Hazardous Waste Management in India – A Review

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Abstract : Hazardous waste is the waste that poses substantial or potential threats to public health and the environment. The sources of hazardous waste are basically agricultural and agro industries, medical facilities, commercial centers, household and the informal sectors. Rapidly growing industries in the country have contributed in the production of large part of hazardous waste material. Therefore, to reduce environmental hazardous, proper attention is required during storage, segregation, transportation and disposal of waste, because it cannot be disposed of by common means like other by products of our daily lives. Hazardous waste management is an important issue in our country now days. Unscientific disposal of hazardous waste and only few secured landfill sites available in the country for disposal of hazardous waste in an environmentally sound manner posed serious risk to the environment system. Rapid industrialization in last few decades have led to the depletion of natural resources and increase in pollution in the country. In India though there are certain rules and regulation cited by the central government for reduction of hazardous waste and for the minimization of hazardous effect on the environment still hazardous wastes are stored, transported, disposed or managed unsystematically causing health and environmental (air, water, soil) related problems. This paper is a review report about the hazardous waste management in India.

IndexTerms **- Hazardous Waste, Waste Minimization, 3R's, TSDF**

I. INTRODUCTION

India is a developing country, and industries is a major source of hazardous waste in developing countries, but industrial hazardous waste sources presents greater risks in developing countries than in developed countries because of poor management and obsolete technologies, multinational companies often set their plants in developing countries so, that they can use technologies banned in their house country. The accident at the Bhopal plant in India, which belonged to union carbide of USA is a prime example of this situation (Khan Danielle J*)*. The major source of hazardous solid wastes in our country are industrial activities, agriculture and argo-industries, medical facilities, commercial centres, household and the informal sector. Small competitive and labour intensive businesses that are not regulated by government is the source of hazardous solid waste that is currently recognized as major problem in developing countries.

Hazardous waste in India has been defined as "any substance, excluding domestic and radioactive wastes, which because of its quantity and/or corrosive, reactive, ignitable, toxic and infectious characteristics causes significant hazards to human health or environment when improperly treated, stored, transported and disposed". Hazardous wastes refer to wastes that may, or tend to, cause adverse health effects on the ecosystem and human beings. These wastes pose present or potential risks to human health or living organisms, due to the fact that they: are non-degradable or persistent in nature; can be biologically magnified; are highly toxic and even lethal at very low concentrations. To determine the nature of hazard, the criteria that would be followed is toxicity, phyto toxicity, genetic activity and bio-concentration of the substance.

II. CLASSIFICATION OF HAZARDOUS WASTES:

Hazardous Wastes are Classified as F, K, P, and U lists

F-List: The F-list contains hazardous wastes from non-specific sources, that is various industrial processes that may have generated the waste. The list consists of solvents commonly used in degreasing, metal treatment baths and sludges, wastewaters from metal plating operations and dioxin containing chemicals or their precursors. Examples: Benzene (F005), Carbon tetrachloride (F001), Cresylic acid (F004) etc.

K-list: The K-list contains hazardous wastes generated by specific industrial processes. Examples of industries, which generate K-listed wastes include wood preservation, pigment production, chemical production, petroleum refining, iron and steel production, explosive manufacturing and pesticide production.

P and U lists: The P and U lists contain discarded commercial chemical products, off-specification chemicals, container residues and residues from the spillage of materials. These two lists include commercial pure grades of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. An example of a P or U listed hazardous waste is a pesticide, which is not used during its shelf-life and requires to be disposed in bulk.

Characteristics:

a) Ignitability:

A waste is an ignitable hazardous waste, if it has a flash point of less than 60C; readily catches fire and burns so vigorously as to create a hazard; or is an ignitable compressed gas or an oxidizer. Ex: Naphtha, lacquer thinner, epoxy resins, adhesives, oil based paints etc.

b) **Corrosivity:**

A liquid waste which has a pH of less than or equal to 2 or greater than or equal to 12.5 is considered to be a corrosive hazardous waste. Sodium hydroxide, a caustic solution with a high pH, is often used by many industries to clean or degrease metal parts. Hydrochloric acid, a solution with a low pH, is used by many industries to clean metal parts prior to painting. When these caustic or acid solutions are disposed of, the waste is a corrosive hazardous waste.

c) Reactvity:

A material is considered a reactive hazardous waste, if it is unstable, reacts violently with water, generates toxic gases when exposed to water or corrosive materials, or if it is capable of detonation or explosion when exposed to heat or a flame. Examples of reactive wastes would be waste gunpowder, sodium metal or wastes containing cyanides or sulphides.

d) Toxicity:

To determine if a waste is a toxic hazardous waste, a representative sample of the material must be subjected to a test conducted in a certified laboratory. The toxic characteristic identifies wastes that are likely to leach dangerous concentrations of toxic chemicals into ground water.

Hazardous Waste can be classified into - (i) Solid wastes (ii) Liquid wastes (iii) Gaseous wastes (iv) Sludge wastes from various anthropogenic sources (Babu and Gupta, 1997). Any product that releases hazardous substance at the end of its life, if indiscriminately disposed of is known as hazardous waste. An efficient Hazardous Waste Management protocol needs to be executed; other-wise it may cause land, surface and ground water pollution (Ramakrishna and Babu,1999a; Rao, 1999, Wentz,1995; Parsa *et al*. 1996; Chakradhar *et al.,* 1999).

Characteristics of Hazardous Wastes

Fig:1 Characteristics of Hazardous Wastes

Hazardous	**Characteristics**
Flammable/ Explosive	This type of waste may cause damage to the surroundings by Producing harmful gases at high temperature and pressure or by causing fire hazards.
Oxidizng	Types of wastes that may yield oxygen and thereby cause or contribute to the combustion of other materials.
Poisonous (Acute)	These waste have high potential to cause death, serious injury or to harm health if swallowed, inhaled or by skin contact.
Infectious Substances	Hazardous wastes containing micro-organisms and their toxins, and responsible for diseases in animals or humans.
Corrosives	These wastes are chemically active and may cause severe damage to the flora and fauna, or to the other materials by direct contact with them.
Eco-toxic	These wastes may present immediate or delayed adverse impacts to the environment by means of bioaccumulation and/or toxic effects upon biotic systems.
Toxic (Delayed or Chronic)	These wastes, if inhaled or ingested or if they penetrate the skin, may cause delayed or chronic effects, including carcinogenicity.
Organic Peroxides	These are organic waste containing bivalent-O-O- structure and may undergo exothermic self-accelerating decomposition

Classification: Hazardous wastes are generally classified into five categories.

a) Radioactive Substance:

Substances that emit ionising radiation are radioactive. Such substances are hazardous because prolonged exposure to radiation often results in damage to living organisms. Radioactive substances are of special concern because they persist for a long period. The period in which radiation occurs is commonly measured and expressed as *half-life*, i.e., the time required for the radioactivity of a given amount of the substance to decay to half its initial value. For example, uranium compounds have half-lives that range from 72 years for U232 to 23,420,000 years for U236.

b) Chemicals:

Most hazardous chemical wastes can be classified into five groups: synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives. Some of the chemicals are hazardous because they are highly toxic to most life forms.

c) Bio-medical Wastes:

The principal sources of hazardous biological wastes are hospitals and biological research facilities. The ability to infect other living organisms and the ability to produce toxins are the most significant characteristics of hazardous biological wastes. This group mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs.

d) Flammable wastes:

Most flammable wastes are identified as hazardous chemical wastes. This dual grouping is necessary because of the high potential hazard in storing, collecting and disposing of flammable wastes. These wastes may be liquid, gaseous or solid, but most often they are liquids. Typical examples include organic solvents, oils, plasticisers and organic sludges.

e) Explosives:

Explosive hazardous wastes are mainly ordnance (artillery) materials, i.e., the wastes resulting from ordnance manufacturing and some industrial gases. Similar to flammables, these wastes also have a high potential for hazard in storage, collection and disposal, and therefore, they
should be considered separately in addition to being listed as hazardous chemicals. These wastes may exist in solid, liquid or gaseous form.

Classification of Hazardous Wastes

Fig:2 Classification of Hazardous Wastes

Waste Category	Sources
Radioactive substances	Biomedical research facilities, colleges and university laboratories, offices, hospitals, nuclear power plants, etc.
Toxic chemicals	Agricultural chemical companies, battery shops, car washes, chemical shops, college and university laboratories, construction companies, electric utilities, hospitals and clinics, industrial cooling towers, newspaper and photographic solutions, nuclear power plants, pest control agencies, photographic processing facilities, plating shops, service stations, etc.
Biological wastes	Biomedical research facilities, drug companies, hospitals, medical clinics, etc.
Flammable wastes	Dry cleaners, petroleum reclamation plants, petroleum refining and processing facilities, service stations, tanker truck cleaning stations, etc.
Explosives	Construction companies, dry cleaners, ammunition production facilities, etc.

Source: Tchobanoglous, et al., (1977 and 1993)

III. WASTE MANAGEMENT – INDIAN SCENARIO:

HPC (2001) defines Hazardous Waste as any substance, whether in solid, liquid or gaseous form, which has no foreseeable use and which by reasons of any physical, chemical, reactive, toxic, flammable, explosive, corrosive, radioactive or infectious characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or environment, and should be considered as such when generated, handled, stored, transported, treated and disposed off.

The hazardous waste generated in the country per annum is estimated to be around 4.4 million tonnes while as per the estimates of Organization for Economic Cooperation and Development(OECD) derived from correlating hazardous waste generation and economic activities, nearly five million tonnes of hazardous waste are being produced in the country annually. This estimate of around 4.4 million MTA is based on the 18 categories of wastes which appeared in the HWM Rules first published in 1989. Out of this, 38.3% is recyclable, 4.3% is incinerable and the remaining 57.4% is disposable in secured landfills. Thirteen States of the country (Maharashtra, Gujarat, Tamil Nadu, Orissa, Madhya Pradesh, Assam, Uttar Pradesh, West Bengal, Kerala, Andhra Pradesh, Telangana, Karnataka and Rajasthan) account for 97% of total hazardous waste generation. The top five waste generating states are Maharashtra, Gujarat, Andhra Pradesh, Telangana and Tamil Nadu. On the other hand, states such as Himachal Pradesh, Jammu & Kashmir, all the North Eastern States excepting Assam generate less than 20,000 MT per annum. Given the wide variations in quantity and nature of waste generated across states and union territories (UTs) and also considering the wide variations in climatic as

well as hydro-geological conditions in different regions of the country, the approach to waste management has to be essentially state specific (NEERI).

Severe pollution of land, surface and ground water may occur (Ramakrishna and Babu, 1999a; Rao, 1999) if the options available (Wentz, 1995; Parsa et al., 1996; Chakradhar et al., 1999) for Hazardous Waste Management (HWM) are not being efficiently utilized by the waste generators. As per the ideal industrial siting criteria in India, the industry should have enough land available within its premises for the treatment and disposal and or reuse/recycling of the wastes generated from it (Murali Krishna, 1995). However, very few industries in India own proper treatment and disposal facilities (Jeevan Rao, 1999). Mostly the large-scale industries and a few medium-scale industries (Ramakrishna and Babu, 1998), and none of the small-scale industries own the above facilities.

Disasters occur due to both the natural and man-made activities. Hazards and Disasters are categorized into four groups, viz., Natural events, Technological events, Man-made events and Region-wise events. There is a growing concern all over the world for the safe disposal of HWs generated from anthropogenic sources. Hazardous Wastes (HWs) are disposed off at Treatment, Storage and Disposal Facility (TSDF), a centralized location catering to the HW generated from the waste generators in the near vicinity. The TSDF will help the small and medium scale industries generating HW in disposing their wastes efficiently. Literature is available on the site selection and other related criteria of TSDF (Ramakrishna and Babu, 1999b; Lakshmi, 1999; Babu and Ramakrishna, 2000; Babu and Ramakrishna, 2003).

IV. LEGISLATIVE FRAMEWORK:

In India, a comprehensive legislative framework has been in place for over a decade for addressing various issues related to hazardous waste management. However, on the implementation front, there is a significant backlog. The present paper discusses the status of hazardous waste generation and management in India. India introduced an amendment into its constitution calling upon the state to protect and improve the environment to safeguard public health, forests and wildlife. The forty second amendment to the Indian Constitution was adopted in 1976, and went into effect on January 3, 1977. The Directive Principles of State Policy (Article - 47) in the Indian Constitution requires not only that the state protect the environment, but it also compels the state to seek the improvement of polluted environments. Ministry of Environment & Forests (MoEF) promulgated Hazardous Waste (Management & Handling) Rules on 28 July 1989 under the provisions of the Environment (Protection) Act, 1986. In September 2008, the said rules were repealed and new rules entitled "Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008" (here after referred as HW (M, H & TM) Rules were notified. These rules were further amended in the year 2009 & 2010.

According to the HW (M, H & TM) Rules of 2010, any waste, which by virtue 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 has been defined as hazardous wastes and include wastes generated mainly from the 36 industrial processes referred under Schedule - I of the said Rules. In addition, some wastes become hazardous by virtue of concentration limits as well as hazardous characteristics listed under Schedule - II of the said Rules. Based on the data provided by the State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs), Central Pollution Control Board (CPCB) has compiled state-wise inventory of hazardous waste generating industries The hierarchy in management of hazardous waste is to reduce, reuse, recycle and re-process and final option of disposal of wastes having no potential for value addition, in disposal facilities in an environmentally sound manner. The disposal facilities may be having only a secured land fill (SLF) or may be having incinerator alone for organic wastes or combination of secured landfill & incinerator. At present, there are 26 common Hazardous Waste Treatment, Storage and Disposal Facilities (TSDFs) in operation spread across the Country in 13 States namely Andhra Pradesh, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh and West Bengal as well as in UT namely Daman, Diu, Dadra & Nagar Haveli. Thirty-five new sites for development of TSDF have been notified by the respective State Governments and these are at different stages of development (Central Pollution Control Board, 2010).

Waste Generation:

Hazardous Wastes generation is maximum in Maharashtra (45.47%) followed by Gujarat (9.73%). Minimum Hazardous Wastes is reported in Chandigarh (0.0069%). The number of industries that generate Hazardous Wastes are maximum in Maharashtra (30.38%) followed by Gujarat (22.93%) (Ramakrishna & Babu ; Agarwal & Gupta, 2011).

Characterization:

The Hazardous Wastes are categorized into three groups viz., Recyclable, Incinerable, and Disposable. The Hazardous Waste generation trends in Maharashtra and the rest of the India are similar. The quantity of disposable Hazardous Wastes (inorganic in nature to be disposed off in landfill) is high compared to the other two categories (Ramakrishna & Babu; Agarwal & Gupta, 2011).

Quantification:

The quantity of Hazardous Wastes generation reported in India is 4415954 TPA from 373 districts out of 525 districts. According to one estimate (SDNP, 2003), the land required to dispose 5.3 million tons of Hazardous Wastes in an engineered landfill, assuming the average density of waste to be around 1.2 tonnes/m3 and the depth of the landfill 4 m, would be around 1.08 km2 every year. This information may be applied to future waste projections to arrive at future land requirements for the disposal of hazardous waste (Ramakrishna & Babu, 1998, 1999a & 1999b ; Agarwal & Gupta, 2011).

Site Selection:

The selection of a suitable site for an effective functioning of TSDF is the key aspect and depends upon several factors such as waste characteristics, site characteristics, public acceptance and prevailing laws & regulations. Though the selection of an ideal site confirming with the above factors is a difficult task, few guidelines are available (Guidelines, 1991) in India for selection of best site for the same purpose. In India, unauthorized dumping of Hazardous Waste is however continuing and in most of the places, the Hazardous Waste is being utilized to fill the low-lying areas (HPC, 2001), which is not acceptable.

Waste Management Strategy:

Waste Avoidance and Waste Minimization at Source:

In the hierarchy of waste management, waste avoidance and waste minimization have to be attempted first. For this a close look at the processes generating hazardous waste has to incorporate to find feasible processes and technologies for waste avoidance and minimization and this should be done on a regular interval. As far as possible cleaner processes needs to be considered.

Reuse, Recovery and Recycling of Hazardous Waste:

Second in the hierarchy of waste management is reuse, recycle and recovery of useful resources from wastes, in that order. MoEF may, therefore, consider constituting dedicated waste specific Task Forces so as to explore options/opportunities of reusing, recovery and recycling of the hazardous wastes in an environmentally sound manner.

Fig. 1. Reuse, Reduce and Recycling

E-Waste:

The recycling of e-waste such as components of waste electrical and electronic assemblies comprising accumulators and other batteries, mercury- switches, activated glass cullets from cathode- ray tubes and other activated glass and PCB capacitors etc. is also required to be regulated due to the presence of hazardous constituents. The guidelines in this regard have already been issued so as to ensure environmentally sound recycling of e-waste. The producers of electronic equipment may be required to have a centralized facility for e-waste of their brand as extended producer responsibility.

Safe Disposal of Hazardous Waste:

Waste which cannot be reused or recycled has to be disposed of in an environmentally sound manner. Depending on the waste category, physico-chemical/bio-logical treatment, secured land disposal, incineration or any other mode of safe and environmentally sound disposal should be adopted. Design and operational norms of such facilities, either captive or common should strictly adhere to the guidelines framed by the Central Pollution Control Board. Supervision of such facilities during construction stage would be necessary to ensure quality of the construction of the disposal facilities as per guidelines of Central Pollution Control Board. Post-closure monitoring of the disposal facilities would also be necessary.

Setting-up of the Common Treatment, Storage and Disposal Facilities (TSDF)

Currently there are 25 Common Hazardous Waste Treatment, Storage and Disposal Facilities in operation in 13 States. In addition to this, 64 sites have been identified and 35 sites have been notified for setting up of the disposal facilities. The notified sites are at different stages of development. The annual capacities of the TSDFs range from 10,000 T/annum to 1.2 lakhs T/annum with an operating life span of 15-30 years. At the initial stages, a certain level of assistance from the State Governments could significantly accelerate the process of setting up of these facilities and also ensure their viability in the initial years which is vital.

Disposal of Date-Expired Drugs and Pesticides:

There are significant quantities of date –expired drugs and pesticides lying in various States, which need to be disposed of. The options available are (i) to have these reprocessed wherever possible by the industry which supplied them (ii) to appropriately incinerate them either through dedicated incinerators of individual industries or through incinerator available with common facilities (TSDF).

National Hazardous Waste Management Strategy:

1. Effective management of hazardous waste, so as to avoid environmental pollution and adverse health effects due to its improper handing & disposal.

2. To have an appropriate strategy for the regulatory bodies, generators of hazardous waste, its recyclers and operators of facilities to minimize, recycle, treat and dispose of left over hazardous waste in an environmentally sound manner.
3. To facilitate implementation of the action plan brought out in "National Environment Policy 2006" on management aspects of hazardous waste, and to fulfil obligations under the Basel Convention on Transboundary movement of hazardous wastes including their
minimization environmentally sound management and active promotion of transfer and use of cleaner technologies.

V. THE BASEL CONVENTION:

India is a Party to the Basel Convention on transboundary movement of hazardous wastes. The Basel Convention is a tool for controlling and reduction of transboundary movements of hazardous and other wastes subject to the Convention, Prevention and Minimization of their generation, environmentally sound management of such wastes and for active promotion of the transfer and use of cleaner technologies. As a party to the Convention, India is obliged to regulate and minimize the import of hazardous waste or other wastes for disposal or re-cycling and also to prohibit export of waste to parties, which have prohibited the import of such wastes. India is also required to minimize generation of hazardous waste in the country taking into account social, technological and economic aspects (NEERI).

VI. SUMMARY & CONCLUSION:

The Ministry of Environment & Forests (MoEF) has elaborately identified various treatment and disposal options of different hazardous waste streams that include physical/chemical treatment, landfill, biological, treatment, incineration etc. still secured landfill is the most used option for disposal of waste. The rules framed by Ministry of Environment & Forests (MoEF) regarding hazardous waste should be followed strictly by the industries and regulatory body should be assigned for regular monitoring purpose. Proper treatment, storage prior to treatment or disposal and safe disposal of hazardous waste is essential for environmental health.

The Indian government promulgated the Environment (Protection) Act in 1986, which is umbrella legislation to protect and improve the environment and to regulate the management and handling of hazardous substances and chemicals. The Ministry of Environment and Forests continuously monitors the progress made by various state governments and union territories with respect to the implementation of India's Hazardous Wastes Rules. Experience in India shows that most industries respond to environmental issues by complying with Government regulations, but if corporations do take an antagonistic position towards regulations, they continue to be burdened with ever-increasing regulations and adverse judicial pronouncements. In the future, the corporations need to be proactive and set voluntary standards for environmental protection and safety that minimize the chance that illogical and ill-conceived regulations and standards are adopted. This, in turn, requires a comprehensive, constructive and cooperative policy-making process to shape national environmental policies and regulations. Even after efforts to reduce waste are undertaken, some residuals will remain that warrant innovative treatment and disposal methods. Developing countries should learn from the experiences of developed nations regarding their hazardous waste management system and its related problems and also keep looking for new and innovative solutions that achieve a better fit with the limited resources available to developing
countries.

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