Chapter

Introductory Chapter: Hazardous Wastes

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1. Introduction

Hazardous wastes can be defined as materials and equipment generated due to either natural or various anthropogenic activities and spiked with hazard ingredients, which there is no further use as well. Therefore, hazardous wastes are materials, direct disposal of which can pose threats to man and his environment. They can be explosive, flammable, oxidizing, poisonous/infectious, radioactive, corrosive and/or toxic [1].

According to the Resource Conservation and Recovery Act (RCRA) [40C.F.R. 261.31-33], a hazardous waste can be defined as a spiked material that poses a substantial threat to human health and/or his environment when segregated, sorted, handled, treated, stored, transported and disposed of under improper as well as uncontrolled conditions. Moreover, as spiked material, it has the capability to cause or can contribute to elevate mortality or a rise in epidemic and dangerous illness.

Hazardous waste generation and accumulation are the most acute brain teaser within the last two centuries, opposing world attention and priority for decision-making. Since the industrial revolution started, the hazardous wastes problem caused great and broaden damage to man's Ecosystems, therefore, it becomes an issue of serious not only for national but also for international concern [2].

Department of Environment and Energy, Australian Government, prescribed hazardous waste as which has any of the following characteristics: explosive; flammable liquids/solids; poisonous, toxic, ecotoxic; infectious substances, clinical wastes; waste oils/water, hydrocarbons/water mixtures, emulsions; wastes from the production, formulation and use of resins, latex, plasticizers, glues/adhesives; wastes resulting from surface treatment of metals and plastics; residues arising from industrial waste disposal operations; wastes which contain certain compounds such as copper, zinc, cadmium, mercury, lead and other heavy metals and asbestos; household waste; or residues arising from the incineration of household waste [3].

However, the US Environment Protection Agency (EPA) summarized that into four characteristics [4]:

- *Ignitability* or something flammable
- *Corrosivity* or something that can rust or decompose
- *Reactivity* or something explosive
- *Toxicity* or something poisonous (EPA, USA, etc.)

Hazardous waste-generating facilities can be differentiated into categories in accordance with the monthly amount of hazardous waste delivered. There are three categories, viz. large-quantity generators (LQGs), small-quantity generators (SQGs) and conditionally exempt small-quantity generators (CESQGs). To be nominated as a LQG, facility should throw more than 1000 kg of hazardous waste per month. Small-quantity generators generate between 100 and 1000 kg per month, while the third category, namely, CESQG facility, delivered less than 100 kg of hazardous waste each month [5, 6].

The nomination of the most famous categorization and the classification of hazardous waste are those based on the source that generates this waste and which can be distinguished from industrial waste, arisen from various industrial facilities; radioactive wastes generated due to the applications of radioisotopes in different fields of our life; medical, and pharmaceutical wastes, that are collected from health care facilities (HCFs), and so on ….

Healthcare waste (HCW) can be defined as the total wastes which are generated from a healthcare facility and would comprise non-hazardous or general waste and hazardous HCW. Besides, it includes the identical types of waste arisen from minor and scattered sources; the non-hazardous HCW is nominated as waste that does not pose any particular biological, chemical, radioactive or physical threats to man or to the environment. This group of waste con is managing following the municipal waste management hierarchy. The hazardous health care wastes (HHCWs) are considered the most crucial part of waste generated from the healthcare facilities due to their dangerous impacts on human and his ecosystems.

The main generators of healthcare waste are hospitals and other health facilities; limited medical centres; clinical centres, laboratories and research centres; mortuary and autopsy centres; animal research and testing laboratories; blood banks and collection services; laboratories for medical analysis; and nursing homes for the elderly [7].

Between 75 and 90% of the wastes generated by healthcare facilities that mainly resemble domestic wastes, therefore, are denoted as "non-hazardous" or "general healthcare wastes." They are collected mostly from the administrative, kitchen and housekeeping functions at healthcare facilities and may also include unspiked packaging waste and waste generated during maintenance of healthcare facilities. The remaining 10–25% of HCW are considered as "hazardous healthcare wastes" and can pose extensive environmental and health threats [8].

It is worth to state that pharmaceutical waste is not onefold category of waste but many and variable; moreover the chemicals that constitute pharmaceutical dosage forms are complex and variable. Healthcare wastes comprise sharps; non-sharps; disposable syringes and plastic equipment; blood, body tissue and parts, patient's excretions, chemicals and pharmaceuticals; chemotherapy ingredients; medical devices; and empty solution bags, bottles and containers, in addition to radioactive materials. The hazardous HCW can be classified into the following waste main groups:

2. Infectious waste

This group of wastes is assumed to contain pathogens (or their toxins) in a concentration that can be disease sources to a host. This group includes discarded materials or equipment, used for the diagnosis, and treatment of disease that has been in contact with body fluids, e.g. dressings, swabs, nappies, blood bags, etc., in addition to liquid waste comprising faeces, urine, blood, sputum or lung secretions.

3. Anatomical waste

Anatomical waste is a pathological category of hazardous HCW and includes body organs and tissues. Whether they can be infected or not, anatomical wastes are denoted in most cases as potential infectious wastes.

4. Radioactive waste

The most commonly used radioisotopes in healthcare facilities (HCFs) are technetium mTc-99 and gadolinium Ga-68 in therapeutic generators and cobalt Co-60, iodine I-131 and iridium Ir-192 for diagnosis and treatment. Low-level radioactive wastes are mainly the waste category generated in HCFs due to the applications of radioisotopes.

5. Hazardous pharmaceutical waste

Hazardous pharmaceutical wastes are a part of HCW generated not only in hospitals and medical centres but also in pharmacy. They comprise contaminated, spilt, unused and expired pharmaceutical products, as well as drugs and vaccines, and in addition discarded items used in the handling such as bottles, vials and connect tubing.

An important item of this category is all the drugs and equipment used for the mixing and administration of cytotoxic drugs. Cytotoxic drugs are used in chemotherapy treatment for cancer.

6. Sharps

Sharps are considered the most dangerous and highly infectious wastes generated at HCFs. They include needles, some surgical tools, syringes, disposable scalpels, blades, etc. Those items can result in cuts and punctured wounds; therefore, they should be collected, packed and handled in an extremely safe, controlled and proper method in the generation points to ensure the safety of the working staff.

7. Highly infectious waste

Body fluids of patients, with highly infectious diseases, microbial cultures and highly infectious stocks constitute what is named as the highly infectious wastes in the HCW scheme and are generated, mainly, from medical analysis and research laboratory activities.

8. Genotoxic/cytotoxic waste

This group of waste is accumulated from drugs generally used in oncology or radiotherapy units. It has high hazardous mutagenic and/or cytotoxic impacts. Excretions of cytotoxic drug- or chemically treated patients, i.e., faeces, vomit or urine, must be included as genotoxic waste. In specialized cancer treatment facilities, the controlled and proper treatment and safe disposal should be followed strictly to avoid contamination of the surrounding environment.

9. Hazardous chemical waste

Chemical waste covers the discarded chemicals that are collected after the disinfecting procedures or cleaning processes and generated in solid, liquid or gaseous form. They can be hazardous, i.e., toxic, corrosive, flammable, etc., and should be handled, treated and disposed of following the stated issues. Otherwise, the nonexplosive residues or small contents of outdated products can be treated as infectious waste.

Bulk chemotherapy waste is, also, managed as hazardous chemical waste and must be collected in hazardous waste containers. Firm management hierarchy should be applied for treating all bulk chemotherapy agents as hazardous waste when discarded.

10. Waste with a high content of heavy metals

Waste streams that have high concentration of heavy metals and their derivatives pose threats to healthcare facility as potentially highly toxic materials, e.g. cadmium or mercury from thermometers or manometers. They are categorized as a sub-group of chemical waste but should be managed separately.

The improper management of the hazardous healthcare wastes puts the healthcare workers, waste handlers and the community under the threats of infections, toxic impacts and injuries including damage of the environment. It also provides possibility for the segregated disposable medical equipment, to be resoled and reused, before their disinfection and sterilization, which can be a serious source for of epidemic disease for surrounding ecosystem [9].

It is conspicuous that hazardous materials being sold by a store, as pharmaceuticals, are not a hazardous waste until they are become expired. In general, the generator has to clearly decide that the material is a waste. In this trend, materials that can be sent to a reverse distributor must still be managed as a product, till the reverse distributor decides to dispose of the item. Loose pills, partial drug packages without all of the information on them, etc. are counted as waste and must be properly handled by the generator and/or the reverse distributor. In other words, for pharmaceutical products that meet the definition of a hazardous waste, their segregation, sorting, handling, transportation, treatment and final disposal must be carried out under the controlled rules. However, when these drugs are disposed of by the consumer, known as "ultimate user," then they are not counted a hazardous waste, since they are categorized as the exempt household waste. On the other hand, expired or un-needed pharmaceuticals at healthcare facilities, e.g., hospitals, pharmacies, medical centres, clinics, or other places dealing with drugs as business, are required to be managed as hazardous waste.

11. Hazardous waste management hierarchy

The management of hazardous wastes is a system carried out in sequences aiming at avoiding the escape of the harmful components from the waste to the man's surrounding environment. This hierarchy usually starts with segregation of the hazardous waste and is terminated by its final disposal. The source reduction can be considered as an issue in the HCW management topics even it takes place at every point of any production [10].

The methodology of a proper hazardous waste management hierarchy includes the upcoming processes in consequences: segregation and sorting, treatment, stabilization and solidification, storage and then final disposal (**Figure 1**). The full goals of this hierarchy, however it performed; when and wherever it carried out, are keeping human and his ecosystem safe, clean and tidy, moreover not burden the coming generation the hazardous problem due to our achievement.

However, pharmaceutical wastes are considered as a category of the healthcare waste, even though the healthcare professionals, always, do not pay the adequate attention to their proper management. There are a number of misconceptions regarding the proper methods for segregating, handling and treatment and disposing of this waste, markedly, at the low-income countries. It is worth to state that high-income countries (HICs) generate nearly up to 0.5 kg of hazardous waste/hospital bed/day; on the other hand, low-income countries delivered, only, about 0.2 kg. Even so, it is rare to find the healthcare wastes being separated into hazardous or non-hazardous wastes in LICs.

The main aim for treating/managing hazardous healthcare wastes is to convert it into to less or non-hazardous materials and stabilize their infectious, toxic and/or radioactive components by various techniques of solidification and encapsulation.

Many treatment methods have been used for healthcare wastes aiming at minimizing the threats of their hazard components and/or reducing the volume of the waste before disposal. Incineration of waste is the most widely applied technique for treatment of HCWs [11]. To avoid the disadvantages of incineration process, alternative methods have been applied such as pyrolysis [12], microwaving [13],

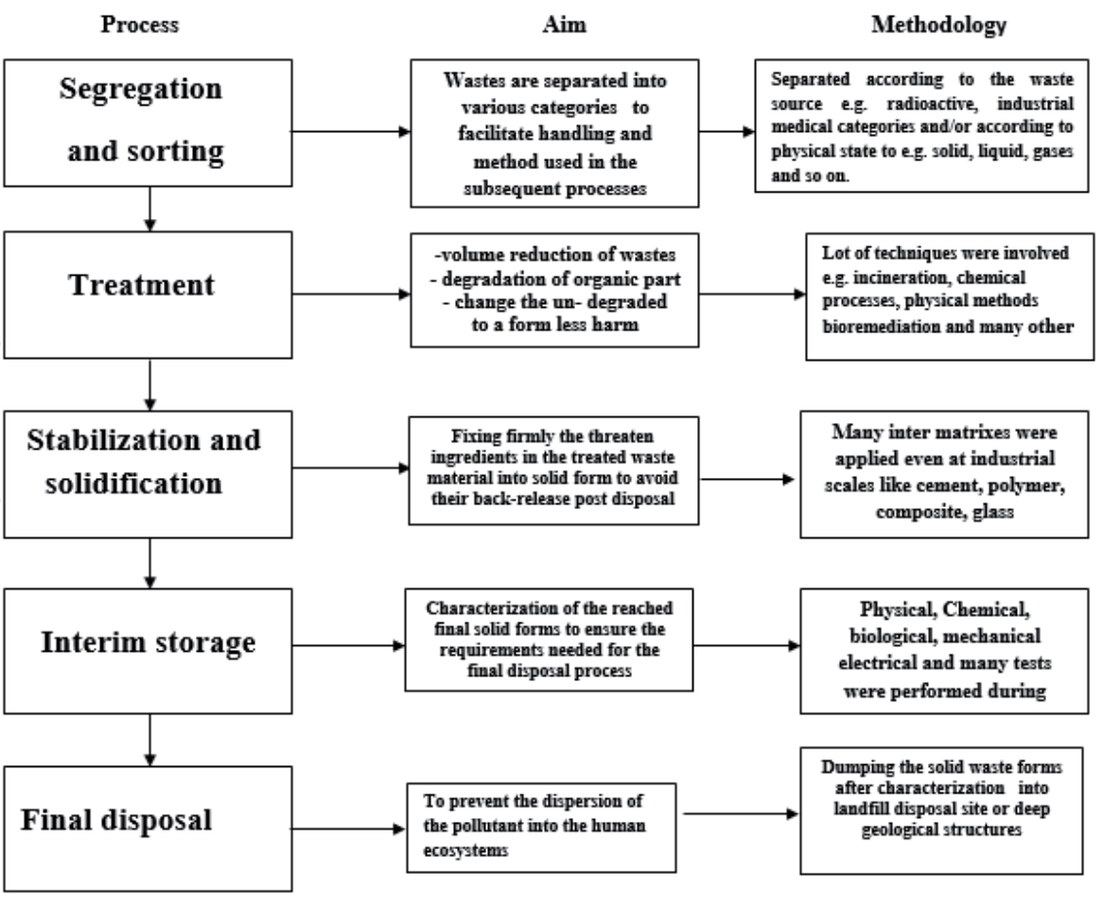

Figure 1.
Diagram for hazardous waste management hierarchy.

sterilization [14], steam treatment [15], thermal processing [16], wet oxidation [17] and many others.

The disposal of untreated or treated and solidified healthcare wastes must be undertaken in well-constructed landfills and in proper ways to eliminate the probability of the contamination of drinking, surface and groundwater.

12. Recommendation

Of the whole segregated waste generated by healthcare activities, nearly 85% is non-hazardous waste; the remaining 15% is regarded as hazardous material that can be infectious, toxic or radioactive. The terrible risks imposed by the unsafe, uncontrolled and improper management hierarchy, including the disposal of healthcare wastes in general, and their hazardous category, definitely, have long been approved all over the world. Insignificant and imperfect management of the healthcare waste puts healthcare human resources, waste handlers and transporters, and moreover the surrounding ecosystems, under the threats of infections, toxic impacts and damages.

Therefore, more researches, studies and efforts have to be undertaken through the World Health Organization (WHO) to raise awareness of the problem creating national and international action plans and to find the solutions, especially in the low-income countries. The WHO has to promote aids on the basis of the well-known five topics: management, training, regulatory and financial issues as well as technologies [18].

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References

[1] Muralikrishna IV, Manickam V. Hazardous waste management. In: Environmental Management: Science and Engineering for Industry. India Butterworth-Heinemann; 2017. pp. 463-494. DOI: 10.1016/B978-0-12-811989-1.00017-8

[2] Orloff K, Falk H. An international perspective on hazardous waste practices. International Journal of Hygiene and Environmental Health. 2003;**206**:291-302

[3] Hazardous Waste Act (Regulation of Exports and Imports). Department of the Environment and Energy, Australian Government; 1989

[4] U.S. EPA Test Methods, SW-846 Methods: 1010, 1020, and 1030, respectively. Available from: http://www.dtsc.ca.gov/LawsRegsPolicies/Title22/upload/OEARA_REG_Title22_Ch11_Art3.pdf

[5] Rosenfeld PE, Feng LGH. The biggest generators of hazardous waste in the US. In: Risks of Hazardous Wastes. UK: William Andrew; 2011

[6] Practice Greenhealth. Managing pharmaceutical waste. A 10-step blueprint for healthcare facilities in the United States. [Accessed: August 2008]

[7] WHO/UNICEF. Water, Sanitation and Hygiene in Health Care Facilities: Status in Low- and Middle-Income Countries. Geneva: World Health Organization; 2015

[8] World Health Organization (WHO). Safe Management of Wastes from Health-Care Activities. Geneva: Blue Book Second Edition; 2014

[9] Paudel R, Pradhan B. Health care waste management practice in a hospital. Journal of Nepal Health Research Council. 2010;**8**(2):86-90

[10] Vallero DA. Hazardous wastes. In: Waste: A Handbook for Management Academic Press, USA; 2011. pp. 393-423. DOI: 10.1016/B978-0-12-381475-3.10027-0

[11] Lerner BJ. Method for minimizing environmental release of toxic compounds in the incineration of wastes. 1997. United States Patent 5,607,654

[12] Eshleman RD. Sloped-bottom pyrolysis chamber and solid residue collection system in a material processing apparatus. 1995. United States Patent 5,417,170

[13] Kameda T, et al. Method of an apparatus for treating infectious medical wastes. 1994. United States Patent 5,322,603

[14] Kantor SL et al. Medical waste treatment unit. 2008. United States Patent 7,361,303

[15] Pappas CA. Medical waste disposal system. 1994. United States Patent 5,348,235

[16] Stevers PH et al. Waste materials processing apparatus and method. 2001. United States Patent 6,176,188

[17] Ghattas NK, Ghattas KM. Method and system for the decomposition of spent ion-exchange resins. 1992. German Patent DE 39 26 252 C2

[18] WHO. Status of Health-Care Waste Management in Selected Countries of the Western Pacific Region. Geneva: World Health Organization; 2015