Chapter 10
Qualitative Characterization of Healthcare Wastes

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Abstract The biological hazard inherent in the clinical wastes should be considered during the management and treatment process as well as the disposal into the environment. In this chapter, the risks associated with the clinical wastes as well as the management of these wastes are discussed. The chapter focused on reviewing the types of healthcare wastes generated from hospitals and clinics as well as the regulations and management practices used for these wastes. Moreover, the health risk associated with the infectious agents which have the potential to be transmitted into the environment. It has appeared that the clinical wastes represent real hazards for the human health and the environment if they were not managed properly.

10.1 Introduction

Healthcare wastes are general terms used to define the wastes containing blood and infectious agents which are generated from healthcare facilities. In some references, these wastes are defined as clinical wastes, medical waste, biomedical wastes, hospital wastes, healthcare waste, infectious waste, and hazard and biohazard wastes. However, this definition excludes the solid wastes which can be recycled or reused even after the treatment process (Noman et al. 2018a, b). Moritz (1995) suggested that the disposable or waste terms should be used for non-recyclable materials, while

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the term of reusable or recyclable is used to define the solid materials which might be reused or recycle. Based on this definition the sharps, cotton, and medical devices are defined as a recyclable materials, while blood, body parts, chemicals, pharmaceuticals, and radioactive materials are wastes. In other meaning, it has to be mentioned that not all the wastes generated from the hospital are classified as clinical wastes. According to the Controlled Waste Regulations 1992 (S1588), the clinical wastes are defined as any waste with human or animal tissue, excretions, blood as well as body fluids, excretions, swabs, syringes, and needles. These wastes are generated from the medical, dental, nursing, veterinary pharmaceutical or similar practice, investigation, treatment, care, teaching, or research centers. Figure 10.1 depicted the recyclable materials and clinical wastes generated from the healthcare facilities.

The clinical waste is classified as a type of the biohazard waste as it is heavily loaded with infectious agents which included Staphylococcus *aureus*, pathogenic strains of *E. coli*, *Salmonella* spp. *P. aeruginosa, Enterococcus faecalis, Klebsiella pneumonia* as well as opportunistic fungi such as *Aspergillus niger*, *A. fumigatus*, *A. tubingensis*, *A. terreus var. terreus,* and *C. lunata* (Banana 2013; Noman et al. 2016a, b; Efaq et al. 2017). In a view for the health risk associated with the presence of infectious agents in the clinical wastes, WHO (2005) classified the pathogens

Fig. 10.1 Clinical wastes classes generated from the healthcare facilities

in the microbiological laboratories based on pathogenicity into four risk classes, where *E. coli* and *Salmonella* spp. are classified within Risk Group 2 (moderate individual risk, low community risk) and Risk Group 3 (high individual risk, low community risk), while *P. aeruginosa, E. faecalis, K. pneumonia,* and *S. aureus* are within Risk Group 2. Subsequently, it can be noted that these wastes lay between the non-hazardous wastes which have microbial loads that belong to the Risk Group 1 (no or low individual and community risk) and high hazardous wastes which contain infectious agents within Risk Group 4 (high individual and community risk).

Human body fluids (HBFs) are among the various types of the clinical wastes which have high potential source for surviving infectious agents due to the presence of the survival factors such as nutrients and growth factors available in the blood (Pruss et al. 1999). Moreover, blood has high nutritive value and can be considered as enriched medium for bacterial and fungal growth (Carrwtero and Pares 2000). In this paper, the quantities and qualities of the clinical wastes as well as the health risk associated with these wastes in the developing countries are reviewed.

10.2 Clinical Waste Generation

The amount of clinical waste generated from different healthcare facilities, which has been increased at a rapid pace in recent years, has drawn serious attention from the society. In Malaysia, it was estimated that the total quantities of the clinical wastes have increased from 3,303 to 18,055 tons per year during the period between 1997 and 2012. In 2010, 8000 tons was generated, while it is expected to reach 33,000 in 2020 (DS 2013; Ambali et al. 2013). Clinical wastes represent more than 50% of the total solid and liquid wastes generated from the healthcare facilities, with 10–25% of them classified as high-risk wastes (Shinee et al. 2008).

The quantities of the clinical wastes vary among countries depending on the total population and healthcare facilities as well as the size and type of the medical institution and number of patient care. In the United States of America, the quantities of the clinical wastes were estimated to be 6,600 tons of waste per day. In 2012, Malaysia had more than 398 hospitals (147 public and 251 private hospitals) with 42707 versus 14165 beds for public and private hospitals, respectively (DS 2013). Based on the daily amount of clinical wastes generated in Malaysia (1.9 kg/bed/day), the estimated quantities of clinical wastes generated from public hospitals in 2012 were 29,617.546 tons/year. However, DS (2013) reported that only 18,055 tons have been handled for destruction by incinerator. It was due to that the maximum loading capacity for incinerators in Malaysia is 18,000 tons/year (Frost and Sullivan 2010). In comparison, Yemen has only 56 hospitals which generate different clinical wastes (MPHP 2012). The quantities of the clinical wastes are between 7000 and 10,000 tons/year.

The studies indicated that the quantities of the clinical wastes generated from the developed countries are more than that for developing countries (Fig. 10.2). For instance, in North America, 5.5 kg/bed/day are generated compared to

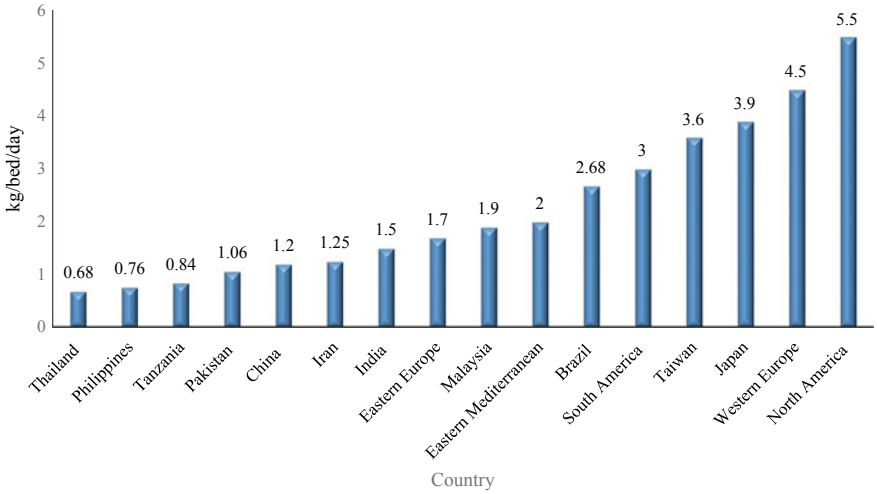

Fig. 10.2 Estimated average healthcare waste generation in different region in the world (WHO 2005; Visvanathan 2006; Johannessen 1997; De Silva et al. 2011; Cheng et al. 2009; Ruoyan et al. 2010)

0.68 kg/bed/day in Thailand. However, the average of the clinical waste quantities is between 0.5 and 3 kg/bed/day (WHO 2000). In Malaysia, the quantities of the clinical wastes generated have increased annually due to the fast increase in the total population (1.5%). The quantities of clinical wastes handled for the incineration increased by 37.1% from 11000 in 2006 to 18000 in 2016 (Fig. 10.3).

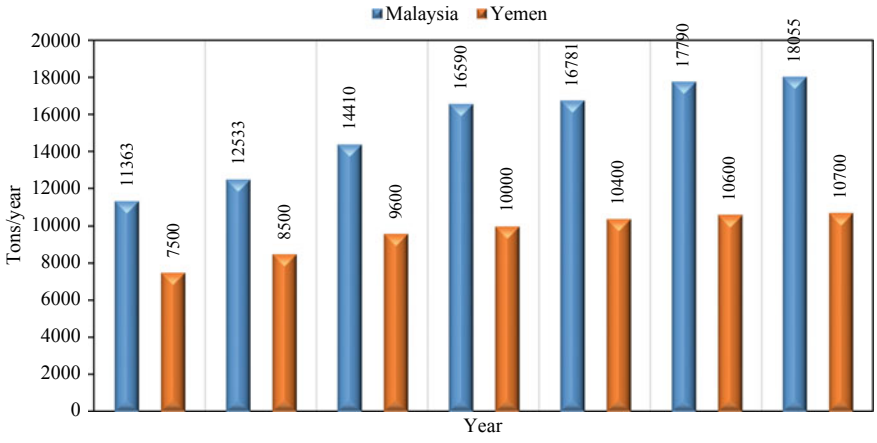

Fig. 10.3 Quantity of clinical waste for destruction at incinerator Malaysia and Yemen. *Source* Department of Environment (DS 2011, 2013; MPHP 2012)

Table 10.1 Solid and liquid clinical wastes generated from healthcare facilities

	Clinical wastes
Liquid wastes	Ascitic fluid, autoclave water, blood waste, CSF, expired fluids, pus, saliva, semen, sputum, test reagents, urine, used water
Solid wastes	Abortus, ampules, amputated body parts, biopsy tissue, blades, blend, bone marrow or lymph nodes, broken glasses, catheters, chemical wastes, excised tumors, expired drugs, feces, gloves, hair, lab cultures, mask, nails, needles, Pasteur pipette, placentae, plastic loops, polyester, polyethylene, polyurethane, respiratory secretions, scalpels, sharps, skin biopsy, skin snip, slides, spandex, specimen bottles, surgical dressings, swabs, syringes, teeth, test strips, tissue paper, tongue depressor, used cotton, used gauze, used rubber, vaginal scraping, yellow and blue tips

According to WHO (2016), 15% of the waste generated from hospitals are considered as hazardous wastes. However, Graikos et al. (2010) claimed that the hazardous clinical waste in Greece was between 13 and 92% of the total wastes. These wastes are classified by WHO into 10 categories based on their characteristics and the treatment method for each type (Table 10.1). It can be noted that the incineration is suggested for five categories including human anatomical waste, animal waste, microbiology and biotechnology waste, sharps and medicines and cytotoxic drugs, while autoclaving is suggested for the treatment of solid wastes (blood and body fluids, microbial cultures). Nonetheless, the clinical wastes are divided mainly into two classes, namely, solid and liquid wastes (Table 10.2), but the main consideration for the classification of the wastes generated from the hospitals as infectious or non-infectious waste is the presence of body fluids. There are two sources for the generation of the clinical wastes including diagnostic laboratories and the clinics (Fig. 10.2). The quantities of the wastes generated from each source are illustrated in Table 10.3. According to Cheng et al. (2010), the maximum generation of clinical wastes in Taiwan was from blood centers (3.14 kg/bed/day), private clinics (1.91 kg/bed/day), medical laboratories (1.07 kg/bed/day), and public clinics (0.053 kg/bed/day) (Fig. 10.4).

10.3 Health Risk of the Clinical Wastes

Among different types of the clinical wastes, the human body fluids (HBFs) represent the most potent source for the infectious agents. In some references, these wastes include identifiable human tissue, blood, and swabs (WHO 2005; MOH 2009). Moreover, these wastes act as a vector for transmission of pathogens from the wastes into the human and environment during the disposal process. The importance of the HBFs belongs to their composition which contains sugars, protein, fats, and starch that support the microbial survival in the hard environment (Hall 1989). The clinical wastes are rich with the nutrients and subsequently the pathogens such as bacteria, fungi, and virus; however, the potential infectious risks associated with HBFs waste management and treatment are still unknown due to the absence of critical reports on

Table 10.2 Qualities of clinical wastes generated from diagnostic labs in Yemen

Diagnostic laboratory	Clinical wastes
Microbiological lab	Autoclave wastewater, blades, blend, blood waste, broken glasses, chemical wastes, CSF, gloves, hair, lab cultures, mask, needles, Pasteur pipette, plastic loops, pus, respiratory secretions, saliva, semen, skin biopsy, skin snip, specimen bottles, sputum, swabs, syringes, tissue paper, urine, used cotton, used gauze, yellow and blue tips, vaginal scraping
Histopathological lab	Broken glasses, slides, blades, chemical wastes, excised tumors, gloves, masks, scalpels, sharps, specimen bottles, tissue paper, used cotton, used gauze
Parasitological lab	Broken glasses, chemical wastes, feces, gloves, mask, needles, Pasteur pipette, sharps, slides, specimen bottles, tissue paper, used cotton, used gauze
Urological lab	Broken glasses, chemical wastes, gloves, mask, needles, Pasteur pipette, slides, specimen, bottles, test reagents, test strips, tissue paper, urine, used cotton, used gauze
Dental labs	Blades, broken glasses, chemical wastes, gloves, mask, saliva, sharps, specimen bottles, tissue paper, used cotton, used gauze
Immunological lab	Blades, blood waste, broken glasses, chemical wastes, gloves, mask, needles, Pasteur pipette, slides, specimen bottles, syringes, test reagents, used cotton, used gauze, yellow and blue tips
Hematological lab	Blades, blood waste, bone marrow or lymph nodes, broken glasses, chemical wastes, CSF, excised tumors, gloves, mask, needles, Pasteur pipette, sharps, slides, specimen bottles, syringes, test reagents, used cotton, used gauze, yellow and blue tips
Biochemistry lab	Broken glasses, chemical wastes, CSF, gloves, masks, needles, Pasteur pipette, slides, specimen bottles, syringes, test reagents, test strips, urine, used cotton, used gauze, yellow and blue tips
Radiological lab	Radioactive wastes

the infection cases caused by the pathogens transmitted through the clinical wastes (Salkin 2003).

In a view for the microbial loads of clinical wastes which were determined by several authors in the literature, it can be indicated that the clinical wastes contain many of the pathogens such as *A. baumannii, Bacillus sp., E. coli, K. pneumonia, P. mirabilis, P. aeruginosa, S. aureus, S. epidermidis, Salmonella* spp., *Legionella, Kocuria sp., Lactobacillus sp*., *Micrococcus spp*., *Brevibacillus sp*., *M. oxydans, and P. acnes* (Eckmanns et al. 2008; Alagoz and Kocasoy 2008; Park et al. 2009). *E. coli* and *S. aureus* have been isolated from the clinical wastes at New Delhi hospital (Savita et al. 2004). Al-Ghamdi (2011) revealed that *Bacillus* sp. was the most predominant bacteria in the hospital environment. According to WHO (1999), human immunodeficiency virus (HIV) and hepatitis viruses B and C are among the infections which are transmitted via healthcare waste.

Table 10.3 Quality of clinical waste generated from clinics

Clinics	Clinical wastes
First aid clinics	Ampules, blades, blood waste, broken glasses, expired drugs, expired fluids, fluid nutritious, gloves, mask, needles, polyester, scalpels, sharps, surgical dressings, swabs, syringes, tissue paper, used cotton, used gauze, used rubber
Emergency	Ampules, ascitic fluid, blades, hair, mask, needles, sharps, surgical dressings, teeth, tissue paper, used cotton, used gauze
Critical care	Ampules, ascitic fluid, blades, broken glasses, catheters, gloves, mask, needles, sharps, surgical dressings, syringes, tissue paper, drugs, used cotton, used gauze, used rubber
Ear, nose, and throat clinic	Used cotton, ampules, blades, blood waste, gloves, mask, needles, sputum, pus, swabs, syringes, tongue depressor, used cotton, used gauze
Respiratory diseases clinic	Ampules, ascitic fluid, gloves, mask, respiratory secretions, saliva, sputum, swabs, syringes, tissue paper, tongue depressor
Kidney and urinary tract clinic	Ampules, gloves, catheters, drugs, polyester, polyethylene, surgical dressings, used cotton, used gauze, tissue paper
Blood diseases clinic	Ampules, blood waste, gloves, mask, needles, Pasteur pipette, surgical dressings, used cotton, used gauze
Heart diseases clinics	Ampules, catheters, gloves, mask, needles, used cotton, used gauze
Obstetrics and gynecology clinic	Abortus, ampules, blood waste, gloves, mask, placentae, surgical dressings, swabs, syringes, used cotton, used gauze
Surgical clinic	Ampules, blades, blood waste, gloves, scalpels, surgical dressings, spandex, swabs, syringes, used cotton, used gauze, chemical wastes, polyester
Internal medicine clinic	Ampules, biopsy tissue, gloves, needles, sharps
Orthopedic clinic	Ampules, blood waste, gloves, needles, scalpels, used cotton, used gauze
Eye diseases clinic	Gloves, needles, used cotton, used gauze, swabs, sharps
Dermatologist and genital clinic	Gloves, hair, mask, nails, needles, scalpels, sharps, skin biopsy, skin snip, semen, surgical dressings, swabs, syringes, vaginal scraping
Dental clinics	Teeth, gloves, needles, saliva, sharps, surgical dressings, swabs, syringes, tongue depressor
Children's clinic	CSF, gloves, needles, surgical dressings, swabs, syringes, tongue depressor
Operating room	Catheters, amputated body parts, ampules, excised tumors, ascitic fluid Blood waste, gloves, mask, needles, scalpels, sharps, surgical dressings, swabs, syringes

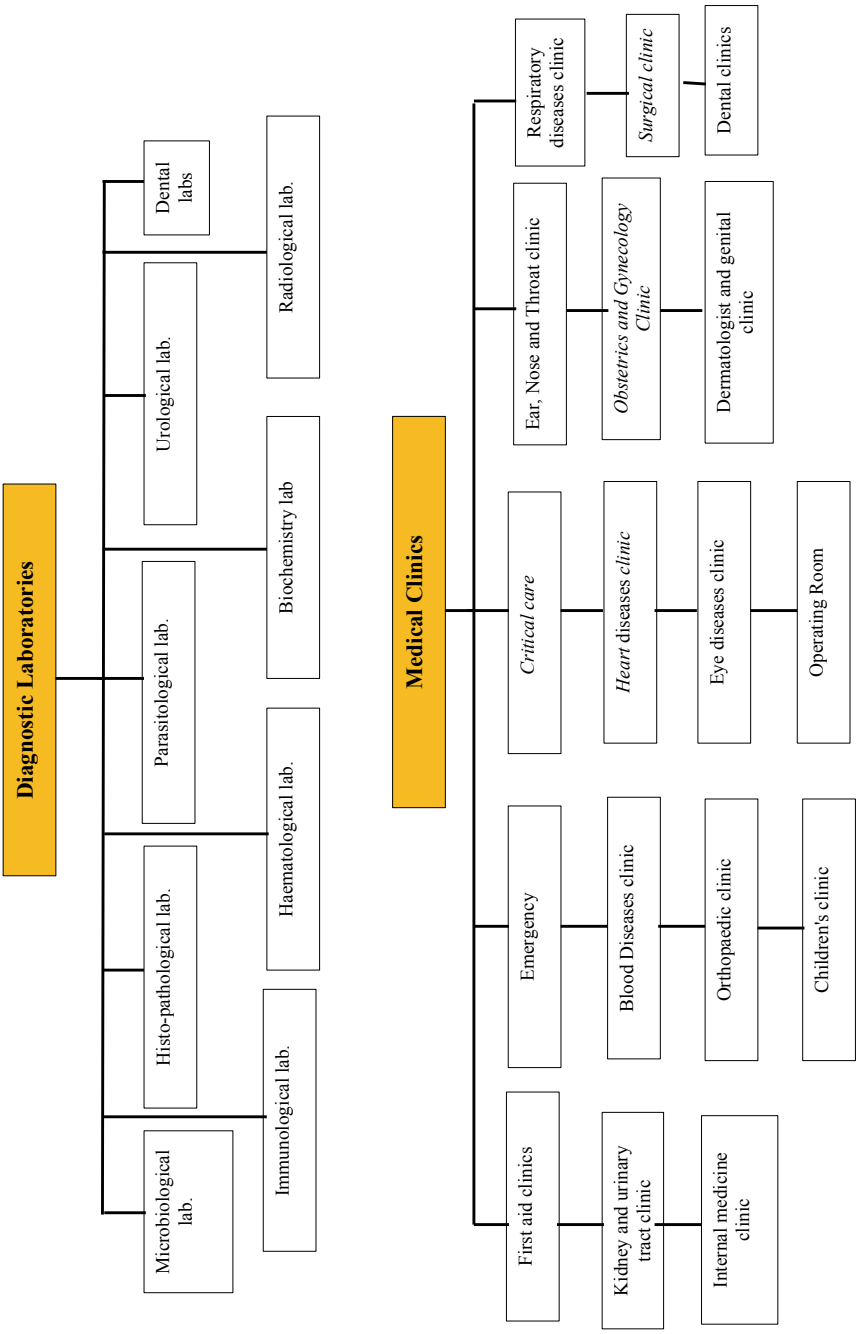

Fig. 10.4 Sources of clinical wastes

10.4 Current Legislation for Clinical Waste Management

Many of the developed countries in Europe regulated a legislation for the production, storage, transportation, treatment, and final disposal of the clinical wastes. The legislation for the clinical waste is different from that regulated for the infectious waste and healthcare waste. In terms of production, it has been mentioned that this process should be accomplished by an effective segregation at source which represents the key factor in the clinical waste management strategy as well as facilitate the storage transportation and the treatment process for the wastes. Moreover, the disposal of clinical wastes into the landfill is becoming non-acceptable discouraged, while the treatment process by the incineration has several disadvantages such as production of toxic by-products (Moritz 1995). The proper waste handling should be started with a proper segregation and resource recycling (Cheng et al. 2010; Efaq et al. 2015). The segregation process at the generation source aims to separate a large proportion of the wastes which are not classified within the infectious and hazardous or clinical waste and then co-disposing with the household waste to municipal incinerators or landfill sites. The application of segregation process would lead to minimize the economic cost for the clinical waste management which needs a special transportation and treatment due to their hazardous contents. The storage process for the clinical wastes before the treatment process or the transportation to the incineration is a temporary process; according to Saini et al. (2004), the storage period should be less than 24 h. However, in the small clinics, these wastes are collected and stored for few months (Noman et al. 2016b). The long period of the storage represents a contamination point for the hospital or clinics with several pathogens.

Some of the clinical wastes such as radioactive and pharmaceutical wastes are classified as special wastes which have specific regulation in UK for their management process. In USA, EPA is proposing to regulate hazardous pharmaceutical waste under the Universal Waste Rule, but there are no specific regulations that have been reported up to date.

Moreover, the legislation and regulation for the clinical waste management aim mainly to reduce the health risk of these wastes. These legislations are regulated in the UK (Department of Health), USA (Environmental Protection Agency), Australia (Ministry of Health), Turkey (Ministry of Environment and Forestry), and in Malaysia (Environmental Quality ACT 1974). In Taiwan, the clinical wastes are classified within the category of hazardous industrial wastes, which include the infectious materials generated from the healthcare facilities as well as the wastes with a toxic nature (TEPA 2004). The country has very strict regulations for clinical waste management. However, the treatment process is conducted by only the incineration. In the regulations related to the management of the clinical wastes, these wastes should be stored temporarily at the point of generation before it is transported and treated in a treatment facility such as incineration. Three-container systems have different colors which should be used for the clinical waste segregation, the infectious wastes are collected in a yellow/red bag, while the general wastes are collected in a black bag; moreover, the sharps are collected in specific container. These regulations are not

applied among many of the developing countries such as Yemen, Iran, and Tanzania due to the absence of awareness about the health risk associated with the clinical wastes (Mato and Kaseva 1999; Efaq and Al-Gheethi 2015).

10.5 Conclusion

Healthcare wastes represent a serious risk for the community as it is heavily loaded with the infectious agents which may survive for long time in the environment. The best management might contribute effectively in minimizing the health risk and protect the environment. The management of the clinical wastes in terms of segregation, storage, transportation, and treatment as well as the disposal process would contribute effectively in the reduction of quantities and risk of clinical wastes.

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