Chapter 7
Hazardous Waste

Industrial revolution has resulted in a grave problem of generation of hazardous waste in large quantities. Outdated technology, knowledge gap, weak enforcing, corruption and waste trafficking are a few of the barriers for effective hazardous waste management systems in many nations. The size and type of industries vary from country to country and so do the volume and qualities of waste.

As per the Hazardous Wastes (Management and Handling) Rules, 1989 (as amended, May, 2003) of India:

> "hazardous waste" means any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances, and shall include-
>
> (a) wastes listed in column (3) of Schedule-1;
> (b) wastes having constituents listed in Schedule-2 of their concentration is equal to or more than the limit indicated in the said Schedule; and
> (c) wastes listed in Lists 'A' and 'B' of Schedule-3 (Part-A) applicable only in case(s) of import or export of hazardous wastes in accordance with rules 12, 13 and 14 if they possess any of the hazardous characteristics listed in Part-B of Schedule-3.

As per the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 which supersede the Hazardous Wastes (Management and Handling) Rules, 1989

> "Hazardous Waste" means any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes damage or is likely to cause danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances, and shall include
>
> (i) Waste specified in column (3) of Schedule-I;
> (ii) Wastes having constituents specified in Schedule II if their concentration is equal to or more than the limit indicated in the said Schedule; and

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Fig. 7.1 Soil contamination due to hazardous waste disposal

(iii) Wastes specified in Part A or Part B of the Schedule III in respect of import or export of such wastes in accordance with rules 12, 13 and 14 or the wastes other than those specified in Part A or Part B if they possess any of the hazardous characteristics specified in Part C of that Schedule.

With the slight modification in definition and the list of waste in the rules the quantity of waste quantification would take new dimension.

As per Waste Management Regulation, 2006, of Kenya:

> waste considered as hazardous, shall be any waste specified in the Fourth Schedule or any waste having the characteristics defined in the Fifth Schedule, and any wastes which do not fit the said categories of classification will be treated as non-hazardous waste.

Infectious substances are addressed in separate rules in India. Whereas 'substances or wastes containing viable micro-organisms or their toxins which are known or suspected to cause disease in animals or humans' is one of characteristics that qualifies waste to be hazardous in Kenya.

Hazardous waste has drawn its significance from the fact that it can damage both health and environment even in small quantity. While degradable matters like vegetable and leaves decay over period of time hazardous waste will have its impact (Fig. 7.1) intact over centuries if not remediated.

7.1 Significance

Hazardous wastes have the potential, even in low concentrations, to have a significant adverse effect on the environment and public health due to its inherent toxicological, physical and chemical characteristics (DWAF 1998). Many hazardous waste generating industries have shifted to the developing countries due to the associated low management cost and nonstringent regulations. On the other hand the developing countries hug the opportunity as an opportunity for investment and learn new technology. The end result is the generation of hazardous waste which is often mis-handled leading to adverse impact on environment.

The quantity of hazardous waste generated in industries is often wrongly reported to avoid statutory obligation. The hazardous waste is often tipped off in virgin environment including forest and sensitive water bodies. The coastal area has advantage to tip off the waste during the night. The waste may be pumped into underground or spread on the ground and covered with a layer of soil. Some time, the waste is set fire and reported as *fire accident* by waste handlers cutting the waste treatment and disposal costs.

7.2 Precautions to be Taken Storage and Transportation of Hazardous Waste

Hazardous waste transport involves *multiple players* which include shippers, carriers, manufacturers, distributors, freight forwarders, emergency responders, government regulators etc. Further *hazardous materials* demand proper tracking and safety precautions. Considering all these constraints principles for hazardous materials transportation can be laid down as: (1) commitment towards the risk reduction, (2) promote risk reduction culture, (3) interaction with those involved in hazardous materials transport chain, (4) communicate risk reduction priorities, (5) act to reduce risk, (6) improve efficiency continuously, and (7) share knowledge about risk.

Unlike MSW, hazardous waste transportation is a new issue and challenge in the developing world and as such countries require to gear up for the following: (1) community awareness, (2) formulation and enforcing new set of regulation, (3) lay down monitoring mechanism, (4) creating a new data base, (5) develop emergency medical response system, (6) training police, officials at check posts, and custom officers.

In countries wherein there are no proper transportation mechanisms, it is difficult to ensure transportation of hazardous waste. The community and transporter also need to develop their own strategy as the traffic and road conditions will be totally different form that of another country.

Proper transportation should have: (1) safe vehicles, (2) trained personnel/regulators, (3) good tracking system, (4) emergency management plan, and (5) system to respond to emergencies.

Each personnel involved in the transportation of hazardous waste (like packaging, preparing the shipping paper or labelling the drum) must have training with respect to applicable law and methodology. But in reality it may not happen as organizations are under staffed to cut the expenditure. In many countries regulating agencies themselves lack the knowledge.

All hazardous waste must be correctly identified. For example, a waste shipping paper shall have the following documents: (1) shipper's name and address, (2) consignee's name and address, (3) details of destination, (4) basic description of waste, (5) details of weight and volume, (6) type and kind of package, (7) emergency response information, (8) emergency response contact number, (9) information on immediate health hazards, fire or explosion, (10) immediate precautions to be taken during accident/incident, (11) preliminary first aid measures, and (12) methods for handling spills or leaks. All these information are usually incorporated in mandatory forms stipulated in legislation.

The above information can supplemented with an MSDS and Emergency Response guidebook. But practically such information does not serve purpose if the driver is illiterate, which is case in many developing countries. Hiring a literate driver some time may not be possible due to low alary associated with the job. In a nutshell such complexity leads to increase in hauling costs and would place greater burden on the waste generators.

7.3 Characteristics and Quantity

As the countries shift from labour intensive industries to machine based manufacturing industries, the waste quality and quantities would also vary. Almost all the countries have legislations with respect to hazardous waste due to international pressure arising from treaties and conventions. However, the definitions they adopt are not uniform all over the world.

Usual practice with respect to disposal of hazardous waste is through a treatment storage disposal facility (TSDF) where a waste generator will make agreement to hand over the waste. The TSDF operator will collect the master samples of different type of waste and analyse the same. Table 7.1 gives some example of waste analysis parameters. It is a usual practice to keep a master sample which is representative of the industry in TSDF facility for nearly period of 5 years as shown in Fig. 7.2.

The quantity of hazardous waste generated in different countries depends on the major industrial activities in the country. As per (Cirillo et al. 1994) 30 % of hazardous waste is produced from electroplating and metal industries in Malaysia, whereas in Thailand the principal hazardous waste is generated from manufacturing (33 %) and metal smelting (47 %) industries.

South Africa generated about 538 million tonnes of waste in the year 1997 with the sewage sludge contributing 0.1 %, domestic and trade 1.5 %, industrial 3.1 %, agriculture and forestry 3.8 %, power generation 3.9 % and mining for 87.7 %, (DWAF 1998). Figure 7.3 shows the hazardous waste quantities in some of the Southeast Asian countries (Cirillo et al. 1994; Hay et al. 1994).

New forms of waste referred as 'nanowastes' contain engineered nanomaterials, nanoparticles or synthetic by-products of a nanoscale, either from production/storage/distribution, or consequential from the end of lifespan of

Table 7.1 Examples of waste analysis parameters

Sl. No.	Rationale for selection	Waste parameter(s)
1	To identify (1) material to make waste container, (2) storage conditions, applicable regulation, (3) health and safety precautions.	pH, total and amenable cyanide/sulphide, Flash Point, Other Appropriate constituent(s)
2	To identify (1) material to make tanks/ancillary equipment, (2) applicable regulation, (3) applicable requirements to treat and dispose waste, (4) corrosion management, (5) health/safety precautions.	pH, flash point, oxidizing potential, halogens, total and amenable Cyanide/Sulphide, appropriate hazardous constituent(s)
3	To identify (1) wastes that may need pre-treatment to ensure optimum effectiveness, (2) relevant health/safety considerations, (3) effects from electrical conductivity, (4) applicable regulations.	pH, total metals, electrical conductivity, total and amenable cyanide/sulphide, appropriate hazardous constituent(s)
4	To identify (1) the presence/absence of free liquids, (2) material that affect landfill liners, (3) relevant health/safety precautions, (4) applicable regulations.	Free liquid content, pH, total chlorine, total nitrogen, liner compatibility, chemical compatibility, evaluations, total and amenable Cyanide/Sulphide, appropriate hazardous constituent(s)
5	To identify (1) wastes that may inhibit combustion or require mixing with high-calorific wastes, (2) moisture content, (3) possible air pollutants, (4) acceptance limits for chlorine content, (5) corrosively, (6) affect incinerator performance, (7) applicable regulation, (8) relevant health/safety precautions	Heat content, percent moisture, chlorine content, ash content, pH, viscosity, total metals, appropriate hazardous constituent(s)
6	To identify (1) wastes that may inhibit combustion or require mixing with high-calorific wastes, (2) moisture content, possible air pollutants, (3) acceptance limits for chlorine content, (4) corrosively, (5) affect incinerator performance, (6) applicable regulation, (7) wastes that may corrode system components, (8) wastes that may not be agreeable to normal conveyance systems, (9)wastes that are prohibited from management in BIFs, (10) wastes that may affect BIF performance, (11) applicable regulation, (12) relevant health/safety precautions	pH, viscosity, calorific value, ash content, total metals, chlorine content, appropriate hazardous constituent(s)

Fig. 7.2 Master samples preserved at a TSDF site

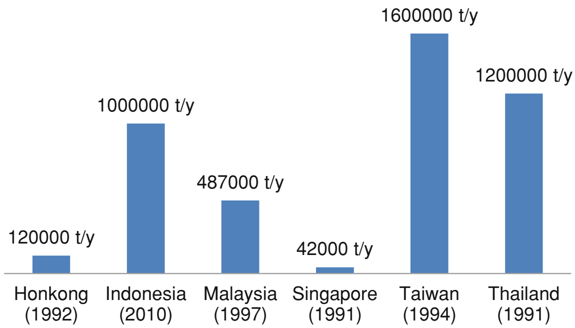


Fig. 7.3 Hazardous waste quantity in some of the Southeast Asian countries

nanotechnologically enabled products and materials. Since the global statistics of nanomaterials and nanoparticles are incomplete, nanowastes generated each year are also unknown.

Figure 7.4 gives the records and manifestations used at different stages of transportation. Records of the quantity of hazardous waste need to be carried out to ensure proper tracking.

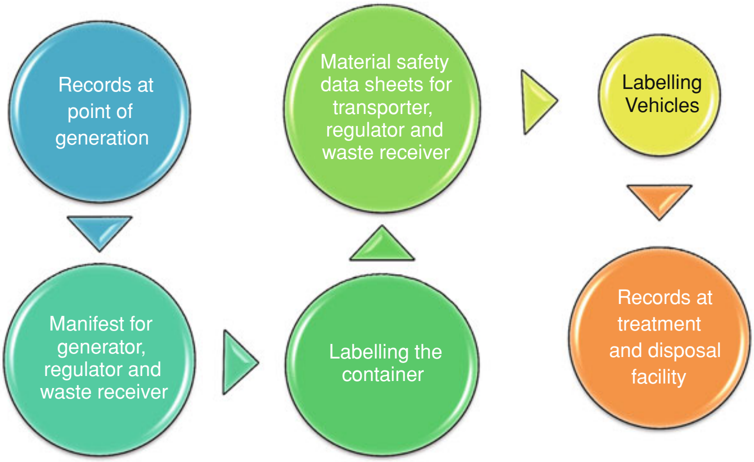
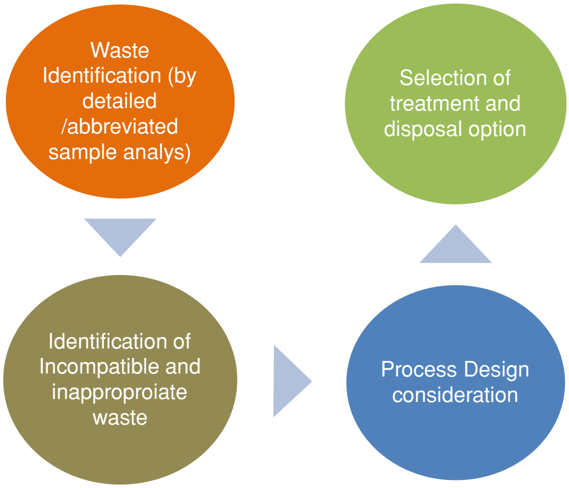


Fig. 7.4 Records and manifest used at different stages of transportation

Fig. 7.5 Correlation of waste analysis with treatment and disposal option



Once the sample is collected preservation techniques must be employed to ensure the integrity of the waste remains intact. Sample preservation may not be required for highly concentrated samples. But low concentration samples require preservation. Sample preservation techniques include: (1) preserving with appropriate chemicals (like sodium thiosulfate to reduce organochlorine reactions, acid to liquids containing metals, adding acid to suppress biological activity), (2) refrigerating samples, and (3) storing and shipping samples in suitable container.

Abbreviated waste analysis, frequently referred to as “fingerprint analysis”, is conducted usually for specific gravity, color, flash point, presence of more than one phase, pH, halogen content, cyanide content, percent water that will provide

Fig. 7.6 Used crackers which comprise of many toxic chemicals

information to verify that the waste received matches the expected characteristics. If there is deviation in analysis results of waste received form waste characteristics of master sample then there would be need for detailed analysis. The analysis results are used to decide mode of treatment and disposal. Figure 7.5 shows correlation of waste analysis with treatment and disposal system.

7.3.1 Household Hazardous Waste and Special Waste

Household hazardous waste (HHW) is a subgroup of hazardous waste commonly found in MSW and in wastewater streams. These special wastes originate in households. HHW pose problems in safe handling. They pose human health and environmental hazards.

Examples of HHW include expired drugs, adhesives, glues, cements, roof coatings, sealants, epoxy resins, solvent based paints, solvents and thinners, painter removers, strippers, oven cleaners, degreasers and spot removers, toilet cleaners, polishes, waxes, and strippers, chimney cleaners, solvent cleaning fluids, insecticides, fungicides, rodenticides, molluscides, wood preservatives, moss retardants and chemical removers, herbicides, fertilizers, batteries, paints, solvents, cleaners, additives, gasoline, flushes, auto repair materials, motor oil, diesel fuel, antifreeze, photo chemicals, pool chemicals, glues, inks, dyes, glazes, chemistry sets, pressurized gas containers, white gas, charcoal lighter fluid, household batteries, ammunition, asbestos, fireworks, lamps, Freon recovered from white goods, and electronics, including computer components, televisions, and other electronic equipments. Figure 7.6 shows used crackers which comprise of many toxic chemicals.

Many of these waste materials are categorized as hazardous because they will have any of the following properties: (1) ignitability with flash point less than 140°F, (2) corrosivity, (3) reactivity with water and other materials, and (4) toxicity to animals and human beings.

The quantities of HHW vary from country to country and house to house. The quantities have been estimated to vary between 0.01 and 3.4 % of MSW by weight (David and Rachel 2002). The variability depends on the development of a country and income of individual. HHW represents the most toxic part of the waste stream. Household hazardous products (HHPs) influence the risks to health and environment during their use and disposal. Chemicals in HHP can affect health through ingestion, inhalation, or absorption. Some HHPs emit toxic fumes which will cause headaches, fatigue, eye irritation, runny noses, and skin rashes. Children and aged people are at a much higher risk compared to others.

Storm water runoff is a leading cause of environmental pollution due to HHP. Chemicals, pesticides and fertilizers used in household will be carried away by rainwater causing surface and groundwater pollution.

Use of HHP like fuels, crackers, combustible substance with low ignitions point has resulted in fire risks all over the world many of which will go unreported. Toxic compounds that are heated during combustion will release in the fire.

HHW in MSW would result in release of toxicity into air and water at dumpsites, land fill sites and incineration plants. HHW may be diverted from MSW as done in Clark County, Washington (David and Rachel 2002).

Special waste is defined differently in different countries, legislations and literature. As per Howard et al. (1986), special waste includes items like street sweepings, abandoned vehicle, dead animals etc. As per Resource Conservation and Recovery Act of the USA enacted in 1976, special waste include: (1) mining waste, (2) oil and gas drilling muds and oil production brines, (3) phosphate rock mining, beneficiation, and processing waste, (4) uranium waste, (5) utility waste (i.e., fossil fuel combustion waste) (USEPA NA 2012).

The Special Waste Regulations 1996 of the UK, special waste is clearly listed in schedule II of the regulations excluded household waste from the definition of special waste.

Special or unusual waste may include items like sludge from, wastewater treatment facilities, tires, and dead animals. These special wastes should be managed in a way to protect human health and environment.

7.3.2 Hazardous Waste From Rural and Urban Area

It is often understood that the industries and urban areas are the origins of hazardous wastes. Irrespective of whether a country is underdeveloped or developed rural areas do contribute the waste which is diluted within in the rural area. Even though the impact is not visible immediately, it would harm the health and environment over period of time. The common hazardous substance used in rural area includes insecticide, pesticide, fungicide, herbicide, chemical fertilisers, chemicals used for fumigation, cleaning agents used in animal husbandry. Further, the use of household hazardous chemicals discussed earlier are also become part of hazardous waste from rural area. The packaging materials are either thrown

Fig. 7.7 Onsite storage of hazardous waste at an industry

haphazardly or reused after washing sufficiently. The impact of such practice will occur over long period leading to decline in earth worms and useful insects, change in soil characteristic, sickness in consumers (humans and animals) which include cancer, water pollution. Quantities are often not estimated and reported. In addition to agricultural activity the presence of mining, quarrying, small scale industry, motels, and garages would also contribute substantial hazardous waste. The fly-tipping of waste from urban area and illegal burying would have impact in the course of long time.

7.4 Storage of Hazardous Waste

Hazardous waste is stored at the points of generation and disposal. Storage at site shall be done considering the climate and safety precautions. Storage in open area as shown in Fig. 7.7 should not be done. Storage yard of hazardous waste should be kept away from storage yard of raw materials and finished products. A dedicated storage yard (Fig. 7.8) with proper ventilation, fire fighting system (Fig. 7.9) shall be provided with access to only trained authorised personnel. The storage containers should be properly labelled (Fig. 7.10) and care should be taken to ensure waste is compatible with material of container.

Storage area or sheds shall confirm the following precautionary measures to avoid hazards: (1) non-compatible wastes must be stored separately preferably in separate shed, (2) storage shed shall adequate openings in order escape during hazards, (3) the storage shall have adequate storage capacity preferably 50 % of the annual capacity, (4) storage area should be capable of withstanding the load of material stocked, (5) construction material shall be capable of resisting the spillages, (6) storage area shall be provided with the flameproof electrical fittings, (7) sheds should be provided with automatic smoke, heat detection system, (8) the

Fig. 7.8 Onsite storage of hazardous waste with a closed structure

Fig. 7.9 Stacking and sprinkler arrangement at a waste disposal facility

Fig. 7.10 Labelling of hazardous waste

storage are shall have adequate fire fighting systems, (9) two storage sheds shall be constructed at least 15 m apart, (10) operation shall be done by trained staff, (11) at least 4 m distance shall be maintained between two blocks of stacked drums to avoid spreading of fire in case of fire hazard, (12) precaution shall be taken to store maximum 300 MT in each block, (13) minimum of ome meter clear space shall be maintained between two adjoining rows of drums in pair, (14) the storage shed shall have at least two routes to escape during fire accidents, (15) storage area should have doors and approaches with suitable sizes for movement of fork lift and firefighting equipment, (16) the exhaust of vehicles in hazardous waste storage area shall be fitted with spark arrester, (17) measures should be taken to avoid entry of rainwater and runoff in the storage area, (18) floor of the storage area shall be at least 150 mm higher than the maximum flood level, (19) the storage area floor shall be provided with secondary containment, (20) storage areas shall have proper peripheral drainage system with the sump to collect accidental spills.

The container used for storage of hazardous waste shall be compatible with the hazardous wastes planned to be stored and stacking of drums should be restricted to three (except the waste with flash point less than 65.5°C). The container shall be stored on wooden frames and necessary measures should be taken to avoid stack collapse. Drums should be opened in designated places for sampling or otherwise outside the storage areas.

7.5 Treatment and Disposal

Treatment and disposal can occur at point of generation or offsite. In many countries TSDF sites are not established. In such countries the disposal is carried out onsite at the locations where hazardous waste is generated.

Depending on whether the hazardous substance is gas/liquid/solid the following methods are employed for hazardous waste treatment.

1. Physical treatment processes

    a. Gas cleaning

i. Mechanical collection
ii. Electrostatic precipitation
iii. Fabric filter
iv. Wet scrubbing
v. Dry scrubbing
vi. Adsorption

    b. Liquids-solids separation

i. Centrifugation
ii. Coagulation
iii. Filtration

iv. Flocculation
v. Flotation
vi. Foaming
vii. Sedimentation
viii. Thickening

c. Removal of specific component

i. Adsorption
ii. Crystallization
iii. Dialysis
iv. Distillation
v. Electro dialysis
vi. Evaporation
vii. Leaching
viii. Reverse osmosis
ix. Microfiltration
x. Solvent extraction
xi. Stripping

2. Chemical treatment processes

   a. Absorption
   b. Chemical oxidation
   c. Chemical precipitation
   d. Chemical reduction
   e. Oxidation
   f. Ion exchange
   g. Neutralization
   h. Chemical fixation and solidification
   i. Dehalogenation

3. Biological treatment processes

   a. Aerobic systems
   b. Anaerobic systems
   c. Activated sludge process
   d. Rotating biological contactors
   e. Sequential batch reactor
   f. Spray irrigation
   g. Tricking filters
   h. Waste stabilization ponds

Treatment of gases/liquids often results in solids which need further treatment and ultimate disposal.

Fig. 7.11 Vehicle mounted mixer at a TSDF facility for mixing stabilisers

7.5.1 Stabilization and Solidification

Stabilization and solidification of hazardous waste have been widely used as pretreatment before landfills. Stabilization is a process of mixing additives to waste to minimize the rate of migration of contaminant to environment. Solidification is a technique of encapsulating the waste, to form a solid material. Fixation is often used as synonym for stabilization. Figure 7.11 shows vehicle mounted mixer at a TSDF facility for mixing stabilisers. Figure 7.12 shows mixing platform at a TSDF site. Figure 7.13 shows improper disposal without stabilization and solidification.

Successful stabilization involves any of the following mechanisms or combination of these mechanisms: (1) absorption, (2) adsorption, (3) detoxification, (4) macro encapsulation, (5) microencapsulation, and (6) precipitation.

Absorption is a process wherein contaminants are taken into sorbent and are electrochemically bonded to stabilizing agents. Detoxification is a process wherein toxicity of a substance is reduced. Macro encapsulation is mechanism wherein constituents of hazardous waste are physically entrapped in larger structural matrix. Microencapsulation is mechanism wherein constituents of hazardous waste are entrapped in the crystalline structure of solidified matrix.

Precipitation is the formation of a solution or another solid during a chemical reaction or diffusion. The following paragraphs discuss some of the stabilizing and solidifying agents which are widely used. Some proprietary mixtures available in the market can also be used after testing their properties.

Cement

Hydration of cement forms crystalline structure resulting in rock like hardened mass and is best suited for inorganic waste. Due to high pH of cement, the metals are retained in the form of insoluble carbonate or hydroxide.

Lime

Lime is a general term for the different forms of calcium oxide/hydroxide and smaller amounts of magnesium oxide/hydroxide. Waste and soil stabilization using

Fig. 7.12 Mixing platforms at a TSDF site

lime is widely established (Sherwood 1993; Chaddock and Atkinson 1997; Aggregate Advisory Service 1999). Lime forms hydrates of calcium silicate, calcium alumina, or calcium alumino-silicate depending on the constituents of hazardous waste and hence typically best suited for inorganic contaminants. Lime can also be added to acidic waste along with other stabilizing agents.

Organically Modified Clay

Organically modified clay is achieved by replacement of inorganic cations of the clay by organic cations. Such clay will adsorb organic molecule within the crystalline structure of clay.

Thermoplastic materials

Thermoplastic include bitumen and sulfur polymer cement (Lin et al. 1995, 1996). Bitumen may be used on their own or in combination with cement (British Cement Association 2001).

Thermosetting Organic Polymers

Thermosetting polymer is mixed with hazardous waste in the presence of monomer such as urea–formaldehyde that acts as a catalyst.

Pozzolanic Materal

Pozzolan is a material that exhibits cementitious properties when combined with calcium hydroxide. Pozzolanic materials include cement kiln dust, ground blast furnace slag, and fly ash. Natural pozzolanic materials are mainly volcanic in origin, and have cementations properties. Some natural pozzolans which are non-cementitious may become pozzolanic when heated (Taylor 1997).

Secondary Stabilizing Agents

These are materials that are not effective on their own but can be used in combination with lime or cement. The secondary stabilizing agents include pozzolans which can react with lime and water to produce cemetitious material.

Silica-fume which is a by-product of smelting process for silicon metal and ferrosilicon alloy production has an amorphous structure and a high SiO_2 content, coupled with a large surface area (20 m^2/g). It can be used with cement in quantities up to 5%.

Fig. 7.13 Improper disposal will only increase quanity of waste as the contaminated soil will also require treatment

Ash from rice husk was found to contain pozzolanic materials for addition to cement (Ajiwe and Okeke 2000; Cisse et al. 1998; Real and Alcala 1996; Riveros and Garza 1986) (Fig. 7.13).

7.5.2 Incineration and Coincineration

Incineration is a widely used method for combustible hazards. Incineration can be done in any of the following kiln or combusting devices: (1) multiple hearth, (2) fluidized bed, (3) recirculating fluidized bed, (4) liquid injection, (5) fume, (6) rotary kiln, (7) cement kiln, (8) large industrial boiler, (9) multiple chamber, (10) cyclonic, (11) auger combustor, (12) two stage combustor, (13) catalytic combustion, (14) oxygen enriched, (15) molten salt combustor, and (16) moving belt combustor.

Modern incinerators combine solid-waste combustion with heat recovery. The heat recovery can be done to generate steam or to dry leachate and slurries. The air from incinerators will pass trough *air-pollution control system*.

The rotary kiln incinerator is widely used as it can be used for a wide variety of wastes including liquid and gaseous waste.

A rotary kiln system is shown in Fig. 7.14 and close view of kiln is shown in Fig. 7.15. It includes requirements for feeding, air injection, ash collection and air pollution control. A rotary kiln system can be constructed with a waste heat boiler for the purpose of recovering energy. The waste heat boiler decreases the temperature of the gas thereby allowing use of fabric filter, for particulate control. Apart from bagfilter, other air pollution control equipment employed with incinerator include wet/dry scrubber. Electro Static Precipitator (ESP) is not suitable in presence of combustible material in hazardous waste. The induced draft fan is

Fig. 7.14 Hazardous waste incinerator

Fig. 7.15 Close up view of a rotary kiln

Fig. 7.16 A Cement Kiln

provided to maintain a negative pressure in the system to avoid leaking of a gas out of the kiln system.

The manufacture of cement, light aggregate etc., use rotary kilns. The use of these kilns for destruction of hazardous waste is practiced since long time. Cement kilns (Fig. 7.16) operate at a temperatures of 1,400°C to 1650°F and provide long residence time which is sufficient to destruct Principal Organic Hazardous Constituents (POHCs).

Cost of thermal energy in cement manufacturing contributes to about 30–40 % of the cost associated with cement production hence co-processing of hazardous waste in the cement industry is a viable concept. Cement kiln co-incineration reached nearly 50 % of the market share with respect to hazardous waste incineration in France (Ian and David 2002). In some countries the plants operate with nearly 60% alternative fuel (Battelle 2002).

Some of the co-incinerating facilities avoid some wastes, e.g., (1) nuclear waste, (2) asbestos-containing waste, (3) wastes containing heavy metals, (4) electronic scrap, (5) explosives, (6) mineral acids, (7) medical/Infectious waste, (8) chemical or biological weapons, (9) entire batteries, and (10) unknown or non-specified waste, (11) material restricted by local regulation. Such wastes are avoided usually because of one or many of the following reasons: (1) personnel in cement kilns are not sufficiently skilled to handle some type of waste, (2) kilns are not equipped with proper pollution control equipments, (3) limited knowledge about the consequences of incinerating waste, (4) sentiments of the customers use of biomedical waste comprising body parts during manufacture of cement, (5) local legislation, (6) business risk, (7) logistics, (8) impact on quality of final product, and (9) safety issues.

Waste can be introduced into cement kiln via: (1) the main burner located at the outlet end of rotary kiln, (2) feed chute at inlet end (for lump fuel), (3) secondary burners to the riser duct, (4) precalciner burners, and (5) feed chute to the precalciner (CPCB 2011).

7.5.3 Landfill

Even though incineration is a preferred mode of disposal, landfill is the best available technology as on date for non-combustible waste. Hazardous waste has to be land filled in landfills constructed and operated exclusively for the purpose. Unlike in MSW landfill (where no descrition is made about different waste), hazardous wastes are tracked from the source till they are placed in mappable units called cells (Fig. 7.17). These cells are formed in order to avoid placing of incompatible substance adjacent to each other which could lead to hazardous reactions. Drummed wastes are usually aligned and covered with other wastes which are compatible with each other. Drums may be placed in single lifts or stacked.

Fig. 7.17 Arrangement of non-compatible waste types in a hazardous waste disposal site

Use of daily cover may not be feasible in hazardous waste landfill sites as the placement of uncontaminated clean soil uses landfill space. Further daily covers create anisotropic environment leading to seepage along daily cover. Hence, in order to overcome operational difficulties the landfilled areas are covered with geomembranes to avoid entry of rainwater in the hazardous waste already placed in landfill.

7.5.4 Precautions and Practices During Incineration and Land Filling Hazardous Waste

The major precautions to be taken during handling hazardous waste are the compatibility, reactivity, combustibility and explosivity of the waste. High precautions have to be taken to know what is being fed into an incinerator. Explosive chemicals might not only damage the facility but also affect life. Reactive and corrosive materials often affect the material of construction on incinerator and lining material of landfills. Hence precautions have to be taken with respect to the lining material and chemicals that reacts with lining material. The poor maintenance and operation of air pollution equipments in hazardous waste incinerator would often emit toxic gases. Properties of these gases may not be fully understood yet by the scientific community. The location of disposal facility has to be considered after knowing sensitivity and disaster vulnerability of the location. The knowledge of the staff operating the facilities is also important and any accident or unsafe incidents could lead to loss of lives and property.

Record keeping is also important with respect to the waste disposed. The source and characteristics of hazardous waste in different cells within the land fill shall be properly recorded as it will be essential in later date if there is any damage to lining or landfill due to unavoidable circumstances.

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