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Economic Impact and Challenges in Waste Management

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Abstract

Wastes are any sort of discarded or undesirable materials which may be solid, liquid, semi-solid or containerized gaseous material. Human activities generate waste in their day to day activities and if these wastes are not properly handled collected, stored, and disposed, it can pose threat to the environment as well to public health. Efficient waste management may have a significant positive impact on the economy of the country as it reduces costs for waste disposal, which can be resourced into other fields. Recycling of waste materials is an important segment of the national and state economy as it designs jobs for unemployed people thus enhancing the employment rate and also saves money for generators of waste. Other indirect economic impacts of waste management may include such factors as the reduction of illness and healthcare costs, enhancement of environmental quality and property values, reduction of disturbances and increase of business volumes. In addition, many organizations can get economic benefits as a result of vending of their recyclable materials. However proper waste recycling has been are a major challenge in the waste management process. The 3R's of an efficient waste management process is Reduce, Reuse and Recycle which helps us to improve the economic condition of a country and reduce the threats of the waste generated. In municipal solid waste management (MSWM) of developing countries the typical problems are insufficient service coverage, operational inefficiencies of services, limited utilization of recycling activities, inadequate landfill disposal, inadequate management of non-industrial hazardous waste for example medical wastes from hospital or health centres if disposed openly may lead to high risk for human infection due to their highly infectious and hazardous content. Efficient handling and management of medical waste is a major challenge because of increasing populations and increasing medical attention at various health facilities. Apart from these, many kinds of radioactive wastes are produced by the nuclear power plants and industries, which are highly hazardous not only to human health but also to animals, plants, crops and environment. Radioactive wastes (RW) if not properly disposed, can cause adverse effects like cancer, haemorrhage, birth defects and contaminate both water and environment. Hence, waste if not managed properly may create a havoc in the environment. Proper waste management is very crucial and is one of the major challenges faced by many countries around the globe.

Keywords Waste management. Biomedical waste. Radioactive waste. Health hazards.

INTRODUCTION

Waste is defined as discarded material, which has no value in normal or for ordinary use. Solid wastes (SW) are those undesirable, useless and unwanted materials and substances from any human activity. To minimize the risk and health hazards, and environmental pollution the segregation, handling, transport and disposal of waste are to be properly managed. Waste is generated in all sorts of ways such as dry waste, wet waste, etc. The economic value of the waste is best realized when it is segregated in proper manner. India is a developing country with 16% of the world population and having 2% of the total land area. According to a study 1,60,000 metric tons of garbage India generates every day (Bagben et al. 2106).

The waste is, any garbage, refuse or rubbish which consists of domestic, commercial and industrial wastes. The waste, which is of dry type can be classified as recyclable (i.e. paper, plastic, glass, metals) and non-recyclable. When through the waste in dust bin, it is important to distinguish whether it is belongs to recyclable or non-recyclable. For example, recycling reduces greenhouse gas emission by preventing methane (CH_4) emission from landfills or open dumps and preventing the consumption of energy for extracting and processing raw materials. Studies say that segregated waste is very much valuable, which can be then used to produce fertilizers, generate biogas and electricity. Whereas, waste dumped unsorted in open, produces harmful liquids and gases that spread diseases and also make that land barren on which it is dumped (Narendra Kumar et al. 2014; Sunil Kumar et al. 2017).

Need of waste management

The need of waste management is to gain an understanding of waste management planning concepts, frameworks, strategies, and also components that are emerging in this field. The sorting of waste is essential as the amount of waste being generated today causes immense problem. In fact, it is believed that a larger portion can be recycled, a part of it can be converted to compost and also only a smaller portion of it is real waste that has no use and has to be discarded (Fig. 1). So, effective and reliable waste management has become a need of the hour (Kadam and Sarawade 2016; Navarro Ferronato and Vincenzo Torretta 2019).

Types of waste

Composition and volume of waste depend principally on consumption patterns as well as the industrial and economic structures in place. Generally, waste can be classified into solid waste, liquid waste and gaseous waste (Siddharth Ghansela 2013).

Fig. 1 Direction to be followed to reduce the waste (Sources: Privatisation: A formula for provision or perversion of municipal solid waste management).

Solid waste

Solid waste is any garbage, refuse or rubbish that we make in our homes and also other places. These includes the old car tires, old newspapers, broken furniture, unwanted electronic's parts and even food waste. Consumer products are the most common renewable materials, which include aluminum materials such as beverage cans, copper materials such as wire, steel from food and aerosol cans, old steel furnishings or equipment, rubber tyres, polyethylene bottles, glass bottles, jars, paperboard cartons, newspapers, magazines, and fiber board boxes. Solid waste also can be classified into two different types depending on their source: 1) Household waste is generally classified as municipal waste, 2) Industrial waste as hazardous waste/ hospital waste as infectious waste (Abdhalah et al. 2016; Arti Pamnani and Meka Srinivasarao 2014; Siddharth Ghansela 2013).

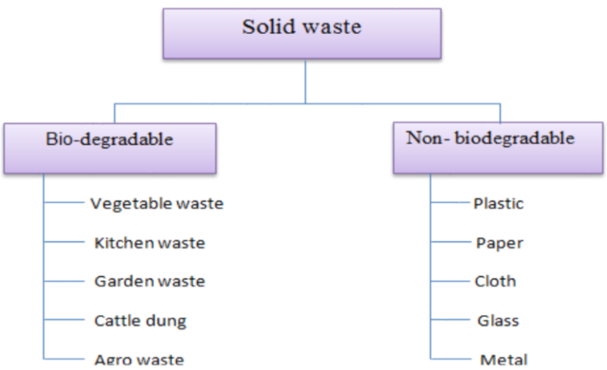

Fig 2. Classification of solid waste (Adopted from Bagban et al. 2016).

1) Municipal solid waste

Municipal solid waste contains the household waste, construction as well as demolition debris, sanitation residue, and waste from streets. Mainly, this type of garbage is generated from residential as well as commercial complexes.

2) Hazardous waste

Industrial as well as hospital wastes are considered hazardous as they may consist of toxic substances. Hazardous wastes could be dangerous for the humans, animals, plantsas well as environment. These are corrosive, highly inflammable, or explosive and react when exposed to certain things e.g. gases. In India, around 7 million tons of hazardous waste is generated every year (Abdhalah et al. 2016; Steven Jerie 2016).

Liquid waste

Liquid waste is the waste generated in the kitchen, bathroom and laundry and also called the Grey water. Black water is waste water generated in the toilet is called Black water, which contains harmful pathogen. Some solid waste can also be converted to a liquid form for disposal purpose. The different sources include point source and non-point source discharges such as storm water and wastewater e.g. liquid waste include wash water from homes, liquids used for cleaning in industries and detergent waste. Most of these are wet waste, which can be used to produce fertilizer and generate electricity (Abdulkadir Kan 2009; Blenkharn 2006).

Gaseous Wastes

The gaseous wastes are generated and released into the environment mainly due to anthropogenic activities. The gaseous wastes include carbon dioxide (CO_2), CH_4, chlorofluorocarbon (CFC), oxides of nitrogen (NO_x), carbon monoxide (CO), oxides of sulphur (SO_x) etc. These gaseous waste can cause serious environmental hazards. It is highly important to take appropriate steps for the proper management and control of gaseous wastes in the environment (Pardo et al., 2015).

Some important control measures are described below:

(i) The gaseous pollutant like SO_2, H_2S, HC1, Cl_2, NH_3, etc., can be removed by absorption in (using appropriate liquid) wet scrubbers.

(ii) The use of smokeless chulhas, solar cookers and biogas can reduce the production of smoke.

(iii) Industries should use precipitators, scrubbers and filters to check production of particulate matter.

(iv) The emission of hydrocarbons can be checked by the use of unleaded petrol.

(v) Large scale of plantation will reduce CO_2 level and increase O_2 level in the atmosphere.

(vi) There should be large chimneys in industries and

(vii) The automobile emission can be controlled by; control of exhaust emission, evaporation emission, crank case emission, using engine alternative to gasoline engine, and use of CNG instead of diesel.

(viii) Air cleaning devices like gravity settlers, cyclone separators, wet collectors, electrostatic precipitators etc. should be used for proper cleaning of air before discharged into atmosphere.

(ix) Public awareness should be created on hazards of air pollutant accumulation in environment.

(x) Adequate legislation (air act) should be implemented to control air pollution ((Pardo et al. 2015).

Reduce; Reuse; Recycle

The 3 R's principle provides excellent solution to control the hazards and management of different types of wastes. The first R (reduce) involves the prevention and reduction of waste (i.e) reducing waste means to minimize amount of waste generated. It could be achieved through legislation, product design, local programmes to keep recyclables and compostable from the waste (Crown, 2012). Waste reduction stresses upon judicious use of resources in manufacturing. Legislation makes a manufacturer to maintain particular standards in designing products or limit production activity (Goldman and Ogishi 2001). Also, separation of waste at source achieves the same goal of waste reduction; intensified by public awareness and education. For instance, India uses student rallies from educational institutions and public meetings as campaign strategies to propagate waste segregation and reduction (Zhu et al. 2008).

The second R (reuse) involves secondary, subsequent and multiple uses of waste materials either in part or whole. Reuse of waste is demonstrated by trade in second-hand goods: cloths, electronics, automobiles, furniture and other merchandise. Reuse is achieved through sorting process done at source rather than disposal site; and, through detailed processes of checking, cleaning, refurbishing, repairing entirely or spare parts (Fewtrell 2012).

The third R (recycle) depends on waste materials, which cannot be reused directly but can be converted into new product or raw material through the processes of transformation e.g., paper is recycled into files, envelops, cards etc., (Practical Action Nepal, 2008). Energy is recovered through recycling through: pyrolysis (combustion of waste in the absence of oxygen to create gases, liquids and solids), incineration (combustion in the presence of oxygen to produce oxidized compounds), anaerobic digestion, and gasification; as well as composting (biological and chemical degradation of organic waste) (Fewtrell 2012).

Together, the ‘3R’s’ aimed to achieve sustainable solid waste management; and, also relates to other global environmental challenges, particularly, climate change mitigation, emission of greenhouse gases that create sustainable development co-benefits and reduction in the emissions of CH_4, CO_2, non-methane volatile organic compounds, nitrous oxide (N_2O), NO_x and CO from landfills (Field and Sroufe 2007). Advanced technologies are required to reduce or eliminate the greenhouse gas emission, include composting of organic waste, high-tech incineration and expanded sanitation coverage, industrial co-combustion for waste-to-energy and landfill gas recovery (Chirico 2009).

Waste Type	**Waste Disposed of (tonnes)**	**Waste Recycled (tonnes)**	**Waste Generated (tonnes)**	**Recycling Rate (%)**
Construction debris	9,400	1,599,900	1,609,300	99%
Ferrous metal	7,800	1,371,000	1,378,800	99%
Used slag	3,100	269,400	272,500	99%
Non-ferrous metals	1,500	92,200	93,700	98%
Scrap tyres	2,900	33,000	35,900	92%
Wood	97,300	326,800	424,100	77%
Horticultural waste	107,600	220,700	328,300	67%
Paper/Cardboard	576,000	568,800	1,144,800	50%
Glass	58,900	12,400	71,300	17%
Food	676,800	133,000	809,800	16%
Ash and sludge	214,800	28,600	243,400	12%
Plastic	763,400	51,800	815,200	6%
Textile/Leather	141,200	9,600	150,800	6%
Others (stones, ceramic, rubber, etc.)	319,300	7,100	326,400	2%
Total	2,980,000	4,724,300	7,704,300	61%

Table 1 Waste management and recycling statistics for 2017
(Source: https://www.towardszerowaste.sg/resources/statistics/waste-management-statistics-overall-recycling)

Fig 3 The 3 R’s principle to reduce the waste (Sources: Australian Recycling forum: Environmental awareness)

Fig 4 Hierarchy of waste management (Source: Southern California conversion technology, w.y)

Economic impact of wastes

Nowadays, accumulation of both solid and liquid wastes became a major problem worldwide. A waste is considered as hazardous, such as being flammable, reactive, explosive, corrosive, radioactive, infectious, irritating, sensitizing, or bio-accumulative (La Grega et al. 2001). Based on several studies economic value of any forms of waste is best realized when it is segregated in proper manner (Bagmen et al. 2106). In India, around 1,60,000 metric tons of garbage produced every day, scientist are trying to convert the waste into wealth through various advanced technologies (Bagmen et al. 2106).

The waste has direct and indirect impact on economic status of a country. The direct impact is with 3 R's (reduce, reuse and recycle), it is possible to reduce the money spent for buying things. Definitely it has a great and direct impact along with another important process called waste to wealth. Another important direct impact of waste is, providing employment for the thousands and thousands of people every day. The indirect impact of the waste, if it is properly segregated, transported, destroyed the infective agents in waste effectively and reduces the quantity of waste using various techniques and then discharged in the isolated area will absolutely produce a little hazards effect on health and environment. Currently, people are spending a lot of money to improve their health (many of the disease are caused by pollution and disease causing microorganisms). Usually disease caused by microbes are categorised as water borne disease, air borne disease, soil borne disease, food borne disease etc., but, days are not faraway to include the term called waste borne disease. Several countries spending major economy to reduce the pollution caused by waste accumulation. So proper management of waste with scientific advancement in this field will helps to improve the economy of a country both directly and indirectly (Amit Ray 2008; Antonisand Zorpas 2017).

More than two decades of sustained economic growth in several countries have worsened the problem of solid waste particularly in Asian countries. Asia generated more than 3 billion tons of solid waste in the beginning of 21st century, which may expected to go up to nearly 9 billion tons by 2050 (Amit Ray 2008). Municipal waste is chiefly produced by households, however similar kind of wastes from sources such as commerce, offices and public institutions are included. The amounts of municipal solid waste (MSW) have been increasing for years in many countries (Antonisand Zorpas 2017).

By the process of recycling, a number of useful and new products can be obtained from the solid wastes helps to improve the economic status of a country.

Some important products obtainable from solid wastes are listed below:

1. Electricity can be generated from incinerated plastics wastes.
2. Synthetic oil can be produced from plastic wastes materials.
3. Waste papers and cardboards from sugar cane bagasse can be used for the production of unbreakable dolls, packing cardboards etc.,
4. Metals can be recycled from the industrial scrap materials.
5. Ethyl alcohol produced from agricultural wastes, can be used as alternate fuel.
6. Heavy metals can be extracted from the solid waste using bioleaching technology.
7. Waste as well as broken glasses can be used for the preparation of new glass bottle.
8. Bricks and concretes can be prepared using ash generated by power plants, slit from water works and red mud from aluminum industry (www.environmentalpollution.in).

Biomedical waste

Biomedical waste (BMW) is a subset of hospital waste, generated as a result of diagnosis, treatment or immunization of patients and associated biomedical research. BMW also generated in research institutions, health care teaching institutes, clinics, laboratories, blood bank, animal houses and veterinary institutes (Pasupathi et al. 2011). Usually BMW is produced during diagnosis, testing, treatment, research or production of biological products for humans or animals, which includes syringes, live vaccines, laboratory samples, body parts, bodily fluids and waste, including sharp needles, cultures and lancets

(Shah and Ganguli 2001). Improper management of BMW generated from health care facilities causes a direct health impact on the society, health care workers and on the environment.

Around 85% to 90% of the BMW generated in health care sectors are non-infectious (free with any body fluids, which is similar to domestic waste). Remaining 10% to 15% of waste that is of concern because it is hazardous and highly infectious. Safe and effective management of BMW is not only a legal necessity but also a social responsibility of the hospitals and allied sectors. Proper handling, waste treatment and disposal of BMW are important features of infection control (Anurag et al. 2013). Appropriate procedure will helps to offer protection to health care workers, patients as well as local community. Proper collection and segregation of BMW important factor along with the quantity of waste generated is equally important (Diaz and Savage 2003). A lesser amount of BMW means a lesser burden on waste disposal work, cost saving and a more efficient waste disposal system.

Hazards of Biomedical waste

In recent days, there has been increased public concern about the management of BMW on a global basis especially in developing countries, where both financial and technological resources on medical waste management are still lacking (Yong et al. 2009; Geng et al. 2013). When hazardous health care wastes are not properly managed, could lead to various pathological conditions, including infections, infertility, genital deformities, hormonally triggered cancers, mutagenicity, dermatitis, asthma, typhoid, cholera, hepatitis, AIDS and other viral infections may be transferred through sharp’s contaminated with blood (Oli et al. 2016). Non-hazardous waste generated in a hospital is related to food preparation, administrative departments, and landscaping, these type of waste is similar to household waste and city waste.

Among all the types of BMW, infectious, pathologicals and sharps are the most dominant types of medical waste (WHO 2010). Whereas medical waste excludes waste containing microbial cultures, urine, saliva, and nasal secretions unless they contain blood (Alhumoud and Alhumoud 2007). BMW hazards and risks exist not only for the waste generators and operators, but also for the general community including children, who play near disposal areas. The possible exposure include direct contact, airborne transmission, contaminate water sources and the environment (Alhumoud and Alhumoud 2007).

Types of biomedical waste

According to the World Health Organization (WHO) BMW are classified into differenttypes:

I. **Infectious:** Material-containing pathogens in concentrations high enough to cause diseases on exposure (waste from surgery, lab cultures, used dressings, and others).
II. **Sharps**: Disposable needles, syringes, blades and broken glasses.
III. **Pathologicals**: Tissues, organs, various body parts, human flesh, blood and body fluids.
IV. **Pharmaceuticals**: Returned drugs and chemicals, spilled, expired or contaminated medicine.
V. **Chemicals**: Diagnostic waste or cleaning materials.
VI. **Radioactive**: Waste contaminated with radioactive material used in diagnosis and treatment of various diseases.
VII. **Pressurized containers:** Including gas cylinders.
VIII. **Substances with high heavy metal content**: Broken mercury thermometers and blood pressure gauges (Zarook and Shareefdeen 2012).

Management of Biomedical waste

Proper segregation of BMW is essential and useful, since it prevents the contamination of non-hazardous waste from the hazardous waste and making the whole waste stream hazardous. The system for segregation, packaging, labelling and marking, which is important for separating the medical waste into different categories, the packaging is done in several coloured bags (Madhya Pradesh Pollution Control Board 2010). Yellow plastic bags are used for the disposal of infectious BMW by means of incineration or deep burial in landfill. However, if BMW are to be treated by autoclave or microwave, they are placed in red plastic bags or containers. Hazardous BMW packaged in either blue or white transparent bags is usually treated by autoclave, microwave, chemical treatment and shredding, or by land filling (Zarook and Shareefdeen 2012).

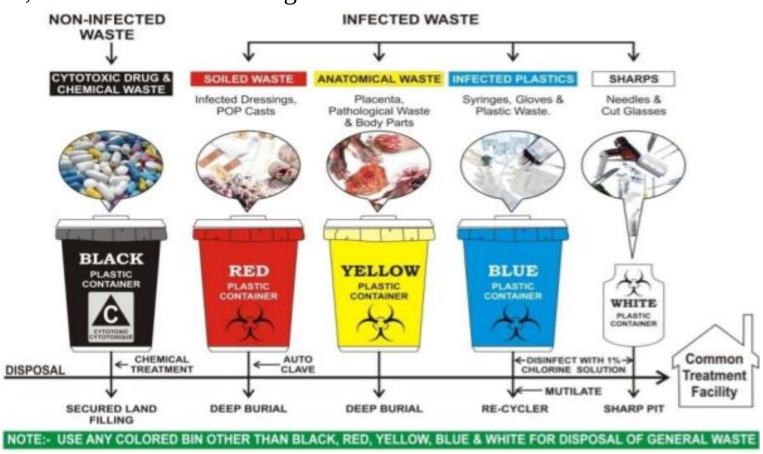

Fig 5 Collection of BMW in different coloured bags for easy handling and disposal (Sources: Times Delhi Magazine, 2017/05/16/staffers ignorance ruins waste management)

Biomedical waste management by physical methods

In steam autoclaving, the waste is decontaminated by steam at elevated temperatures and high pressure. This method is not applicable for pathological, chemotherapy and radioactive wastes. As for labelling and marking, medical wastes are popularly known to have the bio-hazard symbol (Zarook and Shareefdeen 2012). Incineration helps in destructing BMW by burning at elevated temperature in furnace. The process removes hazardous material, reduces the mass and volume and converts them into ash, which is harmless. Incinerators exist in several types; each type has a specific function. The advantage of incineration process is that the volume of BMW for disposal will be reduced by 50 - 400 times (Rutberg et al. 2002). It significantly decreases the volume of wastes; however disadvantages include high costs, smoke generation and pollution risks. All microbiological liquid bio hazardous waste including culture media containing microbial or human/non-human primate or other animal cells, diluted blood and tissue fluids, plasma etc., should be autoclaved and finally put down the sanitary sewer system.

Biomedical waste management by chemicals

In order to reduce the toxicity of BMW, chemical disinfectants (i.e., chlorine dioxide, sodium hypochlorite, or per acetic acid) are sometimes used. In some cases, the disinfectants used for the treatment themselves are hazardous, hence it is not recommended for treating pharmaceutical, chemical and some types of infectious waste. The worker should wear personal protective equipments (PPE), which include a lab coat, latex or nitrile gloves, safety glasses to protect from spillage and aerosols generated during the disposal process of BMW (Arshad et al. 2011).

Solidification

The infectious biomedical liquid waste can be placed into the red or yellow biohazard waste container depends on the type of further treatment options. The solidification process is based on a microencapsulation technology that converts liquid waste into solid form. These are dry granular super absorbent polymers that can absorb and retain large volumes of biomedical liquid waste. Though they can rapidly absorb fluids up to 300 times its weight, the expansion in volume is less than 1% (www.urbanindia.nic.in 2012). In solidification process, pouring a powdered solidifying agent into the liquid waste containers, which turns the biomedical liquid waste content into a gelatinous solid mass after 5 to 10 min, thus eliminates to transport the biohazardous fluids in a liquid form. Then these containers can be disposed of as red bag waste (Wilk and DeLisio 2002).

Radioactive waste

Radioactive waste (RW) is basically emission of effluent gases in the air, effluent liquid into water and left over solid waste, which is extremely dangerous. It is highly hazardous to human being, animals, plants, crops and environment. If RW not properly disposed, can cause deleterious effects like cancer, haemorrhage, birth defects and contaminate both water and environment. Developed countries have devised three basic policies for handling of RW: "concentrate-and-contain, dilute-and-disperse and delay-and-decay (Ali et al. 2015).

The equipment used in extraction of radioactive substances, liquids used to wash the equipment and the vehicles used for transportation of uranium as well as the workers; all contaminates the environment (Ali et al. 2015). All steps involved in this process subsequently add contamination to the environment. Most of the RW is needs to be managed carefully as a harmful material. Disposal of RW produced during various process of mining, fuel fabrication and manufacturing of solid metal are the most difficult complications linked with nuclear power generation.

Hazards of Biomedical waste

Radioactive waste particles easily move through diverse ecological systems and contaminate the entire biosphere. These particles will remain harmful for 10 times of their half-lives and will continue to portend living being for about 7 billion years. Irrespectively it affects air, water, microorganisms, pests, germs, plants, birds and all forms of life in our ecosystem. Major symptoms of radiation sickness include, nausea, weakness/fatigue, hair loss, skin burns, vomiting, diarrhea and haemorrhage. Population living around the nuclear power plant are threatened by genetic defects and various abnormalities like smaller head or brain size, poorly formed eyes, slow growth, and mental retardation, etc., (Tirthankar Choudhury and Bhattacharyya 2016).

Low-level radioactive waste

Radioactive content of low-level RW is much less and are made up of isotopes having much shorter half-lives than most of the isotopes contained in high-level RAW and/or intermediate-level waste. On storage, for a span of 10 to 50 years will allow most of radioactive isotopes in these wastes to decay, then the waste can be disposed of as normal waste. Exposure of mammals to low levels of radiation may indeed be beneficial, causing increased life span, greater reproductive capacity, better disease resistance, increased growth rate, greater resistance to higher radiation doses, better neurological function, wound healing, lower tumour induction and growth (John et al. 1998). Low-level of RW are generated by hospitals, industries, laboratories and during nuclear fuel cycle processing. It contains quite small amounts of mostly short-lived radioactivity and includes paper, rags, tools, and clothing, filters etc., Even though it is less dangerous, it should be disposed more cautiously than garbage. It is generally compacted and buried deep into the ground.

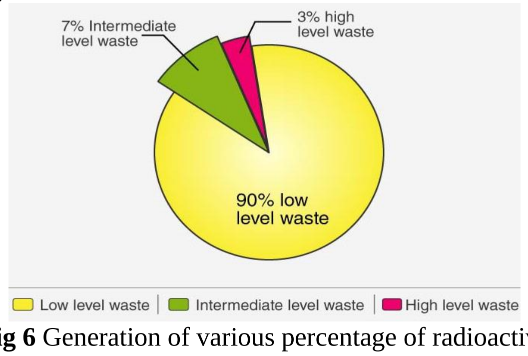

Fig 6 Generation of various percentage of radioactive waste (Low level waste, Intermediate level waste, High level waste).

Intermediate-level radioactive waste

Intermediate-level of radioactive waste contains higher amounts of radioactivity and may require special shielding for proper storage and disposal. It comprises resins, chemical sludge and reactor components, and contaminated materials from nuclear reactors. It may be solidified in concrete or bitumen for disposal. Generally short-lived RW (mainly from reactors) is buried, whereas long-lived RW (from reprocessing nuclear fuel) is disposed off deep underground (Ali et al. 2015).

Waste classes	Typical characteristics	Disposal options
1. Exempt waste (EW)	Activity levels at or below clearance levels… …based on an annual dose to members of the public of less than 0.01 mSv	No radiological restrictions
2. Low and intermediate level waste (LILW)	Activity levels above clearance levels…	
2.1. Short lived waste (LILW-SL)	…and thermal power below about $2kW/m^3$ Restricted long lived radionuclide concentrations (limitation of long lived alpha emitting radionuclides to 4000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package)	Near surface or geological disposal facility
2.2. Long lived waste (LILW-LL)	Long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility
3. High level waste (HLW)	Thermal power above about $2kW/m^3$ and long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility

Table 2 The International Atomic Energy Agency Proposed Waste Classification Scheme (Adopted from: "Classification of Radioactive Wastes", International Atomic Energy Agency Safety Guide, Safety Series 111-G-1.1, IAEA, Vienna, 1994).

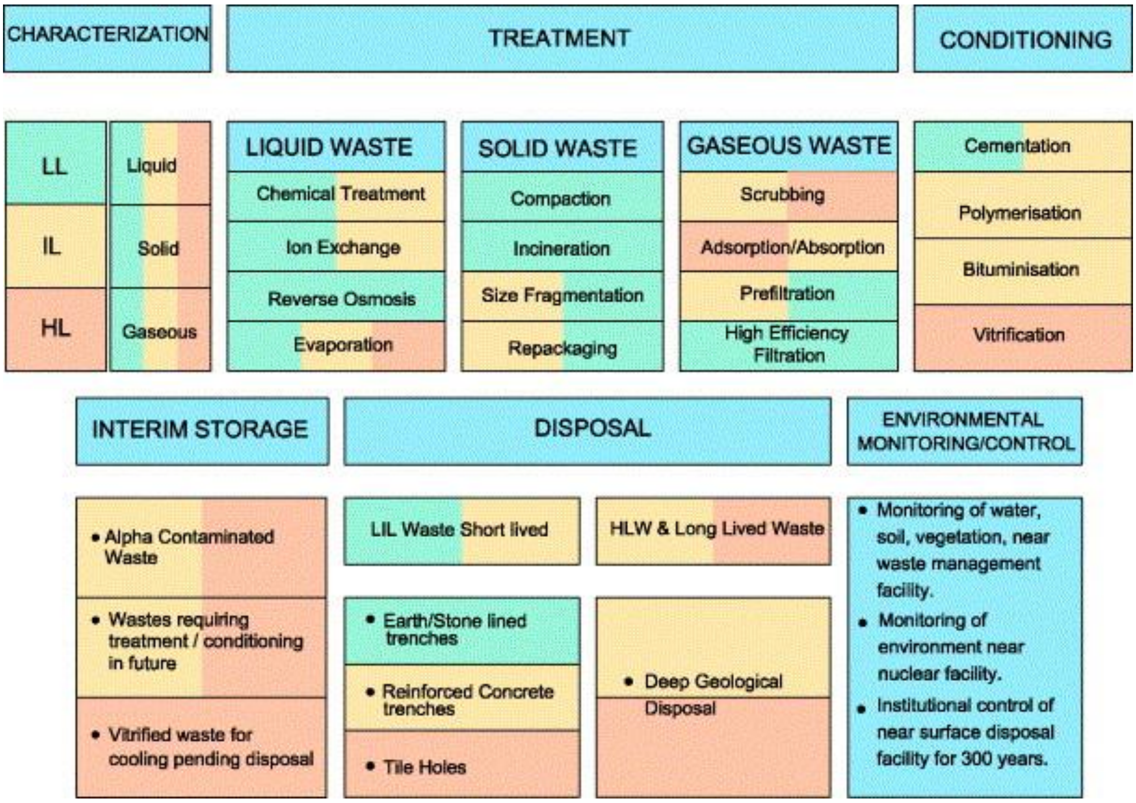

Table 3 Various methods used to treat radioactive waste (Adopted from Raj et al. 2006).

High-level radioactive waste

High-level RW consisting of the spent fuel, the liquid effluents originating from the reprocessing of spent fuel and the solids onto which the liquid waste is converted. It consists of principal nuclear reactor materials including uranium, plutonium and other highly radioactive elements originating from fission, made up of fission fragments (Tirthankar Choudhury and Bhattacharyya 2016). The radioactive fission fragments decay to different stable elements by means of different nuclear reactions about 1000 years causing emissions to harmless levels of radioactivity. Higher degree waste is used in nuclear fuel itself or the principal waste during mining or reprocessing. The nuclear process encompass of all stage of mining, milling, transporting, enriching fabricating, processing and disposal of RW material (Ali et al. 2015).

Electronic waste

Electronic waste (E-waste) is the term used to describe old, end-of-life electronic appliances such as computers, laptops, TVs, DVD players, mobile phones, mp3 players etc. which have been disposed by their original users. E-waste broadly covers wastes from all electronic and electrical appliances and comprises of several things such as laptops, gadget, digital music recorders/players, refrigerators, washing machines, TV, and many other household consumer items. Studies so far reveal that the total E-waste generation in India is approximately 1,46,000 tonnes to 3.3 lakh tonnes a year. E-waste comprises of a multitude of components, some containing toxic substances that can have adverse impact on human health and the environment if not handled properly (Viol 2008).

Heavy metal toxicity in E-waste

Lead: exerts toxic effects on various systems in the body such as the central and peripheral nervous systems, the hemopoietic system, the genitourinary system (capable of causing damage to all parts of nephron) and the reproductive systems. **Mercury**: causes damage to the genitourinary system (tubular dysfunction), the central and peripheral nervous systems as well as fetus. When inorganic mercury spreads out in water, it is transformed into methylated mercury, which bio-accumulates in living organisms and concentrated through the food chain, particularly by fish (Md. Sahadat Hossain et al. 2015).**Cadmium**: is a potentially long-term cumulative poison. Toxic cadmium compounds accumulate in the human body,especially in the kidneys. There is evidence of the role of cadmium and beryllium in carcinogenicity. **Polycyclic aromatic hydrocarbons**: Affects lung, skin and bladder Epidemiological studies in the past on occupational exposure to polycyclic aromatic hydrocarbons(PAH) provide sufficient evidence of the role of PAH in the induction of skin and lung cancers (Kurt Daum et al. 2017).

REFERENCES

Abdhalah, K. Z., Tilahun, N. H., Blessing, M. (2016). A review and framework for understanding the potential impact of poor solid waste management on health in developing countries. *Archives of Public Health, 74,* 55.

Abdulkadir, K. (2009). General characteristics of waste management: A review. Energy Education Science and Technology Part A: *Energy Science and Research, 23,* 55-69.

Alhumoud, J. M., Alhumoud, H., M. (2007). An Analysis of Trends Related to Hospital Solid Wastes Management in Kuwait, Management of Environmental Quality: *An International Journal, 18,* 502-513.

Ali, S., Shahiq, I., Maqbool, S., A. (2015). Nuclear Waste and Our Environment. *American Journal of Social Science Research, 1,* 114-120.

Amit, R. (2008). Waste Management in Developing Asia. *The Journal of Environment & Development*, *17,* 3-25.

Antonis, A., Zorpas, W., Leal Filho, et al. (eds.) (2017). Sustainable Economic Development, World Sustainability Series, Springer International Publishing Switzerland. DOI 10.1007/978-3-319-45081-0_2.

Anurag, V., Tiwari, A., Prashant, A., et al. (2013). Biomedical Waste Management Practices in India-A Review. *International Journal of Current Engineering and Technology, 3,* 2030-2033.

Arshad, N., Shamail, N., Fatima, A. et al. (2011). Hospital Waste Disposal: A Review Article. *Journal of Pharmaceutical Sciences and Research, 3,* 1412-1419.

Arti, P., Meka, S. (2014). Municipal solid waste management in India: a review and some new results. *International Journal of Civil Engineering and Technology (IJCIET), 5,* 01-08.

Bagban, M.A.S., Prajakta, R. K., et al. (2016). An Insight into Different Waste Types and Waste Segregation Methods. *International Research Journal of Engineering and Technology (IRJET), 03,* 2060-2063.

Blenkharn, J.I. (2006). Standards of clinical waste management in UK hospitals. *Journal of Hospital Infection, 62,* 300-303.

Bowan, P.A., Mumuni, A.I., (2013). Urban Solid Waste Management in Ghana: an Assessment of Zoomlion's Approach to Waste Management in the Municipality. *Journal of Environment and Earth Science, 3,* 73-79.

Chirico, J. (2009). There is No Such Thing as "Away": An Analysis of Sustainable Solid Waste Management Technologies School of Public Policy Enterprise Innovation Institute Science, Technology, and Innovation Policy Program Georgia Institute of Technology, Atlanta Georgia, 2009, 1-60.

Guidance on the Legal Definition of Waste and Its Application, (2012). Department for Environment, Food and Rural Affairs, London, pp. 1-69.

Diaz, L.F., Savage, G.M. (2003). Risks and Costs Associated with Management of Infectious Wastes, WHO/WPRO, Manila, Philippines, 1-69.

Fernández-Gonzáleza, J.M., Grindlay, A.L., Serrano-Bernardo, F., et al. (2017). Economic and environmental review of Waste-to-Energy systems for municipal solid waste management in medium and small municipalities. *Waste Management, 67,* pp 360-374.

Fewtrell, L. (2012) Municipal Solid Waste and Health, Research Report for Regional Visions of Integrated Sustainable Infrastructure Optimised for Neighbourhoods (ReVISIONS), CREH, Aberystwyth University, pp. 1-31.

Field, J., Sroufe, R. (2007). The Use of Recycled Materials in Manufacturing: Implications for Supply Chain Management and Operations Strategy. *International Journal of Production Research, 45,* 4439-4463.

Geng., Yong., Wan-xia R., Bing X., et al. (2013). Regional medical waste management in China: a case study of Shenyang. *Journal of Material Cycles and Waste Management, 15(3),* 310-320.

Goldman, G., Ogishi, A. (2001). The Economic Impact of Waste Disposal and Diversion in California: A Report to the California Integrated Waste Management Board, University of California, Berkeley, California, pp. 1-105.

Guillermo, P., Raúl M., Eduardo, A., et al. (2015). Gaseous emissions from management of solid waste: a systematic review. *Global Change Biology*, *21,* 1313–1327.

http://www.environmentalpollution.in/waste-management/waste-management-management-of-solid-liquid-and-gaseous-wastes/377.

http://www.urbanindia.nic.in/publicinfo/swm.

https://www.towardszerowaste.sg/resources/statistics/waste-management-statistics-overall-recycling.

John, E., Tanner, Jr., Ludwik, K., et al. (1998). More on Radioactive Waste Disposal: Other Approaches Proposed, Discussed. *Physics Today, 51*, 15.

Kadam, M.S., Sarawade, S.S. (2016). Study and Analysis of Solid Waste Management Challenges and Options for Treatment (Indian Villages). *IOSR Journal of Mechanical and Civil Engineering, 5th National Conference RDME*, 15-22.

Kalpana, V. N., Sathya Prabhu, D., Vinodhini, S., et al. (2016). Biomedical waste and its management. *Journal of Chemical and Pharmaceutical Research, 8(4)*, 670-676.

Kurt, D., Justin, S., Richard, J.G. (2017). Toward a More Sustainable Trajectory for E-Waste Policy: A Review of a Decade of E-Waste Research in Accra, Ghana. *International Journal of Environmental Research and Public Health, 14*, 135.

La Grega, G., Buckingham, M. D., P. L. and J. C. Evans (2001). Hazardous Waste Management, 2nd Edition, Mc-Graw Hill publications.

Madhya Pradesh Pollution Control Board, (2017). Handling of bio-medical waste treatment and disposal, pp-1-24.

Narendra, K.G., Chandrika, S., Nagadarshini, K.N. (2014). Efficient Garbage Disposal Management in Metropolitan Cities Using VANETs. *Journal of Clean Energy Technologies, 2.*

Navarro, F., Vincenzo, T. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues. *International Journal of Environmental Research and Public Health, 16*, 1060.

Oli, A.N., Ekejindu, C.C., Adje, D.U. et al. (2016). Healthcare waste management in selected government and private hospitals in Southeast Nigeria. *Asian Pacific Journal of Tropical Biomedicine, 6*, 84-89.

Pardo, G.1, Moral, R., Aguilera, E., Del, P.A. (2015). Gaseous emissions from management of solid waste: a systematic review. *Global Change Biolology, 21*, 1313-1327.

Pasupathi, P., Sindhu, S., Ponnusha, B.S. et al. (2011). Biomedical waste management for health care industry. *International Journal of Biological and Medical Research, 2*, 472-486.

Pedro, S., Rui, C. M. (2012). On the economic performance of the waste sector. A literature review. *Journal of Environmental Management, 106*, 40-47.

Practical Action Nepal, (2008). Best Practices in Waste Management in Napeles Cities, *Practical Action Nepal*, Kathmandu. 1-59.

Raj, K., Prasad, K.K., Bansal, N.K. (2006). Radioactive waste management practices in India. *Nuclear Engineering and Design. 236*, 914-930.

Rutberg, G., Bratsev, N., Safronov, A., et al. (2002). The Technology and Execution of Plasma Chemical Disinfection of Hazardous Medical Waste, *Plasma Science, IEEE Transactions*, 30, pp. 1445-1448.

Sahadat, H. Md., Sulala, M.Z.F., Al-Hamadani, Md. et al. (2015). E-waste: A Challenge for Sustainable Development. *Journal of Health and Pollution, 5*, 3–11.

Siddharth, G. (2013). Green Strategy for Reducing E-Waste, *International Journal of Advanced Research in Computer Science and Software Engineering, 3*, 476-480.

Steven, J. (2016). Occupational Risks Associated with Solid Waste Management in the Informal Sector of Gweru, Zimbabwe. Hindawi Publishing Corporation. *Journal of Environmental and Public Health, 2016*, 1-14.

Sunil, K., Stephen, R., Smith. (2017). Challenges and opportunities associated with waste management in India. *Royal Society of Open Science, 4*, 160-164.

The Cadmus Group, (2009). Solid Waste: Generation, Handling, Treatment and Disposal, Solid Waste, *Environmental Guidelines for Small-Scale Activities in Africa (EGSSAA)*, USA. 1-29.

Tirthankar, C., Bhattacharyya, S. R. (2016). Nuclear Waste Management. *International Journal of Pure and Applied Physics, 12*, 29-33.

Viol, N. P. (2008). E-Waste hazard: The impending challenge. *Indian Journal of Occupational and Environmental Medicine, 12*, 65-70.

WHO, (The World Health Organization), (2010). Waste Management at Medical Centres. http://www.who.or.id/eng/contents/aceh/wsh/books/es/ES 08CD.pdf.

www.urbanindia.nic.in 2012.

www.environmentalpollution.in.

Yong, Zhang, Xiao, G, et al. (2009). Medical waste management in China: a case study of Nanjing. *Waste management, 29*, 1376-1382.

Zarook, M., Shareefdeen, (2012). Medical Waste Management and Control. *Journal of Environmental Protection, 3*, 1625-1628.

Zhu, D., Asnani, P.U., Zurbrugg, C. et al. (2008). Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners, The International Bank for Reconstruction and Development/ The World Bank, Washington, D. C. 1-189.