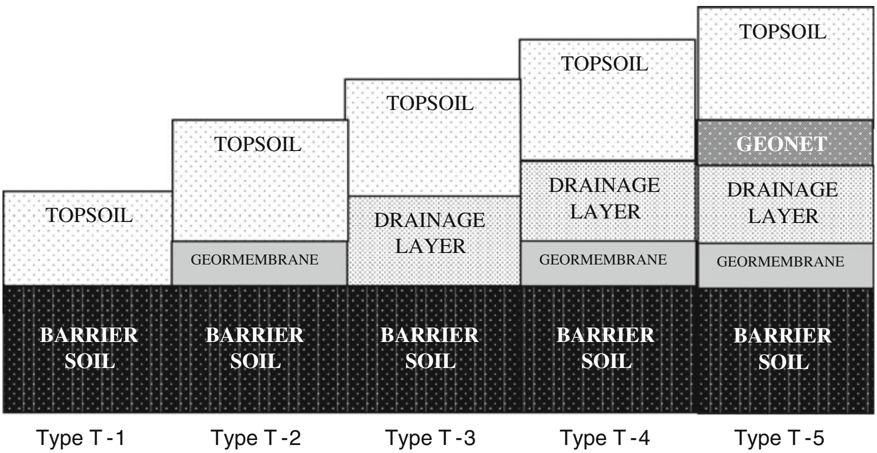

Fig. 6 Types of landfill cover system investigated

10.8 Influence of Cover Systems on Evapotranspiration

The various designs of cover system showed very minimal changes in the values of evapotranspiration. The amount of water evaporated and transpired were consistent at an average value of 1,838 mm. Evapotranspiration process is independent to the type of cover system resulting with consistent value particularly when similar properties of topsoil layer is used. This is also because evapotranspiration is a function of temperature, evaporative zone and wind speed (Oweis 1994).

10.9 Influence of Cover Systems on Lateral Drainage

T-5 depicted the highest volume (1,265.92 mm) of collected lateral drainage due to the presence of geonet. This enhanced passage to drain the liquid from the system (Bagchi 1994). T-4 is less efficient than that of T-5 with leachate collected at 1,062 mm, due to the absence of the geonet material in the design followed by T-3 which collected lateral drainage was recorded at 597 mm. The absence of drainage material resulted with low volume of lateral drainage as in T-1 and T-2. By incorporating the drainage materials water infiltration into waste layer had significantly reduced. As a result, the generation of leachate can also be reduced (Agamuthu et al. 2009a, b).

10.10 Influence of Cover Systems on Leachate Generation

The key indicator of the efficiency of the different cover system can be depicted based on the leachate generation. The highest volume of leachate was generated in system which lacked appropriate lining system that prevents water intrusion. Based on the various combination of the different layering materials, T-1 cover system generated the largest volume of leachate (1,345 mm), followed by T-3, T-2, T-4, and T-5.

T-1 system was found to generate the largest discharge mainly due to the lack of drainage material. Similarly, T-3 system which geomembrane barrier was absent also failed to prevent water intrusion. Thus, the absence of drainage material in addition to the geomembrane layers resulted with the generation of higher volume of leachate. On the other hand, composite cap, such as geomembrane, over a layer of compacted clay (GM/GCL) with an appropriate final cover will avoid water intrusion which can be translated into the generation of lesser amount of leachate in the landfill (Qasim and Chiang 1994).

Different values of WBCs were derived with different layering system where various combination of layering materials was incorporated. The influence of the

Table 18 WBCs values by different cover system

Water balance components (WBCs) (mm)	Type of cover systems				
	T-1	T-2	T-3	T-4	T-5
Precipitation	3,364.05	3,364.05	3,364.05	3,364.05	3,364.05
Surface runoff	168.93	557.05	269.07	244.49	189.47
Evapotranspiration	1,849.59	1,846.57	1,833.06	1,832.02	1,830.06
Lateral drainage collected	–	–	597.32	1,162.48	1,265.92
Leachate generated	1,345.53	960.43	668.67	125.06	78.6

various cover-system namely T-1 to T-5 on the WBCs can be summarized in Table 18.

The WBCs values on precipitation of all cover-system showed insignificant difference. On the other hand, other components namely surface runoff, evapotransporation, lateral drainage collected and leachate generation differed with different cover-system. T-2 exhibit the highest runoff (557 mm), followed by T-3 and T-4. The lowest surface runoff value was by type T-1(168.93 mm). The volume of water collected from lateral drainage was highest by T-5 (1,265 mm) followed by T-4 (1,162.48 mm).. Based on the result, T-1 depicted the generation of 1,345.53 mm, the highest volume of leachate among the five combinations while T-5 produced the lowest at 78.6 mm. Based on WBCs, T-4 and T-5 cover systems were at a level acceptable by USEPA, which is below 300 mm.

Based on the performance in mitigating leachate generation and the cost incurred, T-4 was recorded to be the most cost-effective system for a tropical climate. On the other hand, when heavy precipitation is not a factor, T-3 is more economical since T-3 is slightly more expensive than that of T-4.

10.11 Organic Material as Bio-Cover to Reduce Methane Release

In Malaysia, 95 % of the 30,000 metric tons of MSW generated annually is disposed in landfills. As of 2011, there are 166 operating disposal sites with only 11 being sanitary landfills. However, most of the disposal sites in Malaysia are small dumpsites that are not commercially viable to harvest methane for energy use. Therefore these landfills are still emitting methane passively, which is a potent greenhouse gas, which has a global warming potential 25 times more than carbon dioxide. Since collection of methane gas from these landfills are not commercially viable, the best low cost option would be to mitigate landfill gas emissions using Bio-Cover to oxidize the methane to CO_2.

Bio-Cover is a layer of soil/compost that oxidizes methane to carbon dioxide as the landfill gas pass through the cover material. The methanotrophic bacteria present in the compost are responsible for the methane oxidation. The oxidation potential of different cover materials used could be further enhanced through the utilization of dedicated methanotrophic bacteria

Below are the summary of the Bio-Cover Performance Index (BPI) of different materials tested in landfill and laboratory. The effective microbes applied in the experiments were *Methylomonas sp* and *Methylococcus sp*.

Cover materials	Bio-cover performance index ($\mu g g^{-1} h^{-1}$)
Sewage sludge (20 % sludge + 80 % compost)	108.8×10^3
Empty fruit bunch (60 % EFB + 40 % compost)	92.2×10^3
Sawdust (40 % sawdust + 60 % compost)	28.6×10^3
Compost with effective microbes	26.9×10^3
Compost	18.9×10^3
Compost (laboratory)	0.19×10^3
Black soil (laboratory)	0.09×10^3

The utilization of organic materials, which are normally discarded as waste, is innovative to be used as Bio-Cover material. Under Tropical conditions these material could be effectively used to reduce the methane released from landfills via oxidation.

10.12 Material Flow Analysis and MSW Management

Using Material flow analysis (MFA) (also referred to as substance flow analysis; SFA) as an analytical method of quantifying flows and stocks of materials or substances in a well-defined system such as a landfill. MFA could be incorporated as a waste management tool. Three main areas of application for MFA in waste management are in waste analysis, evaluation of waste management processes and evaluation of waste management systems. MFA can be applied to a waste management system for the illustration of material flows and processes, including different detail grades, considering altered frameworks, accounting and analyzing the regarding system in terms of the material and energy efficiency, supporting the material flow management by analyzing the opportunity to distribute waste, flows to various constructions, considering technical, economic and ecological framework conditions, analysis of critical points, development of measures for optimisation, and as definition of a base line scenario to assess future development. Methodology used for MFA studies include Statistical and MSW management data collection, laboratory work for material and substance data, and material or substance flow modelling using software such as STAN or Excel.

Research was done on the substances, Al, C and N in a landfill. From the results, the composition of waste in the landfill was identified, the input and output was calculated and mass balance done using Excel and STAN to produce the MFA of C, N and Al in a landfill. Material flow determination for C and N showed that, in one year of landfilling, 29 % of the input of the organic C left the landfill via gas pathway while less than 1 % escaped via leachate pathway and more than 70 % of the organic C was still in the landfill sink. The largest part of total-N, almost 80 % remained as landfill stock while less than 5 % N was discharged from landfill via leachate pathway. The 51 % of NH_3-N released from landfill body was of concern in the long run. The landfill gas emissions are made up of $CH_4 = 51$ %, $CO_2 = 36$ % and $CO = 4$ %. Modeling of Al, C and N flow in a sanitary landfill showed that the landfill is a sink for C and Al. C and N was dominantly exported in landfill gas and leachate while Al was dominantly in the soil and leachate. Current research is looking into the MFA modelling and assessment of global warming potential at an organic farm and a conventional farm and also the municipal solid waste flow in Kuala Lumpur.

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State of Municipal Solid Waste Management in the Municipalities of Nepal

Surya Man Shakya and Bhushan Tuladhar

1 Introduction

Municipal Solid waste management (MSWM) is one of the major responsibilities of the municipal governments and is often regarded as a difficult task. Modern waste management techniques, such as source separated door-to-door collection, recycling facilities and sanitary land filling etc., are yet to be introduced in most municipalities. Approximately 15 % of Nepal's populations live in municipalities. According to the JICA study JICA (2004a): municipalities of Nepal produce about 500,000 tons of municipal solid waste (MSW) per year or approximately 1370 tons per day. Less than half of this gets collected and most of the collected waste is being disposed haphazardly in undesignated locations (Fig. 1), (Table 1).

At the local level, the problem of waste management is being technically caused mostly due to: (i) unavailability of sanitary landfill sites (ii) lack of composting facilities (ii) absence of source segregation and efficient collection system, just to mention a few. However, there is plenty of potential for converting this waste as a resource for improving the waste management systems. Because, about two-thirds of the waste that is generated in Nepal is organic, and can be used for producing organic manure through composting.

It is beyond the scope of this chapter to venture into the details on varied aspects of existing state of solid waste management in the municipalities of Nepal. However, an effort has been made to diagnose the existing situation and highlight some priority issues associated with solid waste management. This chapter focuses on waste management only as it pertains to municipal environments, based on existing secondary information. This chapter reviews the existing situation and broad trends related to solid waste management in the municipalities of Nepal. The

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Fig. 1 Map of Nepal

Table 1 Geographical distributions of the municipalities

Development region	Ecological region	Municipality	Number of municipalities
Eastern development region	Mountain	Khandbari	1
	Hill	Ilam, Dhankuta, Triyoga	3
	Terai	Damak, Inaruwa, Bhadrapur, Itahari, Siraha, Biratnagar, Rajbiraj, Lahan, Dharan, Mechinagar	10
Central development region	Mountain	Bhimeshowr	1
	Hill	Panauti, Kirtipur, Thimi, Bidur, Banepa, Dhulikhel, Kathmandu, Bhaktapur, Lalitpur	9
	Terai	Malangawa, Bharatpur, Hetauda, Janakpur, Gaur, Ratnanagar, Birgunj, Kalyaiya, Jaleshowr, Kamlamai	10
Western development Region	Hill	Putalibazar, Lekhnath, Gorkha, Vyas, Waling, Pokhara, Tansen, Baglung	8
	Terai	Butwal, Kapilbastu, Ramgram, Siddharthanagar	4
Mid-western development region	Hill	Birendranagar, Narayan	2
	Terai	Gularia, Nepalgunj, Tulsipur, Ghorahi	4
Far-western development region	Hill	Amargadhi, Dasharathchand, Dipayal-Silgadhi	3
	Terai	Bhimdatta, Dhanghadi, Tikapur	3

Total Mountain = 2; Total Hill = 25; Total Terai = 31

chapter also briefly discusses possible actions required for dealing with this burgeoning problem.

2 Definitions/Classification

Municipal Solid Wastes include household, commercial and institutional waste along with street waste such as waste from trees and plants along roadsides and parks, road dust and roadside litter and waste of stray animals.Household waste includes kitchen waste, paper products, rags, plastics, rubber, leather,bone, glass, crockery, pots, sweepings, metal, fecal matter from poor sanitation facilities, and old furniture.

Commercial Wastes come from a variety of sources, which include stores, tea stalls, business premises, craft works, restaurants, markets, fruit vendors, vegetable grocery stores, hotels, guest houses, slaughterhouses, print shops, tourist facilities and service companies (telephone,electricity, water, road, drainage and treatment plants).

Institutional wastes are those that are generated by schools, government offices, community halls, and religious places. Waste from these sourcesusually contains paper, food waste, boxes, glass, plastic, crockery, plantlitter, garden waste and waste from animals and birds.

Industrial Wastes that are generated as result of industrial work such as manufacturing establishments, breweries, leather industries, carpet factories, chemical industries, food processing industry, repair and maintenance shops etc.

Healthcare Waste include all the waste generated by health care institutions and related research facilities and laboratories. This means any waste that is generated during diagnosis, treatment, or immunization of human beings or animals or in research activities thereto or in production or biological testing.

Agricultural Wastes are produced from agricultural activities and processes as well as waste generated from cottage type of dairies, chicken farms and livestock rearing and waste generated from forests are included in this category.

Construction Wastes are generated as a result of construction activities or from demolition or reconstruction of buildings and facilities. It consists of earth, brickbat, stones, sand, wood, packaging materials, hides, discarded metals, plastic, rags, and old machine parts.

3 Waste Generation and Composition

3.1 Household Waste

Households are the main source of municipal waste in Nepal. The other significant sources include agricultural activities, industries, institutions, commercial

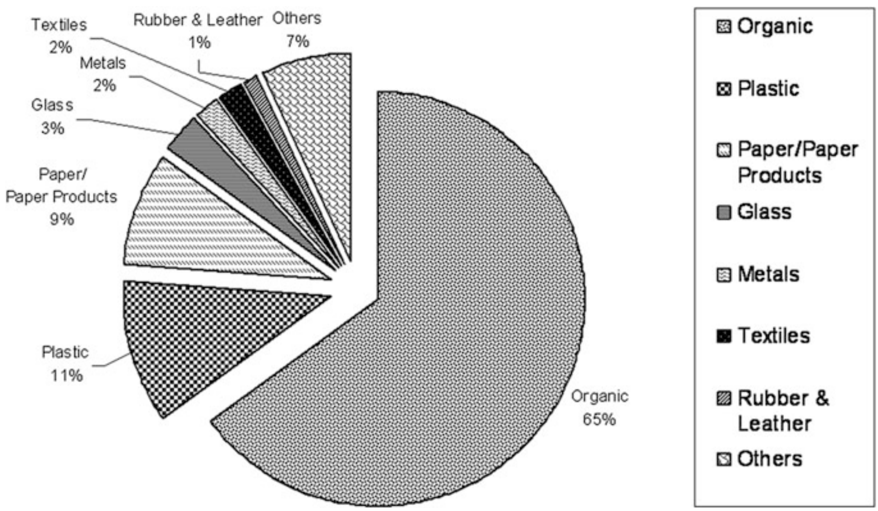

Fig. 2 Waste characteristics (Average)

areas, construction sites and the medical facilities. UNEP (UNEP 2001a) estimated that about 83 % of all waste generated in Nepal is municipal waste, while about 11 % is agricultural waste and 6 % is industrial waste. Rural communities within the municipal areas generally produce very little waste and whatever is generated is often organic waste that is recycled at source. A survey of waste management practices in all 58 municipalities in Nepal conducted by SWMTSC/ADB in 2011 found that the household waste generation rate in Nepalese municipalities varied from 0.08 to 0.7 kg per person per day, with the average being 0.25 kg per person per day. The total municipal waste generation in Nepal in 2003 with an urban population of 3,487,000 was calculated to be 1,369 tons per day or approximately 500,000 tons per year (SWMTSC 2004a) (Fig. 2).

Organic waste is the main component of the waste stream. According to SWMTSC/ADB (2012) the amount of organic matter in household waste varies from 39 % to 95 %. In general, smaller municipalities tend to have higher organic content in their waste. On an average, about 65 % of the household waste generated in Nepalese municipalities was found to be organic matter, while about 20 % consisted of recyclable materials such as paper, plastic and metal, and about 10 % was inert materials.

The waste generation pattern varies from one ecological region to another. Average household waste generation pattern in Terai region is almost double the amount as generated in the mountain region. Similarly, in the hill municipalities, the generation rate is less than the Terai region but is more than the mountain region as shown in (Fig. 3).

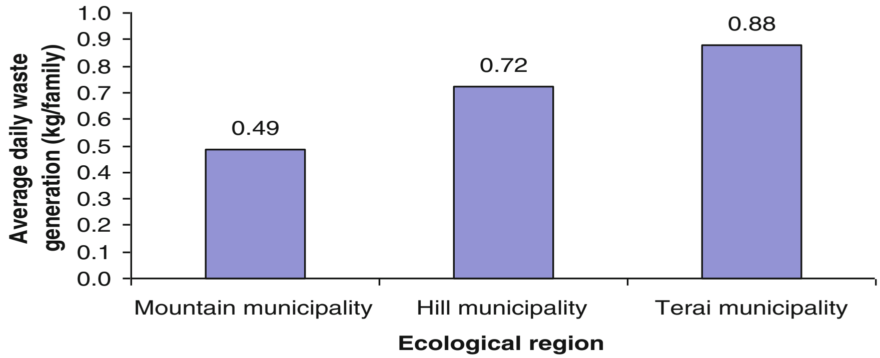

Fig. 3 Average household generation pattern in different ecological region. *Source SWMTSC/ ABD Survey, 2012*

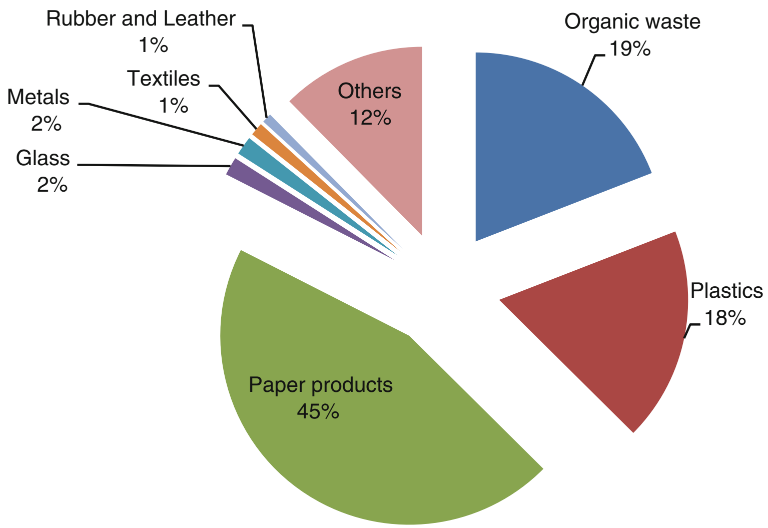

Fig. 4 Average composition of institutional waste of 58 municipalities. *Source SWMTSC/ADB Survey, 2012*

3.2 Institutional Waste Characteristics

Waste generated from offices, schools and colleges were categorized as institutional wastes. The composition analysis revealed 19 % organic wastes, 18 % plastics, 45 % paper and paper products 12 % others with glass, textiles, metals and rubber/leather all below or at 2 % (Fig. 4).

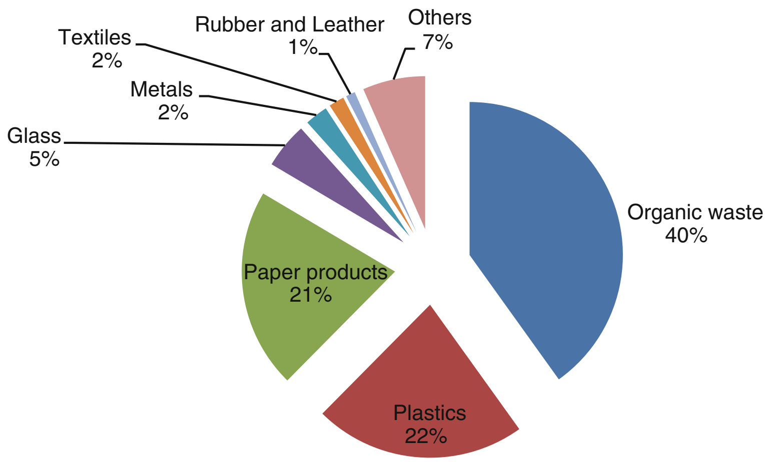

Fig. 5 Average composition of commercial waste in municipalities of Nepal. *Source SWMTSC/ ADB Survey, 2012*

3.3 Commercial Waste

The waste composition of commercial establishments, such as shops, hotels, and restaurants, shown in

Figure 5 was made up of 40 % organic wastes, 21 % paper and paper products, 22 % plastics, 7 % other wastes, 5 % glass, 2 % textiles, 2 % metals and 1 % rubber and leather.

The high percentage of plastics generally found in commercial waste, especially from shops, while organic fraction was observed more in hotel and restaurants. Compared to the household and institutional waste, the high rate of glass in commercial wastes was recorded which indicates the presence of discarded beer and wine bottles by hotel guests.

4 Current Waste Management System

4.1 Collection and Transportation

The total amount of waste collected by municipalities in Nepal is not known for sure because most municipalities do not keep reliable records of the waste they collect. Based on estimates provided by the survey of solid waste generation in the municipalities of Nepal, SWMTSC/ADB (2012) the total amount of waste collected by 58 municipalities in Nepal is reported to be approximately 500,000 tons per year. The waste collection rate is normally higher in the older and bigger municipalities, which have been involved in waste management for a longer time and therefore, have developed better systems for waste management. In smaller municipalities, the waste collection rate is usually lower because these municipalities tend to have less resources and experiences in waste management. Furthermore, most small municipalities have large rural communities where the need for waste collection is less. Some smaller municipalities do not even have a waste collection system and as a result, the collection rate in these municipalities is zero.

Waste collection is considered as the most important component of waste management system. The following systems are being promoted to increase the collection system:

- Containerization and on-site storage of waste;
- Source separation;
- Collection mechanism (roadside collection, door-to-door collection, communal containers, on-time collection etc.;
- Designated and fixed schedule of collection;
- Special collection systems for bulk waste generators;
- Separate collection systems for special waste such as medical waste and hazardous waste;
- Transfer of waste from primary collection vehicles to larger vehicle for secondary transport etc.

4.2 Collection Mechanism

The most common waste collection mechanism practiced in Nepal is roadside collection where waste generators dispose the waste along the road whenever they want and municipal staff sweep the streets and pick up the waste in small handcarts. Sweepers tend to collect the waste in small piles along the streets as they sweep. This is also an inefficient system because it requires a lot of manpower and waste has to be handled several times during collection, which becomes very time consuming and expensive. Some municipalities have set up communal containers, or even tractor trailers at different places in the city for the people to dispose their waste. Once the containers are filled, the municipalities pick them up and are transported to the disposal site. Quite often, the containers are filled and wastes are seen littering around when there is no collection. This is an effective system but it needs active participation from the people as they need to travel to the nearest container to dispose their waste and dispose properly. Some municipalities are practicing on-time collection and door-to-door collection. On-time collection is a system where the waste generator puts the waste directly in the collection vehicle, when the vehicle announces its arrival by giving a signal such as bell or siren. In the door-to-door collection, the waste collector goes door-to-door to collect waste from all households. Both these systems are effective because the waste goes straight from the generator to the collection vehicle. In the on-time collection system requires less staff but it requires the waste generator to be available for disposing the waste when the vehicle arrives.

As dumping of all waste on the roadside or other public places is a very common practice in Nepal, street sweeping for collection of waste is an important activity in the waste management system.

4.3 Collection Through Street Sweeping

Most municipalities employ sweepers who sweep the city streets using simple hand brooms. Major streets are generally swept on a daily basis, sometimes more than once a day, while other streets are swept less frequently. According to SWMTSC/ADB (2012) all municipalities, practice street sweeping and 47 municipalities (82 %) sweep major streets on daily basis.

4.4 Transportation

Tractors with trailers, with capacity ranging from 1.5 to 3 m^3, are the most common vehicles used for waste collection and transport in Nepal. Among the 58 municipalities,

50 (86 %) use tractors with trailers. The use of tractor is popular because it is relatively inexpensive, powerful, versatile, and can be used with several trailers. It is also appropriate for unpaved and dirt roads. Similarly, 14 municipalities (24 %) use trucks or tippers for waste collection and transportation. Few municipalities use specialized vehicles such as trucks with detachable containers. Most of the municipalities also use non motorized vehicles such as handcarts and rickshaws for waste collection and transportation. The biggest advantages of these simple equipments are that they are inexpensive and are easy to operate and maintain. The designs of these vehicles differ from place to place and their capacities normally range from 0.1 to 0.4 m^3. The waste is directly loaded into these vehicles manually and when they are filled they are emptied by tipping. In areas where the landfill site or waste processing site is quite far from the waste collection site, the waste is transferred on to a larger vehicle to reduce the cost of transportation. In most of the municipalities in Nepal, there is no need for waste transfer as the waste is collected in a tractor trailer or truck, which is taken directly to the disposal site when it is full.

4.5 On-Site Storage

In Nepal, very few people have provisions for on-site storage. Many waste generators simply throw away the waste as soon as it is generated. Some modern facilities and large waste generators tend to have containers for on-site waste storage and in recent years, some municipalities have distributed some waste collection bins to limited number of households for waste storage.

4.6 Disposal Mechanism

The area availability for disposal sites varies from 0.025 ha to about 19 ha. The disposal sites are mainly riverbanks, depressed land/dumps, open pit or temporary open piles. The Fig. 6 explains the disposal practices. Only in 5 municipalities it is being disposed off at sanitary landfill sites. In two municipalities there are no defined disposal sites at all.

A brief elaboration on the existing landfilling techniques and interface between sanitary/controlled dumping will be informative

4.7 Special Waste Management

The types of waste under special waste beside municipal wastes are mainly medical waste, dead animals, construction and industrial wastes. It is observed that for medical waste, incineration is done in majority of municipalities by hospitals themselves.

The increasing number of private hospitals and nursing homes are producing significant amount of medical waste. The number of hospitals and nursing homes

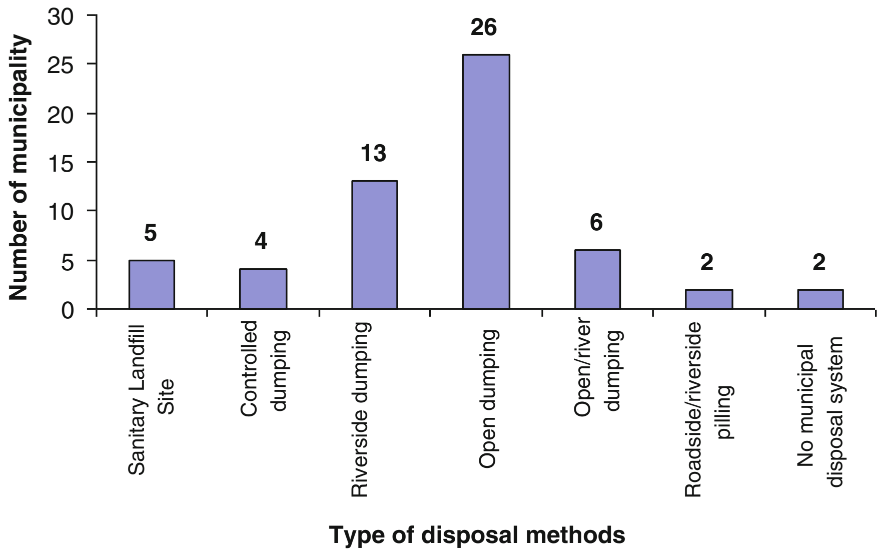

Fig. 6 Disposal Methods. *Source SWMTSC/ADB Survey, 2012*

running in the country are: 92 government hospitals among that 67 are under the Ministry of Health (MoH); 3 community run hospitals; 8 teaching hospitals; 14 nongovernmental hospitals; 74 private health facilities/nursing homes; 16 eye hospitals. It is estimated that 500 tons of hazardous waste is generated per year from hospitals. In Kathmandu valley, a sample survey of 31 private hospitals reveals that hospitals generate 191 kg wastes per day. Total waste generation in the health institutions is approximately 5.71 kg per patient a day; out of this nearly 30 % is hazardous by nature.

Regarding industrial wastes, mainly hazardous and solid effluents are of concern. The type of industries varies from food industries, tanneries, sugar mills, confectionaries, wool and carpet, jute, candles and some other cottage industries. There is no regulation mandated for industries for waste management. The industrial wastes are burnt, dumped, drained in rivers, mixed with municipal wastes, taken to disposal sites/landfill and treated to very less extent.

5 Legal Framework

5.1 Current MSW Policy and Future Developments

The Constitution of Nepal 1990 clearly states the need for environmental conservation in the Directive Principles of the State by saying, "The State shall give priority to the protection of the environment of the country and also prevent damage due to physical development activities by making people conscious of environmental cleanliness and by making special arrangements for the protection of rare animal species, forest and vegetation."

Solid Waste Management National Policy, 1996 was issued with the objectives of (a) to make management work of the solid waste simple and effective; (b) to minimize environmental pollution caused by the solid waste and adverse effect thereof to the public health; (c) to mobilize the solid waste as a resource; (d) to privatize the management work of the solid waste; and (e) to obtain public support by increasing public awareness in the sanitation works. This policy stipulates that solid waste collection and disposal should be organized and managed at the local level, whereas the policy also advocates centralizing institutional responsibility in exceptional situations.

5.2 Solid Waste Management Act 2068 BS (2011 AD)

With an objective to amend and consolidate the laws relating to solid waste management and to arrange for the systematic and effective management of solid waste by minimizing solid waste generation at source, re-using and processing the waste and providing for proper disposal of the solid waste, The Govt. of Nepal enacted Municipal solid Waste management Act 2068 BS (2011 AD) effective from 15th June 2011 AD. This act replaced the previous Solid Waste management and Resource Mobilization Act 1987.

5.3 Environment Protection Act 2053 BS (1997 AD) and the Related Regulations

In the process of internalizing the Environmental Assessment System in development proposals, the Government of Nepal enacted the Environment Protection Act (EPA) 1997 and the Environment Protection Rules (EPR), 1997, which make the integration of IEE and EIA legally binding to the prescribed projects. The Act (Section 7) prohibits the creation of pollution that may cause significant adverse impacts on the environment, or any such act that is likely to be hazardous to public life and people's health, or any act that disposes or causes to be disposed sound, heat, radioactive rays and wastes from any mechanical devices, industrial enterprises, or other places contrary to the prescribed standards. The Act made provision for appointing Environment Inspector in order to effectively carry out or cause to be carried out the acts of mitigation, avoidance or control of pollution or activities required to be carried out in accordance with the IEE or EIA.

Local Self Governance Act, 1999 stipulates that the municipalities will be responsible for all solid waste management (SWM) including collection, transportation and final disposal together with other duties and authority to protect the local environment.

5.4 Organization and Responsibility

Due to the inter-disciplinary nature of SWM, various organizations in the government are designated to be involved in SWM related issues at the policy, planning and implementation levels. The Ministry of Urban Development (MoUD) is the apex ministry at the policy and decision making level, responsible for MSWM. The executive agency at the central level is Solid Waste Management Technical Support Center (SWMTSC) which was formed in 1987 and was formerly known as Solid Waste Management Resources Mobilization Center (SWMRMC). The Local Self Governance Act of 1999 has mandated local bodies, especially municipalities with the core operational responsibilities in managing solid waste within their jurisdictions.

The National Council on SWM, which was established in 1996, is regarded as the ultimate policy making body on SWM at the national level. The Environmental Protection Council has the mandate to deliberate at the highest level, environmental issues of national concern including MSWM.

Important decisions on SWM is taken by the Ministry and the same is approved by the cabinet if it is beyond the jurisdiction of the Ministry. Some decisions are taken at the department level of the concerned ministry. The approval from the Council is needed fro annual programs and budgets of the SWMTSC.

6 Local Case Studies

6.1 Waste Management in Kathmandu Metropolitan City: A Case Study

6.1.1 Introduction to Kathmandu

Kathmandu is the largest municipality and the capital city of Nepal. It is considered as the lead municipality in many of the SWM activities. The city is spread over an area of 49.45 km^2, and lies at an elevation of 1350 m above sea level. The total population as of 2004 is estimated to be 741,008 (JICA) (Map. 1).

KMC HAS A SWM Strategy, which has the following goal:

Map 1 Kathmandu Metropolitan City and its administrative boundary

Establish an integrated waste management system that is environmentally sound, cost effective and suitable to local conditions, with maximum involvement of private sector and local communities.

6.2 Waste Generation

JICA (2004b) has estimated the waste generation rate in Kathmandu to be 0.416 kg per person per day. At this rate, the total waste generation in the city of Kathmandu becomes 308 tons per day.

6.3 Characteristics of Kathmandu's Waste

Although the nature of waste varies according to the living standards and the time of year, municipal waste in Kathmandu can generally be characterized as having high organic content, high density and fairly high moisture content (Figs. 7, 8) (Table 2).

6.4 Non-municipal Waste

The city of Kathmandu also generates large quantities of non-municipal waste such as agricultural waste, commercial waste, hospital waste, industrial waste and dead animals. Although much of industrial and commercial waste is recycled by the private sector because it is generated in bulk and usually contains few contaminants, a significant portion is placed in municipal containers or dumped in public places (Fig. 9).

6.5 Waste Transfer and Transportation

A wider variety of equipment and vehicles are used for waste transfer and transportation in Kathmandu. These range from simple handcarts to hydraulic compactors (see Table 4.3). Handcarts and rickshaws are the simplest type of vehicles and are used to transport relatively small quantities of waste (0.06–0.4 m^3) short distances (100 m to about 2 km) from the source to a larger vehicle or a temporary transfer point.

KMC has a transfer station equipped with ramps that allows split-level transfer where the waste is directly loaded on to a secondary vehicle or container.

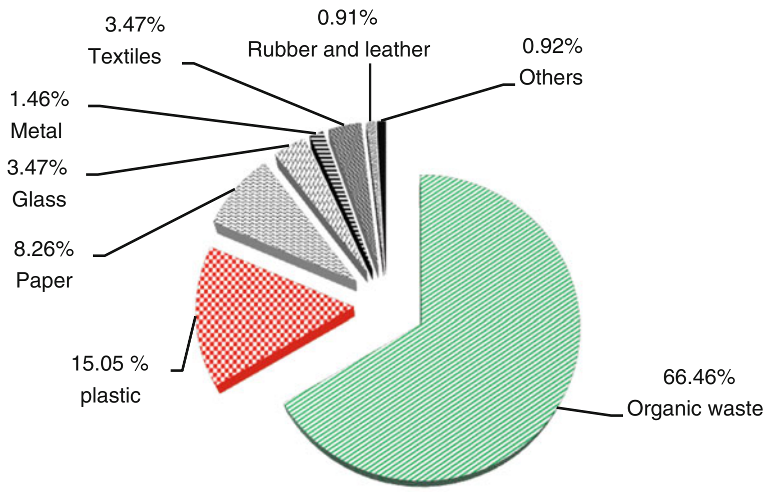

Fig. 7 Characteristic of household waste. *Source SWMTSC/ADB Survey, 2012*

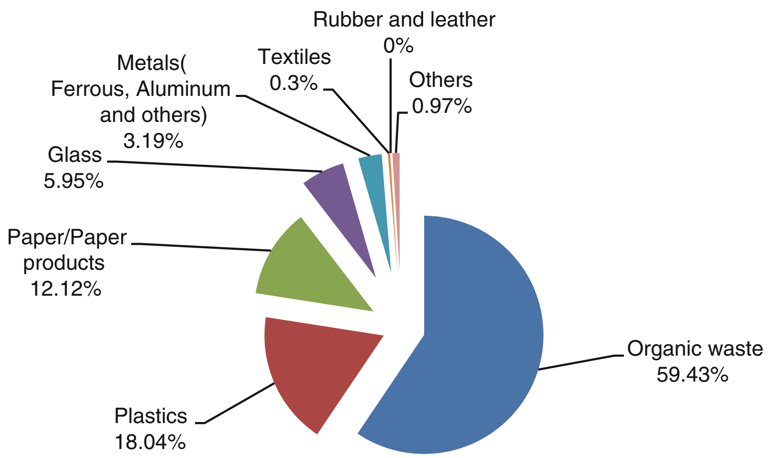

Fig. 8 Characteristic of commercial Waste. *Source SWMTSC/ADB Survey, 2012*

6.6 Composting and Recycling

Although most of Kathmandu's waste can be recycled and KMC's policy is to maximize recycling, very little of Kathmandu's waste is actually recycled. The recycling rate is particularly low for materials, whose market value is low. This includes organic waste, some types of plastics, and broken glass.

Table 2 Composition of Kathmandu's Solid Waste

Component	Percentage of waste (By weight) in the years						
	1976[a]	1981[b]	1985[c]	1988[d]	1995[e]	2001[f]	2011
Organic material	70.5	61.6	67.5	58.6	59.1	70.9	59.43
Paper	6.5	19.3	6.0	6.2	6.0	8.5	12.12
Textile	6.5	5.3	2.7	2.0	8.1	3.0	0.3
Metal	4.9	3.4	2.2	0.4	4.8	0.9	3.19
Glass	1.3	3.4	4.0	1.6	3.6	2.5	5.95
Plastic	0.3	3.6	2.6	2.0	5.4	9.2	18.04
Rubber/leather	0.0	0.0	0.0	0.4	2.3	0.7	NA
Batteries	0.1	0.0	0.0	0.1	3.6	0.0	NA
Inert materials/others	10.0	3.4	15.0	28.9	13.2	4.3	

Notes [a] Mean value of two samplings taken at Thamel on 30/7/76 and at Bhonsiko Street on 3/8/76 (Tabasaran 1976)

[b] Tabasaran and W. Bidlingmaier's Report on Possibility of Compositing Municipal Waste in Kathmandu Valley (Mutz 1990)

[c] Survey of Waste Generation in Households and smaller shops in Kathmandu and Patan (Mutz 1990)

[d] Survey of waste from six different sites in Kathmandu conducted in May 1988 by the Compost Section of SWMTSC (Mutz 1990)

[e] Survey conducted by Nepal Environmental and Scientific Services Pvt. Ltd (NESS 1995)

Survey conducted by Kathmandu Valley Mapping Programme of KMC in 10 locations in Kathmandu

It can be seen that over the years, the composition of waste has changed significantly. It can be noticed that the quantity of paper has increased almost by double from 6.5 % in 1976 to 12.12 % by the year 2011. In contrast, the share of textiles has decreased from 6.5 % to 0.3 % during the same period. Similarly, glass has increased from 1.3 % to a whopping 5.9 % during the same period. There seems to be an alarming situation as far as the increase in plastics is concerned. From a mere 0.3 % in 1976, it has increased up to 18.04 %. The table underscores the need for effective steps to be taken to reduce plastics in the solid waste generated in the municipalities

6.7 Household Composting

In order to promote household composting, KMC is conducting public awareness campaigns, providing training and selling compost bins as well as vermi compost kits.

The compost bin, which is designed and produced by KMC with the brand name "Saaga", is sold at a subsidized price of Rs. 750 (US$10), along with necessary accessories. Survey results on the use of this bin shows that the program has been successful and needs to be continued.

Also in HH composting, may be vermin-composting in practice could be mentioned

6.8 Community Composting

At present one community compost plant that uses an old 3000 L tank with aeration holes and grills at the bottom, is in operation. The plant was set up about a year ago and is being operated by a local NGO, which also has a waste collection service.

6.9 Central Compost Plant

In 1986, a 30-ton per day compost plant was set up with support from the German funded Solid Waste Management Project. The plant operated quite well for four years, although it never utilized its full capacity. The plant shut down after some local people complained about the odor.

6.10 Land Filling

For several years (2000–2005), KMC dumped the waste on the banks of the Bagmati River, which flows through the city. With JICA's assistance, the

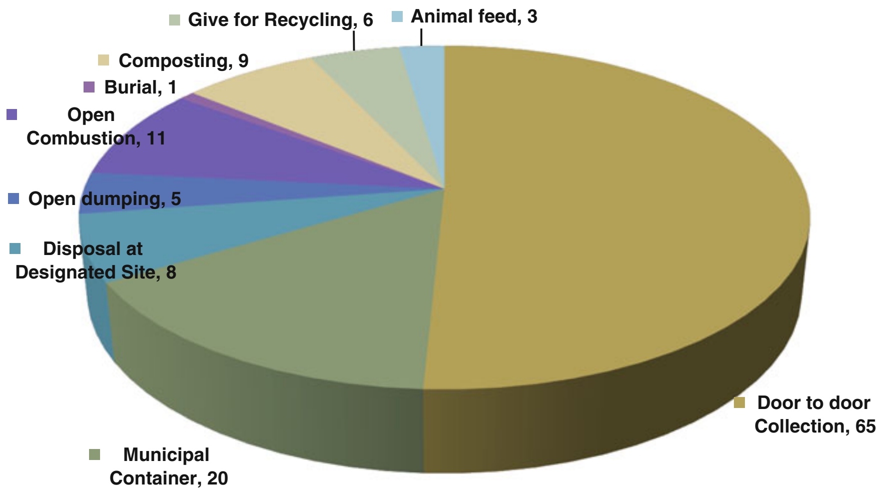

Fig. 9 Waste management practice of households in Kathmandu. *Source* JICA 2004a

government constructed a landfill site and it operated for three years. Two similar landfill sites have been constructed in the area and is being operated at present.

6.11 Special Waste Management

Currently, KMC does not have any systems for managing special waste. KMC has installed an incinerator for management of medical waste and also prepared guidelines for this purpose, but separate collection and treatment of medical waste has not yet started. As a result, most medical waste that is generated in the city, which is estimated to be about 1 ton per day, is mixed with regular waste and are land filled.

6.12 Community Mobilization in Waste Management

KMC has established a Community Mobilization Unit (CMU) within its Environment

Department and initiated several innovative programs to raise awareness on SWM and mobilize local communities, women and children to participate in waste management related activities, particularly composting and recycling.

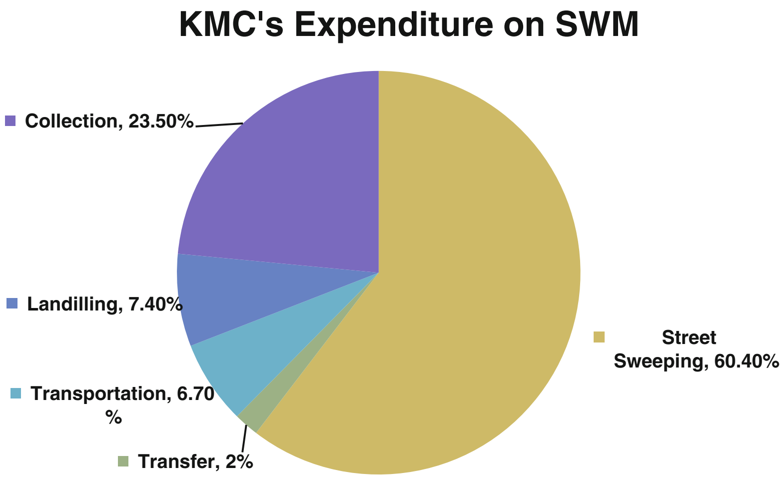

Fig. 10 KMC's Expenditure on SWM. *Source KMC Environment Department, 2004*

6.13 Institutional Aspects of SWM

Environment Department (ED) of the Kathmandu Metropolitan City is the main agency responsible for managing Kathmandu's waste. ED is one of 13 departments within the organizational structure of KMC.

6.14 Financial Aspects of SWM

Currently KMC is spending approximately Rs. 149 million (approximately US$2 million) annually on SWM. This is equivalent to approximately Rs. 200 (US$2.7) per citizen per year or about Rs. 1000 per family per year. KMC spends about 35 % of its total expenditure on SWM (Fig. 10).

6.15 Major Issues and Challenges

Some of the major challenges faced by KMC are as follows:

Landfill site—proper management and operation of existing landfill sites and development of new sites is a difficult undertaking for the KMC.

Central Compost Plant—As the cost of land filling is very high and now with the new landfill operating at Sisdol, which is 28 km away, the transportation cost will be also be extremely high. Therefore, efforts to minimize waste should be implemented immediately.

Collection System—As street sweeping and collection is by far the most expensive activity in KMC's waste management system, the collection system needs to be made more effective and efficient.

Medical Waste Management—At present all of medical waste is mixed with ordinary municipal waste, which should be discouraged. KMC has already initiated some work on separate collection system for medical waste.

Community and Private Sector Involvement in SWM—Although KMC has started to involve local communities and private sector in waste management, this has been a slow process. This process needs to be accelerated in a well-planned manner.

6.16 Challenges Ahead

- Increase in collection efficiency
- Improve efficiency of waste transfer and transportation
- Maximize recycling
- Landfill non-recyclable waste
- Management of hazardous and special waste effectively
- Formulate and enforce of appropriate policies and regulation
- Expand public education and participation, and
- Strengthen institutional capacity for management and monitoring.

Integrated SWM system suitable to local conditions is the long term strategic goal with maximum community and private participation. Cost effective collection, transportation with maximum composting and recycling is the economic goal. Environmentally sound sanitary land filling, special waste management, appropriate legislation, public education, effective management and monitoring is the KMC's environmental goal.

6.17 Conclusion and Recommendation

In the recent study (Jan–Aug 2012) on state of solid waste management in the municipalities, carried out by SWMTSC with financial support from ADB, it was found that average per capita waste generation is 0.16 kg per capita per day. Similarly, the average HH waste generation was found as 0.8 kg/day. The total waste collection rate in the 58 municipality was found to be 1,283 tons/day. The analysis of waste composition indicated that the highest waste fractions were organic matter followed by plastics, and paper. Effective and efficient solid waste management approach was almost absent in majority of the municipalities.

Current waste disposal practices included dumping at either open places or poorly engineered disposal sites. Due to the lack of human and financial resources, and political instability, it has been a challenging task to operate and maintain disposal sites at minimum sanitary standards. The municipalities hitherto do not have sufficient resources to solve the problems, hence municipalities need some assistance and support from the leading center. These helps include both in the forms of hardware and software.

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Solid Waste Management in Pacific Island Countries and Territories

Esther Richards and David Haynes

1 Introduction

The Pacific islands region is as large as it is diverse. Its 22 countries and territories with an estimated combined population of over 8 million extend over an area of 30 million km^2—almost a sixth of the earth's surface and three times larger than either the USA or China. Only two percent of this area consists of land mass in the form of about 7,500 islands and coral atolls, around 500 of which are inhabited. The geography of these varies greatly, and can range from large volcanic landforms with steep and mountainous terrain to tiny, low-lying, coral-based atolls (Secretariat of the Pacific Regional Environment Programme 2010).

The Pacific island countries and territories (PICTs) are generally classified into three sub-regions, namely, Melanesia, Polynesia, and Micronesia, based on their ethnic, linguistic and cultural differences. Across these three sub-regions, the land masses, populations, economic prospects, natural resources, and political systems can vary widely. A few general characteristics of PICTs are presented in Table 1.

Poor municipal solid waste management is a major threat to sustainable development in the PICTs, with potentially negative consequences on public health, environmental quality, water resources, fisheries, agriculture, tourism, trade, and other areas of national development (Secretariat of the Pacific Regional Environment Programme 2010).

The threats arising from poor solid waste management are made worse due to:

- Increasing rates of waste generation caused by economic and population growth;
- The limited availability of suitable land for landfills on small islands and atolls, exacerbated by customary land tenures, and "not-in-my-backyard" attitudes;
- The remoteness of many PICTs resulting in high capital and operating costs;

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Table 1 Population and size of pacific Islands

Country or territory[a]	Exclusive economic zone (km^2)[b]	Land area (km^2)[c]	Population[c]	Density (people/km^2)[c]	2010 Population growth rate (%)[c]
MELANESIA					
Fiji	1,260,000	18,273	847,793	46	0.5
New Caledonia (French Territory)	1,740,000	18,576	254,525	14	1.5
Papua New Guinea (PNG)	3,120,000	462,840	6,744,955	15	2.1
Solomon Islands	1,340,000	30,407	549,574	18	2.7
Vanuatu	710,000	12,281	245,036	20	2.5
MICRONESIA					
Federated States of Micronesia (FSM)	2,978,000	701	111,364	159	0.4
Guam (USA Territory)	218,000	541	187,140	346	2.7
Kiribati	3,600,000	811	100,835	124	1.8
Marshall Islands (RMI)	2,131,000	181	54,439	301	0.7
Nauru	320,000	21	9,976	475	2.1
Northern Mariana Islands (CNMI) (USA Territory)	–	457	63,072	138	−0.1
Republic of Palau	629,000	444	20,518	46	0.6
POLYNESIA					
American Samoa (USA Territory)	390,000	199	65,896	331	1.2
Cook Islands	1,800,000	237	15,708	66	0.5
French Polynesia (French Territory)	5,030,000	3,521	268,767	76	1.2
Niue	390,000	259	1,479	6	−2.3
Samoa	120,000	2,785	183,123	66	0.3
Tokelau (New Zealand Territory)	290,000	12	1,165	97	−0.2
Tonga	700,000	650	103,365	159	0.3
Tuvalu	1,300,000	26	11,149	429	0.5
Wallis and Futuna (French Territory)	–	142	13,256	93	−0.6
Totals	28,066,000	553,364	9,853,135	–	–

[a] This list excludes the Pitcairn Islands, which is a territory of the United Kingdom
[b] *Source* Data of member countries, Secretariat of the Pacific Community Applied Geoscience and Technology Division, 2013
[c] *Source* 2010 Pocket Statistical Summary, Secretariat of the Pacific Community, 2010

- The small and sometimes sparse populations which limit any potential economies of scale; and
- The limited institutional and human resources capacity, and the fact that solid waste financing has not kept pace with growth in waste quantities.

1.1 Roles and Responsibilities

At the regional level, the Secretariat of the Pacific Regional Environment Programme (SPREP) is an inter-governmental organization that provides technical assistance to 21 PICTs in several priority environmental areas, including waste management and pollution control (Secretariat of the Pacific Regional Environment Programme 2011).

At the country and territory level, roles for solid waste management are sometimes divested to several agencies, or in some cases, one entity bears all the responsibility (see Table 2).

1.2 Regional Challenges and Priorities

While municipal solid waste management is one of the priority management issues for the Pacific region (Secretariat of the Pacific Regional Environment Programme 2011), it cannot be considered in isolation, given the limited human, financial and institutional resources available to many PICTs. Furthermore there are potential synergies to concurrently address multiple waste management issues. It is therefore worth articulating the other (mainly hazardous) waste management priorities, which have been identified by PICTs.

1.3 Asbestos

Construction materials such as cement-asbestos sheeting and roofing, which contain asbestos fibers, have been widely used in Pacific island countries for housing and other buildings, and even though health concerns have led to their phase-out, they are still found in many buildings.

The Pacific is subject to periodic catastrophic weather and geological events such as tsunamis and cyclones, which are highly destructive to built infrastructure and can give rise to asbestos waste. Building maintenance and replacement, and the gradual collapse and disintegration of disused buildings with asbestos materials, also create asbestos waste. As a consequence, asbestos containing materials are, or may become, a significant waste and human health issue in many Pacific countries and management and disposal of asbestos in the region is critical to the maintenance of long-term community health.

A regional asbestos waste management strategy (Secretariat of the Pacific Regional Environment Programme 2011) provides background information and guidance on the health risks associated with asbestos exposure and on best practices in asbestos handling, and presents an integrated framework to progressively assess, stabilize, collect and dispose of asbestos containing materials in the Pacific.

Table 2 Waste management roles and responsibilities in PICTs

PICT	Coordinating agency[a]	Monitoring agency[b]	Agency for waste management services[c]
American Samoa	American Samoa Environmental Protection Agency	American Samoa Environmental Protection Agency	American Samoa Power Authority
Cook Islands	National Environment Service	National Environment Service and Ministry of Health	Ministry of Infrastructure and Planning
Fed. States of Micronesia	Office of Environment and Emergency Management	Environmental Protection Agency for each State	Department of Transport and Infrastructure in each State
Fiji	Department of Environment	Department of Environment	Municipalities
French Polynesia	Department of Environment	Department of Environment	Municipalities
Guam	Guam Environmental Protection Agency	Guam Environmental Protection Agency	Department of Public Works
Kiribati	Ministry of Environment, Lands and Agricultural Development	Ministry of Environment, Lands and Agricultural Development	Municipalities
Marshall Islands	Office of Environmental Planning and Policy Coordination	RMI Environmental Protection Agency	Majuro Atoll Waste Company
Nauru	Department of Commerce Industry and Environment	Department of Commerce Industry and Environment	Nauru Rehabilitation Corporation
New Caledonia	Departments of Environment (Provincial)	Departments of Environment (Provincial)	Municipalities
Niue	Department of Environment	Department of Environment	Department of Environment
Northern Mariana Islands	Division of Environmental Quality	Division of Environmental Quality	Department of Public Works
Palau	Environmental Quality Protection Board	Environmental Quality Protection Board	Bureau of Public Works (Ministry of Public Infrastructure, Industries and Commerce), and State Governments
Papua New Guinea	Department of Environment and Conservation	Department of Environment and Conservation	National Capital District Commission (for Port Moresby only)
Samoa	Ministry of Natural Resources and the Environment	Ministry of Natural Resources and the Environment	Ministry of Natural Resources and the Environment

(continued)

Table 2 (continued)

PICT	Coordinating agency[a]	Monitoring agency[b]	Agency for waste management services[c]
Solomon Islands	Environment and Conservation Division (Ministry of Environment, Climate Change and Disaster Management)	Environment and Conservation Division (Ministry of Environment, Climate Change and Disaster Management)	Environmental Health Department (Ministry of Health and Medical Services), Municipalities
Tokelau	Department of Economic Development, Natural Resources and Environment	Department of Economic Development, Natural Resources and Environment	Department of Economic Development, Natural Resources and Environment
Tonga	Ministry of Environment and Climate Change	Ministry of Environment and Climate Change	Tonga Waste Management Authority (Tongatapu only), Ministry of Health
Tuvalu	Ministry of Internal Affairs	Solid Waste Agency of Tuvalu	Kaupule (Island Council)
Vanuatu	Department of Environment	Department of Environment	Municipalities

Notes
[a] Entity with primary responsibility for strategic planning and policy development
[b] Lead entity that regulates environmental quality
[c] Entity that is directly engaged in delivering waste management services (collection, disposal, etc.)

Particularly important is the focus on adoption of minimum occupational health and safety guidelines for workers and citizens involved in asbestos handling operations, either as a routine operation or as part of an emergency response scenario.

Adoption of national asbestos management policies by Pacific island countries will also ensure that the regional transport of waste asbestos is controlled through relevant protocols to ensure its safer transport and disposal.

1.4 Electrical and Electronic Waste

Due to the demand for newer technology, the life span of electrical and electronic products is progressively decreasing. Consequently, older and outdated items such as computers, printers, photocopy machines, television sets, washing machines, radios, and mobile phones are becoming obsolete and being discarded in large quantities and at increasing rates worldwide.

The extent of the electrical and electronic waste (E-waste) problem in the Pacific has not been comprehensively documented, however the limited information available indicates that the use of electrical and electronic equipment is increasing significantly on an annual basis in PICTs. E-waste contains hazardous but also valuable and scarce materials such as metal and alloys, which can be recovered and recycled. Proper management and disposal of E-waste is therefore important to the long-term protection of local and regional Pacific environments.

A regional E-waste management strategy (Secretariat of the Pacific Regional Environment Programme 2012) provides background information on the health risks associated with E-wastes and provides guidance on best practice in E-waste handling and disposal options through an integrated framework to progressively collect, store and dispose of E-waste in the Pacific region. The development and adoption of national E-waste policies will establish a framework for the Pacific that improves management of E-waste and promotes and enforces responsible E-waste management. This framework is expected to incorporate extended producer responsibility, mandatory recycling fees charged at point of sale and/or import taxes or tariffs to effectively finance eventual recycling of all imported electrical and electronic goods.

1.5 Health Care Wastes

Health care waste is a by-product of modern health care. A majority of health care waste is similar to domestic waste, although a small fraction is infectious and/or hazardous and requires special treatment. This waste fraction includes sharps, blood, body parts, chemicals, pharmaceuticals, medical devices and radioactive materials.

Poor management of health care waste potentially exposes health care workers, waste handlers and the community to potential infections, toxic effects and injuries. The extent of the health care waste problem in the Pacific has not been comprehensively documented, but the limited information available (United Nations Environment Programme Division of Technology, Industry and Economics 2012) indicates that quantities of the waste are increasing significantly on an annual basis in Pacific island countries due to increasing population numbers and improved health services.

Proper management and disposal of health care waste is important for the long-term protection of local and regional Pacific environments and for the protection of public health. A draft regional health care waste management strategy released in 2013 (Secretariat of the Pacific Regional Environment Programme 2012) provides background information on the health risks associated with health care waste and provides guidance on best practice in health care waste handling and disposal options including an integrated framework to collect, store (where necessary) and dispose of health care waste in the Pacific region. Development and adoption of national health care waste policies will establish a framework for the Pacific that improves management of health care waste and promotes and enforces responsible health care waste management.

1.6 Regional Initiatives

Waste management in the Pacific region is undergoing a transformation. Beginning in the early to mid 2000s, and with consistent support from the Japan International Cooperation Agency (JICA), there was an emphasis on strategic planning for municipal solid waste management with the adoption of the Pacific Regional Solid Waste Management Strategy (Secretariat of the Pacific Regional Environment Programme 2006) and a number of country solid waste management strategies and action plans. This occurred concurrently with investments by JICA and other development partners to deal with waste management across the Pacific islands, including investments in medical waste management facilities, new landfills, waste minimization activities (including the 3Rs—Reduce, Reuse, Recycle; and household composting), and institutional reforms to improve the efficacy of waste management services.

Within recent times, SPREP has partnered with JICA to implement a US$10 million 5-year (2011–2016) project namely the Japanese Technical Cooperation Project for Promotion of Regional Initiative on Solid Waste Management in Pacific Island Countries (J-PRISM). This project aims to strengthen the human and institutional capacity base in 11 Pacific island countries to manage solid waste in a more effective manner. Specific national project outputs have been tailored to each country's needs and priorities.

Complementing the J-PRISM project is the *Agence Française de Développement* (AFD) Regional Solid Waste Management Initiative for €1 million implemented by SPREP—which has a component to deliver a technical, train-the-trainer style waste management course for Pacific islanders. Together, these two projects will increase the human technical capacity to deliver a cleaner Pacific region. A particular focus is on developing capacity for waste minimization such as the 3Rs, as well as waste collection, and waste disposal. The AFD Project will also develop a program for waste oil management across the region.

Fundamental change in waste management practices is likely to be sustained if such change occurs at the community level. For this reason, it is important to engage at the community level to increase capacity and adjust behaviors and attitudes. Each PICT conducts its own awareness and education programs to effect such changes. At the regional level, SPREP simultaneously undertakes broad-reaching regional campaigns to support and strengthen national efforts.

One such campaign was SPREP's Clean Pacific 2012 Campaign (Secretariat of the Pacific Regional Environment Programme 2012), the goal of which was to provide opportunities to enhance awareness of, and support actions for good waste management and pollution prevention policies and practices. Support for grass-roots actions for waste management under this campaign has provided the region with a range of new, community-based case studies to learn from, and provided successful models to replicate in other communities. These included activities such as composting, waste reduction, recycling, litter prevention, and better waste disposal solutions which help to maintain a clean environment and help control pollution.

Even with the progress being made through these regional initiatives and other national programs, solid and hazardous waste management remains an ongoing and escalating priority problem for the region.

2 Waste Generation and Composition

The specific municipal solid waste quantities and composition generated by selected PICTs are shown in Table 3. In general terms, the waste stream in many PICTs is dominated by organic (decomposable) waste accounting for 50 % or more of the waste stream. This reflects the largely agricultural-based economy in many PICTs. High dependence on imported goods, increasing economic development, and increasing participation in global trade also contribute to shaping the municipal waste stream, and in all likelihood contributes to increasing proportions of packaging waste (including glass, paper, plastics, metals).

3 Collection and Transportation

Historically, the waste collection systems in many PICTs were characterized by inconsistent and unreliable services—caused by the shortage of appropriate collection equipment, poor management, a shortage of trained personnel and financial resources, and limited availability of supporting infrastructure and equipment such as transfer stations and public bins.

Waste collection programs typically cover the main urban areas, with limited service in the rural areas and less populated outlying islands. The 2011 characteristics of the waste collection system in selected PICTs are presented in Table 4.

With the focused intervention of aid agencies and development partners such as the Japan International Cooperation Agency (JICA), the European Union, the New Zealand Aid Programme, and the Australian Agency for International Development (AusAID), the waste collection and transportation systems in the PICTs are steadily improving.

4 Waste Minimization (Reduce, Reuse, Recycle)

The constraints on waste management resources in the Pacific region demand that waste minimization (reduction, reuse, and recycling) strategies be employed in order to reduce residual wastes requiring final disposal and support more effective and efficient utilization of available resources. However, there are currently only a

Table 3 Waste generation statistics in selected PICTs

Waste component	Municipal Solid Waste composition (%) in selected PICTs				
	Fiji (Nadi Town and Lautoka City combined)[a]	Niue (Alofi) (household waste only)[b]	Samoa (Apia) (household waste only)[c]	Solomon Islands (Honiara)[d]	Vanuatu (Port Vila)[e]
Glass and ceramics	4.1	3.1	2.2	0.7	10.0
Metals	1.9	13.2	8.8	8.5	8.7
Organic matter					
Kitchen waste	33.2	27.7	3.8	47.1	43.6
Grass, leaves	37.2		38.7	2.6	
Paper and cardboard	12.5	9.4	7.2	17.5	12.9
Plastics					
Films	5.8	8.0	6.5	16.8	11.7
Other	1.7	12.6	6.5		
Rubber and Leather	0.1	0	0	0.4	0
Textiles	1.2	0.4	6.8	2.1	0.8
Others	2.3	25.6 (Diapers: 16.3 %)	19.5 (Diapers: 15.1 %)	4.3	12.3 (medical waste: 6.3 %)
Totals	100.0	100.0	100.0	100.0	100.0
Unit waste generation rate (kg/person/day)	1.50	0.31	0.38	0.95	0.97
Average waste density (kg/liter)		0.083	0.160	0.366	0.257
Reported methodology	8-day direct sampling of 86 randomly selected households and commercial businesses during dry and wet seasons	7-day direct sampling of 15 randomly selected households	7-day direct sampling of 40 randomly selected households	7-day direct sampling of 21 randomly selected households and 7 commercial businesses	Three 3-week surveys of waste arriving at landfill

Source

[a] 3R Promotion Manual, Fiji Department of Environment, November 2011

[b] Draft Niue National Solid Waste management Plan, Niue Department of Environment, 2010

[c] Solid Waste Characterization and Generation Study 2012—Vaitele, Division of Environment and Conservation, Ministry of Natural Resources and Environment, 2012

[d] Honiara Waste Characterization Audit Report 2011, Honiara City Council and the Environment and Conservation Division, 2011

[e] Draft Solid Waste Management Plan for Port Vila Municipal Council, Japan International Cooperation Agency, 2008

Table 4 Waste collection service characteristics in selected PICTs, 2011

PICT	Access to regular solid waste collection service in urban areas (% of population)	Frequency of household collection service per week in urban areas (number)
Cook Islands	100	1
FSM	Chuuk State: 20 Kosrae State: 70 Pohnpei State: 60 Yap State: 50	1
Kiribati	35	1
Nauru	100	1
Niue	100	1–3
Palau	100	1
RMI	80–90	1
Samoa	100	1–2
Solomon Islands	60 (Honiara)	1
Tonga	73	1
Tuvalu	80	1–2
Vanuatu	>50 (Port Vila)	3

Source Pacific Infrastructure Performance Indicators 2011, Pacific Regional Infrastructure Facility, September 2011

small number of policies that directly support waste minimization in the Pacific region—all of which favor programs that encourage return of waste for recycling. Specifically, FSM, Fiji, Kiribati, and Palau have enacted beverage container deposit legislation, which offers a full or partial refund of a deposit imposed on plastic and aluminum beverage containers at the time of purchase.

Despite the success demonstrated by these programs, other PICTs seem to lack the political will to adopt similar programs. The challenge in the coming years will be to continue the dissemination of these and other waste minimization success stories and to encourage their adoption by PICT governments.

4.1 Waste Reduction

Waste reduction initiatives in the region often take the form of national and regional education and awareness programs encouraging responsible consumer behavior, such as a 2006 regional campaign promoting the reduction of plastic bag consumption and the use of reusable shopping bags (Secretariat of the Pacific Regional Environment Programme 2006). SPREP's Clean Pacific 2012 Campaign (Secretariat of the Pacific Regional Environment Programme 2012) (discussed earlier) is another example of a regional campaign, which recently targeted grassroots actions towards waste minimization and better waste management.

For the majority of PICTs, organic waste often accounts for over 50 % of the domestic waste stream (Secretariat of the Pacific Regional Environment Programme 2010), which makes composting an attractive waste reduction solution.

4.2 Composting

Organic waste composting is generally encouraged at source (*i.e.* at the household level) in order to reduce the management (collection, transportation, and disposal) costs of organic waste, and to produce a beneficial soil additive to support subsistence farming. Recovering the nutrient content of waste organic materials through composting (rather than locking it away in landfills and dumpsites) is particularly crucial to small atoll states such as Kiribati, Marshall Islands, Tokelau, and Tuvalu.

The soils on these atolls are typically alkaline with low levels of certain micronutrients essential for plant growth and health (iron, manganese, copper and zinc). Furthermore, since soil fertility depends on the amount of accumulated organic material (Morrison 1990), any organic material locked away permanently in landfills and dumpsites is unavailable to contribute to improving the soil fertility.

The expected improvement in soil conditions and crop health from the application of compost can potentially reduce reliance on imported food crops, and (with appropriate promotion) contribute to healthier lifestyles. Furthermore, the diversion of organic waste from dumps and landfills reduces leachate toxicity and reduces leachate treatment costs.

For these reasons, organic waste composting is a major component of the J-PRISM project (2011–2016), where pilot programs are being (or will be) implemented in Kiribati, Marshall Islands, Palau, Samoa, Solomon Islands, and Vanuatu. Pilot composting projects will also be undertaken in the Cook Islands and Niue commencing in 2013, under a 5-year project (2013–2018) funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP), entitled *Pacific POPs Release Reduction through Improved Management of Solid and Hazardous Wastes* (United Nations Environment Programme 2012).

Several demonstration projects for composting have also been completed under the Development of Sustainable Agriculture in the Pacific (DSAP) Project (Secretariat of the Pacific Community 2009), which involves 16 PICTs, namely Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Kiribati, Nauru, Niue, Palau, Papua New Guinea, Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna. Composting demonstration and pilot programs have also been initiated by the Taiwan Missions in the Taiwan-allied countries (Fiji, Kiribati, Marshall Islands, Palau, Papua New Guinea, Solomon Islands, and Tuvalu) as part of their technical assistance program for horticultural crop development.

Some of the challenges going forward in organic waste composting include establishing steady demand for the compost, minimizing the duplication of past efforts, building on successful initiatives, and developing mechanisms to support accurate recording and reporting of waste diversion rates.

4.3 Waste Reuse

Reuse activities are driven by local entrepreneurs in each country and typically involve repairing goods (e.g., computers, television sets, radios, printer cartridges) to make them usable again, or modifying items to use for a different purpose (e.g., using tires as decorative planters; empty containers for water storage; empty bottles cut to make drinking glasses, or crushed for aggregate). This informal reuse industry provides a vital service by reducing the waste that goes to landfills, but there is very little accurate information at present about the size of this reuse sector in the Pacific Region. A SPREP project (2012–2014) funded through the United Nations Strategic Approach to International Chemicals Management (SAICM)

Table 5 Recycling activities in PICTs

Recycling activity	PICT	Markets for recyclables
Aluminum cans	CNMI, Cook Islands, Fiji, Guam, Kiribati, Niue, Palau, PNG, RMI, Samoa, Solomon Islands, Tokelau, Tonga, Vanuatu	Australia, California-USA, New Zealand, Korea
Scrap metal (ferrous metal)	Cook Islands, Fiji, Niue, Palau, PNG, RMI, Solomon Islands, Tonga, Vanuatu	Australia, China, Hong Kong, Mauritius. India, Turkey, Korea, Indonesia
Paper/cardboard	Cook Islands, Fiji, Palau, Tonga	Australia, Local, New Zealand, Korea
Glass	CNMI, Cook Islands, Palau, Tonga	Local
Plastics (includes foam)	CNMI, Cook Islands, Fiji, RMI, Samoa, Tonga	Australia
Lead-acid batteries	CNMI, Cook Islands, Fiji, Kiribati, Niue, Palau, PNG, RMI, Samoa, Tonga, Vanuatu	Australia, China, New Zealand
Used oil	CNMI, Cook Islands, Fiji, Palau, Tonga, Vanuatu	Fiji, Indonesia, Nauru, New Zealand, Philippines
Tires	CNMI, Fiji, PNG, Tonga	Indonesia, Malaysia, Korea, Vietnam
Electrical and electronic waste (E-waste)	Cook Islands, Kiribati, Tonga	New Zealand, Singapore
Organic waste (composting)	Cook Islands, Fiji, Palau, RMI, Samoa, Tokelau, Tonga, Tuvalu	Local

Source Pacific Regional Solid Waste Management Strategy 2010–2015, Secretariat of the Pacific Regional Environment Programme 2010 program is investigating options for, and feasibility of reusing the electrical and electronic wastes in-country in the Cook Islands, Kiribati and Samoa.

4.4 Waste Recycling

Waste recycling in the Pacific islands context generally refers to the collection, compaction and shipping of recyclable waste to a recycling facility that is usually located off-island (Secretariat of the Pacific Regional Environment Programme 2010). Various waste recycling activities are being undertaken in PICTs (Table 5), some of which are supported by policies such as container-deposit legislation in the case of beverage containers. In other cases, the absence of sympathetic government policies means that private sector operators rely solely on the economic value of the recyclable materials to support their operation; as such they are more susceptible to fluctuations in the global price of recyclable materials compared to those who operate with the support of government policies.

Two major technical obstacles to cost-effective waste recycling in PICTs are the lack of national recycling and re-processing facilities, and the comparatively small quantities of recyclable waste, which make it uneconomic to transport materials elsewhere for recycling and reprocessing. Some recyclers have also had their shipment of recyclable materials rejected at the port of import due to quarantine violations, which has hampered the development of the recycling sector in those localities. These obstacles are compounded by the absence of a regionally oriented or coordinated recycling mechanism.

The feasibility of establishing such a regional mechanism was investigated by JICA through a 10-month study conducted in 2012. Specifically, the aim was to assess the feasibility of establishing Reverse Logistics and Recycling Ports for five Pacific island countries (Fiji, Samoa, Tonga, Tuvalu, and Vanuatu) (The Overseas Coastal Area Development Institute of Japan 2012).

Reverse Logistics refers to the transportation system for collection of used products and materials and moving those products and materials to remanufacturing points for recycling and/or reuse purposes. Recycling Ports complements the function of reverse logistics, and refers to a terminal for processing and storing recyclable materials that require environmentally-sensitive treatment (The Overseas Coastal Area Development Institute of Japan 2012).

The JICA study focused on bulky wastes (vehicles, white goods, E-waste, furniture, etc.) having the potential to be recycled ("recyclable waste goods"), as well as on recycled waste materials—materials actually processed from the recyclable waste goods (e.g. scrap metal, aluminum and steel cans, plastic bottles, paper, and cardboard).

The preliminary report of the JICA study highlighted a number of barriers related to recycling of bulky wastes and reverse logistics, and proposed several improvement measures including expansion of the collection coverage of recyclable waste goods, improved working standards and conditions at the recycling companies, enhancing the domestic demand for recycled waste materials, adoption of supportive government policies, formation of a water transportation network for recyclable goods, mechanisms for alleviating high freight costs, and improvement in information provision to ensure compliance at import ports.

5 Treatment and Disposal

The overwhelming proportion of municipal solid waste in PICTs is disposed of on land by way of dumps and landfills, with a small component composted and recycled. However, this method of disposal compounds one of the greatest challenges for many PICTs, which is the availability of suitable land for waste disposal.

Coral atolls such as Kiribati, Marshall Islands, Tokelau, and Tuvalu have very little land space with many competing uses (housing, public infrastructure,

Table 6 Modes of municipal solid waste disposal in PICTs

PICT	Mode of municipal solid waste disposal (Donors involved in original construction and/or rehabilitation are in parentheses)
American Samoa	Anaerobic landfill on Tutuila Island
Cook Islands	Anaerobic landfill on Rarotonga and Aitutaki (Asian Development Bank)
FSM	Semi-aerobic landfill on Kosrae (JICA); Controlled dumpsites on Pohnpei and Yap[a]; Open dumpsite on Chuuk
Fiji	Anaerobic Landfill in Suva (European Union); Controlled dumpsite in Lautoka (JICA)
Guam	Anaerobic landfill with gas management facilities
Kiribati	Controlled dumpsites on South Tarawa (New Zealand Aid Programme)
Nauru	Open dumpsite
Niue	Open dumpsite
Northern Mariana Islands	Anaerobic landfill with gas collection on Saipan
Marshall Islands	Controlled dumpsite on Majuro[a] (JICA); Open dumpsite on Ebeye
Palau	Semi-aerobic landfill in Koror State[a] (JICA)
Papua New Guinea	Open dumpsites in Port Moresby[a] and Kavieng
Samoa	Semi-aerobic landfill on Upolu (JICA); Controlled dumpsite on Savaii
Solomon Islands	Open dumpsites in Honiara[a] (JICA)
Tokelau	Open dumpsites on Fale, Atafu, and Nukunonu Islands
Tonga	Anaerobic landfill on Tongatapu (AusAID, Asian Development Bank), Controlled dumpsite in Vava'u[a] (JICA)
Tuvalu	Open dumpsite on Funafuti (European Union)
Vanuatu	Semi-aerobic landfill in Port Vila[a] (JICA)

Notes
[a] These dumpsites are being improved under the JICA/SPREP Japanese Technical Cooperation Project for the Promotion of Regional Initiative in Solid Waste Management in Pacific Islands Countries (J-PRISM)

farming), and their permeable coral soils contribute to the transfer of pollutants from dumpsites and other above-ground sources of pollution to their underlying freshwater lens.

The availability of suitable land is also an issue throughout the Pacific region because the vast majority of land is held under customary tenure (Wilson 2013), which places ownership with communities or family groups. In most countries, customary tenure accounts for more than 80 % of the total land area (Making Land Work 2008). Where a landfill is to be sited on communal or family land, negotiating a land lease can be a lengthy and complex process, in terms of obtaining consent, and agreement on appropriate compensation, particularly where negative perceptions over past operations of waste disposal sites exist, and because customary land has significant cultural, spiritual, environmental, and economic value (Making Land Work 2008).

Despite the challenges, several PICTs, assisted by donors, have upgraded urban dumpsites or have closed polluting dumpsites and constructed new facilities. The various modes of waste disposal in the PICTs are shown in Table 6. Improving waste disposal facilities and practices is also the focus of the J-PRISM project in the Federated States of Micronesia, Palau, Papua New Guinea, Solomon Islands, Tonga and Vanuatu.

The current approach taken by most PICTs, supported by the J-PRISM project and SPREP is to implement the Semi-aerobic Landfill Method (also known as the Fukuoka Method). When managed properly, the Semi-aerobic Landfill is a cost-effective and speedy method of stabilizing waste with high organic (biodegradable) content (Chong et al. 2005).

The Semi-aerobic Landfill Method is a sanitary landfill method in which leachate and landfill gas are continuously removed from the waste mass through a system of leachate collection and gas venting pipes. With proper design and placement of the pipes, the decomposing waste generates heat, which creates convection currents that draw the ambient air through the network of ventilation pipes located throughout the waste mass. The resulting semi-aerobic condition in the waste mass improves the stabilization process and the leachate quality due to the increased aerobic microbial activity, and releases carbon dioxide compared to the methane released under anaerobic conditions. This is critically important as methane is 21 times more potent as a greenhouse gas than carbon dioxide (over a 100-year period) (Global Warming Potentials 2013).

In many cases, a leachate recirculation system is also installed, whereby the leachate is collected in a pond and re-circulated into the waste layers. The waste mass serves as a biological filter, improving the quality of the leachate after each cycle. Leachate is further treated in the leachate collection pond through mechanical aeration to increase microbial activity, and also by passage through a compact wetland before ultimately being discharged into the environment (Kouji 2007).

Table 7 Solid waste management legislation in PICTs

PICT	Legislation
American Samoa	Environment Quality Act
Cook Islands	Environment Act (2004) (Rarotonga); Public Health Act 2005; Sewerage Regulations 2008
FSM (Chuuk)	CSL Public Law 02-94-01; Littering Law CSL- 191-33; Recycling Law
FSM (Kosrae)	Kosrae State Constitution, Article 2; Kosrae State Code, Title 13, Section 13.506; Kosrae State Code, Title 13, Section 530; Kosrae State Code, Title 7, Chapter 22
FSM (Pohnpei)	Constitution of Pohnpei, Article 7, Section 1; State Law 3L-26-92, Pohnpei Environmental Protection Act; Solid Waste Regulations 3/30/95; Pohnpei State Law No 6L-66-06
FSM (Yap)	YSL #4-4 Yap State Public Service Corporation; Recycling Program Law (2008); Recycling Program Regulations (Dec 2008); Recycling Finance Law (2009)
Fiji	Waste and Pollution Regulations 2008; Litter Promulgation 2008; EIA Regulations 2007; Environmental Management Act 2005; Public Health Act; Fijian Affairs Act; Municipal Council Byelaws
Guam	Solid Waste Management and Litter Control Act; Guam Environment Protection Agency Act; Guam Environmental Pollution Control Act
Kiribati	Special Fund (Waste Material Recovery Act 2004; Environment Act 1999
Marshall Islands	Conservation Areas Act 1978; National Environmental Protection Act 1984; Public Health Act; Majuro Local Government Ordinance; Littering Act 1982
New Caledonia	New Caledonia Act 1999
Northern Mariana Islands	Resource Conservation and Recovery Act; Litter Control Act 1989; Safe Drinking Water Act; Solid Waste Management Act
Niue	Environment Act 2003; Public Health 1982;
Palau	Public Law 1-58; Palau National Code 34, subsection 1004; Recycling Law RPPL 7-94; Environmental Quality Protection Act; Solid Waste Management Regulations
Papua New Guinea	Marine Pollution Bill (draft); Environment Act 2000 and regulations; Organic Law on Provincial and Local Level Government; Public Health Act; National Capital District Commission Act
Samoa	Waste Management Act 2010; Land, Surveys and Environment Act 1989
Solomon Islands	Environment Regulation 2008; Environment Act 1998; Shipping Act 1998; Agriculture Quarantine Order 1995; Ports Act 1990; Environmental Health Act 1980
Tokelau	Marine Pollution Regulations 1990; Marine Pollution (Dumping and Incineration) Regulations 1982; Marine Pollution Act 1974;
Tonga	Waste Management Act 2005 (Tongatapu); Public Health Act 2008
Tuvalu	Waste Operation and Services Act 2009; Environment Protection Act 2007; Marine Pollution Act 1991; Public Health Act and Regulation 1926
Vanuatu	Waste Operations and Services Bill; Environment Management and Conservation Act Cap. 283 (2002); Bio-security Bill (draft);

Source Pacific Regional Solid Waste Management Strategy 2010-2015, Secretariat of the Pacific Regional Environment Programme, Apia, Samoa, 2010

6 Legal Framework

Legislation in selected PICTs containing provisions relevant to municipal solid waste management is summarized in Table 7. Some countries have enacted specific laws addressing municipal solid waste management, while in others, broad Environment Acts have been adopted. However, there are still a few PICTs that rely on Public Health Acts for waste regulation, which usually contain inadequate provisions to deal with the complex nature of today's municipal solid waste stream (Secretariat of the Pacific Regional Environment Programme 2010).

In cases where legislation has been enacted, non-compliance is often reported and attributed to low levels of public awareness. There is also limited human and financial capacity within many PICTs to enforce the legislation. This can be compounded by an uncoordinated approach where regulation is spread among a number of agencies without clearly defined roles and responsibilities, lack of consolidated legislation, and social pressure exerted in small communities, where enforcers may be associated with, or related to offenders.

7 Impacts of MSW on Greenhouse Gas Emissions

The Pacific islands region as a whole is estimated to account for 0.03 % of the global emissions of carbon dioxide from fuel combustion despite having approximately 0.12 % of the world's population (Hay and Sem 1999). The specific contribution from the waste management sector has not been assessed, but it is not unreasonable to assume that this would constitute a minute fraction of the region's total emissions.

Low greenhouse gas emissions notwithstanding, the Pacific islands are committed to demonstrating leadership in reducing greenhouse gas emissions through a number of measures including engaging in the Clean Development Mechanism and other carbon-market mechanisms (Secretariat of the Pacific Regional Environment Programme 2011).

The Semi-aerobic Landfill contributes to reductions in greenhouse gas emissions from the waste management sector since the degradation of waste under semi-aerobic conditions favors the production of carbon dioxide over the more potent methane gas. This landfill method (also categorized as passive aeration) is accredited as a new emission-reduction method under the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations Framework Convention on Climate Change (UNFCCC) 2013), and presents a new generation of opportunities for Pacific islands to improve the safe management of waste while simultaneously demonstrating leadership by reducing greenhouse gas emissions.

Table 8 Potential climate change impacts on waste disposal sites

Change in climate	Impacts
Increased temperatures and extreme heat events	• Accelerated decomposition of organic waste • Higher rate of evaporation—more concentrated leachate • Increased problems with odor and vectors • Increased risk of landfill fires
Increased wet season rainfall	• Increased leachate generation • Flood risks and increased contamination of surrounding environment from leachate • Increased likelihood of anaerobic waste decomposition and increased landfill gas (methane, carbon dioxide) generation
Decreased dry season rainfall	• Increased dust issues • Increased risk of landfill fires

8 Impacts of Climate Change on MSW Management

The adverse and long-term effects of climate change present significant risks to the sustainable development of PICTs and threaten the very existence of some (Secretariat of the Pacific Regional Environment Programme 2011). Climate change impacts such as increased sea level rise, increased rainfall, and increased cyclone intensity can damage waste management infrastructure leading to pollution, which increases the man-made stresses on natural systems such as coral reefs and mangroves and undermines the adaptive capacity and resilience of these natural systems. Furthermore, adverse weather events typically generate disaster waste, which must be safely managed to minimize further adverse environmental and public health impacts.

Potential climate change impacts on waste disposal sites in the Pacific may include those listed in Table 8. Impacts such as increased leachate generation, dust issues, and inundation from floods and storm surges, will exacerbate existing poor operating conditions. Building adaptive capacity within the waste management sector to cope with climate change impacts is therefore an important facet of responding to climate change.

To this end, SPREP with the assistance of the AusAID International Climate Change Adaptation Initiative (ICCAI) is implementing a project in Fiji to integrate climate change adaptation planning into the waste management sector (Adapt-Waste Project). The target site is a dumpsite in the town of Labasa on Vanua Levu, the 2nd largest island in Fiji. The dumpsite is an ideal demonstration site for adaptation in the waste management sector since the Labasa area faces the direction from which most cyclones arise, and is susceptible to river flooding, and storm surge inundation.

The anticipated outcomes of the AdaptWaste Project include strengthened capacity within the local council and national government for adaptation planning in the waste management sector, rehabilitated waste disposal site with waste diversion programs to better cope with climate change impacts, national guidelines for climate-related disaster waste management, and enhanced public awareness.

8.1 Waste-to-Energy

There is also a growing interest amongst Pacific island communities in exploring waste-to-energy options to potentially reduce dependence on the importation of diesel generator fuel. This interest is being driven primarily by international companies promoting proprietary waste-to-energy technology. A project under development by the Asian Development Bank, also seeks to potentially implement waste-to-energy schemes for the Cook Islands, Palau, Marshall Islands, and Vanuatu.

With the many challenges facing the PICTs (outlined earlier), and an agreed regional goal of adopting cost-effective and self-sustaining solid waste management systems (Secretariat of the Pacific Regional Environment Programme 2010), the Pacific region must take a cautious approach to the adoption of high-tech solutions, particularly those relying heavily on foreign expertise and supplies. All proposals (including those put forward by the Asian Development Bank and other development partners) should be fully investigated from a technical and financial perspective and within the context of possible contradiction with existing waste reduction philosophies, strategies, and programs currently supported in the Region.

9 Local Case Studies

9.1 Waste Minimization and Recycling Promotion in Fiji (Singh 2012)

Fiji with a population of 850,000 largely depends on the importation of goods and materials from the developed countries. Due to its geographical isolation and relatively small recycling market, it is very difficult to recycle waste within Fiji. In addition, finding a suitable landfill site is quite difficult considering local land issues and customary rights.

The Government of Fiji therefore recognized the need to strengthen the capacity of two municipalities—Lautoka City (population of 45,000) and Nadi Town (population of 12,700)—and the Department of Environment (DOE) to promote waste minimization, and embarked on a 42 month technical cooperation project (2008–2012) with JICA entitled “Waste Minimization and Recycling Promotion Project in the Republic of Fiji Islands” (3R Project).

The project scope included: (i) conducting baseline surveys to assess the existing situation and issues relating to solid waste management; (ii) developing Solid

Table 9 Baseline waste management data of Lautoka City and Nadi Town, Fiji

Parameter	Lautoka city	Nadi town
MSW Generation (ton/day)	48.1	22.4
Household waste generation rate (g/person/day)	432	374
Recycling rate (%)	8.1	2.8
MSW generation rate per person (g/person/day)	1,098	1,902
Budget for solid waste management (Fiji Dollars)	1.06 million (20 % of council's total budget)	1.15 million (28 % of council's total budget)
Highest composition of waste (%)	Grass and wood: 37.4 Kitchen organic waste: 30.1	Grass and wood: 36.7 Kitchen organic waste: 36.4

Waste Management Plans for the two municipalities based on baseline data; (iii) implementing pilot projects to examine the applicability, sustainability and expandability of waste minimization practices such as home-composting, market waste composting, Clean Schools program, separate collection for recyclables, and green waste collection and chipping; (iv) improving the operation and management of the Vunato Disposal Site in Lautoka; (v) developing a wide range of educational tools, which were utilized for extensive awareness raising to citizens through house to house visits, and community meetings; and (vi) expanding viable pilot projects to other areas based on the validity and lessons learnt from the pilot projects.

The key data obtained through the baseline surveys are summarized in Table 9. These results subsequently informed the design of several pilot projects aimed at promoting the 3Rs, including separate collection of recyclables, promotion of home composting, development of market waste composting, green waste collection and recycling, and a Clean Schools program.

As a result of the 3R Project, the total recycling rate was increased from 8.1 % to 10.3 % in Lautoka City and from 2.8 % to 18.3 % in Nadi Town as of October 2011. Concomitantly, the waste disposal volumes from 2008 to 2011 have decreased by 7.8 % in Lautoka City and 38.6 % in Nadi Town.

There were many lessons learned during this project including:

- The importance of learning from others; project staff were able to learn firsthand from the successful experience of Shibushi City in Japan, which contributed to the encouragement and commitment of counterparts to the project implementation.
- The mechanism of joint weekly meetings, which contributed significantly to monitoring and stimulating the progress of the project activities, and also to promoting mutual understandings and friendly working relationships between the two municipalities involved.
- The significant role that all stakeholders can play, in particular the community members in the pilot project communities. The Matavolivoli 3R Pilot Project Committee members in Nadi gained a wealth of experience in practicing the 3Rs

and were effectively utilized as 3R promoters by the Nadi Town Council during the expansion of 3R activities to other communities.

One of the major challenges of the project has been the difficulty in bringing about behavioral change amongst citizens since the 3R concept is a new one and requires voluntarily participation of the citizens to embrace 3R's. Hence, it is expected that the planned enactment of 3R legislation would compel the citizens to engage and practice 3Rs.

In conclusion, the 3R Project is a success story for the Pacific region, wherein vital equipment has been procured and various educational tools, guides, plans and manuals have been developed to assist in promoting and sustaining 3R practices. The technical capacities of the staff from the municipalities (Lautoka City and Nadi Town) have also been greatly developed to support the expansion of 3R practices throughout Fiji and the Pacific region into the future.

10 Towards Sustainable Waste Management Financing in French Polynesia (Ebelewicz 2012)

French Polynesia is an Overseas Territory of France with a substantial degree of autonomy. It consists of five main island groups scattered across five million square kilometres and is located midway between Australia and South America (Central Intelligence Agency 2013).

French Polynesia has a resident population of 250,000, and an estimated 200,000 tourist arrivals annually. Increasing goods imports driven by an increasing population have resulted in increasing quantities of garbage generation. Despite the implementation of waste management programs and waste treatment efforts, the problem remains significant in urban areas and in areas of high human visitation (Gabrié et al. 2007).

In relative terms, the management of solid waste is considered to be significantly more technologically advanced in the main island of French Polynesia (Tahiti) than in other Pacific island countries. The current waste management system is operated under contract by a semi-public company, *Société Environnement Polynésien*, and includes:

- a two-bin system for residential waste collection consisting of a grey bin for general waste and a green bin for recyclables, which are further sorted at a Materials Recycling Facility;
- a recycling and transfer center in Motu Uta for direct re-loading of municipal solid waste, and sorting and bailing of recyclable materials (developed at a cost of US$ 5 million (excluding land acquisition costs));
- waste transfer facilities at Punaauia Municipality and Moorea island;

- a fully lined engineered landfill site located in Paihoro, with leachate collection and treatment (aeration and filtration) facilities, developed at a cost of US$6.7 Million (land acquisition costs excluded); and
- a landfill compaction vehicle which achieves a high waste compaction density of 1,000 kg/m^3.

These systems, while being technically and environmentally sound, required financial subsidies by the Government of France for construction and involve high ongoing operating costs, which are currently subsidized.

The cost for solid waste management was previously covered by a 50 % contribution from the French Polynesia Government (financed through a 2 % environmental tax on all imported goods), a 25 % contribution from 12 of the 13 Municipalities involved, and a 25 % contribution from an inter-municipality equalization fund that included a contribution from the Government of France. These funds were used to engage the managing company, *Société Environnement Polynésien,* to establish and operate the environmentally friendly waste treatment processes.

However, the inter-municipality equalization fund was discontinued in 2009, and the contribution from the French Polynesia Government will be phased out between 2012 and 2017. Consequently, the total cost (100 %) of waste management (collection, treatment (recycling), and landfilling) will become the responsibility of each of the 12 municipalities in 2017, to be ultimately financed from user-pay (household) charges.

A new partnership of Municipalities (*Syndicat Mixte*) is to be esablished to replace the role of the *Société Environnement Polynésien*. Ideally, the proposed partnership should include all Municipalities, however, at the time of writing, Faa'a Municipality remains independent and provides its own collection service (unsorted waste) and operates its own municipal landfill. The partnership will be autonomous in managing the services, and will be able adjust rates to achieve full cost recovery. Municipalities will have to systematically increase the household waste charge over a five-year period (2012–2017) to the level required to achieve full cost recovery, otherwise the current solid waste management system operating in Tahiti is unlikely to be sustainable with the present level of household charges.

In 2012, the *Agence de l'Environnement et de la Maîtrise de l'Energie* (*ADEME*—a French Agency responsible for Energy and Environment) was in the process of reviewing the current system of solid waste collection and recycling in French Polynesia, and assessing the cost/benefit of recycling to the island's population, because the unit cost was thought to be potentially disproportionate to the benefits. The outcomes of this review will not only guide improvements in the waste management financing situation in French Polynesia, but will also be an instructive case study for the Pacific region on achieving financial sustainability in municipal solid waste management.

While the waste management systems established by the managing agency in Tahiti are technically and environmentally sound (if not yet financially self-sustaining), many of the smaller, sparsely populated French Polynesian islands face similar waste management problems as other Pacific island countries due to the lack of space and the contamination risk to freshwater lenses located at shallow depths (Gabrié et al. 2007).

On these islands, efforts are also being made to establish systems for the collection of bulky and hazardous wastes such as motor vehicles, used oil (lubricants), lead acid batteries, tires, cars and dry cell batteries, with future plans to collect other recyclables such as plastics, cans and paper.

11 Summary

The Pacific islands face many solid waste management challenges as a consequence of their physical and geographic characteristics, economic development and specific cultural practices. Climate change, legacy hazardous waste issues, and emerging priorities in hazardous waste management add to those challenges. However, with the assistance of donors and development partners through various regional and bilateral initiatives, progress is steadily being made to improve solid and hazardous waste management policies, systems and practices throughout the region.

The challenge for the future lies in sourcing seed-financing to enable the adoption of self-sustaining and cost-effective systems that will contribute to preserving and restoring the integrity of the Pacific environment for future generations.

12 Defining Terms

Clean Development Mechanism: A provision under the Kyoto Protocol of the United Nations Framework Convention on Climate change under which emission-reduction projects in developing countries can earn certified emission reduction credits. These saleable credits can be used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol, while the revenue from the sales can be used by the developing countries to implement emission-reduction projects.

Customary tenure: A system of land ownership, where land rights are managed by indigenous communities or family groups according to their unique processes, which are linked to underlying social and spiritual belief systems.

Semi-aerobic Landfill (or Fukuoka Method): An engineered, sanitary landfill that contains a network of leachate collection pipes and gas venting pipes, which facilitate the passive aeration of the waste layers by natural convection induced by the heat of the decomposing waste.

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Municipal Solid Waste Management in the Philippines

Albert Altarejos Magalang

1 Introduction

The Philippines like most developing countries in Asia and the Pacific Region faces more pronounced waste management challenges in urban metropolitan centres. As reported by World Bank in 2001, cities within Metro Manila generate almost 25 % of the country's total waste generation.

These challenges can be attributed to high population density that can bring about high levels of concentration and consumption of packaged foodstuffs and goods. Packaging materials are manufactured from raw materials that may contain non-environmentally acceptable products. There remains also a challenge to deal with disposable or throw-away products whose material components are non-durable and of single use. If these materials remain unmanaged, they can contribute to the severity of the present garbage problem in highly urbanized cities.

With a growing population and a rapidly increasing consumption coupled with increasing urbanization, three key trends characterize solid waste management issues in the Philippines—increase in shear volume of waste generated; change in the quality or make-up of waste generated; and the waste disposal methods.

2 Definition of Municipal Solid Waste

The existing law on ecological solid waste management which is the Republic Act 9003 of 2000 defines solid waste as all discarded household, commercial waste, non-hazardous institutional and industrial waste, street sweepings, construction debris, agriculture waste, and other non-hazardous/non-toxic solid waste.

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Unless specifically noted, the term "solid waste" as used in this Act shall not include:

a) waste identified or listed as hazardous waste of a solid, liquid, contained gaseous or semisolid form which may cause or contribute to an increase in mortality or in serious or incapacitating reversible illness, or acute/chronic effect on the health of persons and other organisms;
b) infectious waste from hospitals such as equipment, instruments, utensils, and fomites of a disposable nature from patients who are suspected to have or have been diagnosed as having communicable diseases and must therefore be isolated as required by public health agencies, laboratory wastes such as pathological specimens (i.e., all tissues, specimens of blood elements, excreta, and secretions obtained from patients or laboratory animals), and disposable fomites that may harbour or transmit pathogenic organisms, and surgical operating room pathologic specimens and disposable fomites attendant thereto, and similar disposable materials from outpatient areas and emergency rooms; and
c) waste resulting from mining activities, including contaminated soil and debris

3 Waste Generation and Composition of Solid Wastes

Table 1 was derived from the report by the secretariat of the National Solid Waste Management Commission (NSMWC/S) which shows the daily waste generation by tonnage of the 1,610 local government units by geographical region. The estimated volume was computed by multiplying the average waste generation per capita by the population of each region. The National Capital Region, where Metro Manila is located, recorded the highest waste generation rate of 0.71 kg/capita/day

4 Composition of Solid Wastes

The only data available on waste composition are the results of the waste analysis and characterization survey (WACS) conducted by the Asian Development Bank for Metro Manila in 2003. The WACS was conducted through the technical assistance project of ADB (Asian Development Bank-Metro Manila Solid Waste Management Project, 2002–2003.) specifically for the cities of Makati, Muntinlupa, Pasig, Valenzuela and Quezon City.

The Table 2 shows the results of the findings of the study. Waste generation rates ranged from 0.32 kg/capita/day in Valenzuela City to 0.63 kg/capita/day in Quezon City recorded the highest generation rate of 0.63 kg per capita while Valenzuela City had the lowest of 0.32 kg per capita.

Table 1 Estimated waste generation by region

Region	Daily estimated volume (in tons)	Yearly estimated volume (in million tons)
1	1,640.73	0.5989
2	1,056.57	0.3856
3	3,486.55	1.2726
4-A	3,979.52	1.4525
4-B	873.01	0.3186
5	1,803.51	0.6583
6	2,592.02	0.9461
7	2,501.34	0.9130
8	1,420.22	0.5184
9	1,336.21	0.4877
10	1,626.10	0.5935
11	1,745.25	0.6370
12	1,294.21	0.4724
13	849.26	0.3100
Cordillera Autonomous Region	595.79	0.2175
National Capital Region	8,257.17	3.0139
Autonomous Region of Muslim Mindanao	871.29	0.3180
Total	35,928.75	13.1140

Source NSWMC Secretariat, 2010

Table 2 Results of waste analysis and characterization survey

	Makati	Muntinlupa	Pasig	Valenzuela	Quezon city
Population	421,308	366,674	528,179	519,227	2,301,261
Waste generation average per capita (in kg)	0.57	0.60	0.53	0.32	0.63
Bulk density (avg. kg/cu.m.)	92	172	139	159	218
Moisture content (avg. % air dry)	41	29	33	67	38
Paper	14.7	10.2	12.4	11.3	14.1
Glass	2.4	3.1	5.0	1.4	3.4
Metals	2.7	3.9	11.6	3.1	3.6
Plastics	25.0	28.1	20.9	28.3	21.4
Food waste	32.6	29.1	23.1	38.0	39.9
Other organic	18.9	20.4	18.9	14.2	14.8
Other inorganic	3.5	5.0	6.7	2.2	2.4
Hazardous/special	0.2	0.2	1.4	0.6	0.4

Source ADB Study 2003

Figure 1 shows the composition of wastes from five Metro Manila (5) cities that were covered by the survey (WACS). It was observed that food and other organic wastes comprise about an average of 50 % of total waste generation in each city

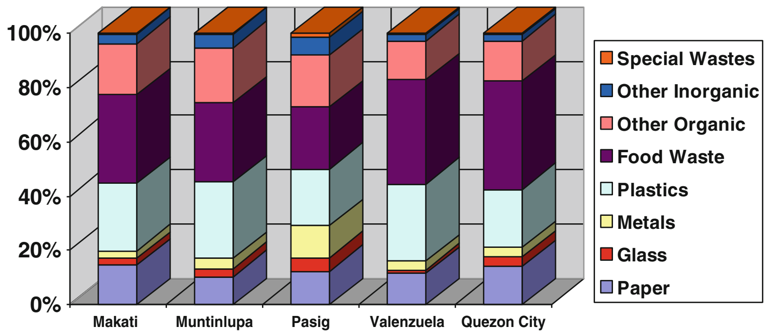

Fig. 1 Comparative waste composition data from five (5) Metro Manila cities. *Source* ADB Study 2003

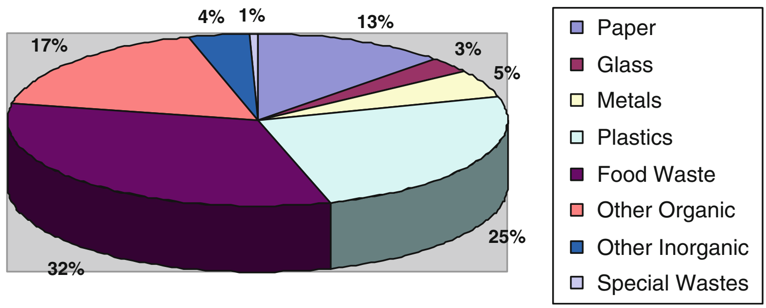

Fig. 2 Average % composition of metro manila wastes

(51.5 % in Makati; 49.5 % in Muntinlupa; 42 % in Pasig; 54.7 % in Quezon City and 52.2 in Valenzuela). The recyclables, including the plastic with 21–28 %, comprise around 42–49 % of the waste. Other inorganics and special wastes comprise about 2–6 % and 0.2–1.4 %, respectively.

The average percentage of the wastecomposition for the five (5) cities was taken in order to get the waste characterization of Metro Manila. Figure 2 shows the waste composition in percentages.

5 Legal Framework

The Ecological Solid Waste Management Act or Republic Act 9003 promotes a paradigm that waste is a resource that can be recovered. The Act puts source reduction and minimization of wastes generated at source and resource recovery, recycling and reuse of wastes as the most preferred options for solid waste management. RA 9003 placed legislated mandatory targets for solid waste diversion, at

25 % waste diversion in the first three years of the Act and increased every three years thereafter.

Other relevant laws enacted at the national level which are relevant to the implementation of RA 9003 are the following:

National law	Description
Republic Act No. 7160	The Local Government Code devolved certain powers to the local governments units, including that enforcement of laws and cleanliness and sanitation, solid waste management, and other environmental matters
Republic Act No. 9275	The Philippine Clean Water Act of 2004 provides for the protection, preservation, revival of quality of fresh, brackish and marine waters of the country to pursue economic growth
Republic Act No. 8749	The Clean Air Act of 1999 which directs all government agencies to adopt the integrated air quality framework as blueprint for compliance. Among its salient provisions are: "Polluters must pay" and the prohibition on the of the use of incineration method which is defined as the burning of municipal, biomedical and hazardous waste or process which emits poisonous and toxic fumes. The prohibition of burning does not apply to traditional small-scale method of community/neighborhood sanitation "siga", traditional agricultural, cultural, health, and food preparation and crematoria. It further mandated LGUs to promote, encourage, and implement segregation, recycling and composting within their jurisdiction. It also required the phasing out of incinerators by July 2003
Republic Act No. 6969	The Toxic Substances and Hazardous and Nuclear Waste Act of 1990. It calls for the regulation and restriction on the importation, manufacture, processing, sale, distribution, use and disposal of chemical substances and mixtures that pose risk and/or injury to health and environment. It prohibits the entry, transport of hazardous and nuclear wastes and disposal into the Philippine territory. It also mandates to provide advance studies and researches on toxic chemicals
Presidential decree No. 856	The Code of Sanitation of the Philippines prescribing Sanitation requirements for hospital, markets, port, airport, vessels, aircraft, food establishment, buildings, and other establishments. Refuse collection and disposal system in cities and municipalities are described in Chapter XVIII of the law.
Presidential decree No. 1586 of June 11,1978	Establishes and institutionalizes an environmental impact system where projects to be undertaken would be reconciled with the requirements of environmental quality. It requires proponents of critical projects and projects located in critical areas to secure an environmental compliance certificate (ECC) areas from the President or his duly authorized representative

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National law	Description
Presidential decree No. 1151	The Philippine Environment Policy whereby all national government agencies and its instrumentalities, government and private corporations, entities, firms are required to accomplish and submit Environmental Impact Statements (EIS) for every action, project or undertaking which significantly affect the quality of the environment
Presidential decree No. 1160	Vesting authority in Barangay Captains (also Barangay Chairmen) enforce pollution and environmental control laws. It also deputizes the Barangay Councilman and Barangay Zone Chairman as peace officers
Republic Act No. 9512	Refers to the Environmental Awareness and Education Act of 2008. This promotes environmental awareness through environmental education. It integrates environmental education in the school curricula at all levels, public or private, barangay day care and pre-school, non-formal, vocational, and indigenous learning

6 Current Waste Management System

The country's current waste management system is clearly defined in the existing primary law on solid waste management which is the Republic Act 9003 of 2000 (Fig. 3). The waste management system involves the formulation of guidelines and setting of targets for waste avoidance and volume reduction through source reduction and waste minimization measures including composting, recycling, re-use, recovery and other processes before collection, treatment and disposal in appropriate and environmentally sound solid waste management facilities.

Under the Act, the local government units are the primary institutional mechanisms for implementing RA 9003. However, the Act also promotes active collaboration between the local government units and the private sector and encourages partnership with cooperatives and associations working on solid waste management.

The waste management law promotes solid waste management following a hierarchy of options (Fig. 4). These options encompass the entire scope of activities involved in waste management starting from volume reduction up to the final waste disposal. The hierarchy also complements with the levels of governance starting from households up to the province or metro wide level of political units.

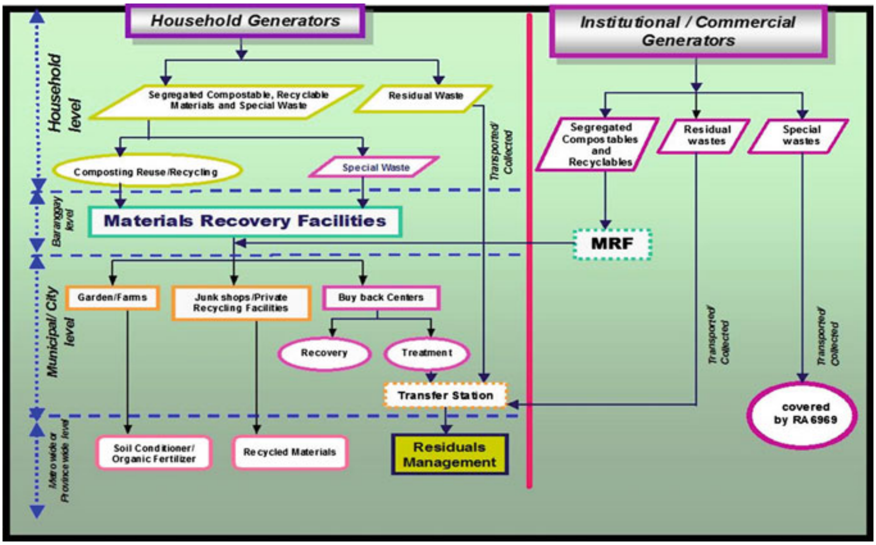


Fig. 3 The SWM system prescribed by Republic Act 9003

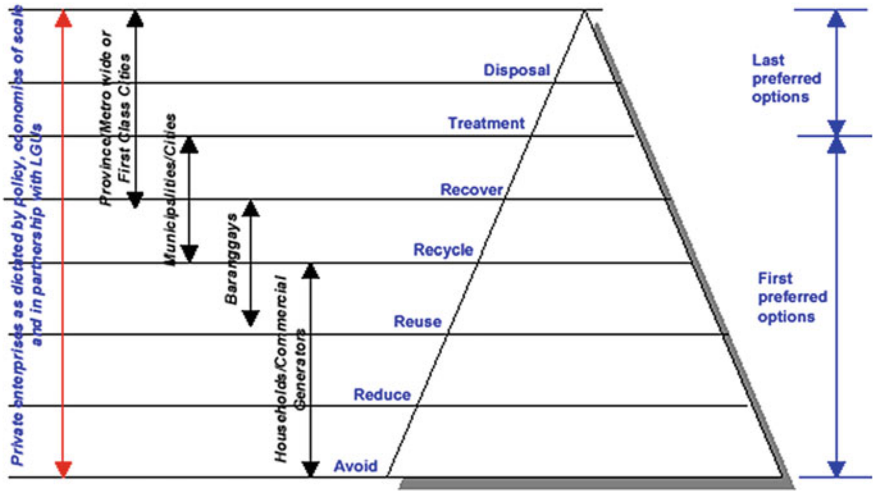


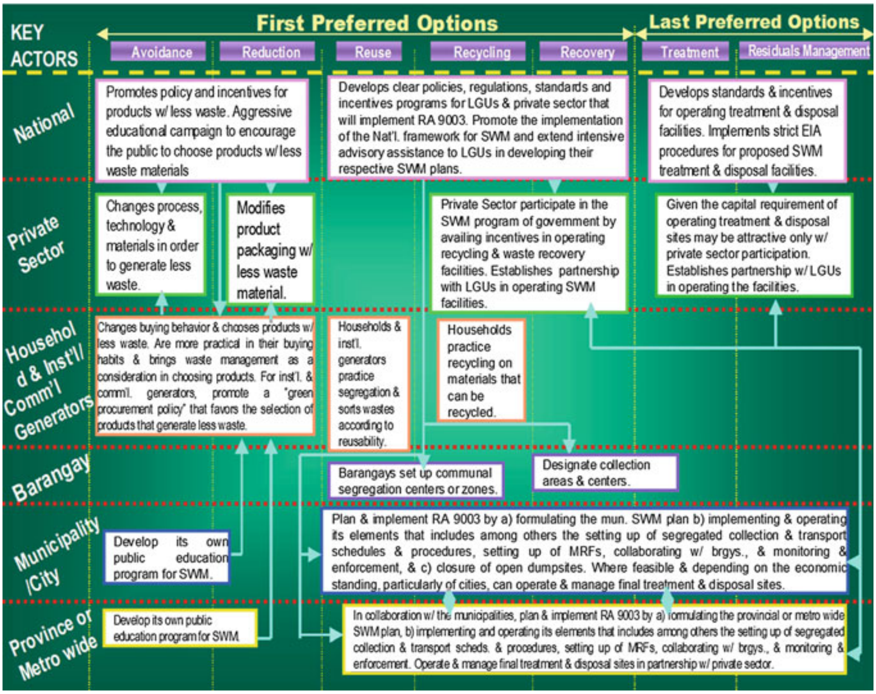
Fig. 4 Ecological solid waste management hierarchy (*Source*: The Philippine National Solid Waste Management Framework, DENR, NSWMC, UNDP 2005)

7 Roles of Local Government Units

The existing waste management system likewise delineates the roles of city or municipal government and the barangays in implementing waste diversion as follows:

a. barangays (or villages) are required to implement mandatory source segregation, to establish materials recovery facility, to collect and process the recyclables and biodegradables. The recyclables are further sorted in Material Recovery Facilities (MRF) and are sold to junkshops while the biodegradables are processed into composts
b. municipal/city government, on the other hand, is tasked to collect and disposed residual and special wastes. For the latter, municipal governments are required to set-up a separate and contained physical areas in their disposal facilities, and whenever feasible, encourage take-back schemes by manufacturers and traders, manage the control, transfer, transport, processing and disposal of solid wastes in the country. This delineation of roles is graphically presented in Table 3.

Table 3 Levels of governance in SWM



Source The National Solid Waste Management Framework

8 Waste Segregation and Volume Reduction at Source

Sorting and segregation of biodegradable and non-biodegradable wastes are done at the household level and all other sources. It is also mandated that wastes segregation shall primarily be conducted at the source, to include household, institutional, industrial, commercial and agricultural sources. Solid wastes shall be segregated and labelled with the following categories: "compostable", "non-recyclable", "recyclable", or "special waste".

The law defines segregation as a solid waste management practice of separating different materials found in waste stream in order to promote recycling and reuse of resources and to reduce the volume of waste for collection and disposal. Some LGUs have strictly enforced segregation at source coupled with segregated collection, through a "no segregation, no collection" ordinance. Compliance of LGUs on the mandatory segregation at source ranges from 53–100 % based on a validation conducted on selected LGUs identified as having good practices on solid waste management.

Role of Materials Recovery Facilities in Waste 3Rs

The law mandates that Material Recovery Facilities (MRFs) shall be established in every barangay or cluster of barangays, The MRF includes a solid waste transfer station or sorting station, drop-off center, a composting facility, and a recycling facility. MRFs serve to reduce the amount of wastes to be disposed of mainly through recycling, composting, and residual treatment. The combination of

Fig. 5 MRFs (Materials Recovery Facilities)

MRF, composting, and other processing activities in some cases are done in so-called Eco-parks.

According to the NSWMC Secretariat, as of 2010, a total of 6,957 MRFs have been established, serving a total of 7,939 barangays from 1,265 MRFs in 2006, serving a total of 1,672 barangays (villages), or an increase of 79 % in the number of barangays covered for a period of four years. Moreover, in recent years, MRFs have also been established in schools, malls, and other commercial establishments (Fig. 5).

9 Collection, Transport and Handling of Solid Wastes

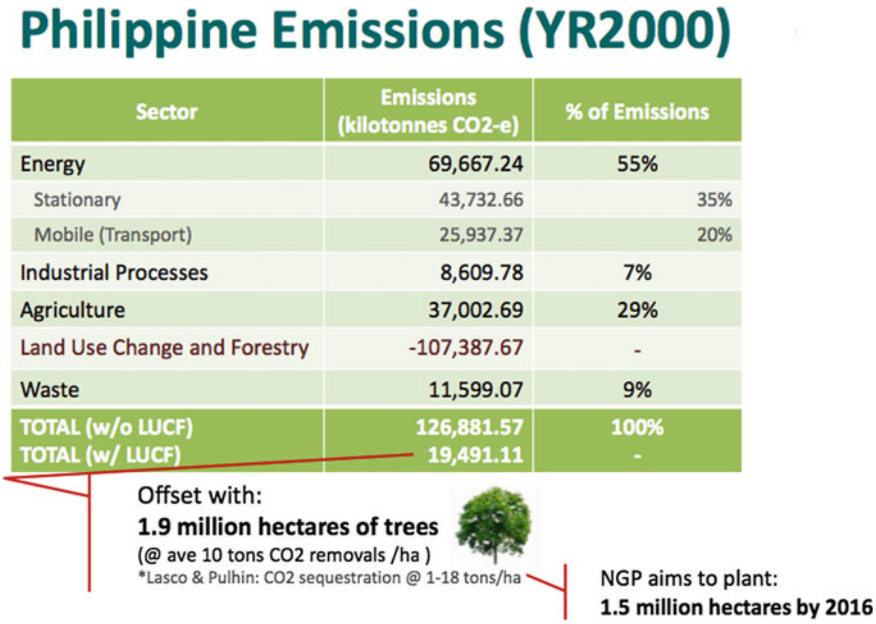
The waste management law defines waste collection as the act of removing solid waste from the source or from a communal storage point. It also provides for a segregated collection of solid wastes. The law further mandates the use of separate collection vehicles, schedules and/or separate trucks or haulers for specific types of wastes.

The vehicles used for the collection and transport of solid wastes have the appropriate compartments to facilitate efficient storing of sorted wastes while in transit. LGUs are primarily responsible for the collection of solid wastes. At the barangay level, waste segregation and collection is conducted specifically for biodegradable/compostable and reusable/recyclable wastes (Rule VIII of the IRR). The cities and municipalities are responsible for the collection and disposal of non-recyclables (residuals) and special wastes using various methods such as: door-to-door collection; stationary collection through the MRFs; and mobile waste collection thru waste collection vehicles.

10 MSW and Climate Change

The results of the latest inventory of greenhouse gases in the Philippines shows that the waste sector contributes 9 % of the total GHG emission which is equivalent to 11,599.07 kilotonnes of CO_2-equivalent (Fig. 6).

But despite of this insignificant GHG emission from the waste sector, the National Climate Change Action Plan, 2011–2028 (NCCAP) recognizes the significance of ecological solid waste management in climate change mitigation and



Sector	Emissions (kilotonnes CO2-e)	% of Emissions
Energy	69,667.24	55%
Stationary	43,732.66	35%
Mobile (Transport)	25,937.37	20%
Industrial Processes	8,609.78	7%
Agriculture	37,002.69	29%
Land Use Change and Forestry	-107,387.67	-
Waste	11,599.07	9%
TOTAL (w/o LUCF)	126,881.57	100%
TOTAL (w/ LUCF)	19,491.11	-

Fig. 6 MSW contribution to GHG emission (*Source*: The Philippine Second National Communication to the United Nations Framework Convention on Climate Change, Philippines, DENR/EMB-CCO 2012)

adaptation as one of its outputs. This is being considered in the Plan's immediate outcome to develop, promote and sustain green cities and municipalities. Relative to this, the following plan of action will be implemented:

a) intensify waste segregation at source, discard recovery, composting and recycling.
b) regulate the use of single-use and toxic packaging materials.
c) Close down polluting waste treatment and disposal facilities.

The specific activities and outputs of the NCCAP in relation to ecological solid waste management are presented in Table 4.

Table 4. National Climate Change Action Plan re SWM: Goals and Outcomes

Table 4 National climate change action plan re SWM: goals and outcomes

Activities	Outputs	2001–2016	2017–2022	2023–2028
3.3.1. Intensify waste segregation at source, discard recovery, composting, and recycling.				
a) Enforce Ra 9003 in every barangay and local government unit.	RA 9003 complied with by all LGUs.	■		
b) Conduct intensive IEC on waste reduction, segregation and composting.	IEC on waste reduction, segregation and composting conducted.	■		
c) Establish at-store recycling programs, especially for electronic wastes (e-waste) and low-value recyclables	At-store recycling program established.	■		
d) Organize informal waste workers-small/medium recyclers-business partnership program to support intensified waste recovery and recycling.	Partnership program between informal waste workers and small/medium recyclers organized.	■	■	■
e) Design and implement incentive mechanisms to strengthen the local recycling industry and expand waste markets.	Incentive mechanisms studied, designed and implemented to strengthen the local recycling industry and expand waste markets.			
a) Identify and create an inventory of toxic and non-environmentally acceptable packaging materials.	Toxic and non-environmentally acceptable packaging materials indentified.	■		
b) Conduct a studey and develop a policy, s appropriate, on regulating single-use and toxic packaging materials.	Policy study on regulating single-use and toxic packaging materials conducted.	■		
c) Develop and implement a system of incentives for the use of reusable bags and containers.	System of incentives for the use of reusable bags and containers developed and implemented.	■		

(continued)

Table 4 (continued)

Activities	Outputs	2001–2016	2017–2022	2023–2028
d) Conduct, in partnership with the private sector and civil society organizations, an intensive IEC program on re-usable bags and "bring-your-own-bag" (BYOP) system.	Intensive IEC program on reusable bags and "BYOB" system conducted.	■	■	■
e) Ratify the Basel Convention Ban Amendment, which bans hazardous wastes exports for final disposal and recycling from what are known as Annex VII countries (Basel convention parties that are members of the EU, OECD, Liechtenstein) to non-Annex VII countries (all other parties to the convention).	Basel convention ban amendment rectified by congress.		■	
3.3.3. Close down polluting waste treatment and disposal facilities.				
a) Close down all dumpsites and waste disposal facilities located in environmentally-critical areas.	Dumpsites and waste disposal facilities located in environmentally-critical areas closed.	■		
b) Implement policy for non-dumping of organic wastes in sanitary landfills.	Policy for non-dumping of organic wastes in sanitary landfills implemented.	■		

Source National Climate Change Action Plan 2011–2028. Climate Change Commission. 2011

11 Case Study: The Plastic Bag Reduction and Recovery Program of Quezon City

On October 2, 2012, the Quezon City local government passed the Ordinance No. SP-2140 or the Plastic Bag Reduction Ordinance, "An ordinance regulating the use of plastic bags and establishing an environmental fee for its use, providing mechanism for its recovery and recycling and providing penalties for violation thereof".

The city government was prompted to enact this Ordinance as a abatement measure to address the following results of the recent WACS it conducted such as:

Parameter	Value
waste intake at Payatas disposal facility	1,259 tons/day or 1,259,000 kgs/day
% and weight of assorted plastic materials in the waste stream	21 % or 264,390 kgs/day
% and weight of plastic bags in the waste stream	12 % or 151,080 kgs/day
density of waste	210 kgs/m^3
Volume of plastic bags in the waste stream	719 m^3 day or 45 10-wheeler truckload

The significant volume reduction of plastic bags in the waste stream as claimed by the city government would result to minimized litter nuisance and would avoid clogging up of sewerage systems and waterways that is causing floods.

Major implementers of the said ordinance are the "relevant retailers" or otherwise the establishments which are classified into two types such as:

	Establishment
Type 1	• shopping malls, supermarkets, department stores, fast food chains, food stalls, etc.
Type 2	• wet and dry markets, talipapa, tiangge, hawkers, etc.

Section 4. Regulations on the Use of Plastic Bags—The following regulations shall be imposed on the use of plastic bags as carryout bag:

a) Distribution of plastic bags by "Relevant Retailers" lower than the regulated thickness of 15 microns is prohibited under this Ordinance.
b) To ensure the recovery of plastic bags from the waste stream, consumers who will not bring with them "reusable bags" and/or redeem "used plastic bags" for a new plastic bag, shall be charged with a "plastic recovery system fee". Said fee shall be indicated in the customer's transaction receipt as a reminder that they can save money if they use reusable bags and/or if they bring used plastic bags in exchange for a new plastic bag.
c) Stall owners/lessees in wet and dry markets will not be allowed to directly distribute plastic bags… The market management shall assign areas within the market where these plastic bags may be purchased with corresponding transaction receipt.
d) Plastic bags with no handles, holes or strings commonly used for wrapping unpacked fresh foods and cooked foods at supermarkets, restaurants, canteen and the like shall not be included under the scheme as the usage of such plastic bag is justified on the grounds of public hygiene.

* * * *

Section 5. Purpose of the "Plastic Recovery System Fee". Primarily, the imposition of the "fee" seeks to change consumer behaviour rather than generate fund. It is a move towards shifting habits from mindless consumption to a lifestyle that is anchored on the 3 R's of Waste Management.

Further, this "Plastic Recovery System Fee" shall be earmarked for a "green fund" that shall be maintained by the stores to fund other initiatives that would benefit the environment.

Source Quezon City Ordinance No. SP-2140, S-2012.

A Plastic Bag Recovery System fee of •2.00 will be charged to consumers who are not using a reusable bag for every carryout bag that will be provided by the retailer. The fee can be refunded by the consumer if the used carryout bag will be brought back to the store provided that the bag is clean, dry and folded.

Retailers are also enjoined to formulate incentive system or point system for consumers who are using reusable bags or to have a "Green Lane" or special cash counters to facilitate store transactions by consumers who are complying with the city ordinance.

The following are the infraction and penalties that will be charged against any establishment that will violate the provisions of the city ordinance.

1st Offense	A fine not exceeding ₱1,000.00
2nd Offense	A fine not exceeding ₱3,000.00
3rd Offence	A fine not exceeding ₱5,000.00 and cancellation of business permit

The City Ordinance is one of the many options that tackles and deals with the "throw-away" mentality of product consumers through its intent of setting up a system of effective reduction and recovery scheme. The participation of both the citizens and the business sector is vital in effecting the regulation related to 3R's of waste management. This likewise requires utmost political will from government enforcers.

Regulations with monetary-based mechanism such as the imposition of an environmental fee could also address the senseless consumption and optimize the use of products. These would further mainstream the use of recyclable and reusable goods in consumption patterns and at the same time, entice significant participation from the general public in sustaining a clean and a healthy environment.

12 Conclusion

The Philippines, through the implementation of Republic Act 9003, adopts an ecological solid waste management program that would involve systematic and comprehensive approaches and procedures.

The provisions of the law would require environmentally-sound methods that optimize the utilization of resources and encourage resources conservation and recovery; set guidelines and targets for solid waste avoidance and volume reduction through source reduction and waste minimization measures; ensure the proper segregation, collection, transport, storage, treatment and disposal of solid waste through the formulation and adoption of the best environmental practices in ecological waste management; and encourage greater private sector participation in SWM; among others.

The enforcement of the law places greater burden on the hands of the local government units in finding ways and means in improving solid waste management at the local level. At the municipality and barangay levels, the local government units need to provide the leadership and persistence in ensuring that waste avoidance and reduction are in place.

Local ordinances that provide enabling mechanism for the effective implementation of national law, are important in promoting compliance with solid waste management rules and regulations. Complementing with the issuance of the ordinance, information and education campaign should be undertaken as a support mechanism.

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Solid Waste Management in Sri Lanka

B. F. A. Basnayake and C. Visvanathan

1 Introduction

Municipal Solid Waste (MSW) is a grave problem in many parts of the country. The problems of waste management have been curtailed to some extent through improved collection systems and awareness programs. Even the quantity of recyclable materials is more than before. In fact, the lacking of final disposal facilities is the critical issue. The government agencies and local authorities (LAs) are in the process of selecting the technologies and implementing best possible options. While the final disposal systems are established and likely to be implemented, it will be an opportune time to put into effect point source separation programs. Both these issues may not be addressed to the required expectations because of inadequate knowledge base on solid waste management (SWM) with the required social development in Sri Lanka. But currently, the Defence Secretary who is also the Secretary to Urban Development mobilized the army personnel to improve the collection system in major towns. Now, the Colombo city is aesthetically very pleasing without garbage being sprawled on the roadsides, pavements and embankments. The walkways, pavements and roads have been improved too. The collection efficiency may have increased to over 90 %. Only about 10 % of the collections have been delayed due to traffic congestions and delays at the disposal sites. After these improvements, the Defence Secretary has handed over once again the responsibilities to the Colombo Municipal Council. In Kandy, although the army was not directly involved in improving the collection

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system, they have been instrumental in providing advice, heavy equipment and logistics. They also assist in the monitoring of collection and disposal of wastes. The collection efficiency may have reached 75 %. Only a small fraction of the total generation of garden wastes is collected.

In the meantime, all of the wastes dumped are continuing to cause serious problems to the health of the population and environment. The IPCC waste model showed that the methane emissions from open dumping are significant for the first 40 years after waste disposal. Based on the available and default values, the estimated total potential methane generation from 1 tonne of waste is 29 kg of CH_4 (Menikpura et al. 2012). The disposal sites are unmanageable with increased quantities of collected wastes. The rate of MSW generation is increasing with increasing population, technological development and ever changing lifestyle which is one of the major reasons for increasing the volume of waste is unsustainable consumption and production. LAs are responsible for execution of SWM services under the LAs Act in Sri Lanka. In most of the urban centers as mentioned before waste is collected, but mixed, without any segregation and dumped in vacant slots, marshy areas, water courses, open quarries and other low lying areas. This has led to numerous negative impacts on the surrounding environment like soil, ground water and air. At present, LAs are facing numerous issues and fail to provide efficient waste management systems. Hence, formulation of sustainable SWM systems is essential.

This chapter is structured to provide basic information about existing waste management systems supported by national level program, policies and regulations, current 3R practices and investments for successful implementation of solid waste related projects. The final segment of this chapter presents the future directions and policy interventions for sustainable SWM in the country.

2 Geography and Institutional Setup

Sri Lanka is an island situated between 5° 55′–9° 50′ North latitude and 79° 42′–81° 53′ East longitude of the equator below the Indian subcontinent. Its span is 447 km from north to south and 219 km from east to west. The island has nine provinces with the total area of 65,610 km^2 of which 62,705 km^2 is land area and 2,905 km^2 inland waters. Sri Lanka has a tropical climate which consists of three major climatic zones namely, wet zone, intermediate zone and dry zone.

It has a decentralized system of government, structured as follows: 9 Provincial Councils (PCs) and 335 Local Authorities (LAs) made up of 23 Municipal Councils (MCs), 41 Urban Councils (UCs) for semi developed areas, and 271 Divisional Councils (DCs) or Pradeshiya Sabha.

3 Population and Waste Generation

Sri Lanka is a multi-ethnic nation with a literacy rate of 91.9 %, which is one of the highest in Asia. The total population of the country is 21 million (1 % growth rate) with population density of 333 persons/km^2. It is a low-income developing country with 0.691 human development indexes and a 74.9-year life expectancy (Central Bank of Sri Lanka 2011). The urban population is distributed throughout 134 cities and towns of which Colombo accounts for about 20 %. Urban populations are expected to grow from 4 to 6.5 million by 2030, at which time 30 % of the population is expected to be living in urban centres.

Sri Lanka is a developing economy off the southern coast of India. In spite of years of civil war, the country has recorded strong growth rates in recent years. The main sectors of the Sri Lanka's economy are tourism, tea export, apparel, textile and rice production. Remittances constitute the most important part of country's revenue. The Gross Domestic Product (GDP) Growth Rate (http://www.tradingeconomics.com/sri-lanka/gdp-growth, accessed 11th Jan 2013) averaged 6.4 % from 2003 until 2012, reaching an all-time high of 8.6 % in December of 2010, fastest since independence and a record low of 1.5 % in March of 2009. The first, second, and the third quarters of 2012 have shown economic growth rates of 7.9, 6.4, and 4.8 %, respectively. In September the Central Bank lowered the 2012 economic growth estimate to 6.8 % from an earlier 7.2 % due to the prolonged drought that destroyed the paddy harvest and forced the power sector to use more expensive thermal power due to lack of hydropower capacity. Growth in the tourism sector was particularly strong, with earnings last year rising by more than 41 %. The inflation rate has also been brought under control, holding out the possibility of lower interest rates in 2013. (Bussiness Times 2012; Colombo Page 2012).

The annual growth rate of waste generation was estimated at 1.2 %. It is likely to have increased within the last few years and the total generation of MSW can be conceptualized as the solid waste generated within the territorial limits of a LA and independently of its source of generation. The data available that would be helpful to estimate the total quantity of MSW generated in the country was not entirely accurate since recent increases in wastes has not been accounted. In 1999, the approximate MSW generation in Sri Lanka was estimated to be around 6400 t/day (UNEP 2001), thus at the rate of 1.2 %, total MSW generation in 2012 would be around 7300 t/day. While the Western Province, the biggest waste generator, accounts for 35 % of the country's waste, the Southern Province accounted only for about 9 % (MoE 1999) at the lowest per capita waste generation in the country. Table 1 depicts the specific population of each area and per capita waste generation in Sri Lanka.

In Sri Lanka, the solid waste from different sources is identified as residential, commercial, institutional, biomedical, construction and demolition, industrial and agricultural wastes. The existence of different waste classification systems in the country based on the source, creates difficulty to interpret the results of waste

Table 1 Population and waste generation trend in Sri Lankan provinces

Province	Western	Southern	Central	Sabaragamuwa	North-Western	Uva	North-Central	Northern	Eastern
Population 2012 (millions)	5.99	2.55	2.74	1.97	2.39	1.35	1.26	1.22	1.59
Waste generation (t/day)	3500	630	775	523	942	389	344	373	483
Per capita generation (kg/day)	0.58	0.25	0.29	0.27	0.40	0.29	0.28	0.31	0.31

quantification and the services provided by the LAs. The primary sources of the MSW are considered as households, markets and commercial establishments while the secondary sources are industries and hospitals.

4 MSW Composition and Characteristics

In Sri Lanka, more than 60 % of MSW is biodegradable organic matter (Fig. 1) which is comparable with the other Asian developing countries like India, Thailand, China, etc. This organic fraction consists as a significant portion of long term biodegradables such as king coconut shells, banana stalks, logs, tree cuttings, saw dust, wood chips and paddy husks. Due to the rapid economic development, a tremendous increase in non-degradable packaging materials such as plastic, polythene, metals and glass can be seen in recent years (Sumathipala 2005). MSW characterized by 70–80 % moisture content and a calorific value of about 600–1000 kcal/kg (De Alwis 2000). On average 60 % moisture content is more applicable (Ecotech Lanka Limited 2011) for cities and towns in the Wet Zone.

5 MSW Collection and Transportation

Waste collection is mainly carried out by door-to-door collection, communal storage bins, kerbside collection and block collection systems. But most popular systems are door to door collection and kerbside collection systems. The MSW collection bins/containers are provided with national colour codes to facilitate the segregated waste collection by municipal/LAs and they are: Green colour bins for biodegradable organic wastes, Blue colour bins for paper waste, Red colour bins for Glass and Bottles, Brown colour bins for Metals and coconut shells, Orange colour bins for Plastics and Polythene. Nevertheless, waste separation at the source level is still not practiced on a large scale. In very few places, the non-government organizations (NGOs) and LAs have successfully initiated waste segregation and implemented various projects. In most of the biogas projects, point source separation is taking place. In Balangoda for example all of the point source separated

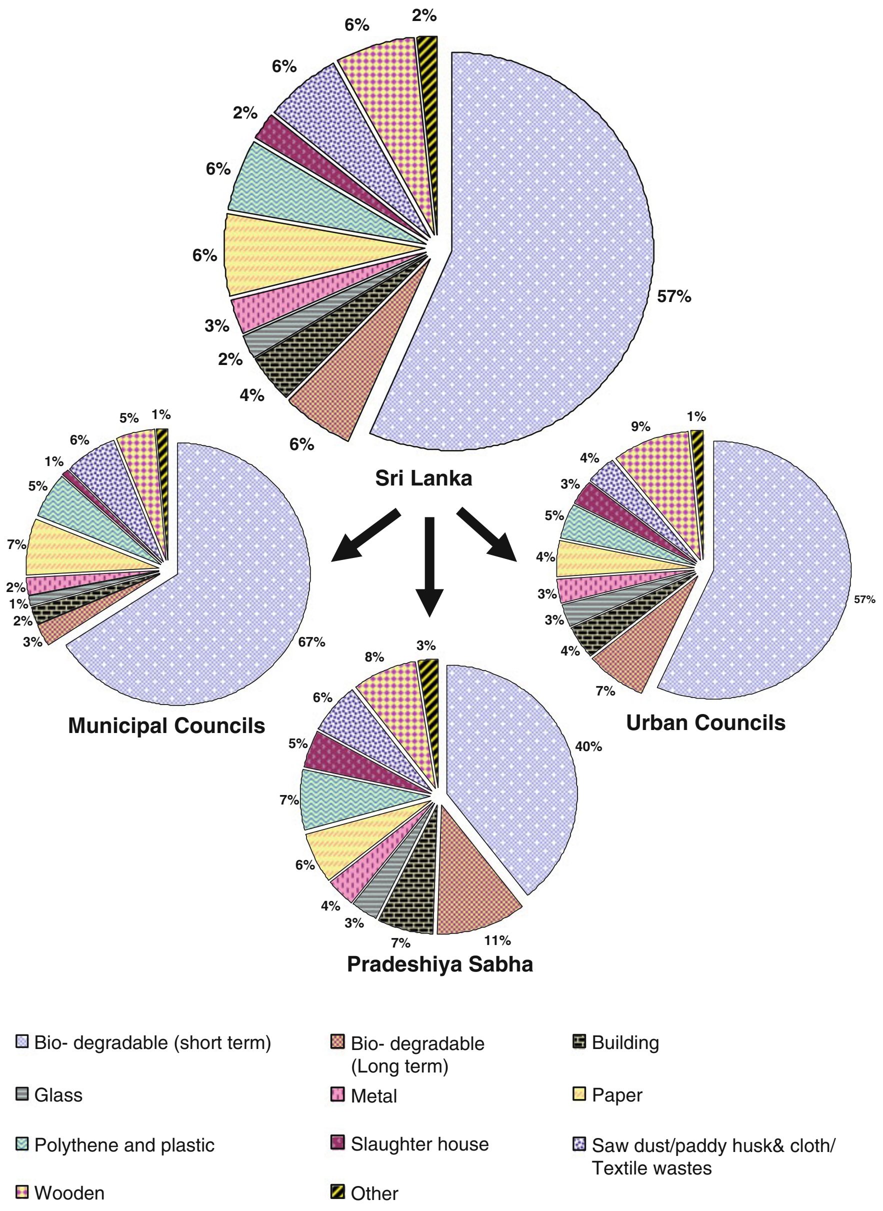

Fig. 1 Composition of MSW collected by LAs in Sri Lanka

organic wastes without any plastic bags are directly loaded into a tractor trailer and transported to the compositing plant. In Kandy, one zone after another are being converted to point source separation programme and it will be one of the most successful large scale operations.

Of the total MSW generated, only 10–40 % is collected by LAs and increasing amount of recyclable materials are collected by the informal sector and or through collection crews. The rest remains either piled up on streets or dumped in lowlands. All the LAs collect household waste, market waste, waste from business centres and small-scale industries that come under their jurisdiction. In 2004, the rate of waste collection by LAs in Sri Lanka was estimated to be about 2,838 t/day. Out of 311 LAs functioning in the country, 261 collected MSW less than 10 t/day, and 159 LAs collect less than 2 t/day. There have been recent changes to the numbers of LAs.

Around 60 % of the waste is collected from cities and towns in the Western Province (WP), which are highly populated, urbanized and developed. The community collection bins have been removed and littering of the waste along roads and in public places is prohibited.

Alternatively, a number of collection centres are established to encourage waste recycling in WP. In the Southern province, current waste collection frequency reported to be around 54.2 % on a daily basis (Vidanaarachchi et al. 2006). In a recent study, waste collection in the country shows remarkable improvements.

Hand carts, carts, two wheel tractors, four wheel tractors (3.4 m^3), tippers (11 m^3) and compactor trucks (8–12 m^3) are commonly used for waste collection. Some LAs have compactor trucks and they are becoming popular. The collection services are improving with increased emphasis on rational route collections. However, the efficiency is hampered with the involvement of the Collection Crew in sorting and separating recyclable wastes. In rural areas, problems of poor collections and waste management still exist. However, more efficient systems have been in operation in certain localities, where both the government and private sector have proven their capacity and capability in ensuring rapid and efficient collection services in Sri Lanka. The role of the private sector, namely "Clean tech of Abans", "Burns Environmental Technologies (Pvt) Limited" (BETL), "Solid Waste Management Holdings (Pvt) Ltd", and "Care Clean" are responsible for garbage collections. Unfortunately, due to inaccessibility, prohibition and poor conditions of the dumpsites, the dominance of the private sector is slowly reducing, except for cleaning of streets.

6 Prevailing MSW Treatment and Disposal Methods

6.1 Open Dumping of MSW

Random disposal of MSW is an immense burden on the environment, particularly in the most urbanized areas such as Colombo, Dehiwala-Mt Lavinia and Kandy. In the Greater Colombo Area, all the wastes end up in Karadiyana and Kolonnawa. All of the dumpsites are located in environmentally sensitive areas and near residential, commercial or institutional establishments.

Due to various factors such as an urban sprawl and severe public opposition to the sifting of landfilling facilities, finding disposal sites in urban areas has become difficult. None of the open dumpsites are engineered to minimize or control pollutants released from the decomposition of waste. Under tropical climatic conditions, methane emission potential of MSW from an open dump is 72 kg/t. Estimated level of methane emission from Karadiyana, Gohagoda and Buthgamuwa dumpsites are 208, 288 and 60 g/m^2/day, respectively. Some of the LAs use a daily topsoil cover to avoid the public opposition and nuisance. These dumps are used to dispose waste such as industrial, healthcare and slaughterhouse wastes along with MSW (Basnayake et al. 2007).

The high moisture content in the MSW leads to excessive leachate generation from these dumpsites, causing numerous problems to the surrounding environment. It is reported that the Kandy Municipal Council is in the process of providing a leachate treatment system by intercepting the leachate, treating it in a Leachate Treatment Bioreactor (Ariyawansha et al. 2011; Ecotech Lanka Limited 2011) and finally in a constructed wetland before discharging to the river. Health problems, nuisance, and air pollution are further increased due to exposing the waste dumpsites to waste scavengers, insects (mosquitoes, flies, etc.), and for open burning (Gunawardana et al. 2009). Apart from that, in dumping sites heavy metal contamination is very high. Moreover, unsorted waste makes recycling nearly impossible (Prematunge 2009). Although, hazardous industrial and healthcare wastes require safe technologies to prevent damage to the environment and people, they tend to be disposed of with other municipal wastes, which will eventually end up in open dumpsites. To address the issues, dumpsites such as Karadiyana, Gohagoda, Kolonnawa, Kalutara Porawatta, Werahera and Bloemendhal will be rehabilitated soon by LAs. In parallel, some LAs and NGOs, have initiated pilot projects on waste segregation at source level for household waste composting.

6.2 *Composting of MSW*

Windrow composting is widely used and about 5 % of the collected MSW is processed in various households and central composting systems. Regarding its operation, household level composting has proved more successful than centralized composting projects. However, Balangoda, Nawelapitiya and few other places have proven to be successful. In Balangoda, night soil is used and promoted, not knowing the consequences. In Matale, after a successful awareness program, point source separation is taking place benefiting the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) initiated composting project (UN-ESCAP 2012). The price for the MSW compost has been stagnant at LKR 10 per kg, for the past 10 years. Nevertheless, number of large scale composting complexes are established in Hikkaduwa, Kolonnawa, Medirigiriya, Anuradhapura and Kalutara (Mudalige 2012a).

Composting has been a failure due to poor quality of compost and high operational costs. Odour nuisance was also another reason for closing down the Sedawatta plant in Colombo. None of the financial institutions are willing to provide any facility for large scale composting. However, the Waste Management Authority of the Western Province is constructing a forced aeration composting system to manage input feed materials of 50 TPD (Tonnes per day) derived from 85 to 95 TPD at Karadiyana. It will be commissioned in July 2013. Perhaps the largest so far operational is the plant in Kalutara handling more than 30 TPD and it will be increased to 50 TPD.

6.3 Incineration, Anaerobic Digestion and Landfilling of MSW

Incinerators are operated for treatment of hospital wastes and some industrial wastes, but not for MSW. Lately, the Waste Management Authority (WMA) of the WP selected an Indian company with Japanese technology for a Waste to Energy, 500 t/day facility to produce only 10 MW. Few more plants will be installed in the Western Province. The Colombo Municipal Council with the support of a private company will be installing a 700 t/day plant to produce 10 MW. Anaerobic digestion of MSW has a long history in Sri Lanka, going back to 1969. The National Engineering Research and Development Centre (NERD) has conducted many research studies and feasibility experiments using MSW, market waste and food waste as feedstock for biogas recovery with little success.

There are few local authorities that have installed anaerobic digesters and out of them Galle has a small unit servicing the Municipality premises. The one at Gampaha is a community based system for five individual houses and they hope to replicate it. Each house owner pays Rs 500/- ($3.94 per month for the services). The installation was done by the HELPO Eco Green Company Ltd (Helpo 2011). The NERD semi-dry batch system at Muthurajawela is functioning (Wickramasinghe 2004), but needs high operational and maintenance costs of removal of wastes after digestion. The odour nuisance and long retention times are issues that need addressing.

The National Engineering Research and Development Centre (NERD) led the anaerobic digestion technology based on dry batch system. The solid retention times are too long with low gas generation yields. The remaining quantities after 3 months are considerable making the operational costs high to remove the sludge from the reactors. The odour nuisance is one of the other drawbacks which the Waste Management Authority of the Western Province is trying to overcome. The Authority is successfully managing 10 small plants of 250–500 kg/day with reduced particle sizes of readily biodegradable materials made into a slurry. Another system that is being promoted is a plug flow one with conversion efficiency of 75 % of the solids to gas. All of the operational units are shallow ones of not more than 2.5 m. The WMA is also converting NERD digester units to continuous feed system after reduction of particle sizes.

There are no incineration plants in Sri Lanka. However, it is intended to install one pyrolyser plant at Horana and a (raw wastes) waste to energy system at Kaduwela.

There is much success shown in the newly developed landfill bioreactor technology with locally developed composite liner system of waste polyethylene sandwiched in between clay soil. The Asian Regional Research Programme on Environmental Technology (ARRPET), coordinated by the Asian Institute of Technology (AIT), funded and assisted the research of the Solid Waste Management Research Unit. This Unit of the University of Peradeniya supported number of projects with the developed technologies in the East Coast of Sri Lanka and continue to support the Kandy Municipal Council and the Waste Management Authority in Western Province. UNOPS-EU ERP (Environmental Remediation Programme) project is responsible for the establishment of solid waste management practices in the entire Ampara District in the East coast.

6.4 Reduce–Reuse–Recycling (3R)

The 3R hierarchy helps to minimize the waste quantity, but currently this principle does not seem to be effective in Sri Lanka. In the year 2004, "Cleaner production policy" was launched with the aim of integrating the cleaner production concept with 3R in the country. In recent days, LAs, private companies and NGOs in the country are attempting to minimize disposing of waste mainly via waste recycling. Recyclables such as plastics, paper, cardboards, metals, textile, glass and leather are recovered from MSW at various points of the waste stream by itinerant waste collectors (from individual houses), street waste pickers (from community bins, roads, etc.) and rag pickers (from final disposal sites).

The cost for individual recyclables, number of major collection and recycling enterprises existing in Sri Lanka are given in Table 2. Most of the collection centers and buyers are confined to the WP. Two major national programs were articulated for facilitating 3R concepts in Sri Lanka and they are discussed in the following sub-sections.

6.5 Pilisaru Waste Management Program

The national level "Pilisaru" program was launched by the Ministry of Environment and Natural Resources (MoENR) on 24th March 2008. The mission of this program is to maximize reuse, minimize the final disposal and make the country free of "garbage" by the year 2012. In order to achieve the target the timeline has been extended. The program integrates private institutions,

Table 2 Number of collection and major recycling centres in Sri Lanka

Waste category	Type of waste	Buying price (LKR) per kg (LKR = $0.01)	No. of collection centres	No. of recycling enterprises
Polythene/plastics	Packing materials, carry bags, other plastic items from household level	12–70	31	20
Paper	Office paper, newspaper and other waste paper from industrial packing	4–20	08	03
Glass	All kinds of glass materials	NA	01	01
Coconut shells	–	NA	NA	02
PET bottles	Drinking water bottles and oil cans	12–24	NA	02
Textile	Umbrella cloth, Tafata, Woollen clothes (cut pieces), B grade garments	10–12	NA	NA
Rubber/tiers	Rubber scraps, tube scraps, tires, leather and others	25–30	02	NA

Note NA not available

NGOs, and various technological specialists to provide the LAs and the Provincial Ministries in PCs and MoENR assistance for efficient MSW recycling. The Treasury has released LKR 900 million for the program.

The Government of Korea through Korea International Cooperation Agency (KOICA) has pledged LKR 600 million as an aid for the program (CEA 2009) and it is implemented through another entity called "Export Development Cooperation Fund" (EDCF) for sanitary landfills and small scale composting plants. The first landfill is constructed at Dompe at a cost of US $4.5 million as a grant with a counterpart funding of US $1.5 million (Mudalige 2012b). The daily disposal rate is not disclosed to the public due to the problems encountered in the beginning of the project. A loan facility will be provided to construct landfills in Hikkaduwa, Anuradapura, Panadura and Udu Nuwera.

6.6 National Post-Consumer Plastic Waste Management Program

The objective of this program is to address the necessary behavioural changes among consumers to ensure proper plastic waste disposal, which will not be harmful to the environment, and to put in place the necessary logistics to enable the collection and recycling. The national program on post-consumer plastic waste management foresees generation of foreign exchange savings to the country along with the maximum recycling of plastic wastes (CEA 2009).

Recently, there have been large quantities of polyethylene wastes collected and recycled through the informal sector. The market is booming with the escalation of crude oil prices. Furthermore, the MoENR has launched a plant to produce fuel from waste, but with little success. Thus there is a reverse trend to produce primary products from plastic materials.

In addition, the increased usage of mobile phones and the disposal of electronic waste have become important issues in the country. The CEA has signed an agreement with 14 companies to manage e-wastes; including shipping the wastes to other counties like China, Malaysia.

7 Governmental Agencies and Policy Regulations

7.1 National and Local Government Agencies

The responsibilities for MSW management in Sri Lanka are generally assigned to the Public Health Department (PHD) under the auspices of the Chief Public Health Inspector (CPHI), except for the Western Province, which has an established WMA. The CPHI and Public Health Inspectors (PHI) employed either by LAs or by the Ministry of Health are responsible for SWM, besides their involvement in public health and sanitation. Figure 2 further illustrates the hierarchy of the MSW management system.

The organization and responsibilities for different aspects of MSW management are divided between different agencies. Primary collection crews belong to PHD workers who are supervised by a health supervisor. Secondary collection crews who normally come from the works department are usually responsible for keeping of vehicle drivers and mobile plant operators at the disposal sites. The role of the government in MSWM is to provide infrastructure facilities to establish proper waste collection and transportation systems, and ensure the safe disposal of wastes.

7.2 Waste Management Authority

The WP contributes to more than 35 % (3500 t/day) of the total national quantity of solid waste generation. LAs, though committed, are unable to handle with their routine MSW management practices. Thus, the WMA was established by the Western Provincial Council in year 2004 with the aim of sharing available resources among the LAs of each zone and working as a group. It created seven “Waste Management Zones”, clustering all 45 LAs to 6 MCs and Kalutara Urban Council. The USAID–USAEP and the Central Government of Sri Lanka (WMA 2009) technically and financially supported this initiative.

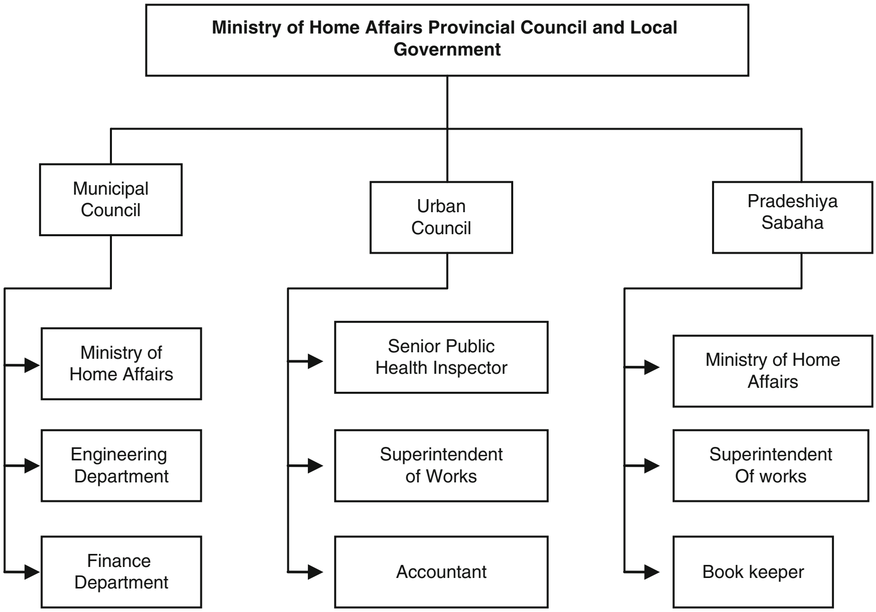

Fig. 2 Hierarchy of MSW management in Sri Lanka (Asian Institute of Technology 2004)

Seven waste management steps were identified to streamline the management and handling of MSW in the Western Province. They are namely; the management of waste at source, proper collection/acceptance of waste from the generating point, cleaning of streets and public places, providing of adequate infrastructure facilities, improved system of waste transportation, use of collected waste as a "resource" and the providing of proper final disposal facilities.

In 2005, a set of rules were established as Municipal "SWM Rules-2005" for execution of these 7 steps in the Western Province. The Waste Management Authority adopted a 5 year action plan in 2010. It has initiated small, medium and large projects from community participatory composting projects to medium scale composting handling altogether over 100 t/day with recycling systems. The proposed large-scale systems are waste to energy system to generate electricity. One of them will be operational in Kaduwela. It is a raw waste incineration system that has been selected.

Further, the "polluter pay principle" based on volume of solid waste will be introduced in 2013 to improve the source segregation of waste in association with the Korea International Cooperation Agency (KOICA). Accordingly Wattala Pradeshiya Saba (PS), Wattala Urban Council (UC), Horana UC, Horana PS, Kalutara UC, Kalutara PS, Negombo Municipal Council (MC), Katana PS, Kaduwela MC, Attanagalla PS, Ja-Ela PS and Seethawakapura UC have been selected for the implementation of the volume based user fee for municipal solid waste. Of these 12 local authorities, Wattala Urban Council, Wattala Pradeshiya Saba and Kelaniya Pradeshiya Saba will be selected to implement it as a model project.

A court order terminated a contract between Colombo Municipal Council (CMC) and a private sector company. The judgment refrain from paying tipping fees and the wastes should be disposed by more than one company. The entire episode of creating a massive mountain of garbage at the entrance to the City of Colombo has left many doubts on the capacity and capability of the private sector services in efficiently managing disposal facilities in Sri Lanka (Mannapperuma and Basnayake 2007). The Waste Management Authority of Western Province through "Pivithuru Suwapiyasa" program expect to launch a program under the slogan "Create Clean Environment, Enjoy Healthy Life" to manage the healthcare waste generated by medical institutions of both government and private sector in the Western Province (Wijayapala 2012). The WMA has installed an incineration plant with a capacity of 7 tonnes/day at Muthurajawela to manage healthcare and clinical wastes. It will be operational in April 2013.

7.3 National Solid Waste Management Support Centre

With the aim of improving SWM of LAs, the Japanese Government through Japan International Cooperation Agency (JICA) completed a 4-year technical cooperation project from March 2007 to upgrade the capacity of newly established National Solid Waste Management Support Centre (NSWMSC) at the Ministry of Local Government and Provincial Councils. With JICA's technical support, the NSWMSC is providing technical guidance to LAs such as MCs, UCs and PSs in preparing plans for SWM and to obtain grants and loans from financial institutions to implement the plans. Under this project, JICA dispatched experts and provided equipment and training opportunities for Sri Lankan counterparts. The project did build up SWM knowledge, experience and know-how through joint implementation of activities for model projects, such as sanitary landfill construction, bell collection system of SW, etc. (Daily News 2007). The outcomes so far are composting plants and landfills in Kuliyapitiya UC, Nawalapitiya UC, Mathara MC and Badulla MC as model projects. Another 5 LAs were selected to introduce such systems. The "Bell collection system" is remarkably popular and several LAs are practicing the system.

8 National Policies and Guidelines

At the national level, the responsibility for policies and implementation of plans concerning LAs lies with the Ministry of Home Affairs, Provincial Councils and Local Governments. The formulation of national level policies in SWM is conducted by the MoENR, while practical regulatory control and management are undertaken by the Central Environment Authority (CEA). The CEA is a government agency appointed to work on the National Environment Act (NEA) in the Country. In order to address the current issues on environment, MoENR has formulated the policies.

The policy was based on poor management of wastes by the local authorities coupled with the total apathy in the part of most citizens in the manner of handling their waste and in keeping the cities clean. Citizens expect the local authority to keep the city clean despite lack of proactive involvement on their part and social responsibility. Therefore, the objectives, principles, statements, waste management, capacity building and R&D, institutional arrangement, financial mechanisms and legal mechanisms were formulated to address the issues of lack of knowledge, awareness, principles like "3R" and "polluter pay", stakeholder involvement, etc. Resource recovery was recognized as an important concern, since all the waste commodities have a value, except healthcare/biomedical and hazardous wastes. However, the rehabilitation and mining of dumpsites have not been viewed as resource recovery potential. Thus it has been conveniently kept out from the policy framework. It could very well be assumed that the Government was not committed to financially support a burden left from the past generations.

The policy that can be improvised/implemented for sustainable waste management are:

1. The Government shall provide financial assistance for rehabilitating dumpsites and ensure compliance of environmental standards.
2. The Government shall promote pilot scale projects preferably with public private partnerships to develop best practices of sustainable systems.
3. The conversion of waste to energy shall be promoted as a priority issue to overcome shortage of power in the cities.
4. The existing dumpsites shall be rehabilitated and mining of wastes to be promoted to reduce the burden on local authorities to search for new lands.
5. The haulage of wastes to country side shall be avoided to prevent spread of diseases and reduce the cost of haulage of wastes.

In the objectives, resource recovery is addressed but how it could be done is not spelt out, like in the case of selection, adaptation and development of suitable technologies of prevention, recycling, resource recovery and conversion of wastes to energy and power. However, composting and land filling technologies have been dealt in the policy document. In so far as principles, "Partnerships" have been mentioned but specificity on public private partnership has not been emphasized. In contrast, healthcare/biomedical wastes are highlighted in the waste management aspect of the document. The policy points towards sustainable financing with LAs ensuring self-financing for waste management by effective revenue generation mechanisms. The important feature of the legal mechanisms is called for an "Effective law enforcement will be ensured as means of maintaining the accountability of stakeholders".

9 Economic Aspects

Financial provisions for SWM in Sri Lanka fall under the health section of the annual budget of the LAs, except for the Colombo Municipal Council which has its separate budget. MCs, UCs and PSs spend approximately 14, 20 and 12 %, respectively, of their budgets on MSW management. The main source of revenue for LAs is through property rates and taxes, supplemented by central Government grants (through provincial council) for reimbursing expenditures on salaries, wages and allowances incurred by LAs. There are no specifications in budget allotment for various tasks involved in MSW management, but it has been estimated that the LAs spend more than 70 % of the allotted budget in collection and transportation of refuse, staffs salaries and vehicle maintenance and fuel. Most LAs hardly spend any money for proper disposal of MSW. The disposal cost covers only the mechanical costs for waste spreading, although processing of wastes is part of the contract. For instance, CMC paid LKR 950/ton for spreading and heaping the waste at the Bloemendal dumpsite.

The government with the assistance of KOICA as mentioned before, JICA, EU and ADB has provided the financial and technical assistance to LAs. The NSWMSC particularly is building capacity rapidly and striving to provide the guided support as intended. These activities of the centre could focus on continuity of the "Pilisaru" program, once the disposal systems are established. The latter provides direct financial assistance as grants, whereas the NSWMSC rely on other funding sources such as the Asian Development Bank (ADB) and the Government of Sri Lanka. So far, ADB funds meant for managing solid wastes remain underutilized. The EU assistance provides total grants in developing infrastructure and management systems in the east coast of Sri Lanka. The WMA of the Western Province is spending government funds wisely and developing sustainable systems.

10 Legal Aspects

The National Environment Legislative Act enacted in 1980 and subsequently amended in 1988 provides for the establishment of the CEA with defined powers, functions and duties. The CEA is responsible for the monitoring and providing the regulatory measures for ensuring environmental standards of the CEA. **Environment Impact Assessment (EIA)**. EIA regulation under the NEA requires a landfill site to undergo environment impact assessment if its capacity exceeds 100 t/day.

(a) **National Strategy for Solid Waste management (NSSWM)**. The NSSWM was launched by the government in May 2000 in recognition of the need to manage solid waste from generation source to final disposal. It also defines the identification of the component strategies for waste avoidance, reduction, reuse, recycling and appropriate final disposal.

(b) **Environment Conservation Levy Act**. The act introduced in August 2008 aims to minimize environmental pollution through measures and activities for developing efficient and sustainable utilization of natural resources, public awareness on sustainable development and sustainable environmental conservation financing.

11 Recommendations and New Strategies

In order to improve the present management scenario of MSW in the Country, the following options and strategies are suggested for national and local governments

(A) National government should be responsible for:

- (a) Engage Stakeholders
- (b) Formulating supporting policies
- (c) Strengthen information management
- (d) A database needs to be maintained for the total waste generated and collected by the individual LAs for designing appropriate waste management practices.
- (e) Capacity building through recruiting staff in LAs for sanitary works and motivating them with proper training in modern waste management technologies.
- (f) The concept of "polluter pays" should be encouraged particularly for maintaining poor or no revenue generation systems like composting and land filling
- (g) Although, the policy document has no inference to WTE projects, particularly with landfill bioreactors and Refuse Derived Fuel (RDF) with a view to developing Integrated Solid Waste Management (ISWM) approaches, it is the right way forward for sustainable solid waste management systems in the country.

(B) Local government should be responsible for:

- (a) Liaise with national government
- (b) Formulate local strategies for implementation
- (c) The private sector and NGOs/CBOs need to be given the required technical expertise and consultancy facilities to enable them to function efficiently.
- (d) Nurture innovative practices etc.
- (e) Creating awareness among people on source segregation, ensuring establishment of efficient waste management systems for collection,

transportation and resource recovery and final disposal, including hazardous wastes.

(f) The country still expects dwelling foreign assistance and investments for capacity building and R&D. It is imperative that the Government considers supporting the local companies bearing the burden of controlling the pollution from dumpsites and involved in R&D activities.

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Municipal Solid Waste Management in Taiwan: From Solid Waste to Sustainable Material Management

Harvey Houng, Shu-Hung Shen and Hsiao-Kang Ma

1 Introduction

Ever since the "Solid Waste Disposal Act" was established in 1974, Taiwan has been developing waste management for nearly four decades. Over the years, the substantial increase in the amount of solid waste and the indiscriminate disposal of waste had caused serious environmental pollution problems. In 1984, the "Municipal Solid Waste (MSW) Disposal Plan" set landfill as the initial goal and incineration as the long-term policy. The "MSW Disposal Plan" was promulgated in 1991, empowering the Government to construct 21 incineration plants to relieve from the burdens of MSW pollution.

To promote the reduction, reuse, and recycling 3R principles, the Taiwan government established the Recycling Fund Management Board and launched a series of practices including: pay-by-bag collection fee system, mandatory MSW sorting, keep trash off the ground, plastic bag limitation, package reduction, one-time-use product reduction and hazardous substance prevention. As a result, Taiwan has had outstanding performance in resource recycling promotion plan for general waste. In 2012, the daily amount of MSW collected per person for disposal was 0.397 kg, which was over 60 % less than the highest record in history (1998). Resource recovery rate was 54 %, proper trash treatment rate was 99 %, and initial MSW disposal problems in the early days had been rectified (EPA, Executive Yuan 2012b).

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2 Legal Structure of Waste Management

2.1 Solid Waste Disposal Act

The "Solid Waste Disposal Act", was promulgated in 1974 and has been amended several times, including the period from 1980 to 1987 when Taiwan's economy began to rise and industry as well as commerce gradually developed. At the same time, environmental pollution also grew to severe levels. The construction of sanitary landfills and incineration plants did not seem to resolve problems as expected. In 2001, the "Solid Waste Disposal Act" was amended in compliance with the promotion of the "Zero Waste" policy and addressed problems of preventing arbitrary disposal of waste. Major Policies and Regulations relevant to MSW Management in Taiwan are illustrated in Fig. 1.

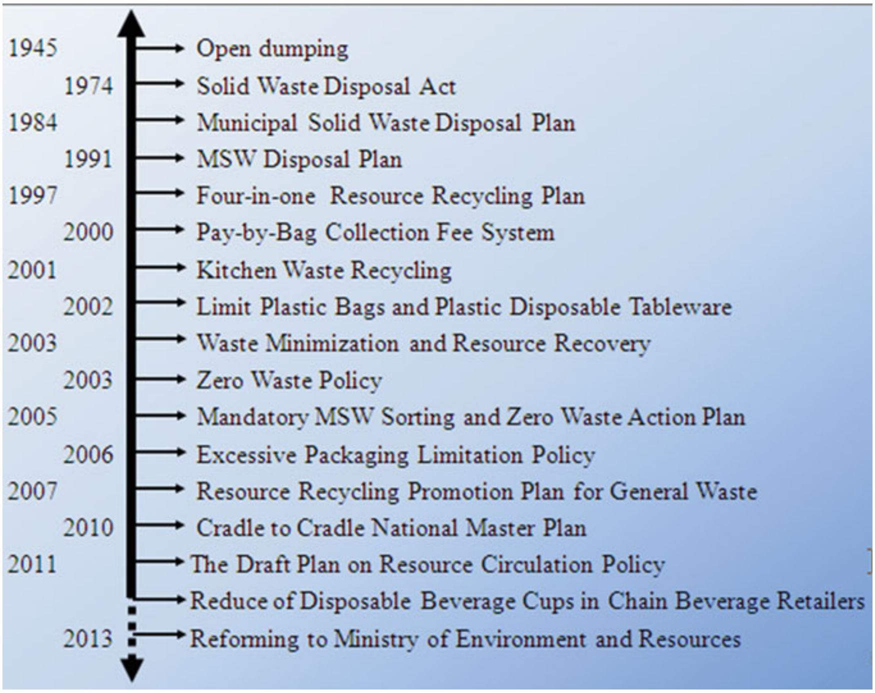

Fig. 1 Major policies and regulations relevant to MSW management in Taiwan (EPA, Executive Yuan 2012b)

2.2 Resource Recycling Act

The regulations of the initial Solid Waste Disposal Act were end-of-pipe control and never provided overall governing from the entire process of product life cycle. Thus, it was necessary for legislation to guide enterprises in designing and producing easy to recycle products, as well as using renewable resources as materials. The "Resource Recycling Act" became effective in 2002, comprising 6 chapters and 31 articles. Keypoints included practicing resource recycling, expanding diversified recycling approaches, and varying recycling methods for different products. All citizens were encouraged to participate to further achieve the goal of "comprehensive resource recycling, zero wasting". Principle rules were established for use of substances and sequence of waste management; the prerequisite of suitability of the principle was "based on feasible technology and economy".

3 Generation and Composition of MSW

3.1 Quantities of MSW

The "Mandatory MSW Sorting and Zero Waste Action Plan" promoted in 2005 started with reducing and recycling by sorting MSW at households. In 2007, MSW was banned from being taken to landfills except in the remote areas. The daily MSW generation per capita per day in Taiwan had decreased from 1.143 to 0.397 kg in 2012, which was 60 % less than the highest MSW generation in history (EPA, Executive Yuan 2012a).

3.2 Composition of MSW

The chemical and physical composition of solid waste in 2012 was analyzed (Table 1, 2), where the results revealed that paper, food waste, and plastic accounted for 92.79 % of the total physical composition, among which food waste had the highest content with 38.33 %, followed by paper with 38.85 %, plastic with 15.61 %, and metal and glass with 0.28 and 1.26 %, respectively. The total contents of leather and rubber, fiber and cloth, and wood and leaf accounted for 4.18 % of the physical composition of solid waste (EPA, Executive Yuan 2013a).

Table 1 Typical physical composition of MSW in Taiwan, 2012 (EPA, Executive Yuan 2013a)

Physical composition (wet basis)	Combustible	Paper (%)	38.85
		Textile (%)	2.52
		Wood, trees, etc. (%)	1.46
		Food waste (%)	38.33
		Plastics (%)	15.61
		Leather, rubber (%)	0.20
		Other metal (including debris below 5 mm) (%)	0.49
		Sub-total (%)	97.46
	Non-combustible	Ferrous-metal (%)	0.28
		Non-ferrous metal (%)	0.22
		Glass (%)	1.26
		Other non-combustible material (Ceramics, sand) (%)	0.78
		Sub-total (%)	2.54

Table 2 Typical chemical composition and energy content of MSW in Taiwan, 2012 (EPA, Executive Yuan 2013a)

Chemical analysis	Moisture content by wt. (%)	53.97
	Ash content by wt. (%)	4.96
	Carbon (%)	22.36
	Hydrogen (%)	3.46
	Oxygen (%)	14.62
	Nitrogen (%)	0.38
	Sulfur (%)	0.15
	Chloride (%)	0.11
Energy content	Dry kcal/kg	5,322.44
	Wet (high value) kcal/kg	2,451.31
	Wet (low value) kcal/kg	1,940.74

4 Collection and Transportation

4.1 MSW Removal Policies

Before 1968, MSW was stored in outdoor trash boxes, and cleaning personnel would collect the MSW from these boxes by man-hauled carts or tricycles and transport the MSW directly to disposal sites or transfer posts. This further evolved into transporting the MSW to transfer posts with tricycles or directly to waste disposal sites with small trucks. Until the 1970s, solid waste transportation still adopted the same method from the 1960s, which was using sealed MSW trucks to collect household wastes. Public trash containers were abolished in 1971. Up until now, MSW collection methods included collection by households (placed at the door or a collection point), collection by stations (MSW trucks or dumpcarts), or collection along streets at fixed locations and times (keeping trash off the ground).

The "Keep Trash off the Ground Policy" is currently implemented in Taiwan, except for specific remote areas. Thus, MSW collection is mostly done by a street collection fleet at fixed locations and times. Where the fixed location collection is not feasible in the remote areas, collection service provided to each household is practiced. The frequency of collection is generally five days per week and once per day. Time of collection mainly depended on the schedule of local habitants; night collection is mostly carried out in urban areas, though there is also morning or daytime collection. Transportation equipment and labor are distributed based on the population and local budget of the area served.

When people discharge MSW, waste recycling and disposal regulations should be followed. Sorting rules established classify MSW into general solid waste, resources, food waste and others as regulated by local governments before handing MSW over to the cleaning squad. As for large MSW such as furniture, the local cleaning squad must be contacted in advance to schedule timely collection.

4.2 Replacement of Old MSW Collection Equipment

Taiwan promotes the "Keep Trash off the Ground Policy", where the MSW collection method involves frequent driving and stopping of trucks. This repetitive acceleration and deceleration cycle during the process of MSW collection consumes a substantial amount of fuel. Fuel consumption of MSW collecting trucks is significantly higher compared to other trucks of similar grade, leading to an increase in the emission of air pollutants, such as NOx and particulate. To enhance cleaning efficiency and reduce vehicle maintenance fees, hybrid hydraulic tanks for MSW collecting trucks were brought in from Germany. The hybrid hydraulic tanks transfer braking energy into hydraulic power using a hydraulic system. The energy is stored and then released through a precise computer control system at the next acceleration. Therefore, the truck can reduce fuel consumption, assist acceleration, decrease brake abrasion and prolong engine life. Other cleaner fuels such liquefied natural gas (LNG), compressed natural gas (CNG), hybrid fuels, and electric engine are under investigation or field test driving for practical utilization on MSW collecting trucks.

As for beneficial assistance to environmental protection, new vehicle NOx exhaustion was reduced by 50 %, and smoke exhaustion (degree of pollution %) also decreased from 35 to 25 %. Furthermore, the EPA implemented environmental driving education and consultation for drivers so that 7 % of fuel consumption are saved through adjusting driving behavior, equivalent to 274 l a year per truck, reducing 740 kg of carbon dioxide exhaustion and saving NTD 8,768 per year (EPA, Executive Yuan 2013b).

5 Treatment and Disposal

5.1 Sanitary Landfills

There were 296 solid waste disposal sites in Taiwan in 1984, among which 147 sites were expected to have less than 1 year of service time. The sanitary landfills used by various townships only accounted for 65.5 % and dumping in low-lying lands accounted for 19.6 % (EPA, Executive Yuan 2013b). The "Comprehensive Regional Waste Disposal Plan" was established on September 21, 1984, which proposed 14 important construction plans for demonstrative waste disposal. The plan involved establishing correct public views towards MSW treatment. Future promotion and establishment of standard waste sanitary landfills would be implemented successfully to prevent illegal dump yards or landfills and improve environmental sanitation.

In addition, in order to provide the concept of sustainable land use, saturated waste yards were to be recovered and transformed into sports and recreational facilities as a feedback to local people. Up until now, there were 110 landfills in operation in 2011, with a total volume of approximately 18,250 million m^3.

5.2 Incinerators

The waste disposal policies in Taiwan shifted from "focus on sanitary landfill" in 1981 to "incinerate aided by landfill" in 1991, with a focus on solving waste disposal problems properly as the primary task. The contents of the "Municipal Solid Waste Disposal Plan" promoted in 1984 included establishing waste management policies, increasing active MSW cleaning machinery, strengthening personnel education and training, building waste disposal plants, and creating basic properties data on municipal solid wastes to increase the proper waste disposal rate from 2.4 % in 1984 to 62.0 % in 1990.

The "Construction Plan for Solid Waste Resource Recycling (Incineration) Plant" established in 1991 handled the construction of 21 incineration plants. The Department of Solid Waste Resource Recycling Plant Construction was setup to be in charge of handling construction related matters. The Plants in Taiwan have a cogeneration system designed for waste heat recycling. Such system uses the heat generated by incinerating solid wastes as the energy source for a heat recovery steam generator (HRSG). The water in the generator is heated into steam that is 400 °C and 40 Bar, to drive the steam turbine to transform heat into electricity. Each incineration plant can generate at least 5,200 kW of power. The electricity generated can be used within the plant; the heat remaining after generation can be reused for a warm water swimming pool, and the remaining electricity can be transformed into 69 kV with a transformer and transmitted back to Taiwan Power Company for use by the general public. As of 2013, 24 large scale incinerator

Fig. 2 Taipei Mu-Zha incinerator and its surrounding areas (EPA, Executive Yuan 2012b)

plants are in operation with more than 95 % waste treated by incineration. The built-in co-generation facilities contribute more than 8 million kWh of electricity per day. The most stringent air emission standards are also applied to all incinerators to safe guard the environment. Part of revenue received by the Incinerator Plant is used for community services such as warm water swimming pool, fitness center, gardens, environmental education centers, etc. (Fig. 2).

6 Reduce, Reuse, Recycle, and Recovery

6.1 Source Reduction

The progression of the view of solid waste disposal focuses first on waste disposal technology and then on resource recycling. However, the focus today is on “pre-generation of MSW,” i.e. “source reduction,” which stresses recycling and encourages enterprises to engage in ecological design in the hope of achieving the prospects of resource reuse maximization and waste minimization (“zero waste”), as well as transforming managerial thinking to developing towards sustainable substance circulation. Source reduction is something that everyone can do. For example, drinking less bottled and canned beverages will generate less waste containers.

6.1.1 Policy Promotion

Promotion of source reduction brings multiple benefits such as lowering operational cost, enhancing corporate image and decreasing MSW generation. In the initial period of various source reduction promotions, the EPA was committed to combining environmental groups, enterprises and local governments in resource guidance to create a trend of source reduction among industries in society. For example, the “Environmental Tableware Package Design Contest” in 1996 encouraged people to prepare their own environment friendly tableware; the “Use Less Plastic Bags” activity was promoted since March of 2001; restaurants began to switch to using washable tableware in June of 2001, and the “Environmental Protection Convention on Use of Shopping Bags Instead of Plastic Bags” activity was executed in September of 2001. These events received enthusiastic response and support from industries, and became the important foundation stone for EPA’s promotion in “Limitation on Use of Plastic Shopping Bags and Disposable Plastic (Including Styrofoam) Tableware”.

6.1.2 Changing Life Styles

Plastic bags became indispensable in people’s lives because of their cheap cost and convenience. Based on statistics taken by the EPA before implementing plastic limitation policies, the annual plastic bag usage amount in Taiwan was 105 thousand tons, among which plastic shopping bags accounted for 65 thousand tons per year. Large amounts of discarded plastic bags appeared in the environment, often leading to clogged drainage ditches, which further caused floods; some piled up at river coasts, sea coasts and mangrove forest at tidal beach, also damaging the eco-environment. Therefore, to change the habit of disposable consumption in people’s daily life, the EPA began to promote the “Plastic Shopping Bags and Disposable Plastics (Styrofoam Included) Tableware Limitation Policy” in public departments in July of 2002 to limit the usage of plastic shopping bags and disposable plastic tableware. In January of 2003, the policy expanded to include malls, shopping centers, hypermarkets, supermarkets, chain convenience stores, chain fast foods stores, and restaurants and cafeterias.

Government agencies and schools had the responsibility of setting good examples and educating of the new generation by promotion of source reduction in Taiwan. After the plastic limitation policy achieved its initial success, the EPA promoted the policy of not providing any disposable tableware (including cups, bowls, dishes, plates, boxes, chopsticks, spoons, knives, forks, stirring sticks, etc.) when dining in restaurants at government departments and schools on July 1 and September 1, 2006. In addition to regulating caterers working for government agencies and schools to reduce MSW generation by switching to using washable tableware, promotion of reducing use of disposable tableware also expanded to restaurants and cafeterias in malls to achieve source reduction. The policies guided people to change disposable living habits and performed indicative demonstration effects. Since the use of plastic shopping bags and disposable plastic tableware was limited in 2002, the annual amount of plastic bags used was reduced by 2 billion bags, a reduction rate of 58 %; the annual amount of disposable tableware used was also reduced by 2 billion bags, a reduction rate of 85 % (EPA, Executive Yuan 2012a).

6.1.3 Product Design

To follow the trend of international source reduction development, product design was taken into account when considering source reduction. The results of "Excessive Packaging Limitation", "Limitation on Manufacture, Import and Sale of Mercury Containing Dry Cells", and "Limitation on Import and Sale of Mercury Thermometers" demonstrated the EPA's efforts in reducing MSW generation, creating a quality living environment for the public, and guiding industries in sustainable development.

Packaging management illustrates one of the ways of source reduction. From the viewpoint of package design, the eco-friendly green concept should be included at the design phase, also known as green package design. From the angle of consumers, choosing a green product is choosing to be eco-friendly. If more people chose green purchasing, it will help to promote more firms to join in on green products, further attracting green consumption. Thus, solid waste may be reduced from the source and allow resources to enter a more sustainable circulation. Surveys taken by the EPA in 2000 and 2003 showed that over 60 % of the public thought gifts were excessively packaged, including too many layers of wrapping, excessive packaging space, excessively high packaging cost, and too many types of packaging materials; over 70 % of the public expressed an unwillingness to purchasing excessively packaged products or those with exquisite packaging for higher prices. In a 2000 survey, 82.4 % of the public supported the government in establishing packaging reduction control policies, and the number increased to 91.4 % in 2003 (EPA, Executive Yuan 2012a). The survey indicated that a majority thought excessive packaging was a serious problem and supported the government in taking control measures.

Therefore, the EPA established the "Excessive Packaging Limitation Policy" in compliance with the Resource Recycling Act on July 1, 2005. The policy included two phases for controlling the packaging volume ratio (<1) and layers (less than two; less than three for pastry box and computer program disc) of gift boxes. The Policy became effective in 2006, and regulated the packaging volume and layers of pastry, cosmetics, processed foods, wine and disc, as well as guided packaging toward reduction and easy to recycle green design, which had reduced 7,300 tons of packaging waste in the first year (EPA, Executive Yuan 2012b).

As for source reduction of toxic substances, the demand for dry cell batteries had increased with the development in electronic instruments and consumption of electronic products. However, there are numerous types of dry cells battery on the market due to differences in manufacturing principles, technology and functional requirements, and some products still contained mercury, a toxic substance harmful to the human health and the environment. If the mercury batteries are not properly recycled and disposed of, their distribution in the environment may cause mercury to accumulate in organisms and environmental pollution, eventually harming the human body. Under the international trend of "Limit Hg Gradually, Ban Hg Ultimately," governments around the world are limiting the use of mercury in certain products, and taking strict control measures toward the final disposition of Hg-containing products. The EPA also referred to the cell directives of the E.U., to establish the “Limitation on Manufacture, Import and Sale of Dry Cell Batteries” to limit the manufacture, import and sale of dry cell batteries containing over 5 ppm of mercury. In 2006, Taiwan began to prohibit the manufacture, import and sale of manganese–zinc cells and non-button type alkaline manganese cells that contained over 5 ppm of mercury.

In addition, Hg-containing thermometers were also an important source of mercury distribution in the environment. Since households and medical facilities used mercury thermometers, they were commonly found throughout the environment. Furthermore, the product shattered easily during use. The spilt mercury is extremely difficult to be collected or recovered for proper disposal. At the same time, production technology for electronic Hg-free thermometers was quite sophisticated with growing adoption rates, and inspection technology regulations had been established. Thus, the EPA announced the “Limitation on Import and Sale of Mercury Thermometer” to restrict the import and sale of Hg thermometers through various phases. Since 2008, the “Limitation on Import and Sale of Hg Thermometer Policy” was implemented and resulted in a reduction of 850 kg mercury each year (EPA, Executive Yuan 2012c).

6.1.4 Voluntary Cooperation

In 2007, the EPA promoted the “Paper Cup Reduction Plan in Government Agencies and Schools” and encouraged restaurants to use washable tableware, people to prepare their own tableware, and hotels to reduce their usage of disposable tableware. The EPA also asked four major chain convenience stores “not to provide disposable chopsticks unless necessary” in July of 2008, in the hope that the public would practice the habit of not using disposable chopsticks. The EPA negotiated with the restaurants and cafeterias in malls and hypermarkets to promote the “Disposable Chopsticks Reduction Activity” in January of 2010. The activity required that stores change to washable chopsticks instead of disposable chopsticks. The EPA hoped to achieve “resource circulation, energy conservation and carbon reduction” society through multiple aspects of movements and collective efforts.

At the same time, in order to reduce packaging waste, the EPA not only restricted the volume and layers of packaging of products through the Excessive Packaging Limitation Law, but also promoted voluntary reductions by industries in 2010. By signing agreements with brand enterprises regarding reduction of waste volume and weight, the EPA and enterprises continued to promote spontaneous lightweight packaging. By engaging in the voluntary reduction agreement, an enterprise could not only express its support for sustainable development of the earth’s resources and increase attraction by enhancing brand image, it could also reduce packaging materials, further lowering costs. Fifteen products from 11 enterprises signed the agreement in 2011, eliminating 1,720 tons of packaging materials. This was expanded to 15 products from 12 enterprises in 2012, and it is expected to reduce even further by 965 tons (EPA, Executive Yuan 2012a).

6.1.5 Economic Incentives

Food and beverage stores have been providing take-out drinks in the recent years, forming a consumption habit of disposable cups. Chain beverage stores, convenience stores and fast food stores use around 1.5 billion cups per year. In addition to consuming a large amount of natural resources, cups are often discarded arbitrarily, causing pollution and damage to the eco-environment. It is necessary to enforce source reduction and strengthen the collection of disposable take-out cups.

Considering the international trend of waste management, the EPA pronounced "Regulations on Rewards for Disposable Take-Out Cup Source Reduction and Collection" in 2011. It regulated chain fast food stores, chain convenience stores, chain coffee shops and chain beverage shops submit discount plans for self-prepared cups to reduce use of disposable cups; in the case a store from the above-mentioned industries did not implement resource reduction, it should recycle the disposable take-out cups from its own chain system. When a customer brought a used cup of the brand to one of its chain stores, the store should offer a reward of NTD 1 for every 2 cups. This was to encourage the public to strengthen recycling, prevent pollution and damage to the eco-environment due to arbitrary disposal, and to achieve the goal to resource circulation and reuse. Since 2011, 388 brands and over 17,000 stores in the chain beverage industry offer discounts for people who bring their own cups. After 1 year of implementation, the ratio of people bring their own cups increased 9.6 % (EPA, Executive Yuan 2012b).

6.2 Reuse

In Taiwan, any old furniture worth fixing was recovered and reused, while those not worth fixing were smashed, and the wood, plastics and metal were separated and recycled for reuse. Because the policies for waste reduction and sustainable resource reuse promoted in Taiwan were accepted by the public, the generation of bulk waste in the nation had decreased from 235,554 tons in 2005 to 140,882 tons in 2011, a reduction rate of 40.2 %. The bulk waste recycling rate in the nation had increased from 12.6 % in 2005 to 57 % in 2011, and the incineration and landfill rate had decreased from 87.4 to 43 %. Statistics from 2007 to 2012 showed that counties and cities in Taiwan have sold 165,000 pcs of renewable furniture and bicycles, amounting to NTD 127.97 million. During the recent three years, over 210,000 persons from agencies, groups and schools visited recycling plants and participated in auctions every year. The "Website for Bulk Waste Recycling" was also established for providing relevant information on bulk waste recycling and links to auction websites of counties and cities, allowing people to acquire the data they required.

6.3 Recycle

The EPA began to implement mandatory MSW sorting in 2006, required people to sort their wastes into three categories: resource, food waste and MSW. When collecting MSW, the crews of sanitation fleets inspect MSW for compliance. After the implementation of this policy, the recycling rates of resource and food waste had increased significantly, reducing the amount of MSW disposal. Survey results showed that the recognition and support of the people toward mandatory MSW sorting measures were 90 %, indicating most people could comply with resource recycling policies.

In order to practice the principles of “users pay” and “polluters pay”, the “Regulations for Collection of Solid Waste Clearance and Disposal Fees” was established in 1991, by which local governments collected clearance and disposal fees from the people according to standards stipulated by the central government. The regulations were amended and implemented in 2002, requiring that each local government should calculate fees to be collected based on actual cost of waste collection and treatment. According to Article 3 of the regulations, municipal and county (city) governments should calculate fees by one of the three methods: amount of water usage, quota per household, or amount of MSW (pay-by-bag collection fee).

Taipei City Government began to promote pay-by-bag collection fees in 2000 to encourage people to practice MSW and resource sorting by using the economic incentive of controlling quantity with price. New Taipei City also began promotion in 2008 and full implementation in 2010. Shigang District in Taichung City is also enforcing the regulations. The EPA started to promote mandatory MSW sorting in 2005, stipulating that people should sort their solid waste by resource, food waste and MSW, and then hand them over to be collected or cleared by sanitation fleets. They should also comply with the Keep Trash off the Ground Policy to reduce MSW and increase resource recycling.

During the promotion, households were reached by applying various channels for the public to understand the policies. For example, education bureaus focused on school teachers, market management focused on vendors, environmental protection bureaus focused on various propagandas and media reports, labor departments held events for strengthening propagandas of foreigners, while information service departments made propagandas on public communication media such as newspapers, broadcasting, television, outdoors e-boards, public bus and MRT car. Ever since implementation of the pay-by-bag collection fee, the amount of MSW in Taipei City had decreased 21.3 % from 1999 to 2000 and it continued to lower yearly; the resource recycling rate also increased 113.5 % (Ma et al. 2009).

The above indicates that outcomes of MSW reduction and resource recycling can be enhanced effectively. The MSW clearance and disposal fees in other counties and cities are currently collected by being added to water fees. However, MSW fees and water usage have no direct relationship, thus implementation of pay-by-bag collection fee system can meet the fair principle of "polluters pay," as well as guide people in the behavior of "less trash, less payment" through economic incentive, to achieve the goals of MSW reduction and resource recycling.

6.4 Methane Gas Recovery

In order to solve the gap in greenhouse gas exhaustion reduction, Taiwan considers energy conservation and carbon reduction as important goals to enhance energy use efficiency.

In general, a sanitary landfill with over 1 million tons of raw MSW is feasible for methane recovery for power generation of one to two MW. Although 400 thousand tons of raw MSW can support a small methane power generator up to 230 KW, it is only sufficient for self contained electricity within the plant. It offers no economic benefits and the cost is relatively high. Since 1996, the Taiwan Government has used the "Air Pollution Prevention and Control Fund" for executing recovery of methane at closed sanitary landfills. Most of these landfills have established methane gas recovery facilities. It was estimated that between 1999 and 2006, landfill methane gas was recovered to generate 5.16 million kWh of electricity, that is equivalent to 114 thousand tons methane gas recovery or 3 million metric tons of carbon dioxide equivalent (MTCO2E). In 2011, Taiwan also pushed for an annual methane generation of 553 million m^3 (5 years service life) at 110 operating landfills. The greenhouse effect is approximately 8.94 MTCO2E per year (EPA, Executive Yuan 2012a).

7 Extended Producer's Responsibility and 4-in-1 Program

7.1 Resource Recycling Fun Management Committee

In 1988, the EPA began to promote the "Extended Producer's Responsibility" system based on the Waste Disposal Act, requesting product producers (responsible enterprises) to be responsible for waste recycling and disposal, and announcing that responsible enterprises should handle recycling, clearing and disposal of containers, tires, lead-acid batteries, lubricant oils, cars and motorcycles, and certain recycling rates must be achieved. Since 1997, EPA began promoting the 4-in-1 Program. Responsible enterprises did not have to recycle the wastes on their own, but pay a recycling, clearance and disposal fee to the

Resource Recycling Management Fund. The Fund Management Committee would use the fund as incentive to combine local sanitation fleets, communities and recycling firms to promote resource recycling. The product list of recycling, clearing and disposal fees payable also included electronic appliances, data processing objects and lighting.

The 4-in-1 Program promoted by EPA combines communities, recycling firms, local governments and recycling fund in the implementation of resource recycling. The public or communities establish recycling organizations to sort resources and general MSW generated by households for separate collection at recycling points or by local sanitation fleets or private recycling firms. The fund is used to subsidize local sanitation fleets and supplement recycling firms for establishing complete resource recycling systems to recycle resources effectively.

As for the recycling fund, the fee rates of manufactures/importers of objects or containers shall be determined by the Committee and paid to a financial institute for establishing a Resource Recycling Management Fund, which will be used for supplementing recycling and disposal of objects or containers to increase the incentive for people to engage in resource recycling. The fees to be paid by manufacturers/importers shall be determined upon factors such as material, volume, weight, recycling value and the previous year's recycling rate. As for the subsidy for recycling and disposal, the Recycling Fund shall pay it after the group certified by EPA had confirmed the quantity of properly recycled and disposed resources. The mechanism of the 4 in 1 program is illustrated in Fig. 3.

There are currently 33 items announced of which the recycling, clearing and disposal are the responsibilities of manufacturers/importers. The Recycling Fund is over NTD 600 million per year and is divided into two parts: 70–80 % is trust fund, used as subsidy for recycling, clearing and disposal; 20–30 % is non-operational fund, used for subsidizing recycling machinery and storage sites for local

Fig. 3 Operation of resource recycling management fund (EPA, Executive Yuan 2012a)

sanitation fleets, supplementing or rewarding communities, agencies and schools for engaging in recycling and propaganda, auditing, inspections, executive administration and research development.

7.2 Recycling System

The resource recycling system in Taiwan has established diversified recycling channels that are based on two major systems. The civil resource recycling system of trash picking and returning old products that has operated for decades is still in operation through economic incentive of the recycling market and subsidy from the government. The other system is the local government recycling system, which uses recycling trucks for collecting resources sorted by people as a convenient recycling channel. The resource to be sorted can be divided into two categories. The first category is the waste or containers that are to be recycled, cleared and disposed of by manufacturers/importers. The other category includes waste that is worth recycling and can operate well without subsidy from recycling market and government interference. For the above two categories, people must sort the resources for collection by sanitation fleets on resource recycling day. After each local cleaning squad collects the abovementioned resources, it will classify the resources or entrust recycling firms based on materials or types into various resources, and send the resources to various materials renewal plants for reuse.

Taiwan has established a labeling system (Fig. 4) for people to distinguish recyclable items and general MSW. Manufacturers and importers are requested to label recycling marks on the recyclable products or containers they produce or import, as well as comply with the 4-in-1 Program. The recycling facilities, such as resource recycling trucks and bins, of each environmental protection unit, public location and vending points are currently required to print visible recycling marks for recognition by the public and strengthening the message of resource recycling. The resource recycling rate in Taiwan has increased from 5.88 % in 1998 to 53.94 % in 2012.

Fig. 4 Regulated resource recycling label (EPA, Executive Yuan 2012b)

7.3 Greenhouse Gas Reduction Benefits

When trash is delivered to a waste-to-energy plant, the energy content of the waste is retrieved, metals are recovered, and electricity is generated. However, waste-to-energy is the last resort for waste management. Through source reduction, reuse, and recycling, the energy and the resources taken to make the product can be tremendously reduced. The Taiwan EPA estimated that the reduction of annual waste from 9.43 million tons in 1998 to 7.35 million tons in 2012 prevented 2.08 million tons of waste from been disposed of in incinerator plants and as a result, reduced 2.25 million metric tons of carbon dioxide equivalent (MTCO2E) in 2012. This estimation let alone the additional carbon dioxide to be generated if coal is to be burnt in an ordinary power plant to generate the equivalent amount of electricity. In addition, through the 3R efforts, the recycled 3.1 million tons of recyclable material also contributed a reduction of 3.23 million MTCO2E in 2012 (EPA, Executive Yuan 2013a).

8 Remarkable Outcomes

Taiwan has achieved remarkable success in reducing, reusing and recycling general household waste. Average daily waste collected for disposal was down from 1.143 kg per capita in 1997 to 0.397 kg per capita in 2012. Total waste volume was down by more than 60 % from the peak in 1997. Furthermore, total recycled materials collected amounted to 3.97 million tons representing a 54 % recycling rate. Over 99 % waste are properly processed, and the problems of waste management in the early days have been effectively addressed. Figure 5 illustrates the trends of waste generation and recycling since 1989.

9 Prospects and Challenges

9.1 State-of-the-Art Technology Application

By using the state-of-the-art technologies, Taiwan EPA initiated an Industrial Waste Control Center in 1997 (Fig. 6). The Center was originally established to manage infectious medical waste and hazardous waste but later expanded to cover non-hazardous industrial waste, agriculture waste, construction waste, commercial waste and part of general waste. Transboundary movement of E-waste is also tracked by the same system. Through internet reporting, government authorities have the instant access to the manifests. The Global Position System (GPS) provides the physical locations of the transporting trucks on real time bases. Online Analytical Process (OLAP), provides précised analytical data and operational

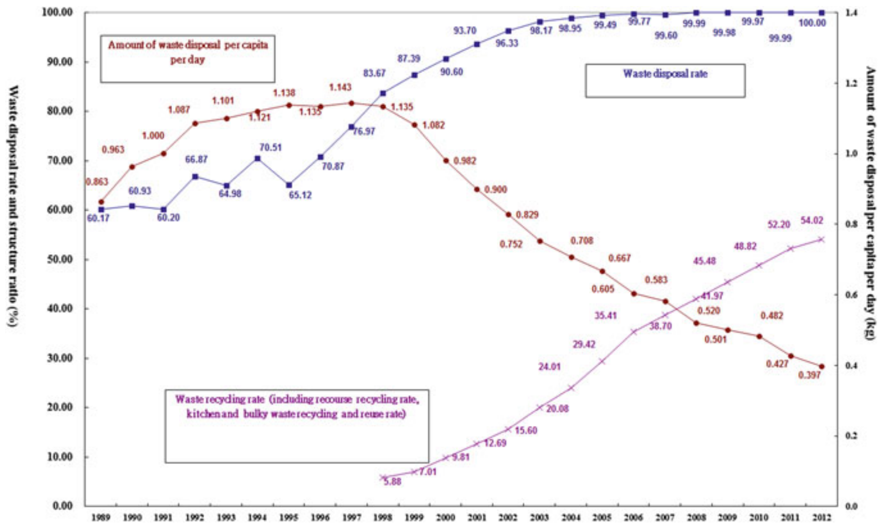

Fig. 5 Remarkable outcomes of waste generation and recycling. (EPA, Executive Yuan 2013b)

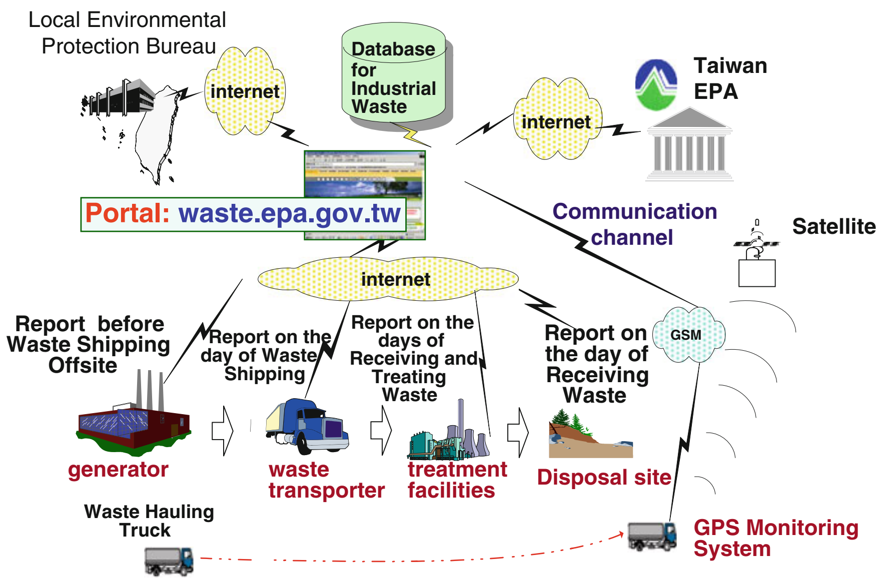

Fig. 6 Industrial waste control center (Houng et al. 2013)

patterns, easily pinpoints any illegal operations. The IWCC functions as an effective tool for compliance monitoring and tracking of wastes and provides a valuable database to assist in the development of effective policies on resource recycling and recovery (Houng et al. 2013).

9.2 Bio-Energy Center and Land Reclamation

To take advantages of the bio-energy in general solid waste, the EPA listed the "Transformation of Incinerators into Regional Bio-Energy Centers for Forestry and Agriculture" as one of the major works for "Zero Waste in a Resource Circulating Society". Retired incinerators will be transformed into regional bio-energy centers. General waste and agriculture leftover materials (such as straws, driftwood and branches not worth recycling) will be used to demonstrate and to verify emerging technologies such as torrefaction, bio-coal generation, high efficiency anaerobic digestion, etc.

9.3 Zero Waste Policy

The waste management policy of Taiwan has advanced from the early "end-of-pipe management" to the modern "zero waste". The latter stresses "source reduction" and "resource recycling", which is consistent with the international trend of valuing sustainable use of substances. Taiwan government established the "Review and Prospects of Waste Disposal Programs" in December of 2003 for stipulating the goal of "zero waste" in the nation. The frame work for reaching "zero waste" including green products, procurement, and manufacturing, as well as mandatory policies is illustrated in Fig. 7 (Ma 2010). At the same time, due to the full promotion of total waste reduction and resource recycling of the "zero waste policy" and other regulations related to resource recycling, the goals of full waste recycling and zero waste were gradually accomplished. The goals of the "Zero Waste Policy" have been drawn to 2020 as shown in Table 3 (Houng 2008, Ma 2010) and the latest data showing that the goals have been accomplished as revealed in Table 4 (EPA, Executive Yuan 2013b).

9.4 Cradle to Cradle

Taiwan promoted the cradle-to-cradle principle in 2010, making it the first Asian country to apply C2C in the planning of resource circulation strategies. The nation entrusted professional agencies in 2011 to propagate and spread C2C prospects and resulted in products from two firms to receive the C2C's silver certification. In 2012, industrial, official, academic and research organizations combined and founded the "Taiwan C2C Association" as an important interflow channel for promotion of cradle-to-cradle.

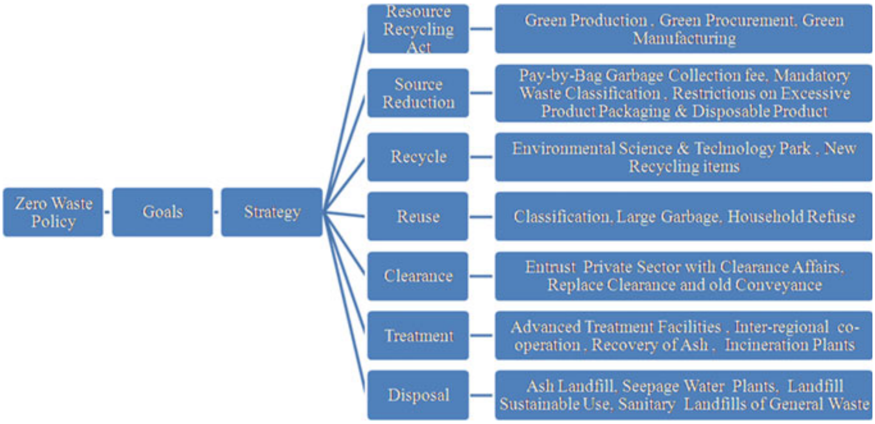

Fig. 7 Zero waste policy frameworkEPA, (Ma 2010)

Table 3 The goals of zero waste policy (Houng 2008)

Year	Reduction targets (%)	Resource recycling (%)	Food waste recycling (%)	Bulky item recycling (%)
2007	25	18.5	4	0.3
2011	40	24	7.5	1
2020	75	38	20	1.3

Table 4 The goals of zero waste policy accomplished in recent years (EPA, Executive Yuan 2013b)

Year	Reduction targets (%)	Resource recycling (%)	Food waste recycling (%)	Bulky item recycling (%)
2011	47.3	36.6	9.7	1.0
2012	48.3	37.2	10.0	1.1

9.5 Resource Productivity

"Reduce Waste Generation" and "Increase Waste Reuse" were adopted in the past, but the direction has shifted towards "sustainable substance/resource management" with the goal of reducing environmental impact and preserving natural resource. As for the increment of economic benefits from product/use/disposal of substance, decrements in resource input in the industries can lower the environmental impact of material extraction and the cost of waste treatment and disposal. It is a good example for substance used in product/use/disposal to achieve a win–win situation in resource sustainability management and economic growth.

9.6 Re-organization of Agency

Along with the idea of sustainable material management, the Taiwan government is establishing a new entity known as the Ministry of Environment and Natural Resources, expanding the scope of the EPA to encompass resources such as forests, agriculture, mining, hydraulics, etc. Taiwan EPA was established in 1987 as the first important milestone in protecting the nation's quality environment. Under the collective efforts of the public over the past 23 years, the environment in Taiwan has improved significantly. To cope with the new challenge in climatic changes brought on by global warming, the Solid Waste Department will be reorganized as the Department of Resource Management. This not only reflects to the prospect of a "proactive and right environmental policy" and responds to global climatic changes; it has also become the second important milestone in protecting the nation's quality environment. The Taiwan EPA has always been fine tuning its policies and keeping abreast with the trend of the global development of waste management. All efforts aim to promote a comprehensive circulating and sustainable society.

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Municipal Solid Waste Management in Thailand: Challenges and Strategic Solution

Orawan Siriratpiriya

1 Introduction

Thailand, covering an area of approximately 513,115 km^2, from North 5° 30′ to 21° and from East 97° 30′ to 105°, is the world's 50th largest country, while its population of approximately 64 million is ranked at the world's 20th most populous country. The GNP per capita was 153,952 Baht (5,047 US$) as of 2010 (Bank of Thailand 2012). The GDP was 373.3 billion US$ as of June 2012 and GDP per capita was 5,497.3 US$ (NESDB Economic Outlook 2012). Geographically, Thailand is located in the tropical zone and has a monsoonal climate with an average temperature 23.7–37.5 °C. It consists of 76 provinces, 926 districts (Amphoe)/minor districts (Ging-amphoe), 7,426 sub-districts (Tambon), and 74,944 villages. Some areas, including all the provincial capitals, are designated as municipalities. The capital is Bangkok with an area 1,568.737 km^2, a 6,710,883 registered population with the number of household being 2,263,680, and population density 4,160 persons/ km^2, while the average population density of the whole country is 133 persons/km^2, as of 2011 (Strategy and Evaluation Department 2012).

In general, the average generation rate of municipal solid waste (MSW) in Thailand is 0.64 kg/capita/day varying from 0.4 to 1.5 kg/capita/day based on the density of population. The moisture content of MSW ranges between 40 and 60 %. In 2008, around 41,064 tons MSW/day was produced, whereas the capacity of the sanitary disposal was approximately 38 % (Pollution Control Department 2008). The society has suffered from waste mismanagement as a result of insufficient know-how, a lack of realistically applicable technology that is suited circumstances and a weakness in the process of public participation, policy implementation and institutional support. Hence, the failure to optimize waste as a raw

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material in addition to reuse and recycling processes has occurred within and beyond administrative boundaries.

At present, a positive sign of change in the role of environmental management has recently taken place with the promulgation of a new constitution for the kingdom of Thailand in August 2007. The 2007 Constitution contains many more provisions affirming the rights and freedoms of the people in relation to their participation in the management of natural resources and environment. In addition, a draft master law for the promotion of waste reduction, reuse and recycling has been produced in order to control waste management from generation until final disposal. In this integrated solid waste management with resource conservation and recovery, the polluter pays principle, and public rights have been included to set up systematic and efficient waste management in Thailand (Pollution Control Department 2009). The drafted master law under the 2007 constitution provides the public right to be involved in waste management in term of the laws on waste reduction, separation, re-utilization as well in relation to information receiving and building up networks to co-ordinate activities. It is, therefore, necessary for Thailand to take this opportunity to strengthen the 3Rs in all respects under the current constitution and in the coming master law which promotes the 3Rs.

This paper attempts to tease out a sequence of perspectives and ideas of what should be the best research and development (R&D) opportunities for MSW management as the challenges and strategic solution in Thailand. Firstly, what MSW actually means by narrowing its related terminology, then waste composition and generation and how well it is collected and transported as well as the available techniques for treatment and disposal. Furthermore, information about the current situation of the 3Rs and an illustration of Thailand's experiences in MSW case studies to elucidate the tension between existing policies and practices are presented. Finally, ways of effectively accommodating a renewed national policy commitment to MSW management are proposed.

1.1 Definition of Municipal Solid Waste

Municipal solid waste (MSW) in Thai terms means waste generated in daily life from any activity within community. This includes organic waste and recyclable waste but by function of waste practices, MSW within the community includes infectious waste, hazardous waste, waste electrical and electronic equipment (WEEE) and packaging waste. Therefore, the definition of MSW in Thailand involves the meaning of the phrase and a pragmatic function. It can be concluded that municipal solid waste means unwanted materials and/or substances generated in a city or municipal area and the components of which generally include food/organic waste, infectious waste, hazardous waste, WEEE and packaging waste. Clear definitions in Thai law of waste, solid waste, hazardous substance, hazardous waste, infectious waste are as follows:

Waste means refuse, garbage, filth, dirt, wastewater, polluted air, polluting substance or any other hazardous substances which are discharged or originate from point sources of pollution, including residues, sediments or remainders of such matters, either in a solid, liquid or gas state [National Environmental Quality Act, B.E. 2535 (1992)].

Solid waste means used paper, worn out cloth, discarded food, waste commodities, used plastic bag and food container, soot, animal dung or carcasses, including other matters swept from roads, market places, animal farms or other places [Public Health Act, B.E. 2535 (1992)].

Hazardous substance means explosive substances, inflammable substances, oxidizing and peroxiding substances, toxic substances, pathogenic substances, radioactive substances, genetic transforming substances, corrosive substances, irritating substances or other substances, whether chemical or not, which may cause danger to human-beings, animals, plants, property or the environment. [National Environmental Quality Act, B.E. 2535 (1992)].

Hazardous waste means waste that contains or is contaminated with hazardous substances or exhibits hazardous characteristics including being flammable, corrosive, reactive, toxic or having specified constituents [The Notification of Ministry of Industry on Disposal of Waste or Unusable Materials B.E. 2548 (2005)].

Infectious Waste means body parts or carcasses of humans and animals from surgery, autopsies and research; sharps such as needles, blades, syringes, vials, glass ware; discarded materials contaminated with blood, blood components, body fluids from humans or animals, or discarded live and attenuated vaccines and items such as cotton, other cloths and syringes; waste from wards [Regulation of Ministry of Public Health B.E. 2545 (2002)].

1.2 Waste Classification

Waste in Thailand can be generally classified into 3 types as municipal waste, industrial waste and agricultural waste. Alternatively, waste can also be classified based on the source of waste generation, its physical appearance, its harmful tendencies, its utilization and disposal techniques.

Types of waste based on generation sources can be classified into household waste, municipal waste, kitchen waste, agricultural waste, construction waste/debris, institutional waste, industrial waste, hospital waste, laboratory waste, automotive station waste, etc. With the focus on utilization, waste can be classified as organic waste, recycled waste, general waste, and hazardous waste. In order to control solid waste disposal effectively and apply sanitation with technical principals, waste is classified into household hazardous waste, infectious waste and general waste. The difference in waste classification above due to specific functions of agencies involved in MSW management sometimes impedes capacities of management and collaboration.

2 Overview of Municipal Solid Waste

Waste generation is inextricably linked to socio-economic development, urbanization, population density and resource consumption. The greater the economic prosperity, the higher the population density and the greater the amount of waste produced. The composition of MSW is varied and diversified by external factors such as life style, economic conditions, culture, social activities, energy sources, weather, etc. Hoornweg and Thomas (1999) has estimated that in 2025 Thailand will generate waste 1.5 kg/capita/day with its urban population at 39.1 % of the total and a GNP per capita 6,650 Baht (1,995 US$) based on historical waste generation patterns, economic trends, population predictions, and per capita MSW generation. Health risks are associated with MSW due to the combination of hazardous waste and infectious waste within the community. Also, the high density of population in urban areas and improper management of the growth of settlement leads to problems of waste collection and, further, to waste treatment and disposal efficiency.

2.1 Waste Generation and Composition

Municipal solid waste in Thailand produced approximately 41,064 tons/day or 15.03 million tons/year in 2008. Between 1993 and 2008 (based on data from the Pollution Control Department 2004, 2007, 2008, 2009), the amount of MSW rapidly increased annually from 30,640 to 41,064 tons/day or in excess of 30 % and seems continuously to increase (Fig. 1). Although the disposal capacity has doubled (from approximately 7,047 to 15,540 tons/day) within 15 years, it still lags far behind the total waste generated, or in other words, there is not enough sanitary space for the waste collected. On average, the MSW generation rate in Thailand is 0.64 kg/capita/day, while in Bangkok, municipality areas including Pattaya and non-municipality areas have generated MSW at a rate of 1.5, 1.0 and 0.4 kg/capita/day respectively (Pollution Control Department 2009). While in 2001, Japan Bank for International Cooperation (JBIC) estimated that MSW generation rate in Bangkok is 1.3 kg/capita/day, and MSW generation (tons/day) in Bangkok will go from 11,138 in 2007 to 15,607 in 2019 with an increasing trend year by year (Department of Environment 2005, 2008).

The composition of the waste stream and the percentage contributed by each component is shown in Fig. 2 for MSW collected throughout the whole country and in Fig. 3 for MSW collected in the Bangkok metropolitan area.

The whole country's MSW data is dominated by organic waste (64 %), which are compostable organic substances with a high moisture content. Notably, the composition of the waste collected in the Bangkok metropolitan area shows how urbanization and rising income can change the MSW composition. Compared to the country data, Bangkok generates a smaller fraction of food/organic waste but a

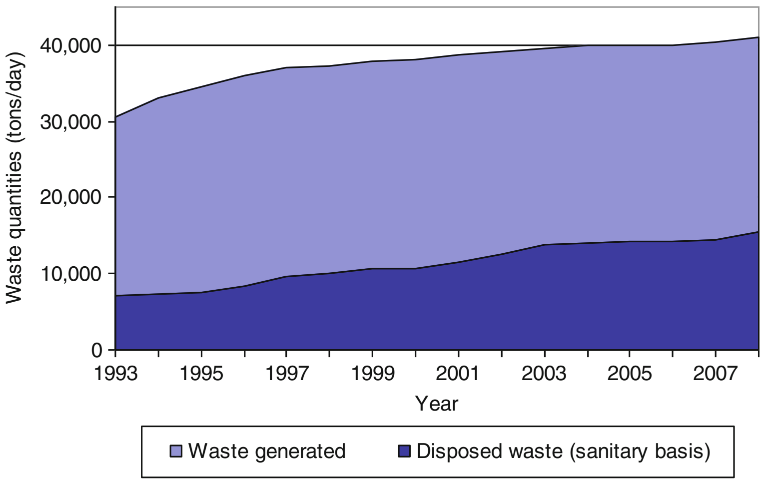

Fig. 1 Trends in municipal solid waste generation and management between 1993 and 2008. *Source* The graph has been prepared based on yearly data from the Pollution Control Department (2004, 2007, 2008, 2009)

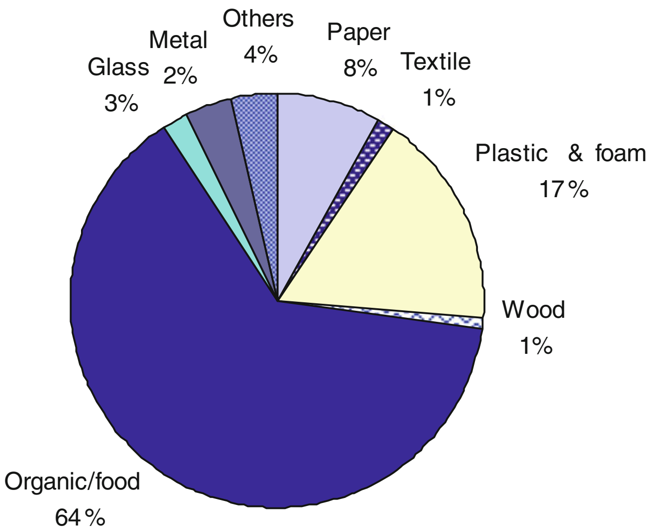

Fig. 2 Composition of municipal solid waste collected throughout the whole country. *Source* Adapted from data of the Pollution Control Department (2004)

larger fraction of packaging wastes like plastic and paper. This demonstrates modern society's demand for convenient purchasing and disposable products attributable in large part to a fast-paced lifestyle.

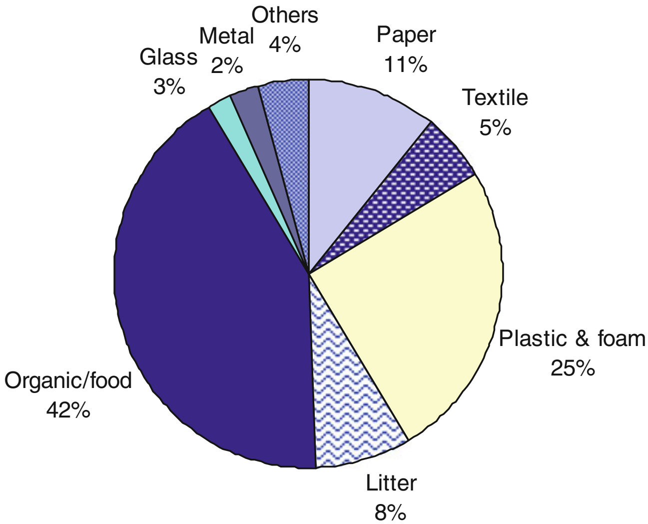

Fig. 3 Composition of municipal solid waste collected in Bangkok in 2008. *Source* The pie chart was prepared based on data from the Strategy and Evaluation Department, BMA (2009)

2.2 Method of Collection and Transportation

Waste is collected directly from households and indirectly via provided containers by truck at a frequency of 2 times/week up to everyday depending on the average waste quantity produced in each area. There are four types of dustbins and bags identified by color and symbol for separating waste e.g. **Green** for food waste, **Yellow** for recyclable waste, **Orange** for hazardous waste, **Blue** for general waste.

The collection and transportation of waste in urban areas is generally better resourced and more efficient than in rural areas. The Bangkok Metropolitan Administration (BMA) directly collects and transports waste generated in the Bangkok metropolis by truck and boat to three transfer stations namely Onnuch, Nong Kham and Saimai. The collection is carried out mainly at night and actual collection hours vary depending upon traffic conditions. Almost 100 % of MSW in Bangkok metropolis is collected. The BMA total expenditure for waste collection was 2,129 million Baht (1 US $ ~ 34 Baht) in 2003 and almost double in 2007 (4,189 million Baht (Department of Environment 2008). However, collection services in rural areas are not comprehensive leading to improper treatment such as open dumping and burning of waste. At present, an integrated approach for collection, transportation and disposal has been set up as a cluster for local administrations based on waste generation rate, distance from the collection area and technology in order to support the proper segregation for recycling, composting, alternative energy etc. before final sanitary disposal.

2.3 Waste Treatment and Disposal

Waste treatment and disposal in Thailand are still viewed as serious problems due to improper segregation at source and insufficient sanitary landfills. Sanitary principles are lacking in practice during the segregation of waste at treatment and disposal facilities. It is very difficult to establish sanitary landfills because local people protest, even though the suitable landfill sites exist and disposal site selection requires initial environmental examination (IEE). Nevertheless, the technical skills of responsible staff and the maintenance budget for waste treatment and disposal systems are insufficient.

Based on the existing high percentage of its organic components and its moisture content, composting is a basically sound treatment for MSW. The BMA has subcontracted a private company to operate a composting plant situated at Onnuch transfer station with the capacity of 1,000 tons MSW/day and a production as compost 300 tons/day. However, the treatment affected by poor separation of biodegradable waste at source resulted in low-quality organic fertilizers (Department of Environment 2008). In the mean time, the BMA has introduced Takakura Home Composting Method to 33 districts to convert food waste into organic fertilizer. In addition, vermicomposing by earthworms has become a popular alternative for producing organic fertilizer from organic waste throughout the country.

Sanitary landfill is the preferable disposal method in Thailand compared with engineered landfill, controlled dumps, and open dumps. Of the 1,000 disposal sites nationwide, only 119 sites have been constructed to appropriate standards through national government funding. Disposal practices in provincial capitals are mainly engineered landfill (54 %), followed by open dumps (20 %), controlled dumps (17 %), and sanitary landfills (9 %). While sub-district (Tambon) municipalities appear to have open and controlled dumps of up to 92 % (Pollution Control Department 2008).

The incineration of MSW is a costly option that requires less space, saves money with regard to transport and produces neither leachates nor gas, when compared to landfill but there is increasing public health concern regarding the pollutants that are emitted from incomplete combustion. Thailand has had operational experience with a capacity of 140 tons/day and 250 tons/day on Samui Island (Surat Thani province) and Phuket province respectively.

In addition, Thailand through related government agencies and academic institutions, has been conducting the feasibility study of waste to energy technologies, such as **anaerobic digestion**, **gasification** and **refuse-derived fuel (RDF)**, to produce energy from MSW and to look for the possibility of further developing projects under the Clean Development Mechanism (CDM).

As of 2008, there are three waste-to-energy plants with their construction finished and their operating systems approved in Thailand. These are the incineration plant (1.5–2.5 MW) in Phuket province, the MSW landfill gas recovery project in Samutprakarn province (1 MW) and the energy and fertilizer plant (MSW anaerobic digestion) in Rayong province (625 kW). The other three waste-to-energy plants that are undergoing operation systems tests include an incineration plant (70 kW) in Trat province, a MSW landfill (870 kW) in Nakornpathom province and a MSW elimination centre (950 kW) in Chonburi province. In addition, a RDF project (10 MW) in Chiang mai province is still under construction and a MSW gasification project (50 kW) is still at an experimental stage in Bangkok metropolitan area (DEDE 2009).

3 Reduce, Reuse and Recycle-3Rs

Problems found in waste management systems, among others, include limited areas for landfill, waste disposal costs, the emission of greenhouse gases and dioxins and concern over health and environmental quality, all of which can be solved more easily in combination rather than individually. In 2008, MSW 3.405 million tons (23 % of total) was utilized by recycling (89 %), as bio-fertilizer and biogas (7 %), and alternative energy for electrical generation (4 %) (Pollution Control Department 2009).

The 3Rs campaign was initiated to reduce the waste quantity and reuse plus recycle based on an increasing awareness of the linkage between waste generation and resource consumption. Activities for the 3Rs in Thailand are encouraged through cooperation among various stakeholders to implement effective waste management. The activities are, for example, a recycle-oriented society, community 3Rs activities, resources efficiency, recycled materials and products, source separation and re-utilization, providing incentives for the 3Rs operation, public participation in the 3Rs, in-house segregation, reuse and recycling activities (waste bank, waste donation etc.), safe composting, etc. The recycling business has been informally established in Thailand for decades. Local waste collectors or scavengers using a tricycle known as a "Saleng" roam around town to trade used materials from villager with money or used clothes. The Wongpanit Company is the leader with the concept waste is gold. The company has been operating recycling work since 1974 and has expanded throughout the country with 500 networks and franchise plus international franchises now.

Campaign 3Rs Activity has been promoted nationwide to enhance the effectiveness of MSW management leading to the awareness and participation of Thai people. Campaigns about integrated waste management systems for waste reduction, sorting, reuse and recycling have been constantly promoted through outreach (brochure, booklet, radio, TV spot, forum, conference etc.) towards municipal administrations, government organizations, communities, NGOs, universities and school networks. The examples for campaign activities that sustain the growth towards a sustainable Thai society are as follows:

Magic Eyes was the pioneer campaign in the early 1980s to reduce littering in Bangkok conducted by the Thai Environment and Community Development Association (TECDA). The famous quote is 'Ah! Ah! Don't litter!, The Magic

Eyes watch you!' had a big impact on environmental awareness and the responsibility of individuals to improve environmental quality. With community-based participation and a social marketing approach, this campaign was highly successful in making the corporate partners of government agencies, private companies, schools, the media, communities, and NGOs put their social responsibility into action, at its resulted in a long term effect of redefining behavior and the life style of Thai people.

Green label is an environmental certification awarded to specific products or services, excluding food, drink, and pharmaceuticals. The criteria to get label is that the products or services performed must have a minimum detrimental impact on the environment when compared with others serving the same function. Participation in the Thai green label scheme is on a voluntary basis. As of 2009, there are 231 products (under 18 groups of products) of 43 companies that have been awarded green label certification. The campaign was initiated by the Thailand Business Council for Sustainable Development, Thailand Environment Institute (TEI) since 1993.

Waste Bank is a campaign for handling waste by buying back waste in terms of a deposit like banking system resulting in efficiency in waste segregation. People are stimulated to use each product to its maximum benefit and realize the value of solid waste, so that it can benefit the community by not only providing a clean environment but also cash flow for extra saving. Moreover, students involved in the project have gained through the learning process and the knowledge repertory of waste management and the networks have exchanged both external and internal learning. Each bank is believed to have reduced the waste generated by 3–5 tons per month or a total of 18,000–30,000 tons/year from all banks together. The waste bank was initiated in 1999 in Phitsanulok province by the personnel of the Wongpanit Company who saw poor pupils are selling the recycled waste and depositing the earnings in the bank. In order to help the pupil, waste bank was set up as pilot project in school. Leaflets with a list of prices were distributed leading to the pupils progressively realizing the unexpected value of waste becoming eager to sort the waste and deposit it directly in the waste bank. At present, the waste bank is one of the most popular 3Rs activities in school, universities and the community nationwide.

Used Lead-acid Battery Recycling is a campaign programme to encourage recycling through tax incentives by taking into account the environmental and operational monitoring system. Up to now, 84 % of used lead-acid batteries have been recycling. The campaign initiated in 2000 by the Pollution Control Department.

Tod Pha Pa Recyclable Waste is a campaign to create a momentum for participation in the segregation of reusable solid waste for donation to monks as a Buddhist activities. People have been stimulated and now realize the handling problem of MSW. The activity was started in 2005 at Tesco Lotus in the Bangapi district, where 142 tons of recycled solid waste were donated. On June 4, 2005 alone, on the occasion of the Environmental Day, 164 tons of recycled solid waste were donated throughout all 50 districts in Bangkok Metropolitan Area. All of the donated waste was sent on to be utilized as recycle products or raw materials for other products at Suan Kaew Temple where unemployed people are trained for careers and which serves as a recycling market. This is one of activities initiated by the Bangkok Metropolitan Administration (BMA) to achieve a 10 % reduction in MSW generation annually.

The outcome of these 3Rs campaigns can be viewed as an illustration of the philosophy of sufficiency economy (see detail in 6.1) and show how the least technically complex can be the most cost-effective solution when small communities participate in MSW management. At the heart of these 3Rs activities is the network established to involve people into the development process. Since the work requires not only coordination with central government and local government agencies but also planning processes jointly devised by meaningful participation of all stakeholders, all of these can certainly be lessons to be learnt by other communities.

4 Local Case Studies on Municipal Solid Waste: Incineration

Phuket and Samui islands are the most popular international tourist destination in the southern part of Thailand. The Phuket incineration plant was constructed in 1995 with a capacity designed to generate 2.5 MW of electricity from MSW 250 tons/day based on a heat value of 1,800–2,500 kcal/kg MSW. However, in reality, the incinerator is overwhelmed by 500 tons MSW/day and it can generate electricity at around 1.6 MW due to the decreasing of heat value down to 1,400–1,500 kcal/kg MSW (Vanapruk et al. 2007). The given reasons are the increased moisture in the waste with a high proportion of food waste and from the addition of rain water due to uncovered-waste bins and substandard collection trucks. The National Human Rights Commission has cited a survey by the Phuket Municipal Authority in 2007, which found that the level of dioxin measured at the province’s garbage incineration was higher than it should be (Bangkok Post 2008).

The Samui incinerator was built in 1997 with a capacity of 140 tons MSW/day. At the beginning the island daily generates only about half of the full capacity, and the incinerator is left to rest with maintenance days while waiting for burning period (IPEN 2006). At present, the waste generation rate there already met the full capacity of the incinerator. The impact from the two MSW incineration plants became substantial, mainly because more than half of the waste is incombustible, which impedes the combustion process, and dioxin is generated because of this incomplete combustion. The situation was worsened by having no specific site to manage infectious and toxic waste, which is mixed with household waste.

In 2004, Greenpeace Southeast Asia, according to tests done by CUB Co. Ltd., found a very high concentration of dioxins, a complex mixture of non-chlorinated hydrocarbons and heavy metals (mercury, copper, and chromium) to have been released from the Samui incinerator. The emission went far beyond the standard set by Ministry of Natural Resources and Environment (IPEN 2006). There were also concerns about the disposal of ash from incinerator which could contaminate ground water supplies.

The successful operation of incineration depends upon several factors other than selecting appropriate technology. To promote incineration as a benign waste management option, appropriate nitrogen dioxide and dioxin removal processes should firstly be provided. In addition, the separation of waste according to its heating value and moisture content and burning with suitable proportion should improve the combustion and reduce the use of fuel. Thus, a high-quality of MSW incinerator can facilitate the electricity production and can also be considered a complement to conventional power production.

5 Current Policies for Municipal Solid Waste Management

5.1 Legal Framework

The Constitution of the Kingdom of Thailand B.E. 2550 (2007**)** advanced environmental management and provisions affirming the public right to access information (Section 56) and to participate in the prevention and alleviation of public hazards, protecting and passing on the national conservation of natural resources and the environment (Section 73). For the planning of any project or policy that might cause a serious impact on the quality of the environment, on natural resources, and on the health of the people, comprehensive public hearings before implementation must be held before they are initiated (Section 67). The State shall promote and lend support to research and development and make use of alternative energy that is naturally acquired and advantageous to the environment (Section 86). Local governmental organizations have powers and duties in connection with the promotion and maintenance of the quality of the environment (Section 290) and must report its work to the people to enable them to participate in monitoring its administration and management (Section 287).

While the draft master law for the promotion of waste reduction, reuse and recycling is in the enactment process (Pollution Control Department 2009), MSW management in Thailand has been under the followings existing laws and regulations:

Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992) is the fundamental environmental law governing environmental standards, including planning, and monitoring environmental quality and establishing a system for environmental Impact Assessment (EIA).

The Public Health Act B.E. 2535 (1992) provides a legal role for local administration to manage MSW by issuing and setting ordinances or regulation to control and protect environmental sanitation and covers collection, transportation and the disposal of waste. This is the most comprehensive law dealing with MSW.

The National Health Act B.E. 2550 (2007) specifies that state agencies have the duty promptly to reveal and provide data and information to the public, and individuals shall have the duty to cooperate with state agencies in creating a good environment.

The Hazardous Substance Act B.E. 2535 (1992) provides a legal basis to control the import, export, manufacturing, storage, transport and disposal of hazardous substances. The Act governs the methods of managing hazardous materials, hazardous waste and infectious waste.

In addition, other regulations which are partly related to solid waste management are the Public Cleansing Act B.E. 2535 (1992), Determining Plans and Process of Decentralization to Local Government Organization Act B.E. 2542 (1999), the Industrial Estate Authority of Thailand Act B.E. 2522 (1979), the Factory Act B.E. 2535 (1992), the Land Transportation Act B.E. 2522 (1979), the Industrial Products Standards B.E. 2511 (1968), the Petrol Act B.E. 2521 (1978), the Land Traffic Act B.E. 2535 (1992), the Highway Act B.E. 2535 (1992), the Building Control Act B.E. 2522 (1979) and B.E. 2535 (1992), and the Official Information Act B.E 2540 (1997).

5.2 National Policy

The national policy and plan of the Thai government regarding the waste aspect, will be to implement an environmental-friendly waste disposal system, enhance the waste disposal capacity of local administrative authorities, and promote the role of the private sector in research and development for recycling of raw materials and clean technology. Moreover, the government will not allow any area of Thailand to become an end receiver of waste, which has to bear the costs of waste and pollution. The National integrated waste management plan has been focused on the sustainable consumption of natural resources and the application of the 'cradle to cradle' concept, including control waste generation at source, increased waste segregation and the enhanced efficiency of waste utilization prior to final disposal. The target for waste minimization is 30 % of the total waste generated within 2009. The concept of the Polluter Pay Principle (PPP) is used to encourage responsibility in producers, importers, and consumers. The 3Rs is promoted as a vital tool for environmentally sound management. The life cycle approach is also integrated in waste management plan to minimize the large volume of packaging waste (Thongkaimook 2006).

The Pollution Prevention and Mitigation Policy 1997–2016 aimed to (1) reduce or control solid waste generation to a rate of not more than 1.0 kg/capita/day (2) have Bangkok and communities throughout the country utilize waste of not less than 15 % of the total solid waste generated (3) all solid waste left from collection in municipal districts was to be collected, and for outside municipal districts not more than 10 % of total solid waste was to be left, and (4) ensure that each province has a master plan for sanitary solid waste disposal (Pollution Control Department 2009).

The Environmental Management Plan 2007–2011 was formulated to create a balance between the use for development and the need to preserve, conserve and rehabilitate natural and environmental resources at their optimum level, consistent with the carrying capacity of ecosystems and rising life standards of people. The goal is that people can participate and receive benefits from the sustainable maintenance of natural resources and the environment. This plan also promoted solid and hazardous waste management to attain Thailand as the Asian tourism hub as well as the world's kitchen (ONEP 2009).

The fast growing of MSW management seems to urge the private sector to provide services in collection, transportation and disposal at policy level. However, it should be noted that **privatization (public sector involvement) for MSW** management requires not only a proper legal framework according to the State Enterprise Capital Act B.E. 2542 (1999) and matched investment cost and capacity, but also the transparence of the central and local government sectors when employing private sector.

6 Future Development of Municipal Solid Waste Management

6.1 Philosophical Concept of Sustainable Development

His Majesty the King Bhumibol Adulyadej of Thailand graciously conferred the philosophy of **sufficiency economy** based on Buddhist principles of self-reliance, self-satisfaction and the middle path on the entire nation in 1997. (www.sufficiencyeconomy.org) The philosophy has been incorporated into the Thai National Economic and Social Development Plan since 2002 as it is trusted to lead the nation to balanced development in a more secure way and it will lead to a more resilient and sustainable economy, better able to meet the challenges arising from globalization and other changes, while preserving Thai national identity. The philosophy guides and conducts the livelihoods and behavior of people at all levels, from the family to the community and to the country, on matters concerning national development and governance. Well-being is focused upon rather than wealth based on understanding the requirement for basic human need and security, strengthening capability building to develop to is highest potential, providing effective self-immune mechanisms as safeguards for all changes, and including perseverance, wisdom, prudence, honesty and integrity in one's life style. The fundamental basis for sustainable development in the Thai context lies in the philosophy of sufficiency economy.

Being sufficient means that, whatever we produce, we must have enough for our own use. We do not have to borrow from other people. We can rely on ourselves, having enough and being satisfied with our situation. The characteristics of sufficiency included moderation, reasonableness and effective self-immunity. All plans and every step of implementation should be ensured by intelligence, attentiveness, knowledge, extreme care, the common interest, the public benefit and keep abreast of ethics and moral. The approach is to maintain balance and be ready to cope with surrounding rapid physical, social, and environmental changes. The concept is applicable to every person in every profession, living in both urban and rural areas, and thereby to the 3Rs campaign and the integrated management of municipal solid waste to meet the country sustainable development.

6.2 Research and Development Opportunities for Municipal Solid Waste Management

One of the most challenging issues is how to utilize waste as raw material while including the 3Rs properly and safely for the people, the environment and the quality control of manufacture. As a result the opportunities to involve the business community in 3Rs enterprises are growing following the increasing awareness and realizable the value of waste connected with natural resources and environmental quality. In addition, MSW management should also expand opportunity on CDM and waste to energy technology to serve climate change mitigation perspectives.

The next question is how to utilize management technology to ascertain sustainable development without knowing first what good for us. Many severe effects on human health and environmental quality have resulted from the mismanagement of MSW and the lack of source separation indicates that the implementations of the regulatory procedures (pollution control standards, waste collection fees, etc.) in Thailand have failed to bond MSW management with institutional functionality and have affected environment together.

To identify the most practicable technology for targeting communities from various sources of knowledge through the transfer of the proven technology, an investment should be made in R&D at an initial stage in order to assure the suitability for the country contexts, and this can be developed into cost-effectiveness, socially acceptance, and environmental sound business practice in the long-term perspective (Fig. 4). Consequently, to enable prompt action for the transferring of the proven technology to target communities, R&D study is also required at every stage when developing specific laws, regulations and guidelines, sanitary standards as well as applying the technology into pragmatic work of MSW management. This must be conducted based on the Thai environment, the carrying capacity of the target area, the knowledge base, local wisdom, behavior, attitude and life style in conjunction with culture and politics.

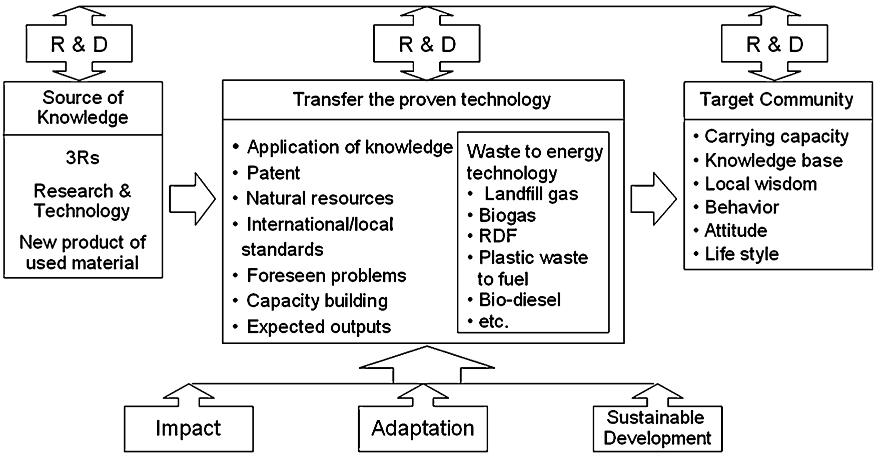

Fig. 4 Conceptual framework for R&D applied to municipal solid waste management (Siriratpiriya 2007)

The applying of the "**Polluter Pay Principle**" to make waste collection and disposal fees closer to waste generation rates is suggested at policy level **for both the public and government**. In this regard, further R&D study is required for setting up criteria to identify different stakeholders in order to resolve the disparity between residential and non-residential sources. The business community has great potential for direct user charges which will allow commercial, institutional and industrial waste for self-financing. The general community must also actively participate in the solutions by modifying their behavior. For instance, there is a need to exert discipline in separating waste and exercising environmentally friendly purchasing habits. However, proper waste services and capacity building to develop an attitude for proper MSW management and social values reinforcement are needed for communities that consist of the poor and minorities.

MSW management in Thailand is going in the direction of sustainable development through an integrated waste management system, including the minimization of the production of waste and the maximizing of the waste recycling and reuse. The things to overcome include efficiency of segregation at sources, excluding infectious waste and hazardous waste from general waste in addition to collection, transportation, treatment and disposal.

Prerequisite factors to be considered for R&D applied to MSW management are proposed in Fig. 5. These are a holistic approach suited to any process designed for production, transportation, segregation, collection and disposal of waste mainly including options for waste management and interaction with human heath and environmental risks, public education, technology, research and collaboration, etc. In addition, more locally suitable technologies are needed for recycling agricultural and household waste to bioenergy as well as for reducing greenhouse gas emissions from waste.

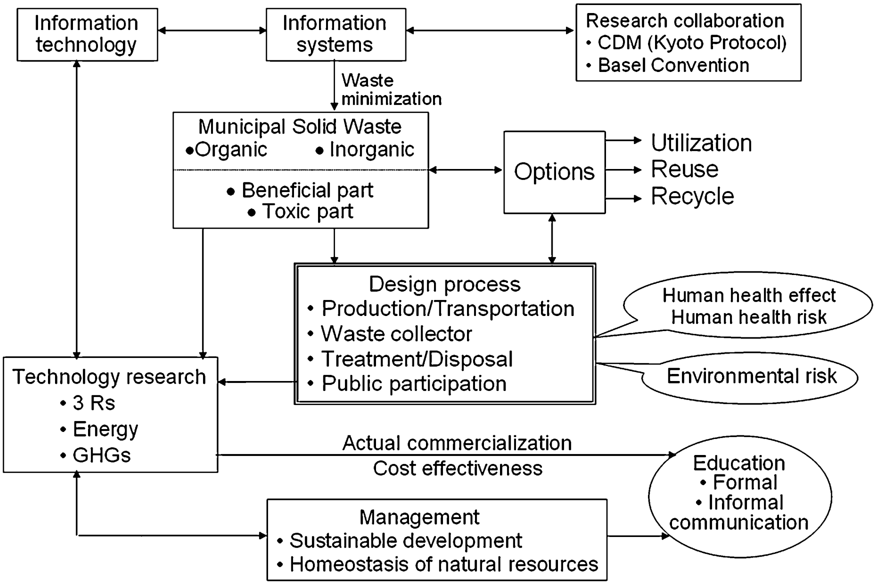

Fig. 5 Prerequisite considerations for research and development (R&D) applied to municipal solid waste management (adapted from Siriratpiriya 2005)

The **Pollution Prevention and Mitigation policy 1997–2016** reflected the **current status of MSW management in Thailand**, particularly waste segregation and household hazardous waste that obstruct the waste to be utilized downstream as well as solid waste disposal site under pollution control standards. This implied the urgent need to put strategies into practices for all types of waste beginning with urban community. In addition to specific policies and regulations as well as financing mechanisms, successful MSW management requires cooperation from local government and other levels of government, business and the general community because there is no strategy that will work if people do not feel it necessary to engage with one another on the follow-up activities.

Significantly, one prerequisite factor that is not yet clearly seen from the policy but should be seriously emphasized is the need to have **public participation in MSW management** in the real sense. Although the rights to public participation are already guaranteed by the current constitution, there is still a lack of clear measures to promote public participation towards the society. From the national assessment of environmental governance (Nicro and Vassanadumrongdee 2007), people are still unable to participate at the level of decision-making, operations, monitoring and implementation. It is crucial to note that most public hearings are held after some major decision has already been taken. In addition, there is no clear evidence to show that opinions and recommendations acquired from public hearings have been used in the decisions made by government and state agencies.

Public participation in MSW management related to policy and planning processes is still limited due to lack of skilful resources and tools to put it into effect. The meaningful inclusion of public participation needs more details of the significant stakeholders to be involved, employed knowledge, actual procedures, collaboration and coordination among government agencies, and the serious development of approaches for public relation (PR) to build up people's trust in the state administration of MSW management.

Last but not least, national policy must also target the **provinces to prepare suitable land for the long-term disposal of solid waste**. Constructing waste disposal facilities such as landfills and incinerators causes arguments about environmental and health impact and often generates most of public concern. Involving the community and following a technically sound and transparent site selection process are suggested to be the best way to minimize public opposition to new facilities (Hoornweg and Thomas 1999). However, this paradigm still contradicts what happens with public participation in reality. The general public is entitled to participate only at the information and the consultative levels, whereas only the authorized decision-makers of the representative from all the stakeholders participate at the partnership level. The barrier factors mainly include the culture of political and institutional dominance in decision making, the need for more specific legislation and guidelines for MSW related issues, clarifying procedures and the continuity of measures, and the pragmatic mechanism of effective management. Hence, to build up public trust, **public participation should be taken into account from the beginning of the project** and prior to decision-making on land use as well as into the monitoring programme of the disposal facility (interval time within 25 years of operation) to prevent the dispersion of pollution.

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Municipal Solid Waste Management in Vietnam Challenges and Solutions

Nguyen Thi Kim Thai

1 Introduction

Vietnam is located in the Center of South-East Asia. The national capital which is Hanoi City has a total land area of 329,560 km^2; a coast line of 3,260 km and Mainland border of 3,730 km (Fig. 1).

Vietnam is developing rapidly and undergoing urbanization. According to the Vietnamese Governmental Decree No. 42/2009/ND-CP dated May 7th 2009 titled Classification and Management of Urban Towns, six categories of urban towns were classified based on the function, population, and population density of the towns. There were **762** urban towns up to the year 2005, of these 2 cities are of the special class; 5 Cities are first class; 13 cities are in the second category; 21 are in the third category; 54 are in the fourth category, and 586 are in the fifth category, according to the classification criteria for urban towns in Vietnam. The GDP per capita is $2,600 and GDP real growth rate 8.5 % (Vietnam Statistical Year Book 2012).

Up to the year 2009, according to the General Survey on Population and Housing in Vietnam, the total population of this country was 85789000 with a average population growth rate of 1.3–1.7 % and the urban inhabitants made up to 28 % of the total population of the whole country.

Presently the solid waste generation is assessed to be more than 15 million tons per year with approximately 80 % from municipal sources, 17 % from industrial sources and the remaining 3 % from other sources. By year 2010 the expected solid waste generation is 24 million tons per year, with a likelihood of reaching 52 million tons by year 2020.

As a part of SWAPI book on Municipal Solid Waste Management in Asia and the Pacific Islands-2012, this chapter presents a comprehensive set of data and analysis of Municipal Urban Solid Waste over the last 5 years in Vietnam. The analysis consists of:

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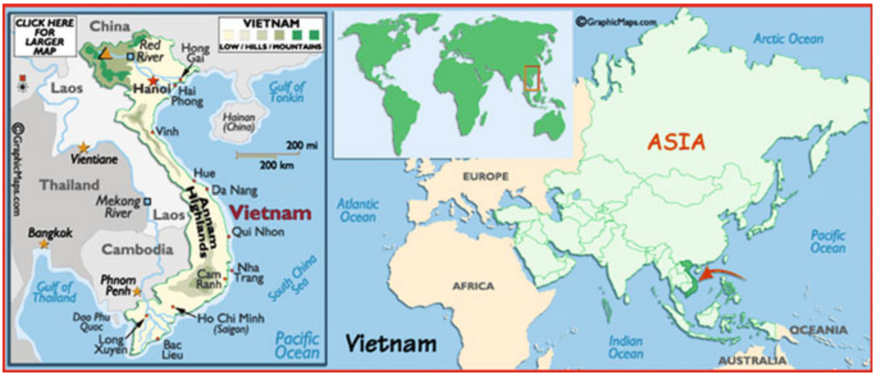

Fig. 1 Location of Vietnam in the Asia Pacific region

- Waste generation (quantity, composition and distribution)
- Waste handling (collection and disposal)
- Waste recycling, composting, and reuse
- Environmental and social concerns (environmental impacts, perception, priorities, cost contribution, public campaigns)
- Landfills (technical and management issues, ecological impacts, costs)

2 Definitions of Waste

According to the Vietnamese Law on Environmental Protection:

- Wastes mean materials that take a solid, liquid, gaseous, or other form, which are discharged from production, service, daily life or other activities.

Under the Law, the Decree No 59/2007/ND-CP on Solid Waste Management issued By the Government, the following definitions are provided:

- Solid Waste means waste in a solid form, discharged from production, business, service, daily life or other activities. Solid waste includes ordinary solid waste and hazardous solid waste. Solid Waste generated in daily-life activities of individuals, households or at public places is collectively referred to as daily-life solid waste. Solid waste generated in industrial production, craft villages, business and service activities or other activities is collectively referred to as industrial solid waste.
- Hazardous Solid Waste means solid waste containing substances or compounds that exhibit any of the characteristics of radioactivity, ignitability, explosiveness, corrosiveness, infectiousness, toxicity or other hazardous characteristics.

There is no specific definition for Municipal Solid Waste (MSW) in Vietnam.

3 Waste Classification

According to the Vietnamese Standard (TCVN 6705-2009- Non hazardous solid wastes -Classification), solid wastes are classified as follows:

- Domestic solid waste: including the solid wastes generated from house holds, commercial, and services activities;
- Construction and Demolition Solid Wastes: The wastes arising from construction/demolition activities.
- Industrial Solid Waste: The wastes arising from processing and non-processing industries and utilities.

4 Sources of Wastes

Most municipal solid waste in Vietnam comes from households and businesses. According to the report by IESE (2010), the solid waste generated from households, shops, offices, institutions, hotels and restaurants was more than 65 % of the total municipal waste generation while the industrial solid waste accounted for about 15 %; construction and demolition waste was 12.20 %, and medical waste was 1.8 % depends on the different economic regions. Table 1 shows the volume of domestic solid waste generated in six economic areas in Vietnam in 2008.

5 Waste Generation and Composition

Waste generation quantities and characteristics are strongly related to regional economic conditions, and change with economic growth. Other socio-economic factors that affect waste generation include:

Table 1 The volume of domestic solid waste generated in six economic areas in Vietnam in 2008

No	Region	Volume (tons/day)
1	Northern midland and mountainous region	1,053
2	Red River Delta and Northern key economic zone	4,953
3	North Central Region, Central coastal region and Central key economic zone	3,110
4	Central highlands	919
5	Southeast region and the southern key economic zone	9,314
6	Mekong River Delta	2,195
	Total	21,543

Source National strategy for integrated management of solid waste to 2025 with a vision to 2050 issued attached to decision no. 2149/QD-TTg on December 17, 2009

- Housing development plans
- Rural/urban drift
- Road construction programs
- Improvement programs for marginal settlements

Socio-economic conditions that enable an increase in standards of living of the regional economy will influence the per capita rate of waste generation and the composition of waste generated. Per capita waste generation levels generally increase, in correlation to improvement in the standard of living. According to the data reported by provinces, the average daily generation rates in kg/person/day range from 0.8 to 1.2 kg/person-day in big cities and from 0.35 to 0.5 kg/person-day in small towns. The generation rates depend on the living conditions of the residents in urban areas, category of urban areas, the topography and the socio-economic development in each province. The increase in quantity of solid waste generation in Vietnam is shown in Table 2.

Composition of municipal solid waste is very diverse and is characterized by the (living customs, civilization level, and development rates). Generally there are some common characteristics as follows:

- Composition of organic origin accounts for a high rate (50–66 %);
- Containing a lot of soil, sand and fragment of brick, stone.
- High moisture content, lows specific heat energy (900 kcal/Kg).

The composition of urban solid waste in several provinces is shown in Table 3. The data in Table 3 is based on average figures from the analysis of the composition of solid waste in different places such as in residential areas, in markets and at the landfill sites.

The figures in the Table 3 show that the percentage of recyclable materials and hazardous waste component are different between big cities and small cities in Vietnam.

Industrial Solid Waste: Together with urbanization there was a rapid growth in establishing industrial zones. According to State of Environment Report (SOE) by the end of 2009, Vietnam had 249 industrial zones covering an area of 63,173 ha, their occupancy rate was 48 %. The development of industrial areas has generated a large quantity of solid waste, especial hazardous wastes. Recent inventory of hazardous waste in the country indicates that the main industrial sectors that generated hazardous wastes are:

Table 2 Increasing of quantity of solid waste generation in Vietnam

Type of solid waste	Unit	2003	2008
Municipal solid waste	Tons/year	6,400,000	12,802,000
Industrial solid waste	Tons/year	2,638,400	4,786,000
Medical solid waste	Tons/year	21,500	179,000
Rural solid waste	Tons/year	6,400,000	9,078,000
Craft village solid waste	Tons/year	774,000	1,023,000

Source Annual Report on Environment- MONRE (2011)

Table 3 Average composition of solid waste in typical urban cities in Vietnam (% By weight)

No	Composition	Hanoi [a]	Da nang[b]	Hue[c]	Pleiku[d]
1	Organic substances	53.80	66.0	55.0	60.49
2	Plastic	3.42	4.0	5.2	12.77
3	Paper, carton	4.2	3.1	4.4	9.65
4	Metal	1.4	4.9	7.0	1.16
5	Glass	1.0	0.9	1.8	0.13
6	Inert substances	28.18	16.4	23.0	12.6
7	Rubber	4.9	1.6	1.5	2.8
8	Textile rags	1.7	2.3	3.0	0
9	Hazardous substances	1.4	0.8	0.8	0.4
Total		100	100	100	100
Moisture content (%)		43.04	51.2	50.0	50.5
Ash content (%)		13.70	16.0	15.5	13.9
Bulk density, tom/m^3		0.41	0.40	0.40	0.38
Recyclable materials		16.62	16.80	22.90	26.51

Source Monitoring report by IESE (2009), *Note* [a] special category city, [b] first category city, [c] second category city, [d] third category city

- Electrical mechanics
- Food processing
- Chemicals;
- Mechanical
- Metallurgy

The average quantity of Hazardous wastes generated by major industries in 33 provinces in Vietnam is shown in Table 4.

According to the National Environmental Status Report by the Ministry of Natural Resources and Environment (MONRE) (2011), the industrial solid waste generation from several cities is shown in Table 4.

Compositions of the industrial solid waste are very complicated, depending on the raw materials, technological processes and final products of each production center and its related services.

Typical components of industrial hazardous waste in Dong Nai Province –one of the Southern economic regions is illustrated in Fig. 2. A summary of a survey on components of industrial hazardous waste in Vietnam is shown in Table 5.

Medical waste: The major sources which generate the medical solid waste are hospitals. According to the report from MOH in 2009, total solid waste generated from hospitals were 100–140 tones/day of which 16–30 tones/days were hazardous. Waste generation rate are varied according to the activities of departments in the hospitals (Table 6).

There have been limited studies on the composition of medical waste in Vietnam. Under the task given by the Ministry of Natural Resource and Environment (MONRE), the Centre for Environmental Engineering of Towns and Industrial Areas (new name is Institute for Environmental Science and

Table 4 The average quantity of industrial solid wastes generated in some cities of Vietnam in 2010

Type of category	Province/city	Normal industrial solid waste (tones/day)	Hazardous industrial solid waste (tones/day)
Special category city	Ho Chi Minh city	4606.12	4606.12
First category city (Belonging to the Central Government)	Da Nang	553.79	83.07
	Can Tho	136.25	27.25
	Ha noi	254.7	67.42
First category city (Belonging to the Provincial Government)	Dak Lak/Buon Ma Thuot	63.08	9.46
	Khanh Hoa/Nha Trang	1767.19	441.80
	Lam Dong/Da Lat	70.48	10.57
	Binh Dinh/Quy Nhon	810.19	121.53
Second category city (Belonging to the Provincial Government)	Dong Nai	990.07	990.07
	Tien Giang	249.20	62.30
	Ca Mau	93.80	9.10
	An Giang	120.33	11.31
	Binh Thuan	464.78	102.25
	Gia Lai	189.75	18.98
	Ba Ria-Vung Tau	274.01	274.01
Third category city (Belonging to the Provincial Government)	Bac Lieu	29.02	2.96
	Ben Tre	120.29	24.18
	Dong Thap	512.03	76.80
	Ninh Thuan	116.80	17.52
	Kon Tum	39.67	2.1
	Kien Giang	34.26	6.85
	Quang Ngai	455.18	159.31
	Soc Trang	172.10	30.98
	Quang nam	433.00	82.27
	Long An	110.45	22.09
	Binh Duong	830.38	830.38
	Tra Vinh	248.00	37.20
	Phu Yen	194.80	37.01
	Hau Giang	160.05	16.01
	Vinh Long	177.33	25.00

Source Annual Report on Environment- MONRE (2011)

Engineering—IESE) has conducted a survey on medical waste composition in some hospital in Vietnam. Table 7 shows the composition of waste in some hospitals in Vietnam. The data shows that the hazardous portion from medical waste various according to the type of the hospital.

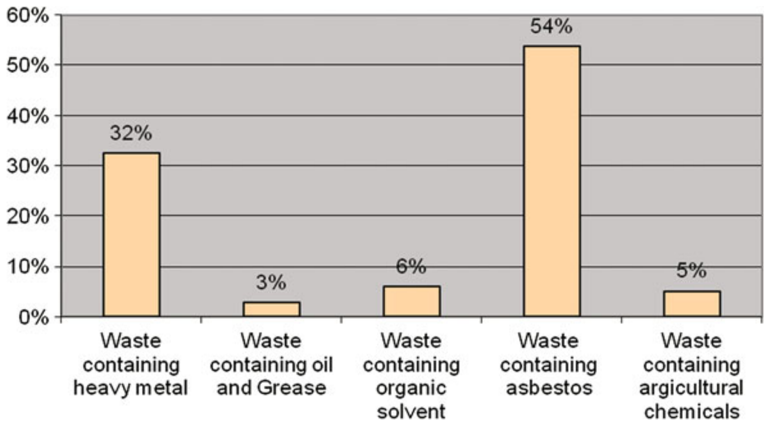

Fig. 2 Typical components of industrial hazardous waste in Dong Nai Province. *Source* Institute of Environmental Science and Engineering (2008)

The hazardous medical waste is estimated to be in a wide range (0.11–0.16 kg per bed per day from a total waste arising of 0.7–0.73 kg/bed/day) and makes up about 20–26 % of the total solid waste generated from hospital activities.

Special Hazardous Wastes: It is mentioned that together with normal hazardous waste, several specific hazardous wastes which belong to Persistent Organic Pollutants (POPs) such as used solvent, E-wastes; PCB containing from industrial activities wastes are being paid special attention to by the Vietnamese Government. These types of waste are potentials for recycling activities due to the fact that they are partly valuable waste.

In Vietnam, PCBs have not previously been considered as chemicals which need to be fully controlled, thus data and assessment of PCBs are insufficient and unsystematic. Sources of PCB releases into the environment are mainly from uncontrolled discarded waste oils from transformers or capacitors. An initial inventory conducted by Energy of Vietnam (EVN) shows that the total quantity of likely PCB-containing oils in Vietnam is approximately 73,600 liters in the form of isolating fluid and 5,297,000 kg in (old transformers and capacitors. The amount of oil suspected of containing PCBs account for 19 % compared to the total amount of oil in the transformers.

E-waste contains a number of toxic substances such as lead and cadmium in circuit boards; lead oxide and cadmium in monitor cathode ray tubes (CRTs); mercury in switches and flat screen monitors; cadmium in computer batteries; polychlorinated biphenyls (PCBs) in older capacitors and transformers; and brominates flame retardants on printed circuit boards, plastic casings, cables and polyvinyl chloride (PVC) cable insulation that release highly toxic dioxins and furans when burned to retrieve copper from the wires (Source: Vietnam National Implementation Plan for Stockholm Convention on Persistent Organic Pollutants toward 2020- MONRE 2006). Due to the hazards involved, disposing and

Table 5 The components of industrial hazardous waste in Vietnam

No	Industrial sector	Ratio hazardous waste (HW)/Generated waste (GW) (%)
1	Mechanical industries	47.4 % where: • 12.5 % Corrosive • 28.1 % Toxic • 6.3 % Combustible • 0.7 % Mixed
2	Electric, electronic industries	76.8 % where: • 0.8 % Corrosive • 60.4 % Toxic • 12,8 % Combustible • 2.0 % Mixed
3	Chemical industries	69.3 % where: • 18.2 % Corrosive • 43.8 % Toxic • 4.5 % Combustible • 2.8 % Oxidized
4	Food processing industries	23.6 % where: • 0.5 % Corrosive • 5.3 % Combustible • 17.5 % Bio-degradation • 0.3 % Mixed
5	Textile, leather and dying industries	46.5 % where: • 25.3 % Toxic • 4.9 % Combustible • 15.8 % Bio-degradatable • 0.5 % Mixed
6	Metallurgy	42.8 % where: • 14.2 % Corrosive • 26.5 % Toxic • 0.5 % Combustible • 1.6 % Mixed
7	Construction materials	23.5 % where: • 1.2 % Corrosive • 18.4 % Toxic • 3.5 % Combustible • 0.4 % Mixed

Source Vietnam Environmental Protection Agency (2006) Vietnam National implementation plan for the Stockholm convention on persistent organic pollutants toward 2020

recycling E-waste has serious legal and environmental implications. When this waste is land filled or incinerated, it poses significant contamination problems. Likewise, the recycling of computers has serious occupational and environmental implications, particularly when the recycling industry is often marginally profitable at best and often cannot afford to take the necessary precautions to protect the environment and worker health.

Table 6 The waste generation rate of the different generation sources in hospitals of Vietnam

Generation sources	Waste generation Rate (kg/bed-day)				Hazardous waste generation rate (kg/bed-day)			
	Central hospital	Provincial general hospital	District hospital	Average	Central hospitals	Provincial general hospital	District hospital	Average
Hospital emergency	0.97	0.88	0.73	0.86	0.16	0.14	0.11	0.14
Care Dept.	1.08	1.27	1		0.3	0.31	0.18	
Incretology Dept.	0.64	0.47	0.45		0.04	0.03	0.02	
Pediatric Dept.	0.5	0.41	0.45		0.04	0.05	0.02	
Surgery Dept.	1.01	0.87	0.73		0.26	0.21	0.17	
Obstetric Dept.	0.82	0.95	0.74		0.21	0.22	0.17	
Ophthalmology Dept.	0.66	0.68	0.34		0.12	0.1	0.08	
Paraclinical Dept.	0.11	0.1	0.08		0.03	0.03	0.03	

Source Ministry of Health (2009)

Table 7 The composition of medical waste in some hospitals in Vietnam

Composition of solid waste	Type of hospital		
	General hospital	Skin disease hospitals	Maternity hospitals
Organic waste	42.5	45.0	41.5
Package paper	21.6	3.4	8.8
Sharps, injection	2.98	3.0	2.5
Package paper	7.48	8.0	4.7
Organes	5.39	0.5	1.6
Plastics	4.70	5.6	2.2
Metal	2.40	0.6	1.5
Glass	1.79	2.63	2.0
Expired medicines	0.60	0.1	1.0
Others	10.56	31.17	34.2
Hazardous waste (%)	18.86	16.78	14.00
Non-hazardous waste (%)	81.14	83.22	86.00

Source Nguyen thi Kim Thai- CEETIA (2007)

The status of solid waste separation at source: In most urban areas, solid waste has not been sorted at its source. Only a few households sort solid waste in order to sell certain waste such as bottles, jars, metal and paper to scrap collectors. In recent years, pilot solid waste sorting was implemented in some big cities as Hanoi, Da Nang and Ho Chi Minh City. However, these efforts were generally not successful for several reasons including the lack of community awareness and the lack of treatment facilities to process separated solid waste, which makes sorting at the source meaningless as all solid waste ultimately buried in landfills. Currently, urban domestic solid waste is also being sorted by waste collectors at its generation sites, waste gathering sites or at landfills.

6 Collection and Transportation of Municipal Solid Waste

At present, the average rate of solid waste collection is about 72 % for the whole country, of which the collection rate in urban areas is increasing from 80–82 % (2008) to 83–85 % (2010) and in rural areas about 40–45 %; the reuse and recycling rate ranges from 18 to 28 %. Wastes generated in areas outside of the current services are dumped in garden areas, by the roadside, in ditches or lakes. Wastes are also burnt in areas adjacent to properties or the roadside by residents and commercial waste generators.

Solid wastes from households are collected by handcarts or waste collection vehicles running through streets according to a planned schedule. In areas where waste collection is provided, wastes are dumped in the street without any containment and can be blown about by wind or washed into the drains and ditches of the city drainage system by rainfall, thereby contributing to littering of the city and surface water pollution, respectively.

Collection of domestic solid wastes and street sweeping are often undertaken at night. The collection time is from 10.00 p.m. to 6.00 am. So many trucks are seen on the streets carrying waste at that time, causing pollution to the environment and spoiling the appearance of the city. Reasons for this practice include avoiding working in the high daytime temperatures, a public preference for discarding wastes in the evening, and the desire to avoid times of traffic congestion. A result is that sweepers—often female and working alone—can be found working with a handcart and broom late into the night, and often in streets where there is poor street lighting, or perhaps none at all. It is common in the evening to find domestic wastes dumped on the streets. In some places handcarts are left at street corners until the evening cleaning operations and so the wastes can be put into these carts. Some wastes are discarded in small plastic bags. However, a high percentage of the wastes are simply tipped out onto pedestrian pavements or roadside curbs, where they are sorted through by waste pickers (scavengers) before being picked up by waste collection workers.

Some Vietnamese cities use an ingenious collection system that has been developed in Hanoi. The handcarts have hoppers that can be lifted from the chassis and tipped into the top of a high open body. This is a very efficient transfer system, provided that carts can rendezvous with trucks without either carts or truck having to wait for a long time. The flow of waste is shown in Fig. 3.

Socialization of Solid Waste Collection: The public or Community-Based Organizations (CBOs) are interest groups formed by the member of a local community to take charge of their interests or to influence solid waste collection activities. CBOs are very varied groupings ranging from neighborhood committees

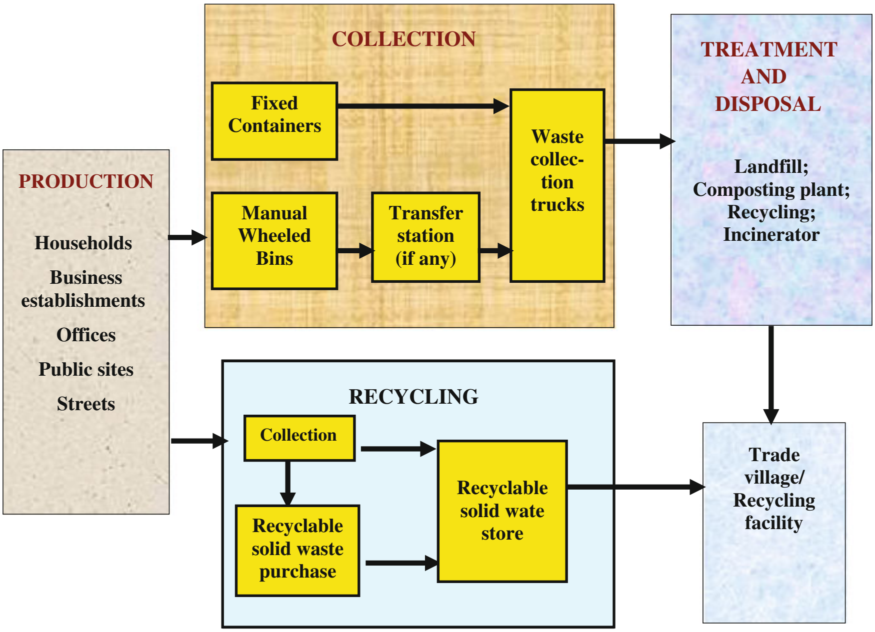

Fig. 3 The common flow of solid waste in the urban areas in Vietnam

through youth or women groups to interest groups of all possible characteristics. In a waste collection system, CBOs can be valuable partners in service provision, and they can directly participate in primary collection of domestic waste.

The participation in secondary collection, transport and final disposal of waste is usually beyond the scope of community groups, but possible on rare occasions in actively participating in solid waste management such as enhanced primary collection systems, source separation, litter prevention or domestic hazardous waste prevention.

At present, it appears that under the changes, in Vietnam the primary responsibility for street cleaning and waste collection will pass from URENCO to the Urban Wards. The Urban Wards will be responsible for employing workers in Cooperatives (It is estimated that each Ward will require between 10 and 15 workers) to clean the streets and take the collected wastes to the waste collection Points. The wastes at the waste collection Points will be picked up and transported to the landfill disposal facilities at the Landfill by Urgency's refuse collection vehicles.

In Phu Yen Province, a Program of Work named "Collection of Domestic Waste from Urban Wards in Toy Hoax Town" has been approved by the Town People's Committee (TPC). This Program has been on since April 2002 up to the present. By this Program, Ward People Committees organized "Collection Units" to conduct primary collection from households to the transfer/collection points. The location of transfer points also have been approved by TPC with notice at each place so that the collection worker can temporarily dispose waste for further collection by vehicles/trucks of the town's collection enterprise.

Because of many narrow alleys in the town, the "tricycles" with a capacity of app. 1 m^3 are used for primary collection and this model is quite efficient the primary collection in the urban wards.

Private companies and cooperatives are becoming more active in community solid waste management in urban areas of the whole country. There is one city on the northern border of Vietnam—Lang Son—where a private company has a monopoly in waste collection and disposal and has replaced the Urban Environment Company (URENCO) as the operator. In Buon Ma Thuot in the Central Highlands, a private company is collecting municipal waste along with the local URENCO.

Beside the waste collection service provided by URENCO in the City, solid waste is collected by local sanitation cooperatives. According to URENCO, this waste is normally dumped in the collection area of URENCO. It is needed to overcome "NIMBY" (Not in My Back Yard), which is likely to dominate and needs to be handled very delicately.

7 Treatment and Disposal of Municipal Solid Waste

In Vietnamese urban centers, solid waste is generally disposed of in landfills. Almost every urban center of category IV or higher has at least one landfill. According to provincial statistics, there are about 450 landfills in Vietnam, 80–85 % of which are not sanitary and pose a risk of environmental pollution by odor and/or leachate *(Source: Technical Infrastructure Administration—Ministry of Construction)*. In addition to landfilling, Vietnam also applies incineration, composting and recycling technologies; products of recycling are construction material and construction by-products.

Incineration Technologies: Municipal solid waste of Vietnam is usually of high humidity and low calories (900–1,100 kcal/kg), therefore incinerating waste is not a common practice in Vietnam. This technology is applied for treatment of hazardous waste; a few hospitals in the country have incinerators. Very little data is available on the amount or type of waste being incinerated because they do not keep records. Whatever the case, even though the incinerators are assessed by the government for technical standards and gas emissions, Vietnam lacks the technology to be able to analyze dioxin concentrations emitted by the incinerators (Ministry of Health 2008).

Recently, a number of incinerators and other treatment facilities have been applied for treatment of hazardous wastes from hospitals and industries before dumping them with domestic waste at the landfill. The type and quantity of incinerators which are applied in Vietnam are shown in Table 8.

It was estimated by MOH that only 37 % of total health care wastes were treated by incinerators and the remains were treated in improper ways.

Table 8 The type and quantity of incinerators which have been applied in Vietnam (up to the year 2008)

Type of incinerators	Capacity of incinerator (kg/day)	Quantity	Percentage (%)
Very small size incinerator	<100	7	3.6
Small size incinerator	100–399	159	80.7
Medium-size incinerator	400–999	29	14.7
Large-size incinerator	≥1000	2	1.0
Total		197	100

Source Ministry of Health (2008)

In 2003 under a research project funded by MONRE, Centre for Environmental Engineering of Towns and Industrial Areas (CEETIA) in cooperation with Hanoi URENCO produced a pilot scale incinerator to treat industrial hazardous waste for Hanoi City. The capacity of this incinerator was 150 kg/h.

Composting: Composting is potentially a very useful form of recycling of organic waste to produce a clean soil conditioner, and can help to increase the recovery rate of recyclable materials. This can contribute to a more efficient municipal solid waste system, but it is not yet widespread for a number of reasons, including inadequate attention to the biological process requirements; poor feed stock and poor quality of the fertilizers; and, poor marketing experiences. To support composting, the development of a strong market for intensive agriculture is needed (Table 9).

Centralized composting facilities are large-scale waste management plants that draw on an urban area for their organic waste supply. Several of these facilities are currently operating in Vietnam (Table 9). The compost produced at these plants often contains broken bits of glass and metals, and is therefore difficult to sell it.

Since centralized composting plants in other Asian countries have failed when relying on mixed municipal waste as their main feedstock, 12 source separation initiatives are being tested in Vietnam. In Hanoi, for example, wastes from markets or separated household wastes from test areas are being used as clean sources of organic matter. In addition, without successful composting, efforts to expand or sustain source separation will be less effective, although it can still be targeted to recyclable materials and general awareness purposes. The lessons learned from the existing Composting plants in Vietnam can be described as follows:

- The demand and market for the compost products are no carefully conducted,
- The operational practices of the plant are not suitable. Dry waste feeding is manually carried out with out a regulator and the area is narrow. As a result, the loading capacity is unstable;
- Separation is still done completely manually. Fine fraction of particles, glass and metal are not well sorted. Hence, the materials projected for fermentation is not high in purity. It means a waste in transportation cost and the recovery of materials is not satisfactory.

Table 9 The Information from some typical composting plants for treatment of organic waste in Vietnam

Name of composting plant/city	Trang Cat Hai Phong city	Cau Dien Hanoi city	Thuy Phuong Hue city
Treatment capacity (tones of waste/day)	150	140	200
Technology	Imported from Korea Forced air suply	Imported from Spain Forced air suply	Domestic technology Tam Sinh Nghia Forced air suply
Year of Operation	2009	1992	2006
Production (tones of compost/day)	30	40	50
Average price (VND/tone of compost)	600,000	750,000	500,000

Source Institute for Urban Environment and Industry of Vietnam (INEV) (2011)

- The composting of organic solid waste can be an appropriate technology in Vietnam only if it can be done in an affordable manner. The affordability is based on: market requirements; quality of compost products and acceptable prices to meet the ability of the farmers.

Disposal of municipal solid waste: Disposal has, until recently, generally involved uncontrolled open dumping. The use of un-hygienic landfills for dumping of municipal solid waste is normal in most urban areas in Vietnam. Up to the year 2007, there was only 19/85 from 66 Provinces having landfills that meet the national sanitary standards. The lack of facilities and responsible entities to treat and dispose many types of waste including hazardous waste has caused serious pollution to the environment and affected public health. The landfills in all localities including major cities which have already been built do not reach sanitary standards and are not planned to match the rapid development of industrialization and urbanization. The summarized current situation of landfill management in Vietnam is shown in Table 10.

The existing landfill sites are not controlled for hazardous waste, stinking smells and leachate which are a potential source of pollution of land, water and the environment. In addition, landfill sites of urban areas in the Mekong Delta still encounter flooding in the rainy season which leads to unexpected negative impacts on the environment. The key issues of dumping sites in Vietnam are shown in Table 11.

Table 10 Summarized current situation of landfill management in Vietnam

Situation	Number of landfills
Landfill sites in the whole country of which:	85
Landfill sites with total area more than 50 ha	06
Landfill sites with total area from 30 to 50 ha	08
Landfill sites with total area from 10 ha to less than 30 ha	18
Landfill sites with total area from 1 ha to less than 10 ha	53
Solid waste disposal sites for residues of composting	08
Separated sites for construction waste	02
Open dumps and poorly operated landfills	56
Engineering designed but unsanitary operated landfills	19

Source IESE (2009)

Table 11 Key Issues of dumping sites in Vietnam

Cause	Effects
Accepting all kind of wastes	• Hazardous wastes get mixed and cause Environmental contamination
Poor landfill sitting 100–150 m from the nearest residents	• Odor, irritating dust, noise from refuse vehicles, especially at night, risk to public health.
Municipal and industrial waste, sludge hospital and hazardous waste are dumped in excavated pits, without any impermeable layer or liner.	• Serious risk of contamination of the upper aquifer, and thus of private wells. Due to lateral flows, also possible contamination of the lower aquifer, this is important for water intake for public water supply.
Transport to the landfill A narrow dilapidated concrete road leads to the landfill through a residential area.	• Refuse collection vehicles cause noise especially during the night-time (busy night shift), odour, and irritating dust. • Risk of traffic accidents and injury.
Insufficient operation of landfills No fencing and no soil cover	• Waste littered in the surroundings, reproduction of flies, odour, and landfill gas emissions to atmosphere.
No separation or compacting of waste	• Risk of subsidence due to unstable structure • Risk of emissions of toxic and carcinogenic volatile organics
No collection, control or treatment of runoff water or leachate	• Serious risk of contamination of surface waters and groundwater. • Risk of contamination of surface waters and negative impacts to public health.
No landfill gas collection	• Risk of explosions; • Waste of potential source of energy • Risk of contamination • Odor • Increase of global greenhouse effect

Source Ministry of Natural Resource and Environment

8 Current Waste Reduction, Reuse and Recycling Situation in Vietnam

Activities of recycling of non-organic materials: Recycling plays a critical role in reducing waste quantities, returning resources back to use, and minimizing the financial and environmental burden of MSW management. An extensive partially tiered system exists for waste recycling within each city/province comprising scavengers, small household/commercial recyclers, larger recyclers and manufacturers to produce recycled products.

It is estimated that each city in Vietnam has up to 700 scavengers. They are made up of poor unemployed women or farmers that come into the city from surrounding provinces at times when there is less agricultural activity, looking for ways of earning money. The scavengers walk the streets of the city each day to collect all type of waste from households, institutions, dumping sites, waste collection points, restaurants, hotels etc. which could be reused or recycled, and sell the collected items to the recyclers.

The recyclers collect recyclable waste materials from scavengers and factories. They separate wastes in accordance with each waste type such as paper, metal, aluminum, nylon and plastic. The waste is then compacted or packaged and sold to factories or manufacturers that use the materials in their manufacturing process. Some larger recycling operations deposit money with small recycling activities to enable them to have sufficient funds to buy wastes from scavengers. These larger recycling operations usually sell larger quantities of recyclable waste materials and act as an agency to supply secondary raw materials to manufacturers or factories. According to statistical data, there are 6,000 recyclers and scavengers in Hanoi City. These people come from other provinces. The Nam Son landfill site, it was observed that there were about 600–700 scavengers working at the landfill. The quantity of recycling materials is app. 10–15 tones/day an d consists of:

	tone/day
Paper	0.5–1.0
Metals	0.1–0.2
Glasses	3.0–4.0
Rubbers	1. 5–3.5
Plastics	0. 5–1.0
Rags	0. 5–1.0

Vietnam's potential for recycling is high but there is not much information available about the amount of waste recycled in Vietnam every year at the additional level. However, it is known that approximately 20 % of the municipal waste in Hanoi is recycled.

Solid waste sorting at source is a relatively new activity in Vietnam, which has not yet become a common practice and has been only experimented on household garbage in some big cities including Ha Noi, Ho Chi Minh and Da Nang. With underdeveloped infrastructure and an uncoordinated management system, in many programs and projects, as a result of which have separated wastes had been collected and disposed together with other wastes. The effectiveness of these projects, therefore, has not been significant and as a result, people have not developed a habit of separating organic and non-organic wastes before dumping them.

Waste reduction in production, services and consumption is still almost neglected. There are no incentive policies or legal enforcement to encourage people to practice solid waste reduction in a concrete manner. Similarly, there are very few programmes encouraging people to save natural resources. There are some whose results have not been recognized. Only about 200 out of 200,000 enterprises (about 0.01 %) have been applying the cleaner production approach, which can be very effective in reducing wastes in production activities.

Waste reuse and recycling are more common and implemented by a system of individual garbage collectors and buyers. Most households in Vietnam have the habit of separating recyclable wastes such as plastic, paper, metal, etc. to be sold. Through this system, recyclable and reusable materials are collected separately and delivered to recycling facilities in craft villages. According to a general assessment, these activities contribute to solid waste reduction by about 15–20 %.

Some craft villages which recycle paper, plastic and metal, etc. have been effectively developed and contributed to job creation, poverty reduction and improved people's income and lives. Statistics in 2003 showed that about 52,000 tons of paper, 25,000 tons of plastic and 735,000 tons of waste metal were recycled by craft villages in the North. However, most recycling technologies used by craft villages are old, out-of-date, and some have caused serious pollution problems in the villages which recycle paper, plastic and metal, thus impairing people's health and lives.

Recycling organic waste from old dumping sites: Organic waste decomposes naturally in landfills and, if it is not contaminated by glass, heavy metals, or other pollutants, can be recovered for use as a soil conditioner. A private enterprise extracts waste from the Dong Thanh landfill in Ho Chi Minh City and separates organic matter which is then sold as a soil conditioner. This practice has been banned in Vietnam due to its potential health and environmental impacts.

Recovery of landfill gas: Landfill gas is produced by the degradation of organic matter in waste and contains approximately 50 % of methane, a potent greenhouse gas. Composting can also reduce landfill gas emissions by removing organic matter that would otherwise degrade under landfill conditions.

Some studies have been conducted by the Japan Engineering Consultant Co. Ltd. (JEC) in Vietnam for promoting of CDM. The typical CDM projects which have been submitted for approval are as follows:

- The model project for renovation to Increase the efficient use of energy in a brewery in Tan Hoa
- Thu Duc power plant unit 3—fuel switch project
- Landfill closure and gas recovery and utilization in Hai Phong city

- Landfill closure and gas recovery and utilization in Ho Chi Minh city
- Environmental forestation in A Luoi district, Thua Thien Hue province
- Thanh Hoa rice husk power plant in Tien Giang province

9 The Challenges of Solid Waste Management in Vietnam

The challenges of solid waste management in Vietnam can be summarized as follows:

9.1 Technical

- The unavailability of a solid waste classification and recycling system. Organic waste and nylon bags can be easily recognized in all dumpsites.
- The collection rate is low because the waste collectors only gather solid waste in village entrance sites or disposal sites.
- The lack of proper trolleys and other collection facilities for primary waste collection prevents waste collectors from hygienic working conditions
- Improper collection sites
- Lack of solid waste treatment facilities (recycling, composting etc.)

9.2 Environment, Public Health and Safety Issues

- Insufficient collection coverage
- Non-standard landfill sites. Insufficient collection and/or improper dumping bring about diseases as waste facilitates vectors like rodents, flies and mosquitoes.

9.3 Institutional and/or Organizational Issues

- Poor coordination between collection, transportation, treatment and final disposal;
- Inactive community participation in waste management. The households need to take part more directly in waste classification and treatment (e.g. composting)
- Lack of law and regulation enforcement in solid waste management

9.4 Financial, Economic and Social

- Low affordability of users
- Finance shortage (for investments and operation)
- Low ratio of cost recovery from users.

Awareness:

- Low awareness among local people in waste management.

10 The Solutions Improvement of Municipal Solid Waste Management in Vietnam

According to the results of the 2009 Population and Housing Census, with the average solid waste volume per capita in 2009 was about 1.1 kg/person-day based on the structure of Vietnam's urban population and QCVN 07:2010/BXD the quantity of municipal solid waste generation was projected for the year 2020 and 2030 (Fig. 4).

Technical Solutions: The general layout of the proposed future urban solid waste management system is shown in Fig. 5. The system is based on the 3R principle: Reduce, Reuse and Recycle.

The main components of the system are:

- Sorting at source
- Collection from households
- Transportation
- Transfer stations (in bigger cities)
- Treatment complexes

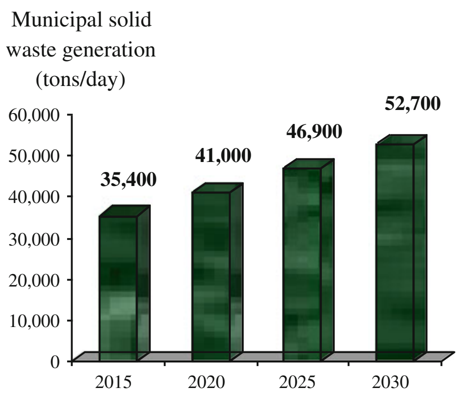

Fig. 4 The projection of municipal solid waste generation in Vietnam to the year 2020 and 2030

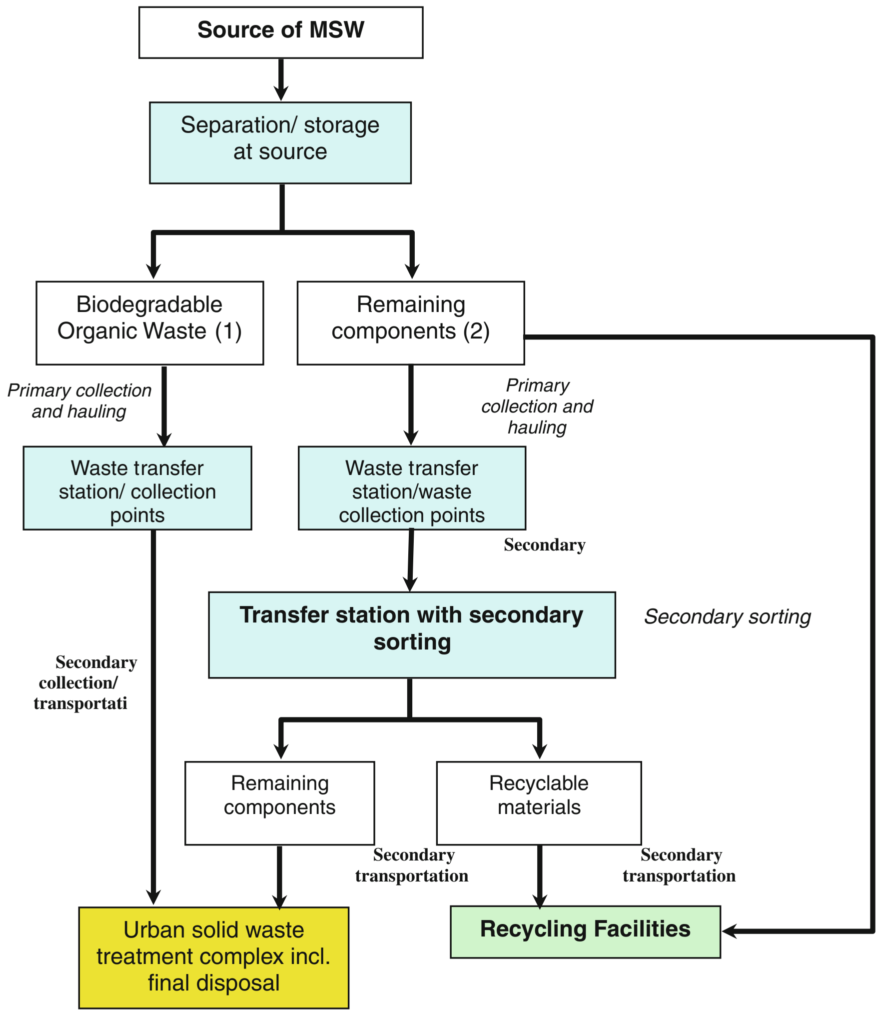

Fig. 5 General layout of urban solid waste management system in Vietnam for the future development

Treatment complexes may consist of one or several of the following facilities for sorting, composting, incinerating and final depositing in sanitary landfills. It should be noted that no matter which treatment method is applied there will always be residual waste and therefore sanitary landfills will be needed in any treatment complex.

The full implementation of the 3R principle will result in a substantial reduction of the volumes of waste to be treated and finally deposited.

Within the environmental protection policy, the “3R Initiative” of Reduce-Reuse-Recycle has been raised as an important issue in need of close attention.

There are a number of challenges in implementing 3R in Vietnam because of the increase in quantity, types of waste and the level of hazard of the waste generated while the technical infrastructure for handling and managing the waste is inadequate and the laws on environmental protection are equally lacking. However, it is lucky that Vietnam has received much support from the Government of Japan to conduct a "Project for Implementation Support for 3R Initiative in Hanoi City to Contribute to the Development of a Sound Material-Cycle Society (3R-HN Project)", for three years from November 2006. The project aims to establish a balanced and unique 3R system centered on source separation and recycling of raw waste under the 3R Initiative, and connect this to the formation of a "Sound Material-Cycle Society" in Hanoi City. The experiences gained from the 3R-HN Project will be useful in the implementation of such projects in other urban areas of Vietnam in the future.

The government viewpoint is that the development of solid waste treatment technology must be in accordance with the urban sustainable development in order to create "Environmental Friendly Products." The selection of treatment technology needs to be based on the 3R strategy (reduce, reuse, recycle) with a pollution prevention orientation.

To 2020, solid waste treatment technologies are mainly recycling, composting and landfill. After 2020, recycling, composting and incineration with energy recovery will be promoted while the volume to be dumped shall be minimized. Solid waste treatment complexes in key economic regions should be constructed in accordance to Decision No. 1440/2008/QD-TTg and Decision No.1873/2010/QD-TTg of the Prime Minister. Recycling, composting facilities, incinerators with energy recovery and sanitary landfills can be included in these complexes.

All landfills must be equipped with leachate treatment facilities that can treat effluent to meet environmental requirements of the receiving water bodies.

Policy's Adjustment: In order to improve the quality of life of the people through municipal solid waste management, the Vietnamese government passed amendments to the Law on Environment 2005, adopting the Prime Minister's decision known as "Vietnam Agenda 21," which aims for sustainable development.

The amended Law on Environmental Protection (2005) has provided for organizations and individuals engaged in the recycling of wastes and products to be entitled to preferential policies in accordance with the solid law. The organizations and individuals that invest in the construction of waste recycling facilities shall be entitled to preferential treatment of tax, financial support and land use given by the State for constructing waste recycling facilities. Reusing or reprocessing of solid waste is being done in concentrated Industrial zones based on an information system for waste exchange, as solid waste in one place can be used as raw material in another place.

Vietnam Law on Environment Protection also states that the advanced technologies for recycling and reuse of waste to create raw materials and generate energy shall be encouraged, and the minimization of solid waste volume to be buried whereby saving land needed for disposal shall be an important part of waste management policy for Vietnam.

The Government issued Decree No174/2007/ND-CP dated 29 November 2007 which requires that all waste producers must pay a fee for environmental protection. The environmental protection charges for wastewater as well as for solid waste will be a contribution to State revenue.

A Decree on Solid Waste Management was issued in 2007 stipulating that solid waste disposal facilities shall be merged to serve more than two provinces or shall be combined in a complex treatment facility which will include garbage incinerators with energy recovery, organic waste fertilized plants, sanitary landfills for ordinary solid waste and landfills for hazardous solid waste.

A new Construction Standard issued in 2008 dictates that the amount of solid waste that requires land-filling shall be cut down to 15 % of the total volume of collected wastes while 85 % shall be treated through proper treatment technologies.

In spite of current policies, waste reduction, reuse and recycling practices in Vietnam have been conducted simultaneously and mostly controlled by private sectors. Meanwhile, the economic and social development often goes with ever-increasing quantities, compositions, diversity and toxicity of wastes, which eventually cause serious pollution in some places and impacts on people's health.

In 2009, The National Strategy on integrated management of solid waste in Vietnam to 2025 and vision to 2050 has been approved by the Prime Minister.

The solutions for implementing the strategy:

- Improving the legal documents system and policy mechanism of solid waste management
- Planning schemes of solid waste management
- Establishing the database and data observing system of solid waste in the whole country.
- Developing strategy resources for implementing
- Promoting doing scientific research to apply effectively to general management of solid waste
- Propagandizing, educating to promote awareness

The enhancing reduction, reuse, recycling solid waste can be reached through several ways such as: Promoting classification of solid waste at source; enhancing reuse of solid waste; encouraging using recycled products; developing and applying preferential policies for recycling activities however, the handling of solid waste including reuse, recycling, collection, treatment and disposal is crucial to providing a cost effective waste management system that is able to public health and environmental risks.

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