Associated factors of medical waste management practices in developing countries: a review

Timothy Kurannen Baaki

Department of Built Environment,
Liverpool John Moores University,
Liverpool, UK
and
Department of Building Surveying,
University of Malaya,
Kuala Lumpur, Malaysia
Email: t.k.baaki@ljmu.ac.uk

Mohamad Rizal Baharum*

Department of Building Surveying,
University of Malaya,
Kuala Lumpur, Malaysia
Email: mrizal@.um.edu.my
*Corresponding author

Michael Pitt

The Bartlett School of Construction and Project Management,
University College London,
London, UK
Email: michael.pitt@ucl.ac.uk

Samantha Davies

Estates and Facilities,
University of Plymouth,
Plymouth, UK
Email: samantha.davies@plymouth.ac.uk

Abstract: The heterogeneous composition of waste from healthcare facilities has historically been a significant challenge with management efforts concentrating primarily on treatment and disposal solutions. This has left a legacy of issues with the management of this type of waste, especially for developing nations. This paper has examined the associated factors of medical waste management (MWM) practices in healthcare facilities in developing nations. Medical waste (MW) definitions have been examined, and factors associated with its management, from regulation and policy formulation to disposal, have been identified through desk research of existing studies. This paper found that in some countries where MWM legislation and policies exist, some are either poorly formulated or are an offshoot of general environmental

Commented [A1]: Author: Please reduce abstract (should be up to 150 words only).

waste management regulations. More specifically for developing countries, this study found that training, segregation, handling and disposal practices and implementation of MWM programs were often at a poor standard. Poor regulatory frameworks, poor risk awareness and training, poor financing, influence of social factors such as cultural norms, poor infrastructure and technological advancement were some of the factors identified as key issues. This paper viewed the challenges of MWM practices in developing countries to be much more of a management issue than a technological issue and has identified advanced routine management approaches within an integrated sustainable MWM framework as a tool to drive improvements in MWM programs.

Keywords: developing countries; healthcare facilities; HCFs; medical waste; sustainable medical waste management; waste management practices.

Reference to this paper should be made as follows: Baaki, T.K., Baharum, M.R., Pitt, M. and Davies, S. (xxxx) 'Associated factors of medical waste management practices in developing countries: a review', *Int. J. Environment and Waste Management*, Vol. X, No. Y, pp.xxx–xxx.

Biographical notes: Timothy Kurannen Baaki is a Senior Lecturer at the Department of Built Environment, Liverpool John Moores University, UK. He was formerly a Research Assistant at the Centre for Building, Construction & Tropical Architecture (BuCTA), University of Malaya, Malaysia. He has seven peer reviewed publications, four as first author. He specialises in facilities management, particularly in the subjects of waste management and performance assessment.

Mohamad Rizal Baharum is a Senior Lecturer at the Department of Building Surveying, Faculty of Built Environment, University of Malaya, Malaysia. He is also a Consultant at the University of Malaya Consultancy Unit. He has been involved in teaching, program development, research and consultancy projects for more than ten years. He has more than ten peer reviewed publications. He specialises in facilities management, in particular, waste management, strategic management and supply chain management.

Michael Pitt is a Professor of Facilities Management Innovation and Director of Teaching and Learning at The Bartlett School of Construction and Project Management, University College London, UK. He has extensive teaching and research experience in property and facilities management (FM) spanning three decades. His recent projects have included workplace productivity, waste management trends, life cycle management, sustainability strategies and performance measurement systems. He is also a Visiting Professor at the University of Malaya and editor of *Journal of Facilities Management*.

Samantha Davies is a sustainability professional with ten years' experience of leading sustainability strategy in the construction, facilities management, consultancy and higher education sectors. She is the Chartered Manager with CMI, qualified IEMA Lead Environmental Auditor and PhD in environmental Policy. Currently, she is the Environment and Sustainability Manager at the University of Plymouth, UK with four peer reviewed publications.

This paper is a revised and expanded version of a paper entitled [title] presented at [name, location and date of conference].

Commented [A2]: Author: If a previous version of your paper has originally been presented at a conference please complete the statement to this effect or delete if not applicable.

1 Introduction

The World Health Organization (WHO) defines medical waste (MW) as all waste generated in the process of providing healthcare services (Chartier et al., 2014). Although, MW represents only a small amount of the entire waste generated within a community, medical waste management (MWM) is considered a critical problem worldwide (Wahab and Adesanya, 2011). According to the WHO, only about 10% to 25% of waste generated from healthcare facilities (HCFs) is considered infectious or hazardous; the remaining 75% to 90% is non-risk (Chartier et al., 2014), but this small percentage of infectious and hazardous waste has the ability to cause health and environmental problems because of its highly infectious properties. If handled improperly, the 10% to 25% can contaminate the entire waste stream, a situation that exist in developing countries with poor practices posing high health and environmental risks and creating high disposal costs through landfilling and incineration. Following desk research of existing studies and literature on the subject of MWM practices in particularly developing countries, this paper aims to review MW definitions and characterisations, identify the factors associated with MWM programs in HCFs with the view to advancing routine management approaches to deliver improvements in the MWM system.

2 Context of MW

2.1 Definition

Significant variations exist in MW definitions across the world. This is because not all waste generated from HCFs come from clinical activities or core business of healthcare such as treatments and surgeries. While some view MW as clinical waste, i.e., waste arising only from actual treatments and diagnoses for example (Jang et al., 2006; Bdour et al., 2007; Verma et al., 2008; Wahab and Adesanya, 2011; Shareefdeen, 2012), some have referred to all waste from healthcare establishments, including waste generated from support activities such as offices and administrative activities as medical or healthcare waste (HCW) (Kumari et al., 2013; Lee and Huffman, 1996; Patil and Pokhrel, 2005; Ananth et al., 2010; Prüss et al., 1999; Sawalem et al., 2009; Tsakona et al., 2007; Tudor et al., 2005). The WHO has defined MW as "all waste generated by healthcare establishments, research facilities and laboratories including the waste originating from 'minor' or 'scattered' sources – such as that produced in the course of healthcare undertaken in the home (such as dialysis and insulin injections, etc.)" (Prüss et al., 1999). In the European Union, MW is defined in Chapter 18 of the European Waste Catalogue and Hazardous List to include "wastes from human and animal healthcare and related research activities, excluding of wastes from kitchen and restaurants not arising from immediate healthcare" (EPA, 2002). While the European Waste Catalogue lists what comprises HCW to cover waste from diagnosis, treatment and or prevention of disease in humans and animals and natal care: it does not define what 'immediate healthcare' means as such it is not clear whether wastes generated from kitchens in healthcare establishments should be regarded as MW since the link between such wastes and 'immediate healthcare' activities is not clear. Table 1 illustrate the discrepancies in the

definition and classifications of MW. There is no consensus on whether all waste from HCFs and activities should be termed MW. In this paper, MW definition follows the definition provided by WHO to include all waste that is generated in the course of providing any form of healthcare service. Understanding the scope of MW is crucial to developing better management strategies; the classification on MW significantly impacts the cost of management and the availability of disposal options (United States Congress, Office of Technology Assessment, 1990).

Table 1 Definition and general classification of waste arising from HCFs

Reference	*Definition*	*Classification*
Shinee et al. (2008)	Healthcare waste	General waste and medical waste
Mohamed et al. (2009)	Healthcare waste	Hazardous and non-hazardous waste
Miyazaki and Une (2005)	–	Infectious waste and non-infectious waste
Lee et al. (2004)	Medical waste	General waste and special waste
Cheng et al. (2009)	Medical waste	Infectious waste and general medical waste
Nemathaga et al. (2008)	Hospital waste	General waste, medical waste and sharp
Abd El-Salam (2010)	Medical waste	Domestic waste and hazardous waste
Sarkar et al. (2006)	Hospital waste	Hazardous and non-hazardous waste
Gai et al. (2010)	Healthcare waste	Medical waste and general waste
Jang et al. (2006)	Medical waste	Tissues and other
Patwary et al. (2009a, 2009b)	Medical waste	Hazardous and non-hazardous waste

Source: Hossain et al. (2011)

Commented [A3]: Author: Please provide full reference or delete from the text if not required.

Commented [A4]: Author: Please provide full reference or delete from the text if not required.

Commented [A5]: Author: Please provide full reference or delete from the text if not required.

2.2 Classification

Different authors, studies, policies and regulations have classified MW based on different criteria. The classifications can be summarised as: type of waste (e.g., clinical or general/domestic-type MW, etc.) (Oke, 2008), composition of waste (e.g., chemical and biological properties) (United States Congress, Office of Technology Assessment, 1990; Prüss et al., 1999), nature of waste (e.g., solid, liquid) and degree of risk (e.g., hazardous or non-hazardous) (Da Silva et al., 2005; Patwary et al., 2011). Despite MW streams consisting of a high proportion of non-infectious/hazardous waste – 75% to 90% of the total waste generated from HCFs (Chartier et al., 2014) – studies have placed more emphasis on the 10% to 25% which is considered infectious or hazardous due to the associated health risks. Chartier et al. (2014) without giving any further classification of general waste from HCFs noted that such waste should be handled by municipal waste disposal systems. Table 2 summarises the classification of hazardous MW as provided by the WHO.

A more comprehensive categorisation of waste from HCFs is provided by the Technical Guidelines on Environmentally Sound Management of Biomedical and Healthcare Waste (see Figure 1).

According to Diaz et al. (2008), one essential element of waste characterisation involves the determination of the composition of waste. A clear understanding of the constituents of the waste stream, especially the constituents of the non-infectious

categories of the waste stream, is important in the development and implementation of a realistic waste management plan.

Table 2 Categories of hazardous HCW

Waste category	*Description and examples*
Infectious waste	Waste suspected to contain pathogens, e.g., laboratory cultures, waste from isolation wards, tissues (swabs), materials, or equipment that have been in contact with infected patients, excreta
Pathological waste	Human tissues or fluids, e.g., body parts, blood and other body fluids, foetuses
Sharps	Sharp waste, e.g., needles, infusion sets, scalpels, knives, blades, broken glass
Pharmaceutical waste	Waste containing pharmaceuticals, e.g., pharmaceuticals that are expired or no longer needed, items contaminated by or containing pharmaceuticals (bottles, boxes)
Genotoxic waste	Waste containing substances with genotoxic properties, e.g., waste containing cytostatic drugs (often in cancer therapy), genotoxic chemicals
Chemical waste	Waste containing chemical substances, e.g., laboratory reagents, film developer, disinfectants that are expired or no longer needed, solvents
Wastes with high content of heavy metals	Batteries, broken thermometers, blood-pressure gauges
Pressurised containers	Gas cylinders, gas cartridges, aerosol cans
Radioactive waste	Waste containing radioactive substances, e.g., unused liquids from radiotherapy or laboratory research, contaminated glassware, packages, or absorbent paper, urine and excreta from patients treated or tested with unsealed radionuclides, sealed sources

Source: Prüss et al. (1999)

2.3 Sources

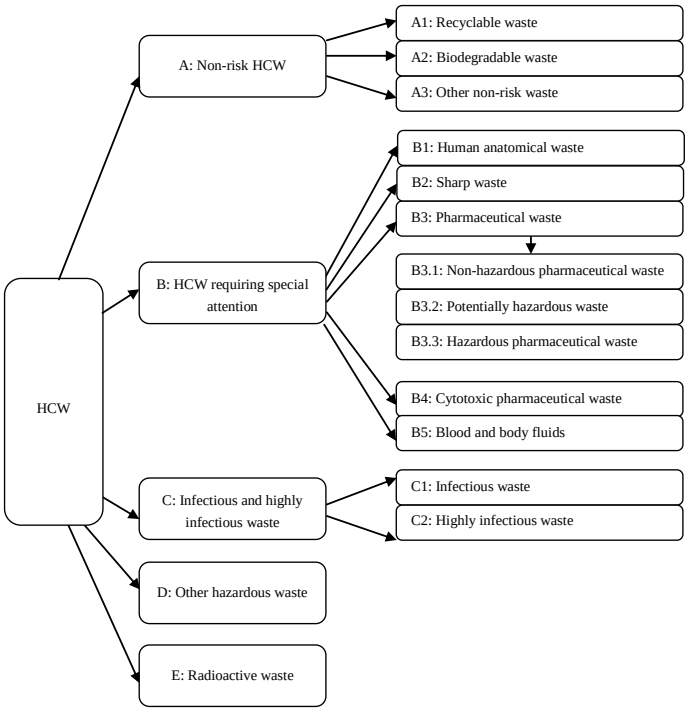
The most common sources of MW are HCFs: hospitals, dispensaries, laboratories, mortuary and autopsy centres and medical research centres (Ananth et al., 2010). According to the MWM Act, Section 117705 of the California Health and Safety Code, any person whose activity or process creates MW is a MW generator (California Department of Public Health, 2017). Further, the MWM Act identifies two types of MW generators:

a large quantity generators (LQG) (generating MW in excess of 200 pounds/month)

b small quantity generators (SQG) (generating MW short of 200 pounds/months).

How small the amount of MW generated from any source is, it is an important factor to consider when determining appropriate management options owing to the high risk to human health and adverse effect on the environment.

Figure 1 Categories of MW



Source: Slovak Environmental Agency (2008)

2.3.1 Categories of HCFs

HCFs are institutions that provide health or medical care for human beings and animals. They include hospitals, clinics, outpatient care centres, and specialised care centres and psychiatric care centres. The WHO (2014) defines HCFs to comprise hospitals, isolation camps, burn patient units, primary healthcare centres and feeding centres. HCFs comprise all, but are not limited to, teaching hospitals, general hospitals specialist hospitals (orthopaedic, eye clinics and plastic surgery clinics for example) and veterinary clinics. HCFs, especially hospitals and clinics, consume great and varying amounts of items in the course of delivering healthcare (Wahab and Adesanya, 2011). The result of this consumption is the generation of a heterogeneous composition of waste containing various forms of hazardous/infectious properties. Despite the type, size, and nature of HCFs being a significant factor in the nature and amount of waste generation (Abor, 2008; Cheng et al., 2009), the evidence from previous studies show that there is no common criterion for categorising HCFs (see Table 3).

Commented [A6]: Author: Please provide full reference or delete from the text if not required.

Commented [A7]: Author: Please provide full reference or delete from the text if not required.

Table 3 Categories of HCFs

Reference	*Categorisation*	*Criteria*
Komilis et al. (2012)	• Public	• Ownership
	• Private	
Cheng et al. (2009)	• Medical centres	• Socio-economic status
	• Local (community)	• Nature of care services provided
	• Regional	
	• Independent and others	
Coker et al. (2009)	• Primary	• Size
	• Secondary	• Function
	• Tertiary	
	• Diagnostic	

3 MWM practices in HCFs and associated factors

Baaki et al. (2017) noted that MWM practices in many developing countries still focus on 'safe' management and argued that a successful MWM program should achieve safe, efficient and sustainable management. Goddu et al. (2007) demonstrated the distinction between MWM practices in developing and developed countries. The study examined MWM practices in hospitals in India and England and reported that, while principles guiding MWM in England ensure 'stringent' compliance, and management practices are satisfactory, the situation in India is still 'bleak' despite the Bio-medical Waste Management and Handling Rules of 1998. While the WHO has reported a relative improvement especially in the areas of regulatory frameworks, national plans, and innovative approaches to addressing waste management issues in developing nations, it identified inadequate funding and resource commitment as the main mitigating factor to proper MWM.

3.1 Regulations

For regulations regarding hazardous waste management across international borders, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989) remains the most fundamental piece of guidelines. The objective of the Basel Convention is to reduce or prevent the adverse effect of hazardous waste on human health and the environment. Its scope of application covers a wide range of both hazardous wastes, including MW (Annex I and VIII) and other wastes, such as household and incineration ash (UNEP, 2011). Beyond this is the more generic Agenda 21 adopted by the United Nations Conference on the Environment and Development (UNCED) in 1992. This recommends measures for waste management to include prevention and minimisation; reuse or recycling where possible; treatment by environmentally sound and safe means; and final disposal to appropriate sites. The Agenda 21 also emphasise that any waste producer be responsible for the treatment and final disposal of their waste and if possible, communities should dispose of their waste within their boundaries (Prüss

et al., 1999). On the back of these, countries have gone on to establish various regulatory frameworks for the management of wastes generated from HCFs. Table 4 shows legislations/regulations on MWM in some developing countries. Although some of these regulations exist, many have argued that they are either poorly formulated, obscure, and inadequately implemented and enforced. For instance, Mbongwe et al. (2008) describe legislation on clinical waste management in Botswana as 'obscure'. Mohee (2005), while praising the enactment of these regulations and policies noted that, most do not adopt a holistic approach, are poorly formulated, and implemented inadequately due to lack of staff awareness, financial inadequacy, poor training initiatives and monitoring. Moreira and Gunther (2013) also cited MWM regulations such as National Health Surveillance Agency (ANVISA) Resolution No. 306:2004 and National Environmental Council of Brazil (CONAMA) Resolution No. 358:2005 in Brazil as been up to date but reported that no performance assessment was conducted following the implementation of MWM plans. Manga et al. (2011) noted that for the formulation and implementation of any waste management program to be effective, it must be within a 'specific and sustainable regulatory policy framework'.

Table 4 Waste management regulations in some developing countries

Reference	*Country*	*Legislation*
Goddu (2007), Chandana et al. (2018)	India	Bio-medical Waste Management and Handling Rules of 1998, Biomedical Waste Management Rules 2016
Da Silva et al. (2005), Moreira and Gunther (2013)	Brazil	National Health Surveillance Agency (ANVISA) Resolution No. 306:2004, National Environmental Council of Brazil (CONAMA) Resolution No. 5:1993, Resolution No. 283:2001, Resolution No. 358:2005
	Egypt	Law of the Ministry of Environmental Affairs and Ministry of Health and Populations
Manga et al. (2011)	Mongolia	2002 Removal and Disposal of Hazardous Wastes and the 2003 Improvement of Healthcare Waste Management
Mohee (2005)	Mauritius	Act 1925 and the 2001 Standards for Hazardous Waste Regulations
Abah (2011)	Nigeria	National Policy on Healthcare Waste, 2007 (Draft)
Ali et al. (2017), Dawar (2017)	Pakistan	Healthcare Waste Management Rules 2005

Commented [A8]: Author: Please provide full reference or delete from the text if not required.

Commented [A9]: Author: Please provide full reference or delete from the text if not required.

3.2 Practices and associated factors

MWM remains a global problem. The WHO has provided a general guidebook for the management of wastes arising from healthcare provision. It sets out the guidelines for 'safe' and 'sustainable' management of these wastes. Understanding the MWM process from generation to disposal is vital to its management. There is wide literature and studies on MWM practices in both developing and developed nations (Abah, 2011; Abor, 2008; Akter, 2003; Bdour et al., 2007; Chaerul et al., 2008; Coker et al., 2009; Da Silva et al., 2005). The following constitutes the MWM process:

a generation

b segregation

Commented [A10]: Author: Please provide full reference or delete from the text if not required.

Commented [A11]: Author: Please provide full reference or delete from the text if not required.

Commented [A12]: Author: Please provide full reference or delete from the text if not required.

Commented [A13]: Author: Please provide full reference or delete from the text if not required.

c onsite transportation

d temporary storage

e treatment/disinfection

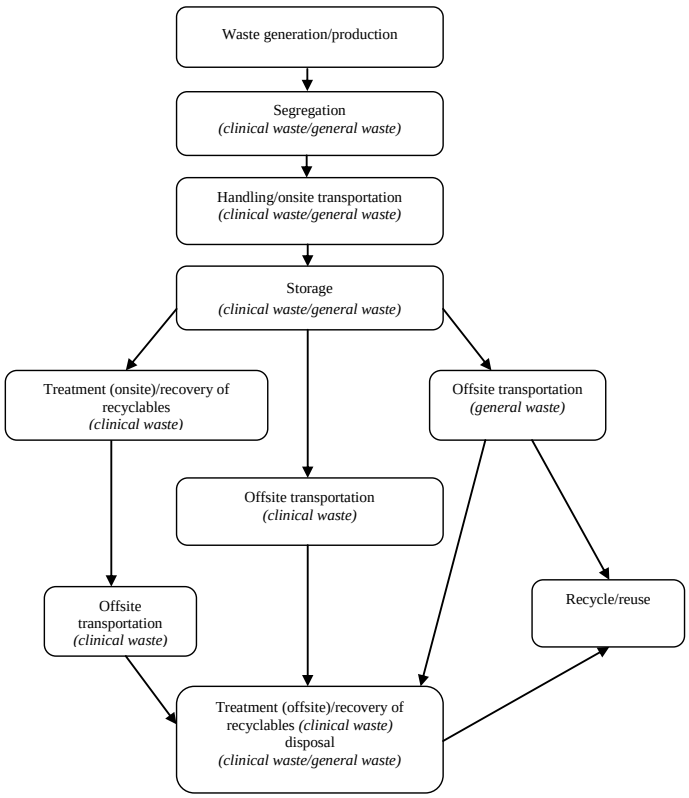
f offsite transportation

g final disposal

h recycle/reuse (see Figure 2 for an illustration of the process flow).

To note in the MWM process is the absence of waste minimisation, which clearly do not take into account one of the essential elements of the waste management hierarchy: waste prevention and minimisation. Until recently, the general disposition toward HCW is to consider it bound for disposal once generated, with little attempts made at instituting measures to prevent and minimise generation.

Figure 2 MWM from generation to disposal



3.2.1 Generation

Medical activities are the fundamental sources of MW generation. Most of the waste is non-risk. It is therefore important to understand factors that result in the nature, and amount of waste generated at HCFs. Abor (2008) and Gitipour et al. (2017) identified type of healthcare services provided by a hospital, number of beds, economic, social and cultural status of patients; nature of segregation program, and the general condition of the area the hospital is located as factors responsible for the amount and nature of waste generated by HCFs. Sharma and Gupta (2017) found that bed capacity and number of doctors were key factors affected quantity of waste generation. In Taiwan, Cheng et al. (2009) observed that insurance reimbursement and number of beds were the chief factors predicting the generation of infectious waste. Komilis et al. (2012) observed the rate of waste generation from public and private hospitals in Greece. Public hospitals generated between 0.012 kg/bed/day to 0.72 kg/bed/day, while private hospitals generated between 0.0012 kg/bed/day to 0.49 kg/bed/day. The lowest generation rates for both public and private hospitals was from psychiatric hospitals while the highest generation rate for public and private hospitals was from university hospitals and birth clinics respectively, agreeing with Abor (2008) that the nature of healthcare services provided by HCFs factor in the amount of waste generated from HCFs. In a study in 2006 to develop a standardised measurement unit for waste generated from healthcare activities, Tudor (2006) grouped these factors into two main categories:

a department type

b activity levels.

3.2.2 Segregation

This entails separating different types of waste streams according to their classifications. Waste segregation is the most essential aspect of the MWM process, and it is the least adhered to in developing nations. It is either not practiced or is carried out in a highly unsatisfactory manner (Ali et al., 2017; Baaki et al., 2017). The aim is to separate infectious/hazardous waste from non-infectious/non-hazardous waste and prevent contamination. Appropriate segregation goes beyond just separating clinical waste from general MW as this would lead to better treatment and disposal practices as well as recovery of potential recyclables. Wastes with very high infectious properties such as pathological and anatomical waste must be separated from pharmaceutical waste; the same must be done with sharps and radioactive waste, for example. A study in Bangladesh by Akter and Trankler (2003) showed that apart from separating syringes/needles, hospitals did not practice waste segregation, while Abor (2008) observed in South Africa that apart from separating clinical waste from general waste, further segregation was not practiced. Factors responsible for improper segregation practices have been identified to include poor risk awareness (UN-Habitat, 2006), lack of awareness, training and badly formulated policies (Mohee, 2005), and improper MWM plan implementation strategies (Moreira and Gunther, 2013). Segregation must begin at source, i.e., at the point of waste generation. Chartier et al. (2014) noted that at the point of waste generation, segregation is the absolute responsibility of hospital personnel. Table 5 shows colour-coding and labelling best practice as recommended by WHO.

Commented [A14]: Author: Please provide full reference or delete from the text if not required.

Commented [A15]: Author: Please provide full reference or delete from the text if not required.

Commented [A16]: Author: Please provide full reference or delete from the text if not required.

Commented [A17]: Author: Please be informed that Table 4 was changed to Table 5. The succeeding tables have been renumbered as well.

Table 5 Colour-coding recommendations for MW

Type of waste	*Colour of container and markings*	*Type of container*
Highly infectious waste	Yellow, marked 'highly infectious'	Strong, leak-proof, plastic bag, or container capable of being autoclaved
Other infectious waste, pathological and anatomical waste	Yellow	Leak-proof plastic bag or container, labelled with biohazard symbol[a]
Sharps	Yellow, marked 'sharps'	Puncture-proof container
Chemical and pharmaceutical waste	Brown	Plastic bag or container
Radioactive waste[1]	-	Lead box, labelled with the radioactive symbol[b]
General healthcare waste	Black	Plastic

Note: [1]Only generated in major technologically advanced hospitals.

Source: Prüss et al. (1999)

3.2.3 Handling, onsite transportation and storage

Handling and transportation personnel must be well equipped with personal protection equipment (PPE) such as masks, protective eyewear, protective clothing, puncture and water-proof boots, general purpose gloves, hard hats (Abor, 2008; Razali and Ishak, 2010; Vieira et al., 2009). However, studies have reported various inadequate and inappropriate waste handling and onsite transportation practices in developing countries (Coker et al., 2009; Oli et al., 2016). For instance, Coker et al. (2009) found that wastes were collected at the point of generation into inappropriate equipment such as metal dustbins, drums, baskets, pans, cartons, buckets, bowls and transported on shoulders by waste handling personnel instead of appropriate wheeled bins. The study further suggests the lack of awareness or training on the potential risks of improper waste handling as a possible factor.

Regarding temporary storage, Chartier et al. (2014) suggest that unless a cold room is provided for temporary storage of infectious/hazardous MW, such wastes should not be stored for longer than three days and two days in a temperate climate during winter and summer respectively; and two days and one day during the cool and hot seasons in warm climates, respectively, cytotoxic should be stored in separate secure locations, and radioactive stored behind lead shielding in dispersion-proof containers. Temporary storage areas should also be inaccessible to unauthorised personnel and animals such as rodents, dogs and cats for example. Temporary storage facilities have been found to be non-existent, inappropriate and poorly operated (Ali et al., 2017; Baaki, 2014; Coker et al., 2009). Coker et al. (2009) found that all types of MWs awaiting disposal were stored in a common area. Baaki (2014) on the other hand found that inappropriate storage media were used to store MWs and for periods exceeding temporary storage recommendations.

Commented [A18]: Author: Please be informed that Table 4 was changed to Table 5. The succeeding tables have been renumbered as well.

Commented [A19]: Author: Please confirm what this letter (**a**) stand for or delete from the text if not required.

Commented [A20]: Author: Please confirm what this letter (**b**) stand for or delete from the text if not required.

Commented [A21]: Author: Please provide full reference or delete from the text if not required.

3.2.4 Treatment, offsite transportation and disposal

Treatment is the process of disinfecting infectious MW. Several treatment technologies exist for treating infectious MW. Incineration or combustion has been identified as the most widely used method of waste treatment in developing countries (Abor, 2008; Diaz et al., 2005; Razali and Ishak, 2010). Lee and Huffman (1996) reported incineration as the best treatment technology for MW treatment as it significantly reduces the waste volume, can destroy hazardous organics and pathogens and render the waste unrecognisable. However, despite the existence of rotary kiln incinerators, which have two combustion chambers and air pollution control, Diaz et al. (2005) observed that combustion of MW generates chemical compounds and particulate matter that can potentially have health effects on humans and the environment, especially in the case of developing countries where makeshift combustion devices and systems are prevalent. The lack of management commitment, financial and technological capacity has been identified as factors hindering the establishment and operation of appropriate treatment facilities in developing countries (Abah and Ohimain, 2011; Baaki et al., 2017).

While some studies have shown prevalent practices of disposing considerable amounts of MW around the premises of HCFs in developing nations (Akter and Trankler, 2003; Coker et al., 2009; Baaki, 2014), other studies show that offsite transportation of MW is generally outsourced (Abor, 2008; Diaz et al., 2005; Razali and Ishak, 2010). The waste is then transported to either landfills or treatment and disposal facilities. This, however, does not eliminate improper handling and transportation practices, especially in developing countries (Abor, 2008; Coker et al., 2009; Baaki, 2014). Chartier et al. (2014) noted that, it is the responsibility of the HCF to properly package MW and recommends that transportation of infectious/hazardous MW should follow WHO Guidelines for the Safe Transport of Infectious Substances and Diagnostic Specimens.

In choosing disposal options, it is not enough that the option provides safe disposal; it should as well be a sustainable option. Poor practices such as using municipal bins, dumping grounds and burial of such waste as placenta/foetuses within and around the hospital premises even among residential areas have been reported in some developing countries (Abor and Bouwer, 2008; Akter and Trankler, 2003; Oke, 2008; Coker et al., 2009; Patwary et al., 2011) making it possible for wastes with hazardous and infectious properties to be accessible to children scavenging dumpsites (Coker et al., 2009; Oke, 2008). This shows the lack of awareness on the health and environmental risks associated with such disposal practices (Patwary et al., 2011). Abah and Ohimain (2011) argue that the capacity to dispose huge amounts of HCW is lacking in many developing countries. Financial and social factors might also affect certain disposal practices. Chartier et al. (2014) observed that in certain countries, religious and cultural practices might make it unacceptable to collect anatomical waste in yellow bags and dispose of it as per the MWM policy; such should therefore be disposed of safely in accordance with local customs. Table 6 shows best practice treatment/disposal technologies/methods of various categories of MW as recommended by the WHO.

3.2.5 Recycling/reuse

As mentioned earlier, the percentage of infectious/hazardous waste constitutes only about 10% to 25% of the total waste generated from healthcare institutions with the remaining 75% to 90% considered non-risk/domestic-type. This 75% to 80% of the waste stream

Commented [A22]: Author: Please provide full reference or delete from the text if not required.

Commented [A23]: Author: Please provide full reference or delete from the text if not required.

Commented [A24]: Author: Please provide full reference or delete from the text if not required.

has high recycling potential (Hutchins and White, 2009; Scally, 2009; Marmot, 2010), however, extensive studies discussing the potential of recycling wastes from healthcare facilitates particularly in developing countries are lacking. A study by Hossain et al. (2011) involving 14 countries, mostly developing countries, found that only 3 out of the 14 recycled parts of the waste generated from HCFs. Lack of, or poorly formulated regulations and policies, poor infrastructural state, and low level of technological advancement could be seen as factors (Mbongwe et al., 2008; Mohee, 2005). Also, the fact that if improperly handled, non-risk waste could easily get contaminated could be the reason behind limited enthusiasm towards MW recycling, particularly in developing nations (Baaki et al., 2017).

Table 6 Treatment/disposal methods/technologies for MW [1]

Technology	*Method*	*Waste handled*
Thermal	• Autoclave • Hybrid autoclave • Continuous steam • Microwave technologies • Frictional heat treatment • Dry heat • Incinerators	• Autoclaves: cultures, stocks, sharps, material contaminated with blood and body fluids, isolation and surgery waste, laboratory waste excluding chemical waste, soft waste from patient care, etc. • Microwave: same as for autoclaves plus pathological waste, bottles containing fluids • Frictional heat: cellulosic material, glass, plastics, metals, liquids and pathological waste • Dry heat: sharps and small amounts of infectious waste • Incinerators: same as for autoclave plus large beddings, cadavers, large anatomical remains, cytotoxic waste
Chemical	• Chlorine • Glutaraldehyde • Lime slurry • Calcium oxide • Alkaline hydrolysis	• Chlorine-based: liquid waste, infectious waste, microbiological cultures, sharps • Alkaline hydrolysis: pathological waste, organs, tissues, cadavers, anatomical parts, stocks and cultures, chemotherapeutic agents
Irradiative	• Electron beam • UV-C (germicidal UV) • Irradiation	• Radioactive waste
Biological	• Enzyme treatment • Composting • Vermiculture	• Biological waste

Notes: [1]General waste not reflected. According to Prüss et al. (1999), such wastes should be handled by municipal disposal mechanisms.

Source: UNEP (2013)

Commented [A25]: Author: Please provide full reference or delete from the text if not required.

After examining the MWM practices in developing nations, the following key factors have been identified:

- lack or poorly formulated MWM specific regulations and policies

- poor risk awareness, sensitisation and training on MWM
- poor financing and inadequate investment in MWM programs
- influence of social factors such as cultural norms and social status
- improper implementation of policies and best practices
- poor infrastructure and low level of technological advancement.

4 Achieving integrated sustainable medical waste management (ISMWM) in HCFs

The heterogeneous composition of MW has made discussions on its management primarily focused on treatment and disposal technologies in what seems to suggest that a one-size-fits-all technological solution to deal with its management could be the solution. This has left, especially developing nations, with serious burdens. According to Ananth et al. (2010), HCW must be seen as "contiguous blocks of individual actions requiring appropriate management strategies to control it." Waste definition and composition must be explicitly understood before appropriate management strategies can be developed. Sustainable MWM strategies must be formulated bearing in mind that first, waste generation has to be avoided (where possible and applicable); second, minimisation of waste generation; third, adopting appropriate treatment methods; and fourth, recycling initiatives. The first point of consideration is whether such waste should end up at disposal mechanisms at all. This would create an atmosphere for conscious attempts to minimise waste generation, observe detailed segregation practices, identify potential recyclables thereby ensuring that only waste that defy any of these measures ends up at disposal mechanisms.

The concept of integrated sustainable waste management (ISWM), setup in the early 1990s, tackles primarily waste management issues in developing countries. Formulated to counterpoise the common technology-driven approach of waste management, it is built upon the overarching concept of sustainability. The ISWM identifies three essential perspectives of waste management (Klundert, 2001):

a what? (scope of the waste system, covering physical composition, planning and management concerns such as strategic planning, financial appropriation and management, public participation)

b who? (stakeholders – all those involved with and affected by the waste management situation)

c how? (path to achieving strategic objectives and implementing waste management solutions).

The concept of ISWM, however, is a primarily municipal solid waste management concept. Only in 2007, the WHO published what it called 'WHO core principles' for safe and sustainable management of health care waste. The 'WHO core principles' for safe and sustainable management of MW emphasises the importance of the active participation of all stakeholders involved in the MWM chain in order to successfully implement sustainable MWM. The WHO core principles stipulate that, all associated

with financial and or supporting healthcare activities should provide for the cost of managing HCW. Also, manufacturers of healthcare products should bear in mind the concerns of MWM while developing and marketing their products (WHO, 2007).

Based on the identified associated factors of MWM in developing countries, the following recommendations can be made.

4.1 Regulations and policies

4.1.1 Strategies

- While there are international recommendations, specific regulations formulated within a sustainable design framework at both external (national/ministry) and internal (HCFs) levels would provide legally binding provisions on formulated policies. For instance, a disposal regulation on diverting certain waste streams such are potential recyclables from landfill and incineration. Such legislation could prohibit disposal of such waste streams through high disposal costs and severe fines.
- Presently, there are a variety of terms used to refer to waste generated from HCFs. There is need for a single definition and classification criteria of waste generated from HCFs. While this could be achieved at a global level, national waste management policies should clearly define and classify all waste arising from healthcare activities.

4.2 Implementation

Implementation is one of the important elements of any plan if it is to be successful. Only a well-executed plan could yield useful results.

4.2.1 Strategies

- Goal setting/action plans: Despite the overarching objectives of MWM plans, implementation involves setting short-term goals and action plan frameworks, the day-to-day operational activities critical to the actualisation of the bigger picture.
- Measurement of waste generation rates: This is essential as you cannot manage what you do not know. Appropriate measurement units should be adopted. Tudor (2007) proposed a 'kg/person/month' standardised measurement unit for MW generation, arguing that other units of measurements, for instance, kg/bed/day were prone to fluctuations, failed to take into account proper measurement of waste generated from non-patient activities and could provide false data as beds could be either unoccupied or over-occupied.
- Waste minimisation and extensive segregation practices: Waste minimisation and segregation should take into account recycling potential of MWs. As it has been noted, 75% to 90% of waste generated from HCFs in domestic-type waste with high recycling potentials. By adopting waste minimisation approaches such as sustainable purchasing, and segregating potential recyclables from the waste stream, the total amount of waste generated or heading down treatment and disposal options would be

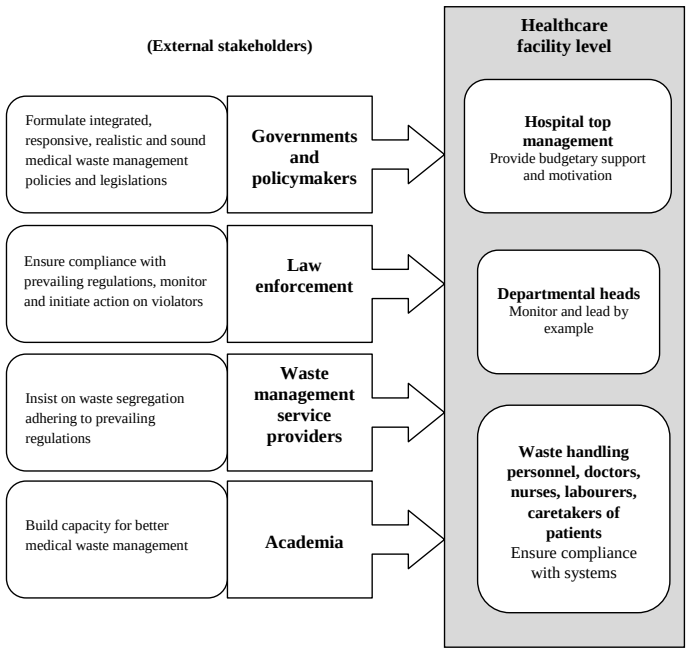
significantly reduced, resulting in resource efficiency, costs savings on disposal and less adverse impact on the environment.

- Performance assessment: Performance evaluation and measurement is a way of making sure that performed actions are yielding desired results, and if they are not, what corrective actions to be instituted. A performance evaluation and measurement framework should be in place to assess the level of conformity to set goals and objectives.

4.3 Sensitisation, awareness and training programs

The success of any MWM plan implementation would be greatly affected by how well people are aware of the issues surrounding MWM. This suggest core focus on the people in terms of conditioning individuals to be aware of health and environmental risks of MW as well as understand the objectives and aspirations of the waste management program.

Figure 3 Distribution of responsibilities



Source: Adapted from Ananth (2010)

Commented [A26]: Author: Please provide full reference or delete from the text if not required.

4.3.1 Strategies

- Training programs should be dully administered to waste generators, waste handling staff, and even patients and their relatives on both the risks and recycling potentials of MW.
- Constant awareness and sensitisation should be created through signage posting to discourage waste generation as well as encourage people to practice the simple acts of putting waste types in their designated waste collection mediums.

4.4 The role of stakeholders

Designated roles of stakeholders, i.e., everyone involved with and or affected by a MWM program, should be detailed in MWM policies and action plans that should in turn be duly and clearly communicated to all stakeholders (see Figure 3).

5 Conclusions

To achieve holistic and successful waste management practices, MWM has to be understood from the point of generation all through to disposal. While most of the associated factors of MWM have been identified to being of managerial nature, attempts to curb the situation have still taken a more technological route. In some countries, specific MWM regulations and polices do not exist. In some where they do exist, implementation has been either poor or non-existent. Waste management staff and personnel often lack knowledge and basic skills. Managerial incompetency and lack of dynamic strategies pose a huge challenge to any complex technology. The formulation of MWM-specific regulations, policies and frameworks at both external and internal levels is the starting point. Reliance on a one-solution-fits-all could result in hiking costs of MWM programs, especially with regards to disposal options. This paper thus argues that the success of a safe, efficient and sustainable MWM program, particularly in developing countries must be formulated around a holistic and integrated process, where simple management strategies assume a much more predominant role. It is important to note that this paper only relied on a general review of existing literature on MWM, as such the proposed recommendations are broad. It is suggested that further research empirically investigate how these broad recommendations could be applicable in specific MWM situations in specific developing countries or regions.

References

Abah, S.O. and Ohimain, E.I. (2011) 'Healthcare waste management in Nigeria: a case study', *Public Health and Epidemiology*, Vol. 3, No. 3, pp.99–110.

Abd El-Salam, M.M. (2010) 'Hospital waste management in El-Beheira Governorate, Egypt', *Journal of Environmental Management*, Vol. 91, No. 3, pp.618–629.

Abor, P.A. and Bouwer, A. (2008) 'Medical waste management practices in a southern African hospital', *International Journal of Health Care Quality Assurance*, Vol. 21, No. 4, pp.356–364.

Akter, N. and Trankler, J. (2003) 'An analysis of possible scenarios of medical waste management in Bangladesh', *Management of Environmental Quality*, Vol. 14, No. 2, pp.242–225.

Ali, M., Wang, W. and Chaudhry, N. (2017) 'Assessment of hospital waste management in a major city of Pakistan', *International Journal of Environment and Waste Management*, Vol. 19, No. 2, pp.97–104.

Ananth, A.P., Prashanthini, V. and Visvanathan, C. (2010) 'Healthcare waste management in Asia', *Waste Management*, Vol. 30, No. 1, pp.154–161.

Baaki, T.K. (2014) *An Evaluation of Medical Waste Management Practices in Healthcare Facilities in Benue State, Nigeria*, unpublished Master thesis, University of Malaya.

Baaki, T.K., Baharum, M.R. and Akashah, F.W. (2017) 'Critical success factors of medical waste management implementation in health-care facilities in Nigeria: a case study', *Journal of Design and Built Environment*, Vol. 17, No. 1, pp.18–35.

Bdour, A., Altrabsheh, B., Hadadin, N. and Al-Shareif, M. (2007) 'Assessment of medical wastes management practice: a case study of the northern part of Jordan', *Waste Management*, Vol. 27, No. 6, pp.746–759.

California Department of Public Health (2017) *Medical Waste Management Act: California Health and Safety Code Sections 117600-118360*, California Department of Public Health, California.

Chandana, P.S., Bhargav, P.R.K. and Gayathri, K.B. (2018) 'Implications and implementation of Biomedical Waste Management Rules 2016 in hospitals and a common biomedical waste treatment facility in Andhra Pradesh, India', *International Journal of Environment and Waste Management*, Vol. 21, Nos. 2–3, pp.201–216.

Chartier, Y., Emmanuel, J., Pieper, U., Prüss, A., Rushbrook, P., Stringer, R. Zghondi, R. et al. (Eds.) (2014) *Safe Management of Wastes from Health-care Activities*, 2nd ed., World Health Organization, Geneva.

Cheng, Y.W., Sung, F.C., Yang, Y., Lo, Y.H., Chung, Y.T. and Li, K.C. (2009) 'Medical waste production at hospitals and associated factors', *Waste Management*, Vol. 29, No. 1, pp.440–444.

Coker, A., Sangodoyin, A., Sridhar, M., Booth, C., Olomolaiye, P. and Hammond, F. (2009) 'Medical waste management in Ibadan, Nigeria: obstacles and prospects', *Waste Management*, Vol. 29, No. 2, pp.804–811.

Da Silva, C.E., Hoppe, A.E., Ravanello, M.M. and Mello, N. (2005) 'Medical wastes management in the south of Brazil', *Waste Management*, Vol. 25, No. 6, pp.600–605.

Dawar, A.B.K. (2017) *Hospital Waste Management Rules 2005 and Current Practices in Selected Hospitals of Peshawar Khyber Pakhtunkhwa, Pakistan*, unpublished Master's thesis, Norwegian University of Life Sciences.

Diaz, L.F., Eggerth, L.L., Enkhtsetseg, S. and Savage, G.M. (2008) 'Characteristics of healthcare wastes', *Waste Management*, Vol. 28, No. 7, pp.1219–1226.

Diaz, L.F., Savage, G.M. and Eggerth, L.L. (2005) 'Alternatives for the treatment and disposal of healthcare wastes in developing countries', *Waste Management*, Vol. 25, No. 6, pp.626–637.

EPA (2002) *European Waste Catalogue and Harzadous Waste List*, Environmental Protection Agency, Ireland.

Gai, R., Xu, L., Li, H., Zhou, C., He, J., Shirayama, Y., Tang, W. and Kuroiwa, C. (2010) 'Investigation of health care waste management in Binzhou District, China', *Waste Management*, Vol. 30, No. 2, pp.246–250.

Gitipour, S., Pour, F.A. and Firouzbakht, S. (2017) 'Assessment of medical waste in Tehran province hospitals', *Journal of Environmental Studies*, Vol. 42, No. 4, pp.709–718.

Goddu, V.K., Duvvuri, K. and Bakki, V.K. (2007) 'A critical analysis of healthcare waste management in developed and developing countries: case studies from India and England', *Proceedings of the International Conference on Sustainable Solid Waste Management*, Anna University, Chennai, India, 5–7 September, pp.134–141.

Hossain, S., Santhanam, A., Nik Norulaini, N.A. and Omar, A.K. (2011) 'Clinical solid waste management practices and its impact on human health and environment – a review', *Waste Management*, Vol. 31, No. 4, pp.754–766.

Hutchins, D.C. and White, S.M. (2009) 'Coming round to recycling', *BMJ*, Vol. 338, p.b609, DOI: 10.1136/bmj.b609.

Jang, Y., Lee, C., Yoon, O. and Kim, H. (2006) 'Medical waste management in Korea', *Journal of Environmental Management*, Vol. 80, No. 2, pp.107–115.

Klundert, A. (2001) *Integrated Sustainable Waste Management*, Waste, Gouda [online] http://www.eawag.ch/forschung/sandec/publikationen/swm/dl/integrated_Sustainable__Solid_Waste.pdf.

Komilis, D., Fouki, A. and Papadopoulos, D. (2012) 'Hazardous medical waste generation rates of different categories of health-care facilities', *Waste Management*, Vol. 32, No. 7, pp.1434–1441.

Kumari, R., Srivastava, K., Wakhlu, A. and Singh, A. (2013) 'Establishing biomedical waste management system in medical university of India – a successful practical approach', *Clinical Epidemiology and Global Health*, Vol. 1, No. 3, pp.131–136.

Lee, C.C. and Huffman, G.L. (1996) 'Medical waste management/incineration', *Journal of Hazardous Materials*, Vol. 48, Nos. 1–3, pp.1–30.

Manga, V.E., Forton, O.T., Mofor, L.A. and Woodard, R. (2011) 'Health care waste management in Cameroon: a case study from the Southwestern region', *Resources, Conservation and Recycling*, Vol. 57, pp.108–116.

Marmot, M. (2010) *Fair Society, Healthy Lives: Strategic Review of Health Inequalities in England Post 2010* [online] http://www.parliament.uk/documents/fair-society-healthy-lives-full-report.pdf.

Mbongwe, B., Mmereki, B.T. and Magashula, A. (2008) 'Healthcare waste management: current practices in selected healthcare facilities, Botswana', *Waste Management*, Vol. 28, No. 1, pp.226–233.

Miyazaki, M. and Une, H. (2005) 'Infectious waste management in Japan: a revised regulation and a management process in medical institutions', *Waste Management*, Vol. 25, No. 6, pp.616–621.

Mohamed, L.F., Ebrahim, S.A. and Al-Thukair, A.A. (2009) 'Hazardous healthcare waste management in the Kingdom of Bahrain', *Waste Management*, Vol. 29, No. 8, pp.2404–2409.

Mohee, R. (2005) 'Medical wastes characterisation in healthcare institutions in Mauritius', *Waste Management*, Vol. 25, No. 6, pp.575–581.

Moreira, A.M.M. and Gunther, W.M.R. (2013) 'Assessment of medical waste management at a primary health-care center in Sao Paulo, Brazil', *Waste Management*, Vol. 33, No. 1, pp.162–167.

Nemathaga, F., Maringa, S. and Chimuka, L. (2008) 'Hospital solid waste management practices in Limpopo Province, South Africa: a case study of two hospitals', *Waste Management*, Vol. 28, No. 7, pp.1236–1245.

Oke, I.A. (2008) 'Management of immunization solid wastes in Kano State, Nigeria', *Waste Management*, Vol. 28, No. 12, pp.2512–2521.

Oli, A.N., Ekejindu, C.C., Adje, D.U., Ezeobi, I., Ejiofor, O.S., Ibeh, C.C. and Ubajaka, C.F. (2016) 'Healthcare waste management in selected government and private hospitals in Southeast Nigeria', *Asian Pacific Journal of Tropical Biomedicine*, Vol. 6, No. 1, pp.84–89.

Patil, G.V. and Pokhrel, K. (2005) 'Biomedical solid waste management in an Indian hospital: a case study', *Waste Management*, Vol. 25, No. 6, pp.592–599.

Patwary, M.A., O'Hare, W.T. and Karker, M.H. (2011) 'Assessment of occupational environmental safety associated with medical waste disposal in developing countries: a qualitative approach', *Safety Science*, Vol. 49, No. 8, pp.1200–1207.

Commented [A27]: Author: Please provide the access details (date when the site was accessed/visited).

Commented [A28]: Author: Please provide the issue number.

Commented [A29]: Author: Please provide the access details (date when the site was accessed/visited).

Patwary, M.A., O'Hare, W.T., Graham, S., Elahi, K.M., Hossain, S.S. and Sarker, M.H. (2009) 'Quantitative assessment of medical waste generation in the capital city of Bangladesh', *Waste Management*, Vol. 29, No. 8, pp.2392–2397.

Prüss, A., Giroult, E. and Rushbrook, P. (Eds.) (1999) *Safe Management of Waste from Health-care Activities*, World Health Organization, Geneva.

Razali, S.S. and Ishak, M.B. (2010) 'Clinical waste handling and obstacles in Malaysia', *Journal of Urban and Environment Engineering*, Vol. 4, No. 2, pp.47–54.

Sarkar, S.K.A., Haque, M.A. and Khan, T.A. (2006) 'Hospital waste management in Sylhet city', *Journal of Engineering and Applied Sciences*, Vol. 1, No. 2, pp.32–40.

Sawalem, M., Selic, E. and Herbell, J.D. (2009) 'Hospital waste management in Libya: a case study', *Waste Management*, Vol. 29, No. 4, pp.1370–1375.

Scally, G. (2009) 'Environmental waste in health care', *BMJ*, Vol. 338.

Shareefdeen, Z.M. (2012) 'Medical waste management and control', *Journal of Environmental Protection*, Vol. 3, No. 12, pp.1625–1628.

Sharma, S.K. and Gupta, S. (2017) 'Healthcare waste management scenario: a case of Himachal Pradesh (India)', *Clinical Epidemiology and Global Health*, Vol. 5, No. 4, pp.169–172.

Shinee, E., Gombojav, E., Nishimura, A., Hamajima, N. and Ito, K. (2008) 'Healthcare waste management in the capital city of Mongolia', *Waste Management*, Vol. 28, No. 2, pp.435–441.

Slovak Environmental Agency (2008) *Strategies on Bio-medical (Healthcare) Waste Management*, United Nations Environmental Programme, Bratislava.

Tsakona, M., Anagnostopoulou, E. and Gidarakos, E. (2007) 'Hospital waste management and toxicity evaluation: a case study', *Waste Management*, Vol. 27, No. 7, pp.912–920.

Tudor, T.L. (2006) 'Towards the development of a standardized measurement unit for healthcare waste generation', *Resources, Conservation and Recycling*, Vol. 50, No. 2007, pp.319–333.

Tudor, T.L. (2007) 'Towards the development of a standardised measurement unit for healthcare waste generation', *Resources Conservation and Recycling*, Vol. 50, No. 3, pp.319–333

Tudor, T.L., Noonan, C.L. and Jenkin, L.E.T. (2005) 'Healthcare waste management: a case study from the National Health Service in Cornwall, United Kingdom', *Waste Management*, Vol. 25, No. 6, pp.606–615.

UNEP (2011) *The Basel Convention of the Transboundary Movements of Hazardous Wastes and Their Disposal: Protocol on Liability and Compensation for Damages Resulting from Transboundary Movements of Hazardous Wastes and their Disposal*, United Nations Environmental Programme, Basel.

UNEP (2012) *Compendium of Technologies for Treatment/Destruction of Healthcare Waste*, United Nations Environmental Programme.

UN-Habitat (2006) 'Managing biomedical waste in Dakar, Senegal', *World Urban Forum III, an International UN-Habitat Event on Urban Sustainability*, Vancouver, Canada, 19–23 June.

United States Congress, Office of Technology Assessment (1990) *Finding the Rx for Managing Medical Wastes*, OTA-O-459, Washington DC.

Verma, L.K., Mani, S., Sinha, N. and Rana, S. (2008) 'Biomedical waste management in nursing homes and smaller hospitals in Delhi', *Waste Management*, Vol. 28, No. 12, pp.2723–2734.

Vieira, C.D., de Carvalho, M.A.R., de Menezes Cussiol, N.A., Alvarez-Leite, M.E., dos Santos, S.G., da Fonseca Gomes, R.M. and de Macêdo Farias, L. (2009) 'Composition analysis of dental solid waste in Brazil', *Waste Management*, Vol. 29, No. 4, pp.1388–1391.

Wahab, A.B. and Adesanya, D.A. (2011) 'Medical waste generation in hospitals and associated factors in Ibadan Metropolis, Nigeria', *Research Journal of Applied Sciences, Engineering and Technology*, Vol. 3, No. 8, pp.746–751.

World Health Organization (WHO) (2007) *WHO Core Principles for Achieving Safe and Sustainable Management of Healthcare Waste* [online] http://www.who.int/water_sanitation_health/medicalwaste/hcwprinciples/en/.

Commented [A30]: Author: Please cite the reference in the text or delete from the list if not required.

Commented [A31]: Author: Please provide the issue number and page numbers.

Commented [A32]: Author: Please cite the reference in the text or delete from the list if not required.

Commented [A33]:
(1) Author: Please confirm the year of publication whether 2014 or 2007.

(2) Author: Please provide the access details (date when the site was accessed/visited).