DOI: 10.1007/s00267-002-2874-5

ENVIRONMENTAL ASSESSMENT

Analysis of Scavengers' Activities and Recycling in Some Cities of Nigeria

J. C. AGUNWAMBA*
Department of Civil Engineering
University of Nigeria
Nsukka, Nigeria

ABSTRACT / The state of solid waste recycling by scavengers in Onitsha, a heavily commercial city in Anambra State, and some other urban areas such as Nsukka, Enugu, and Port Harcourt was analyzed. Data were obtained through interviews of scavengers who deal with recyclables. Although the activities of scavengers are sub-optimal, they can have a great impact on Nigerian economy with respect to resource conservation, creation of job opportunities, and reduction of the magnitude of waste disposal problems. A cost analysis is presented to compare the different forms of recycling utilized by municipal solid waste management. It is shown that a well-planned recycling program with recycling and composting would result in 18.6% savings in waste management costs and 57.7% in landfill avoidance costs. However, if the compost materials are not recycled, the corresponding savings in cost become 8.6% and 28.6%, respectively. The option with the lowest cost involves encouraging individual households to separate at the source their recyclables, which are bought by scavengers. This results in 78.0% savings in waste management cost and 79.5% landfill avoidance cost. A low-cost approach aimed at the integration of scavenging activities into conventional solid waste management is presented.

Many communities throughout the world are battling with the problem of how to safely and effectively manage their municipal solid waste. Solid waste recycling is now becoming a common practice in the developed countries as people become more conscious of pollution problems caused by uncontrolled waste generation and disposal (Morris and Dickey 1991). Through proper legislation, coupled with education and intensive citizen participation, relevant agencies at local, state, and/or federal government levels, have been able to reduce the amount of waste disposed of in incinerators and landfills by adopting appropriate recycling program (Kelley 1992).

In order to reduce the possibility of contamination and increase the rate of capture of the recyclables, sorting at the source is emphasized. The recyclables are placed in a special container at the curbside, separate from another container where the non-recyclables are kept.

Well-planned and well-implemented recycling programs have been very successful at reducing waste and costs. In Wilkes-Barre, Pennsylvania, it resulted in a savings of $500,000 in landfill avoidance costs within the period between 1988 and 1991. A 60–70% reduction in waste was achieved in Leeds, England in 1991.

KEY WORDS: Scavenging activities; Recycling; Cost analysis

Published online September 4, 2003.

*Author to whom correspondence should be addressed, *email:* mis@aol.com

Apart from cities, university communities are also increasingly involved in recycling programs. At the University of Colorado, the reduction in waste as a result of implementation of a recycling program was 30%. The corresponding values for Stanford University, the University of Michigan, and the University of Minnesota were 28%, 15%, and 25%, respectively. The landfill avoidance costs for Colorado, Stanford, and Michigan were 50%, 20%, and 25%, respectively.

Planned recycling does not exist in Nigeria as it does in developed countries. In Nigeria the problem of solid waste management has become more complex in recent times due to rapid population growth, urbanization, and industrialization and the rising standard of living. Both the quantity and diversity of waste now being generated have increased. This problem is further complicated by political, economical, and sociological factors.

Solid waste is managed at the municipal level by either the state government agency or contractors who are involved in waste collection, transfer and transport, and disposal. Usually, waste collection and disposal is restricted to the urban areas and has not been extended to the rural areas. Urban waste management is still fraught with many problems like lack of financial resources, collection and transportation facilities, poorly developed dumping grounds that are potentially threatening to public health and environmental health, and poor management.

In the eighties, when the economy was booming, technological, socio-economic, and marketing considerations encouraged more people to buy the new goods

and discard the old. There was general disregard for the potential reuse and recycling of waste material. In recent times, however, the bad national economy has forced some people into reusing their old materials. In some homes, waste paper, cans, and glass are stored separately and sold to scavengers when they visit. There is little or no literature on the activities of scavengers in Nigeria (Agunwamba and others 1998). Neither has a cost analysis been done on a well-structured, Nigerian recycling program. Such information is very important for evolving efficient recycling programs not only in Nigeria but also in other developing countries.

Hence, the aims of this research are to present the state of solid waste reuse and recycling in Nigeria, discuss the problems, propose a recycling program, and highlight how useful such a program could be in solving Nigerian solid waste problem. Also, a cost analysis of waste management with different recycling options will be presented.

State of Solid Waste Reuse and Recycling in Nigeria

Data were obtained through interviews. Questionnaires were not used because of the level of illiteracy among the scavengers. The four cities selected for the study are Nsukka, Onitsha, Enugu, and Port Harcourt. Nsukka was chosen for its lack of industrial development compared with Port Harcourt, a highly industrialized city. Onitsha is a heavily commercial city, while Enugu has average commercial and industrial activities. These four are typical of most cities in Nigeria.

The total number of scavengers and middlemen interviewed was 13 in Nsukka, 27 in Onitsha, 35 in Enugu, and 10 in Port Harcourt. An estimated 20–30% of the total number of active scavengers were interviewed. The percentage of total scavengers interviewed was lowest in Port Harcourt (20%). It was very difficult to interview the scavengers. Some of them were very unwilling to disclose information on their activities for fear of being prosecuted. There was an air of secrecy around them, perhaps bolstered by feelings of inferiority.

About 77% of those interviewed in Nsukka were male, 85% in Onitsha, 83% in Enugu, and 70% in Port Harcourt. These figures show that men are dominating the profession. Figure 1 gives the number of years the scavengers that were interviewed had been in the business. Figure 2 shows the number of scavengers dealing with various recyclables. The various categories of scavengers are discussed below.

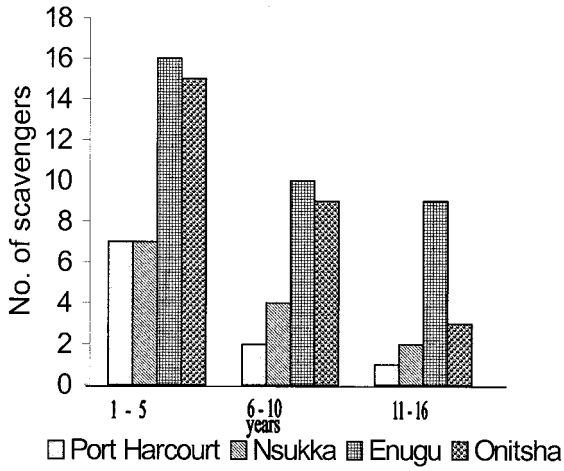

Figure 1. Number of years some scavengers have been in the business.

Curbside and Call-On Scavengers

Curbside and call-on scavengers go from house to house and from bin to bin looking for discarded but usable materials. Economic needs motivate some households to practice a type of source separation. Used beverage cans with lids, newspapers, and waste papers are stored in some homes and later sold to the scavengers. The market conditions always determine the type of materials purchased by the scavengers.

This category of scavengers are rarely involved in recycling in the strictest sense. Rather, they reuse by either selling the materials as they found them or after simply washing them. Recycling is more than the mere collection of useable materials from the waste can. In addition, it involves processing, marketing, remanufacturing, and then repurchasing of those valuable materials (RRS Newsline 1991). The materials collected many become cleaner as a result of washing before they are resold by the scavengers, yet no remanufacturing of these materials is involved. The processing is usually limited to washing, and no physical change is involved. This greatly limits the quantity and type of material collected and how they are marketed. The percentage of the overall waste reused is too low to have much impact on waste management.

Early in the morning scavengers leave their villages and stream into the urban areas. Often they call at houses where other scavengers have already visited. Their operations are haphazard and are characterized by the waste of human resources. That a scavenger meets the occupant of a house does not mean that he will buy the material. The sale depends on whether the material is available and agreement is reached on the

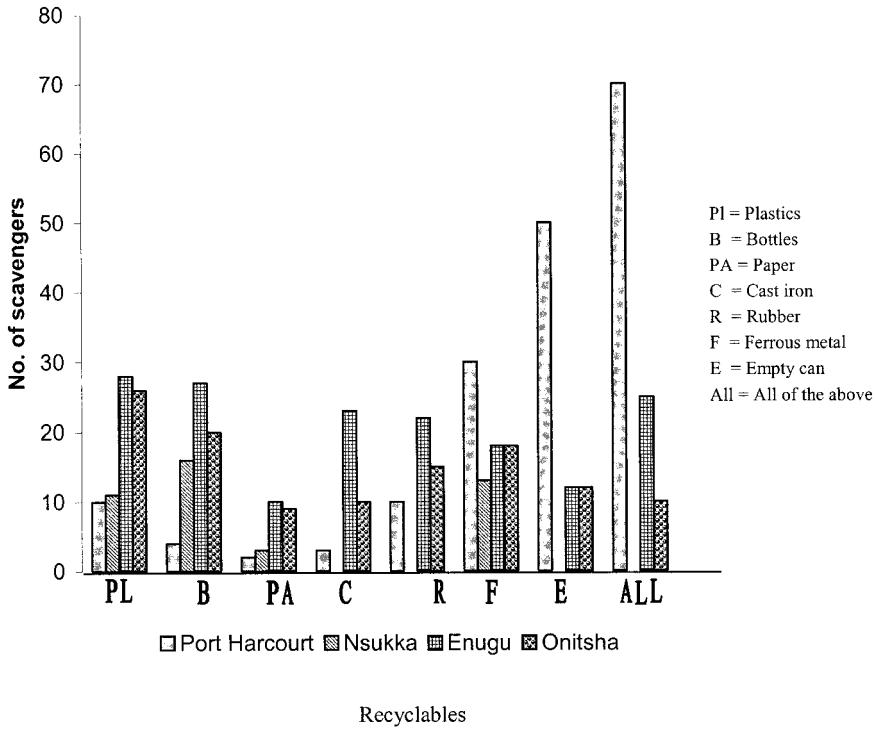

Figure 2. Number of scavengers dealing with various recyclables.

price and whether the occupant has another special customer.

Interviews carried out in Nsukka, Enugu, Onitsha, and Port Harcourt showed that the activities of the scavengers are seasonal and highly dependent on market opportunities. For instance, most of them operate less frequently in the rainy season. During this period the market women who usually buy waste paper for wrapping their wares instead use leaves collected from the bush.

Built-Up Dump Scavengers

Built-up dump scavengers operate within the built-up dumps found in Enugu, Nuskka, and Onitsha. Usually they are employees of the Environmental Sanitation Authority who look after the dumps and/or a few other individuals that they allow. The typical quantities of materials that could be sold in a day and their prices are given in Table 1.

Like the first group discussed, the activities of this group are limited. Sorting times are squeezed around official working hours, and most often only directly reusable materials are sorted out.

Scavengers at Disposal Sites

Scavengers also operate in the final disposal sites. In Nigeria, solid wastes are usually disposed of in water (e.g. some parts of Lagos), burrowed pits (e.g. Kano State), open dumps (e.g. Enugu, Lagos, and Nsukka), and sanitary landfills (e.g. Onitsha). In Lagos State, incinerators are also in use (LSWDB 1991). Open dumps are very common in most cities and towns and the sorting activities of scavengers are similar.

Table 1. Daily quantities of items collected by built-up dump scavengers and their selling prices

Item	Quantity (No.)	Unit Price (US cent)
Beer bottles	20–30	2.5
Soft drink bottle	30–40	2.5
Gallon (plastics)	4–8	10.0
Pomade bottles	50–60	2.5
Liquid milk tins	50–80	1.0
Powdered milk tins	4–8	5.0
Newspapers	30–50	0.5
Rubber slippers	10	1.0

At the sanitary landfill in Onitsha (located at Nkwelle), about seven people sort the recyclables every day, although only four work on a more permanent basis. They make their livings by selling the collected recyclables to middlemen. The disposal sites allow the scavengers to sort these materials at no cost, although sometimes the landfill officers collect a small amount from them. The officers also control the movement of the scavengers about the landfill to minimize injury and

Table 2. Quantities of recyclables collected by disposal site scavengers and selling prices to middlemen

Component	Unit Prices to Buy* N/kg (US cents)	Unit Price to Middlemen (US cents)
Aluminum	40	50
Plastic	7.5	10
Rubber	7.5	10
Brass	20	25
A barrow full of cast iron	125	150
Ball of cartons (1 m^3)	12.5	15
Liquid tins (3)	0.5	1
Powdered milk tins (3)	2.5	10
Hot drink (medium-size) bottles (2)	2.5	5
Schnapps bottle (1)	2.5	5
Small medicine bottles (4)	2.5	10
Shoe sole	10	15

*Prices at which the scavengers are willing to buy if they stumble on other sellers on the street.

infection. For example, they would usually prevent any scavenger who has an open wound from sorting so that he would not be infected with a disease.

Usually, the scavengers wait for a tipper load of waste to arrive at the disposal site. Then, they move into the region where the waste has been dumped and begin to sort out the recyclables. They continue to sort out more materials as the bulldozer pushes the waste into the landfill.

The recyclables and prices at which they are sold to middlemen are given in Table 2.

The average amount and value of items recycled per day is difficult to measure, as all are not weighed. In addition, the prices of metals vary by type. For instance, the selling price of a barrowful of high-quality cast iron may be as high as US$7.50.

All the materials sorted out are usually sold, except when the buyer considers the market poor. One of the scavengers interviewed earns about $10.00 from two-days of sorting in the landfill. Although financial problems may sometimes arise when the middlemen do not pay on time (the middle man sells before paying the scavengers), the scavengers are able to make their living on this business. About 77.1% of those interviewed in Enugu agreed that the business is lucrative, while the rest (22.9%) felt that it is not. The corresponding percentage who agreed that the business is lucrative in Port Harcourt is 70%, as did 69.2% in Nsukka. It is obvious that the majority took to the business because of its profitability and are sustained economically by it. The monthly profit ranges from $90.00 in Port Harcourt, $64.00 in Enugu, $52 in Onitsha, to $21.50 in Nsukka.

Table 3. Comparison of scavenger's income and the minimum wage

	Monthly Scavenger Income ($)		
City	Income	Savings[a]	Minimun Wage ($)
Port Harcourt	153.0	90.0	75.0
Nsukka	48.3	21.5	35.0
Enugu	99.3	64.0	35.0
Onitsha	84.9	52.0	35.0

[a]Amount generated after subtracting the capital.

This is the net amount after covering all other expenses, including feeding. A comparison of the incomes of the curbside and built-up dump scavengers and the minimum wage in the respective cities is presented in Table 3.

The minimum wage is the lowest salary paid to a public employee. The incomes of the scavengers are higher than the minimum wage in their corresponding city. It should be noted that the difference between a scavenger's income and savings in each city is small since the scavengers are squatters and hence do not pay rents. They also dodge tax payments and operate at virtually zero overhead cost. Despite the profit generated, the scavengers want those in authority to improve their work by providing the following: protective kits; bulldozer to uncover as much recyclable material as possible; machines to help them in sorting; and motivation which will encourage more middlemen to participate in the business.

Middlemen

The middlemen who purchase from the scavengers were also interviewed. They depend on the business for livelihood and each makes an average gain of about US$70.00 for a two-day supply sold to his buyers, who later sell to companies or their agents in and around Onitsha. Table 4 shows the market for the various materials.

Generally, bottles are refilled with drugs, drinks, and cosmetics, while plastic and rubber materials are remolded. Scavengers use machines to grind plastic into small particles and reduce its bulky nature. Broken bottles or glasses are sometimes bought by the international glass industry through their agents. Each item has its own market.

Some scavengers also sort metal scraps. Such scraps are used in the production of shovels and locally produced cooking pans and musical instrumentals.

As a commodity, recycled paper follows the market forces of supply and demand. The waste paper supply is inelastic in the short term: An increase in demand does

Table 4. Recyclables and their markets

Recyclable	Market	Remark
Bottles (glass)	Breweries, cosmetic, and pharmaceutical companies	Usually bought in crates or cartons after they have been washed thoroughly.
Plastics	Plastics industries	E.g. Enamel Company, Onitsha.
Empty gallon containers	Vegetable oil companies	
Beverages and milk containers	Market women	Oil sellers, etc.
Paper	Paper industries, market women	
Iron and other metal parts	Steel industries, blacksmiths, etc.	E.g. Delta Steel, Okpoko
Egg shells		Production of local abrasives for washing pots, floors, etc.
Aluminum and copper	Industries	Production of cables, pots, etc.
Shoe sole	Shoe making industries	

not necessarily lead to an increase in supply. During period of very high demand the prices rise rapidly because of the resulting shortage. Different grades of paper are produced from waste paper. The value of waste paper is directly proportional to its economic substitution for virgin fiber. Paper and old corrugated containers have the lowest volumes of fiber because they are highly contaminated, low in brightness, and require substantial processing.

A flow chart for the operation of scavengers is given in Figure 3.

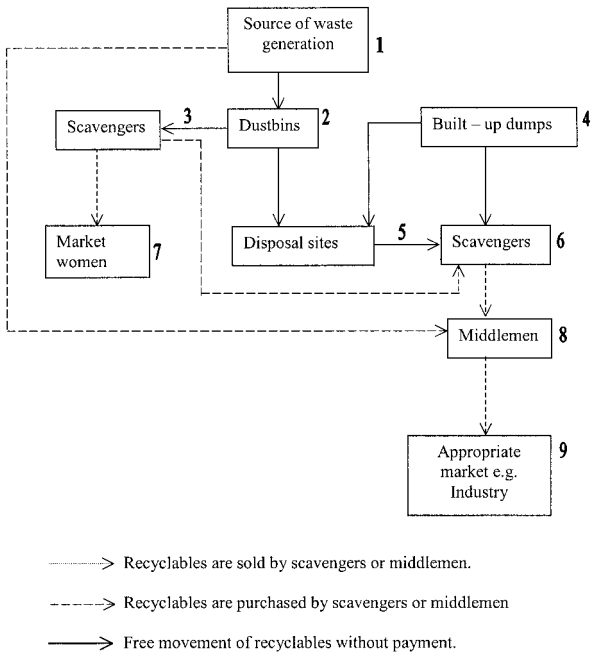

Figure 3. Operations of scavengers in Nigeria.

Need for a Planned Recycling Program

The activities of scavengers can have a positive impact on the national economy if the scavengers are motivated and encouraged and their activities better coordinated.

Currently, about eight different pathways exist through which recyclables are collected by scavengers and then disposed of. With reference to Figure 3, these paths are: 1–3–7; 1–8–9; 1–3–6–8–9; 1–2–3–7; 1–2–3–6–8–9; 1–2–5–6–8–9; 1–4–5–6–8–9; 1–4–6–8–9. The recyclables collected from the landfills have the greatest potential for being contaminated, whereas those collected at home should be the purest. However, the recyclables separated at the source (in homes) will be the least profitable to the scavengers because they have to buy the materials. In addition, the uncoordinated movement of the scavengers from house to house constitutes a waste of human resources.

Generally, the present state of waste recycling in Nigeria is characterized by the disadvantages discussed below.

Low Quantity and Quality of Recovered Materials

In most cases only a few items are recovered because of the generally poor level of recycling and lack of technology. Furthermore, only a few middlemen buy from the scavengers, thereby limiting the operations of the scavengers. Materials of higher quality could be recovered in greater numbers if processing industries are encouraged.

Areas Served by Scavengers Are Limited

Not every home is interested in source separation. It depends on the family's economic status, general interest, and location. Some high-density areas do not permit scavenger operations.

Health Hazards

The salvaged material may find its way back to the market in its contaminated state. It is not uncommon to

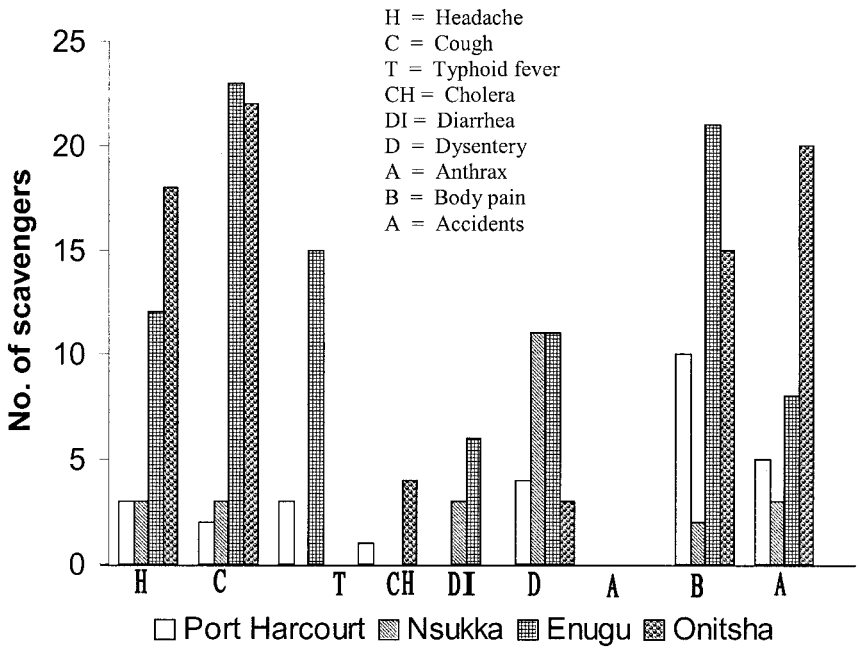

Figure 4. Types of diseases contracted or accident suffered by scavengers during their activities.

see edible food material wrapped with dirty recovered paper. Even where the paper appears neat it may still have been contaminated by toxic substances, especially when the material did not undergo source separation. Some of the people involved in this business are illiterate and may not appreciate the importance of hygiene and its role in the transmission of diseases.

Scavengers scatter the refuse in dumps and refuse bins in their search for recyclables. This action spreads places for disease vectors to breed, raises collection costs, degrades environmental aesthetics, and produces foul odors.

Aesthetics

Scavengers are usually dirty in appearance. This only reinforces the poor public image associated with their work. For instance, 60% of the people interviewed complained of societal neglect because of the nature of their work. Some have even been accused of stealing.

About 54% of those interviewed in Enugu had contracted a disease due to scavenging. The figures stood at 82% for Onitsha, 50% for Port Harcourt, and 85% for Nsukka. The ailments include headache, cough, typhoid, cholera, diarrheas, dysentery, and body pain. Scavengers also suffer from skin and blood infections resulting from direct contact with waste, and from infected wounds. Their exposure to infected dust, smoke, and fumes causes eye and respiratory infections. They also suffer from infectious diseases transmitted by insect vectors as well as those caused by the bites of animals that feed on wastes (Fig. 4). In addition, a large proportion of the persons interviewed had had accidents: 23% in Enugu, 50% in Port Harcourt, 23% in Nsukka, and 74% in Onitsha.

The accidents they are vulnerable to include: poisoning and chemical burns from contact with hazardous compounds; wounds from contact with sharp objects; bites from rats, snakes, and scorpions; and bone and muscle disorders resulting from the handling of heavy containers.

Wasted Manpower

In some localities scavengers move from house to house inquiring whether any useable and sellable materials are available. They may try for several hours without getting much material. It is common to see some calling at houses other scavengers had just left.

In view of the above problems, the government should improve the status of waste recycling in Nigeria by: (1) stimulating and facilitating the emergence of small to medium-scale recycling industries; (2) the provision of the enabling institutional and financial resources; (3) organizing enlightenment programs for education on the serious dangers of handling contaminated materials; and (4) provision of protective gadgets.

Advantages of a Well-Structured Recycling Program

A well-structured recycling program has several advantages over other more conventional disposal tech-

nologies because waste is recovered rather than thrown away (Lindeberg 1991; RRS Newsline 1991 Multi-Family Recycling Guide 1991).

Less Expensive Than Disposal Operations and Landfills

Recycling is less capital-intensive than landfills, incinerators, or waste-to-energy facilities. This is particularly advantageous in the Nigerian context because the dwindling national economy allows waste management government agencies only very meager financial support. The avoidance of landfill costs have been reported as a strong benefit in cases where such programs were tested (Caman and Curcio 1991—Carmon in reference section; Multifamily Recycling Guide 1991).

Extends the Lifespan of Landfills

The amount of waste reduction in source separation schemes varies from 30% to 80% of the MSW stream (Stentiford 1991). For instance, in Leeds a waste reduction of 75% has been achieved in a source separation scheme for 12000 households. Such a reduction will help to prolong the life span of landfills. This is very advantageous because good landfill sites are not easy to come by.

In some parts of the United States, communities were forced to develop appropriate recycling methods because their landfills were filling up. Nigeria needs to integrate recycling into its waste management plans to help prolong the usefulness of its limited landfills.

Avoidance of Environmental and Public Health Risks

In terms of the organic fraction, source separation reduces the amount of potential contaminants. In order to have clean (and therefore more valuable) materials for recycling, it is vital to separate materials that could be contaminates, such as the biodegradable, organic fraction (Stentiford 1991). Disposal of municipal solid waste poses a problem because of the environmental effects of organic matter as it degrades. Hence, source separation prevents the pollution of surface and underground water source.

MSW makes poor quality compost because of its high heavy metal content and high amount of glass and plastic material (Krogmann 1991).

Backyard composting reduces the cost of yard waste collection and processing and recovers valuable organics that improve the soil. Hence, smaller quantities of fertilizer are purchased for farming (RRS Newsline 1991).

The organic waste content can be separated and used in soil regeneration (Albaladejo and Diaz 1990). This is particularly important since scant organic content is one of the characteristics which favor soil erosion (Ortiz Silla 1990), and several parts of Nigeria are seriously threatened by erosion.

Table 5. Percentages by weight of solid waste components in Onitsha

Waste	Waste Component (%)	Waste-Generation Rate (kg per capita per day)	Population (2000)
Paper	23.1		
Glass	9.2		
Cans	2.8	0.60	806,000
Plastics	9.2		
Metals	3.4		
Biowaste	31.8		
Others	20.5		
Total	100.0		

Source: Agunwamba and others (1998).

Job Opportunities

By diversifying the types of recyclables and establishing recycling plants, more permanent employment could be provided for the scavengers and other people, thereby improving the economy. In Cairo, for instance, waste recycling provides an income for 16,000 people while protecting the environment. Similarly, in Mexico City more than 10,000 people make their living on the city's dump (Safe Water 2000; UNDP 1990). This advantage could also be enjoyed in Onitsha. From the interview, it is estimated that only about 60 people actively depend on the city's waste for their income. Far more than this could live comfortably on the city's waste. This will be illustrated below.

From an earlier study by Agunwamba and others (1998), the percentages of waste components in Onitsha are given in Table 5.

Assume that the profit average made by both scavengers and middlemen for each kilogram of the following item sold is 1 cent for paper, 5 cents for glass, 5 cents for cans, 5 cents for plastics, and 20 cents for metals. If the capture rate is 40%, then (from Table 5) the gain made from the recyclables is: $1/100\ [23.1 \times 1.0 + 9.2 \times 5.0 + 2.8 \times 5.0 + 9.2 \times 5.0 + 3.4 \times 20] \times 0.40 \times 806{,}000 \times 0.60 = 262885$ cents = \$2628.85 per day. For 24 working days in a month, this amounts to \$63,092.39. This will provide jobs for over 288 persons, each earning more than what a person with an undergraduate degree currently earns in public service. This is also supported by the information gathered from the scavengers and middlemen. As was mentioned above, a scavenger operating in the landfill zone earns \$10.00 in two days. In a month of 24 working days, he will earn \$120. The income of the middleman is even far more

attractive—he earns about $840 per month. A cost analysis on recycling is presented in a subsequent section.

Other advantages include conservation of energy and natural resources, reduction of litter, and aesthetic improvement of the environment. It is also easier to find locations for recycling facilities than landfills.

Cost Analysis

Onitsha is used as a case study of solid waste management in Nigeria because its planning, equipment, and work crew are better than most other cities. Although record-keeping is not satisfactory, data exist on the quantity of refuse disposed, operation routes, and so on. In addition, some analysis of waste components has been done at Onitsha (Agunwamba and others 1998), which is important for the present study.

Onitsha is a heavily commercial city in Anambra State (Nigeria) with a population of approximately 806,000 in 2001 and an area of 13,249 h.

Before 1985, waste was managed by the Onitsha Local Government Council. Handicapped by inexperienced personnel and lack of equipment, this council dumped MSW waste into waterways. In response to a cholera outbreak in 1984, attributable to poor waste management, the responsibility of waste management was given to the Anambra State Environmental Sanitation Authority (ASESA), assisted by the UNEP–World Bank.

ASESA ensures that residents store their waste in bins and later transfer them into collection containers placed at strategic positions. Curb service is provided in residential areas and a hauled container system is practiced. In the commercial areas, businesses sweep around their shops and dump the waste into built-up dumps and waste containers for the ASESA crew to collect the next day. Industrial wastes are taken from the premises to the disposal site by a trash-trailer system.

All the wastes are disposed of at Nkwelle Sanitary Landfill, which occupies an area of 2100 m^2. The average volume of waste disposed daily is 450 m^3.

Economic necessity has encouraged the public to develop a form of recycling culture. Newspapers, waste papers, and empty beverage tins with lids are stored in many households and sold to scavengers. Huge quantities of paper are sold to paper mill where they are processed as recycled paper. Sometimes some farm owners empty the entire contents of public waste bins on their farms. The nutrient content of MSW is generally recognized, but most people are ignorant of health risks and contaminants associated with heavy metals and some hazardous household waste (e.g. batteries).

Table 6. Recyclable separation efficiencies and market prices

Component*	Recyclables Separation Efficiency (%)	Source Separated Market Prices (US$ per ton)
Mixed paper	85	10
Recyclable glass	50	50
Tin food/beverage cans	40	50
Plastics	35	50
Compost materials	90	6

Metals (aluminum, etc.) were omitted because they are rarely found.

Based on the above background information, a simple economic analysis of four MSW management options—no recycling and composting, recycling alone, recycling plus composting, and the separation of recyclables and compostables at the source to be sold to scavengers—was performed to compare the savings in waste management cost and landfill avoidance costs. The required data are: (i) the waste components and percentage of components in solid waste, (ii) the unit market price of the recyclables, (iii) the cost of sorting, collection, and disposal.

The waste collection and disposal costs per ton were determined from the data gathered from ASESA, while the components of waste and waste generation rate had been determined as shown in Table 5 (Agunwamba and others 1998). The collection cost (c_f) is $20/t and the disposal cost (c_d) is $3/t, based on the 1992 cost data converted to US$ at the rate of US$1 = N20.

The separation efficiencies of the recyclables shown in Table 6 were obtained from Morris (1991).

The following assumptions are applicable to the first three options: (i) A two-bin system is adopted whereby the composable and other materials are placed in one bin and the recyclables are placed in the other. (ii) The materials in the two sets of bins are collected separately in the cases where recycling is involved. (iii) A market exists for all the captured recyclables and compostables. (iv) The materials are sorted out at a central location on the landfill. (v) The operations of scavengers are integrated into MSW recycling program, hence, the quantity of recyclables lost to scavengers is negligible.

When a curbside recycling program is introduced, the collection cost of recyclables increases. There is also a cost to sort these materials. Sorting cost and the increase in collection cost are obtained as $7.62/t and $1.69/t, respectively, from the literature (PRF 1991a).

Based on the above assumptions, the costs of MSW management without recycling, with recycling alone,

Table 7. Costs of MSW management without recycling, with recycling, and with recycling and composting (483,600 t MSW/year)

Cost Components	Without Recycling ($\times \$10^3$)	No Composting ($\times \$10^3$)	Recycling with Composting ($\times \$10^3$)	Option 4 ($\times \$10^3$)
i. Collection	3530.28	3828.59	3828.59	784.86
ii. Landfill	529.54	78.09	226.67	108.56
iii. Sorting	0	641.58	1069.30	
iv. Revenue	0	1135.60	1818.66	
v. Net cost [(i + ii + iii) − iv]	4059.82	3712.66	3305.90	893
vi. Savings		8.6%	18.6%	78.0%
vii. Landfill avoidance cost		28.6%	57.7%	79.5%

and with recycling and composting are shown below. Also included is the fourth option, where households are encouraged to separate their recyclables to sell to by scavengers. In this case it is assumed that a market exists for all the captured recyclables and compostables.

The methods for calculating costs are discussed below.

Without Recycling

The total quantity of waste collected per day is: 0.60 × 806,000 × 365 kg ~ 176,514 t. Hence, the collection and landfill costs without recycling are \$20 × 176,514 and \$3.0 × 176,514, respectively. The net cost is the sum of these two components as shown in Table 7.

With Recycling (No Composting)

In this case, the compostables still go to the landfills. The extra collection cost is: \$1.69 × 176,514 = \$298.31 × 10^3. Hence, the total collection cost is: (\$3530.28 + \$298.31) × 10^3. The landfill cost is now reduced because there is less material to dispose. It is equal to:

$$\left(1 - \frac{1}{100}\sum_{i=1}^{1} Q_i E_i\right) TC_d$$

where E_i is the separation efficiency for recyclable waste component i and Q_i is the fraction by weight of recyclable waste component i. N, T, and C_d represent the number of recyclables (4), annual quantity of waste collected (176,514 t), and disposal unit cost (\$3.00/t), respectively. Hence, the landfill cost is \$378,093.00.

The sorting cost is: 7.62 (1 − 0.205 − 0.318) 176,514 = \$641,582.50. The compost and other materials (apart from the recyclables) are not sorted. The total revenue generated by selling the recyclables is:

$$T\sum_{i=1}^{N} Q_i E_i$$

where P_i represents the unit market price of waste component i. The other symbols are as defined before. Hence, the total revenue is \$1135600. The net cost is found to be \$3,712,660. The savings expressed in percentage are: 100 (4059.82 − 3712.66)/4059.82 = 8.6%. The percent of avoidance costs is: 100 (529.54 − 378.09)/529.54 = 28.6%.

With Recycling and Composting

In this case, compostables need to be sorted out. However, because of the assumption that the sorting center is located on the landfill, the collection costs will be the same as in the case with recycling but without composting (above). If the sorting center and the landfill do not share the same approximate location, then the collection cost for recycling and composting will be higher than with recycling alone because the material will first have to be sorted at the center, and then the unusable remainder taken to the landfill.

The other cost components are the same as for recycling alone (above). The only difference is that the compost component is added to the sorting cost, but subtracted from landfill cost. In addition, N becomes 5 instead of 4 when computing the total revenue.

Option 4

In this option, it is assumed that the recyclables and compostables are separated at the source by the scavengers. The waste collection agency only needs to collect the residue for disposal. Hence, no revenue is generated for the municipality through recycling. However, the municipality benefits from a reduced net cost of \$893,420 which translates to a savings of 78.0% over the case when there is no recycling at all. Apart from yielding the highest savings, this option results in the highest landfill avoidance cost when compared with the other three options.

Implications in MSW Management

The total amount of solid waste to be collected through the curbside recycling program is about 176,514 t/year. This is only an average value since the amount fluctuates with season, economic changes, population growth, and characteristics, etc.

The percentages of some components in Onitsha municipal solid waste are comparable to those reported in the literature. For instance, compost materials lie between 30% and 40% of MSW (Krogmann 1991). On the other hand, the percentage of paper (Delecroix 1991) appears too small compared with the expected 35–40%. Because of the low level of industrialization, it is not surprising that the percentage of biowaste (food and yardwaste) is very high compared with that of beverage cans.

Also the ratio of disposal to collection cost is too small compared with values for the developed countries (Morris 1991). This is a reflection of the poor management practices in the less developed countries, where minimal attention is devoted to waste disposal.

The separation efficiencies quoted in Table 6 depend very much on the level of citizens education and participation (RRS Newsline 1992). Naturally, some of the recyclables will be placed in the wrong bins and then end up in the landfill site.

The cost for collecting and landfilling the 176,514 t/year of MSW is \$3,530,280. With the introduction of recycling without composting, this increased to \$3,828,590. But this cost is offset by the revenue generated from the sale of the recyclables ($\$1135.60 \times 10^3$) and the avoided landfill costs (\$378,090). From the analysis, about 28.6% of MSW is recycled and 71.4% goes to the landfill. With 28.6% of the waste recycled, the life span of the landfill will be extended by simple proportion from a minimum value of 10 years to approximately 14 years: $(10 \times 100)/71.4$.

The exclusion of compostables from the landfill introduces a significant difference in the cost components. The landfill will receive 42.3% of the total waste and as much as 57.7% will be recycled. This quantity of waste recycled will not only result in the job opportunities but it will also lead to other advantages already discussed. Savings are increased by 10% while the landfill avoidance cost increases from 27.8% to 57.7%. The increase in savings is due to the low unit cost of disposal and the high revenue from the sale of compost materials. The advantage of the increase in landfill avoidance cost should be lower than the figure shown when it is noted that the compostables are degradable, and hence reduce in volume with time.

The life span of the landfill is now extended to about 17.5 years by composting, 3.5 more years than when composting is not done.

The fourth option provides the lowest-cost management strategy. As much as 79.5% of waste will be recycled and only 21.5% will end up in the landfill. The solid waste municipal authority will spend less (79.5% reduction) as the burden of much of the waste collection cost will be shared by the scavengers. This option offers the huge advantage of diminishing the need for collection equipment, personnel, and facilities.

In all these cases, the actual revenue and savings will be lower than estimated because the separation efficiencies used are from societies with highly educated and motivated populations. It must also be noted that all the above advantages depend very much on the existence of markets for the recyclables and some other previously noted conditions that are essential for successful recycling.

Appropriate Recycling Program

In many cities in developed countries, the incorporation of source separation into recycling programs is becoming popular because it leads to the highest recovery rate and minimizes the contamination of the recyclables. Although there are various forms of it, source separation basically involves placing the recyclables in one bin and the non-recyclables in another (Stentiford 1991). The bin for the non-recyclables is divided in two sections, one for non-decomposable items and the other for decomposable items. The non-decomposable and the decomposable items are sent straight to the landfill and central compost processing plant, respectively. The recyclables are taken to the recycling units.

Such an approach may not be successfully implemented in Nigeria without some special adaptation with respect to its social, cultural, environmental, and financial conditions (Bhamidimarri 1989). Some considerations are: (i) One's socio-economic status affects the way one treats waste. The fact that one could sell the recyclables may prevent one from dropping them into the public bins. (ii) Most state environmental sanitation authorities are so financially handicapped that they cannot implement regular conventional collection, transportation, and disposal of waste. The mounting heaps of refuse scattered around Nigerian cities makes this evident. It is obvious that they may not be able to effectively manage such recycling systems because it will involve greater initial capital investment, greater expertise, and much more intensive public education programs, than conventional solid waste management.

These problems will be reduced by integrating the activities of the scavengers into the programs of the respective sanitation authorities so as to effectively collect recyclable while maximizing human resources and minimizing health risks. Generally, the state of recycling in Nigeria could be improved by undertaking policy measures in education, government incentives, training, market research, and record-keeping as discussed below.

Education

A more comprehensive and culturally-oriented educational media program should be adopted to increase public awareness and stimulate public participation. Television, posters, radio stations, and advertisements should be used to encourage citizen participation. Because of high illiteracy rate, community leaders could also be used in their various communities. Without an involved public, the overall effectiveness of any recycling program will suffer (Caman and Curcio 1991). This aspect is very important. Before implementing source separation, Leeds carried out an extensive education program, aimed at different facets of the community (Stentiford 1991).

The education program should be sensitive to the particular needs and the socio-economic realities of the community involved. The program should encourage a culture of maintenance and reuse, and promote products containing recycled materials. The public should be told what type of waste should be separated or not and how to separate and store the recyclables. The impact of not recycling on public health, the economy, and the environment should also be explained to the public.

Government Incentives

The government should encourage scavengers and middlemen by giving them loans and stimulating the market for the recyclables. The government should help expand the range of materials that can be recycled by sponsoring research and encouraging new businesses and industries related to recycling.

Recognition and incentives could be given to companies and institutions that create successful recycling programs for their waste. This will also help promote the participation of the private sector in research.

Training

People with the expertise required to run or work in different recycling ventures are important. Training opportunities should be encouraged.

Market Research

A comprehensive study of the market for salvaged and recycled material is useful to form an economic guide to the feasibility of composting and recovering specific materials.

Record-Keeping

Waste management agencies in Nigeria rarely keep complete data. Data should be kept regularly in the following areas: population and developmental projects within the area so that future estimates of generation rates could be made, percentage by weight of waste components and organic fraction, income and details of expenditures. These data are very important for planning successful waste recovery strategies.

Conclusion

The state of waste management in Nigeria needs much improvement. Where collection services exist they are costly, poorly financed and managed, and almost ineffective. Suitable disposal sites are not easy to come by as cities crowd into rural areas. Leachates from improper landfills pollute ground and surface waters and open dumping is practiced in most cities, both of which pose health hazard. The situation could be improved by waste recycling.

For the sake of effectiveness, economy and public health waste recycling should not be left in the hands of scavengers alone. Waste recycling as it is currently practiced in Nigeria is so crude and limited in application that it offers few benefits. The scavengers could be trained, properly educated, and integrated into more generalized, useful, and scientific government-based or privately-owned recycling ventures.

An important goal of a successful solid waste management program is to handle and dispose waste at a reasonable cost while minimizing adverse environmental effects. A well-planned recycling program may help achieve this goal while also creating job opportunities and conserving material resources. Recycling and composting have been practiced advantageously in many cities of the developed countries.

In order to assess the economic viability of such program in less developed countries, the case of Onitsha municipality was considered. It is shown that a good recycling and composting program could result in savings of 18.6%, with a reduction 57.7% in landfill avoidance costs, provided a good market exists for the recyclables. If compostable materials are not recycled, the savings and landfill avoidance costs become 8.6% and 28.6%, respectively. These savings could alleviate the

financial problems hampering successful waste management in Onitsha and similar municipalities. However, the consideration of local social and cultural factors is vital for selecting the right recycling program and implementing it successfully (Carmon and Curcio 1991; Plastics Recycling Foundation 1991).

References

Agunwamba, J. C. and others. 1998. Solid Waste Management in Onitsha, Nigeria. *Waste Management and Research* 16(1): 23–31.

Albaladejo, J., and Diaz, E. 1990. Degradation y regeneration del suelo en el litoral mediterraneo espanol: esperiencias en el proyecto Lucdeme. Pages 19–21 in J. Albaladejo, K. A. Stocking, and E. Diaz (eds.), Soil degradation and rehabilitation in Mediterranean environmental conditions.

Bhamidimarri, S. M. R. 1989. Appropriate industrial waste management technologies: The New Zealand meat industry. *Water, Science and Technology.*

Carmon, M. K. and S. J. Curcio. 1991. Recycling in Pennsylvania: citizen participation and media relations. Paper presented at the sixth International Conference on Solid Waste Management of Secondary Materials, Philadelphia, PA, pp 7.

Delecroix, P. 1991. Anaerobic digestion of MSW evaluation of industrial facilities after three years of continuous operation. Paper presented at the seventh International Conference on Solid Waste Management of Secondary Materials, Philadelphia, PA, 9 pp.

Gang, A. H. A., and M. P. Hector. 1991. Feasability of curbside recycling of municipal solid wastes in Winnipeg, Canada. Paper presented at the sixth International Conference on Solid Waste Management of Secondary Materials, Philadelphia, PA, 8 pp.

Kelley, K. E. 1992. Multi-family recycling guide. Solid Waste Authority, Palm Beach County, FL, 12 pp.

Krogmann, U. 1991. Separate collection of biowaste Technical University of Hamburg, Hamburg, Germany, 8 pp.

Lagos State Waste Disposal Board. 1991. Activities of the board and plan of action for 1991.

Lindeberg, J. D., S. L. Drew, C. Dekosia. 1991. Composite site design model: a computer-aided tool for efficient sitting. Proceedings of the 15th National Waste Processing Conference and Exhibit, Asme Solid Waste Processing Division, 8 pp.

Lindebergy, J. D. 1991. Material recovery facilities: integration into the future. Resource Recycling Systems, Ann Arbor, MI.

Morris, J., and L. W. Dickey. 1991. Three 80s a for the 90s will cut waste in half. Resource Recycling Systems, Ann Arbor, MI, 5 pp.

New Jersey Commission on Science and Technology. 1991. Plastic recycling: from vision to reality. Plastic Recycling Foundation

Posser, H. J. 1990. Oppurtunities and barriers to plastic recycling in the UK. Paper presented to PIRA Conference on impacts of Plastics Technology on Packaging, 7 pp.

Ohio Co-operative Extension Service. 1990. Community composting. Columbus, OH, 5 pp.

Ortiz Silla, R. 1990. Mecanismos y processes de degradation del suelo con especial referencia a las condiciones ambientales mediterraneas. Pages 47–68 in J. Albaladejo, M. A. Stocking, and E. Diaz (eds.), Soil degradation and rehabilitation in Mediterranean environmental conditions.

Plastics Recycling Foundation. 1991. Annual report, Washington, D.C., 22 pp

RRS Newsline. 1992. Solution for colleges and universities. Resource Recycling Systems, Ann Arbor, MI, 4 pp

Safe Water. 2000. 1990. Waste management: turning trash into cash in Cairo. United Nations Development Program

Stentiford, E. I. 1991. The effect of the source separation of MSW on compost and composting. Presented at the 7th International Conference on Solid Waste Management and Secondary Materials, Philadelphia, PA, 10 pp.

Thome Kozmiensky, K. J. 1986. Waste management in developing countries. Fur Energic and Unweltechnick, Berlin