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INVESTIGATION OF THE FACTORS ENABLING THE DEVELOPMENT OF MEDICAL WASTE TREATMENT IN KATHMANDU, NEPAL

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ABSTRACT:
Medical waste generated from healthcare facilities (HCFs) is one of the most hazardous wastes worldwide. In the context of Kathmandu, medical waste management is found to be insufficient, because of various factors that results in mixing medical waste with the municipality waste as well as the potential negative consequences of open burning. Also, using low standards in incineration leads to Persistent Organic Pollutants (POPs) into fields, soil, and water sources thus contaminating daily consumer products such as fish, and vegetables. Notably, there is inadequate medical waste treatment facilities in Kathmandu (also entire Nepal). *The research question seeks to identify factors that enable the development of a suitable medical waste treatment facility in Kathmandu district*. The objectives include inquiry of the categories, characteristics, and volume of healthcare waste. Furthermore, the research discusses current healthcare waste management and the adoption of suitable technology.

The literature ascertain different types of medical waste, management of the medical waste, stakeholders' activities, economic factors, and capacity building in choice of technology. A background analysis of the case profile: Kathmandu, Nepal has also been provided from which secondary data has been retrieved for designing the survey questionnaire. In Kathmandu district, a total of 1 072 Health Care Facilities (HCFs), which includes both government and private centers, are registered in the government database. Nonetheless, there are several HCFs without proper registration or operating license from the government. A google form survey questionnaire was sent via emails to representatives of the HCFs and also direct phone calls were made from Finland to Nepal during the data collection periods. The findings revealed that a total of 1 072 HCFs generated approximately 11 315,55 kg/day of hazardous medical waste and 27 350,1 kg/day of non-hazardous medical waste that made a total of 38 665,65 kg/day of medical waste in Kathmandu district. Besides, other findings revealed that autoclave is the most popular technology in the area. Yet, the majority of the HCFs have not received adequate medical waste management training even once a year. The research divulges that most of the HCFs do not record any injury-related to the handling of medical waste. Surprisingly, the results showed that 75,5% of the respondents preferred a healthcare waste treatment facility and they wish to have it built outside of their healthcare unit.

In conclusion, this research recommends that: *government should establish a medical waste treatment facility in Kathmandu by having autoclave as the choice of technology*. Private sector healthcare facilities should also be involved to bring together a sustainable medical waste management system for the city as well as more medical waste treatment facilities in Nepal. There should also be strict government rules and regulations regarding medical waste management.

KEYWORDS: Medical Waste (MW), Medical Waste Management (MWM), Medical Waste Technology (MWT), Kathmandu, Nepal

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ABBREVIATIONS

ADB	Asian Development Bank
AIDS	Acquired Immune Deficiency Syndrome
BKM	Bhaktapur Municipality
CEPHED	Central for Public Health and Environmental Development
DDA	Department of Drug Administration
DoHS	Department of Health Services
DWSS	Department of Waste Supply and Sewerage
ENPHO	Environmental and Public Health Organization
EPI	Environmental Performance Index
GDP	Gross Domestic Product
GEF	Global Environment Facility
GNI	Gross National Income
GTZ	Technical Cooperation of Germany
GGHH	Global Green Healthy Hospitals
GoN	Government of Nepal
HCF	Health Care Facility
HECAF	Health Care Foundation
HMIS	Health Management Information System
HP	Health Post
HCRW	Health Care Risk Waste
HCW	Healthcare Waste
HCWH	Health Care Without Harm
HCWM	Healthcare Waste Management
HR	Human Resources
HIV	Human Immunodeficiency Virus
ICRC	International Committee of the Red Cross
LSMC	Lalitpur Sub-Metropolitan City
ISWA	International Solid Waste Association

INGO	International Non-Governmental Organization
IT	Information Technology
JICA	Japanese International Corporation
KMC	Kathmandu Metropolitan City
KRM	Kirtipur Municipality
MoEST	Ministry of Education Science and Technology
MoH	Ministry of Health
MoHP	Ministry of Health and Population
MOLD	Ministry of Local Development
MoPE	Ministry of Population and Environment
MTM	Madhyapur Thimi Municipality
MW	Medical Waste
MWM	Medical Waste Management
MWT	Medical Waste Technology
NFN	NGO-Federation of Nepal
NGO	Non-Governmental Organization
NHRC	Nepal Health Research Council
NPHF	Nepal Public Health Foundation
PET	Polyethylene Terephthalate
PHC	Primary Health Center
POP	Persistent Organic Pollutants
PVC	Polyvinyl Chloride
SARS	Severe Acute Respiratory Syndrome
SBC	Secretariat of Basel Convention
SEF	Save the Environment Foundation
SWM	Solid Waste Management
SWMRMC	Solid Waste Management and Resource Mobilization Center
SWMTSC	Solid Waste Management Technical Support Center

UDM	Urban Development Ministry
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VDC	Village Development Committee
WB	World Bank
WHO	World Health Organization

1 INTRODUCTION

1.1 Background

Approximately 2 million tons of healthcare waste is generated around the world annually (Anthony 2015). That corresponds to about 5 500 tons of healthcare waste being generated daily. On top of that, each year, globally 5,2 million people die from various waste-related diseases (Dehghani et al. 2008). Among those deaths, around 4 million are accounted for children. Furthermore, the World Health Organization (WHO) stated that nearly 16 billion injections are registered around the world every year (WHO 2018). However, not all syringes and needles are correctly separated and disposed of safely. The WHO (2018) reports that there are yearly 1,7 million, 315 000, and 33 800 cases of hepatitis B, C, and HIV infectious respectively. Wafula et al. (2019) state that healthcare waste is the second most counted and dangerously generated waste worldwide. Radiation waste comes is in the first place.

On top of that world faces from time to time some pandemic situation. Pandemics affect healthcare sectors hard which means that an additional amount of medical waste is generated. At the moment coronavirus (COVID-19) pandemic is spreading globally. COVID-19 is not only causing the death of thousands of people but also at the same time it generates both infectious, non-infectious waste and other types of municipalities waste at the same time (United Nations Environment Programme 2020).

According to the World Health Organization, there are mainly two types of medical waste; hazardous and non-hazardous waste (WHO 2018; Baaki et al. 2017; United Nations Environment Programme 2012) sometimes it also called infectious and non-infectious waste or risk and non-risk waste. Additionally, some researchers name healthcare waste as medical waste as well.

Because the population is increasing new healthcare facilities are being established daily, which leads to more healthcare waste in the current situation (Ali et.al 2017). The authors added that the waste management system is up to date in developed countries compared to developing countries. The authors emphasized that this is because developed countries have followed the proper steps of handling and managing healthcare waste such as separation, storage, transportation, and treatment and disposal of healthcare waste according to guidelines and regulations. In developing countries, the healthcare waste management handling system falls behind, because of various limitations which lead to mismanagement of hazardous waste. In practice, hazardous waste is being mixed with other non-hazardous waste. Thus, turning all non-hazardous waste to hazardous as well (Ali et. al 2017).

This research is focusing on the Kathmandu (Kathmandu district) in Nepal. Kathmandu is the capital city of Nepal. Kathmandu valley is constantly growing with 3,5% population year by year (Muzzini & Aparicio 2013). The authors describe this as the fastest-growing city in South Asia. Kathmandu valley is made of three districts Kathmandu, Lalitpur, and Bhaktapur. According to Thapa and Murayama (2010) the core factors that influence the influx of people towards the capital city are the economic and social opportunities, political situation, accessibility, facilities, land value, upgrade lifestyle, and the environment.

Kathmandu city is facing various environmental issues such as air pollution, congestion, inadequate available space, and shortage of water to name a few (Ishtiaque et al. 2017). Moreover, in 2018, the environment performance index (EPI) analysed and compared the air pollution for 180 countries (Wendling et al. 2018). According to this report, Nepal's air quality ranked in 176th place. Hence, Nepal is one of the most air polluted countries which requires an urgent solution in order to protect the environment and public health from harmful emissions.

Also, healthcare waste is becoming Nepal's most crucial challenge (Ministry of Health and Population 2014). Adding more, open burning, pit burning, and or incineration as

a common type of method using to dispose of healthcare waste. Conversely, those methods are established at a very low standard level. Yet another, the common disposal site of the healthcare facilities is a municipality disposal area for most of the 60% of the country's larger healthcare facilities. Additionally, as per the Ministry of Health and Population (MoHP) (2014), improper management of waste such as dumping waste outside the facilities into the river, roadsides, open field, or collecting the waste into municipality containers are other big challenges. Some healthcare facilities hire contractors that transport healthcare waste directly to the municipality landfill (WHO 2017a). On top of that, the WHO (2017a) states, Nepal does not have any central treatment center.

As reported by the MoHP (2014), mismanagement of healthcare waste produces various infectious diseases that hamper to both the public and the surrounding environment along with staff who are taking care of the waste. Furthermore, a common issue in Kathmandu city is that waste is not separated (Shrestha 2015) including medical healthcare waste. As stated in the Global Environment Facility (2016), a low level of incineration creates persistent organic pollutants (POPs) as it considered a chemical substance which names also bio-accumulate. These chemical substances have found their way into many consumer food products such as fish, vegetables, as well as in the field, soil, and water in Kathmandu.

Due to all of these reasons mentioned, the main aims of this research is to seek a better way of handling medical waste by identifying a suitable medical waste technology (MWT) for the establishment of a sustainable environmentally friendly medical waste treatment facility in Kathmandu district, Nepal. In order to achieve the goal, the researcher has investigated further on healthcare waste categories, characteristics, and the volume of medical waste as well as the current situation on the medical waste management system in Kathmandu.

1.2 Research gap, question, and objectives

This thesis discusses the current situation of medical waste management and the technologies that are used in medical waste management in Kathmandu.

There are a number of researches on medical waste treatment from around the world. Hong et al. (2018) explains various medical waste treatment technologies and does a comparison between them. The researchers also study how technologies impact the economy and the environment. Another, study by Pinho et al. (2015) revealed that alternative waste treatment for sterilization or disinfection could be alkaline hydrolysis treatment. Jiang (2012) has conducted a study on medical waste treatment in China and compared the situation before and after the outburst of severe acute respiratory syndrome (SARS) in 2003. Prior to epidemy medical waste was managed in a decentralized way, mostly within own healthcare premises or simply illegally disposed of. The incineration technology used by hospitals often lacked controlling devices for air pollution. The situation changed rapidly after the epidemic. Construction of about 300 facilities started soon after the epidemic with other technologies being implied as well. Prior to 2003, virtually all treatment was by incineration. In 2010 that number reduced to 50%. A few of the alternative technologies used by China include autoclave, chemical disinfection, and microwave.

However, the amount of research available on medical waste treatment in Nepal is limited. Nevertheless, a few notable studies have been conducted. Chaudhary et al. (2015) studied the present situation of biomedical waste in Nepal and emphasized the importance of the waste management system. They suggested that each healthcare facility should establish a hospital waste management committee that would take care of proper plans and policies to be put in place. The study also emphasized the importance of continuous employee training programs. Furthermore, proper waste management should also be followed by appropriate overseeing, monitoring and execution. The study also gave a short overview of the pros and cons of a few

common methods of waste treatment. Those were incineration, autoclave, microwave, chemical disinfection, and plasma pyrolysis.

Asian Development Bank (2013) states that hazardous medical waste is being sometimes mixed with municipal waste or simply illicitly dumped. According to this paper, there is no suitable waste management system in place at most of the healthcare facilities in Nepal. Sometimes it means burning the waste in the open air. Similarly, as in the study conducted by Chaudhary et al. (2015), also the Asian Development Bank (ADB) highlights that medical personnel usually do not have enough knowledge of potential risks involved with improper hazardous waste disposal. Therefore, the ADB also recommends that personnel should be trained to safely dispose of healthcare waste. Joshi et al. (2017) carried out research across Nepal on 62 healthcare facilities (HCFs) with bed capacity above 25. They found that most of Nepal's HCFs do not comply with governmental policies on medical waste treatment and disposal. That correlates with the findings of previously mentioned studies.

Overall, all the above mentioned research in Nepal is limited. They either deliberate on the importance of medical waste management or emphasize more on the effect of improper waste management on the health and environment. They do not research nor provide solutions for proper waste disposal. None of them mentioned anything about environmentally friendly centralized treatment centers.

There is very little attention paid to the topic of medical waste in Nepal even among healthcare personnel. Although some rules and regulations do exist the implementation of them is a major drawback. Singh (2014) has written about the existing waste management issue in Kathmandu and how that could be solved. In an article Singh proposed that problems could be solved by bringing a few new solutions, for instance, one suggestion was to enhance the present landfill site. Singh (2014) pointed on possible organic treatment. Furthermore, a study (Thapa & KC 2011) was done for specifically landfill sites in the various region of Nepal. With the focus put mostly on two issues, Firstly, to see if the existing rules for the management of waste have

complied with the landfill site. Secondly, concerning the classification of waste being disposed to those landfills. Their research results have shown that organic waste constitutes a major part of the waste. However, most of the research mentioned have addressed only the current situation of waste in the country and focused on the negative impact of improper waste management on society, economics, and the environment of the country. It is therefore evident that there is no sustainable treatment center either in municipality solid waste management or medical waste sector which ultimately turns waste into energy.

A few organizations have conducted research on medical waste management system and solutions in the context of Nepal, those were (Poudel et al. 2005); Save the Environment Foundation (SEF) in 2001, Environment and Public Health Organization (ENPHO) in 2000, Kathmandu Metropolitan City (KMC) in 1999, IIDS in 1997, Department of Waste Supply and Sewerage/World Health Organization (DWSS/ WHO) in 1995 and Technical Cooperation of Germany (GTZ) in 1987.

The main purpose of this research is to identify the technology for the establishment of an environmentally friendly waste treatment center with a special focus on medical waste. Below is the main set of question in order to complete this research:

What are the factors enabling the development of medical waste treatment in Kathmandu, Nepal?

The objectives of this research are as follow:

- *To find categories, characteristics, and volume of healthcare waste generated in Kathmandu, Nepal.*
- *To research the present situation of healthcare waste management in Kathmandu, Nepal.*
- *To recommend suitable technology in Kathmandu, Nepal.*

1.3 Research design

The core target is to enable the development of a medical waste treatment center in Kathmandu that generates sustainable benefits, not only to the healthcare facilities but also for the society and the environment.

The empirical part was done as a quantitative method where data was collected through a survey questionnaire. The questionnaire was created by using Google form. The survey questionnaire was sent via e-mail to all representative HCFs and in some cases, the printed paper was delivered via a third party. The direct phone call was made from Finland to Nepal when the data was collected. The primary data comes from the survey. All the secondary data are taken from various internet resources, government websites, scientific articles, and NGOs (Non-governmental organizations including both national and international NGOs).

1.4 Definitions and limitations

The intention of this section is to specify the context and meaning of each of the main keywords. These words are medical waste, medical waste management, medical waste technologies, and Kathmandu, Nepal. This is done to provide the reader with a better understanding of the author's intended meaning for those terms.

Medical waste defines all kind of waste that is generated by various healthcare facilities. It requires proper separation, handling, and collection. There are two types of medical waste; hazardous and non-hazardous waste (Kerdsuwan & Laohalidanond 2015). Examples of hazardous waste include infectious, radioactive, pathological, sharps object, cytotoxic/genotoxic, chemical, and pharmaceutical waste (Hung et al. 2012). Similarly, non-hazardous waste includes biodegradable medical waste.

Hazardous waste (infectious waste) can be defined as a type of waste that carries the risk of infecting humans and animals. This form of waste also includes any kind of waste generated while treating patients to be known to have a communicable disease (e.g. bandages, disposable medical devices, swabs) (WHO 2018).

Radioactive waste consists of radioactive substances (UNEP 2012). Radioactive materials are used e.g. in functional imaging and radiation therapy (Hung et al. 2012).

Pathological waste contains organs or fluids, animals' parts, human tissues, and human body parts removed during medical and surgical procedures (WHO 2018).

Sharps object waste includes any kind of item that can potentially puncture or cut. Usually, it means needles, syringes, knives, scalpels (WHO 2018). All sharp objects should be considered as an infectious waste as well. No matter if the sharp objects were used to treat patients with an infectious disease or not (Hung et al. 2012).

Cytotoxic/Genotoxic waste is considered being very hazardous due to its capability of producing mutations. Usually generated by the oncology and radiotherapy units of the healthcare facility. Typical sources of that kind of waste are (Hung et al. 2012), cytotoxic drugs, and chemical compounds. Also, vomit, urine, and feces from patients treated by HCFs units.

Chemical waste is defined as waste containing chemical substances. Chemicals are used commonly in HCFs and all chemicals are not considered to be hazardous. Waste is produced during laboratory work, disinfection, sterilization, photographic processing. In general, chemical waste can be classified as hazardous due to the following properties: flammable, toxic, reactive, genotoxic, or corrosive (Hung et al. 2012).

Pharmaceutical waste contains any kind of drug that is not meant to be used anymore (UNEP 2012). It can be due to it being expired, and not used in treatments anymore so on. Pharmaceutical waste is further divided into three categories: non-hazardous, potentially hazardous, and hazardous pharmaceutical waste (Hung et al. 2012).

As a limitation, this research covers only sharp objects, chemicals, and pharmaceutical waste for hazardous waste.

Non-hazardous (can be referred to as bio-degradable medical waste) is free from infectious materials and which is not harmful otherwise biologically, chemically, physically. These materials do not contain radioactive properties beyond the norm. Bio-degradable materials can be decomposed naturally in the environment. For this research, the focus will be only on such medical waste that is considered as physically or chemically biodegradable.

Medical waste management is defined as a process that minimizes and manages the healthcare waste at the source by providing the proper training for both medical and non-medical employees (Jovanovic et al. 2016). The various elements are involving medical waste management such as medical waste generation, medical waste characteristics, and classification, handling, separation, collection and storage, transportation, labeling, treatment, and disposal (Hung et al. 2012) as well as the government policy and guidelines.

Medical waste technologies describe the various type of processes and technologies that are used in medical waste treatment to minimizes and destroy pathogenic waste. The following are the processes and technologies that are used in medical waste treatment: thermal, chemical, biological, irradiative, and mechanical processes. The research will focus only on thermal and chemical processes as a limitation. The thermal process covered microwave, autoclave, and incineration. In the chemical process, various chemical substances will be discussed.

Thermal processes are a very common uses process around the world (UNEP 2012) which uses low to high heat technologies. Some examples of the thermal process; autoclaves, retorts, microwaves reverse polymerization, thermal depolymerization, incineration, and plasma pyrolysis (Datta et al. 2018; Health Care Without Harm 2004).

This research focuses on a summary of low, medium, and high heat thermal processes and technologies.

Chemical processes are used mostly on liquid medical waste such as the hospital's wastewater, blood, stools, or urine to name a few. This is done in order to destroy or minimize the disease in liquid medical waste (Hung et al. 2012).

Biological processes are used to destroy organic waste using biological enzymes to speed up the process (UNEP 2012). The burial of waste is an additional natural process. Most of the healthcare kitchen waste and other organic waste is managed by a biological process (UNEP 2012). The biological process is a non-burn process (Health Care Without Harm 2004).

Kathmandu is the capital city of Nepal. Nepal is a country located between India and China. The research shortly describes the country profile such as history, politics, population, area, and gross domestic product (GDP). Also, on Nepal's medical waste policy and regulations. However, as a limitation, the research will focus on only the Kathmandu (Kathmandu District), Nepal.

1.5 Structure of the thesis

Chapter one includes a brief introduction to medical waste treatment with a focus on Kathmandu. After considering the general gap that is in the medical waste treatment area, it presents the research question and objectives along with defining keywords while highlighting the limitations of this thesis.

Chapter two provides a profile of Kathmandu, Nepal. It includes a short background of the country where history and economic landscape is described. Also, the second chapter addressed policy, rules, and regulations on medical waste management in Nepal. After that, the chapter focuses on medical waste management and types

of medical waste in Kathmandu. Finally, the chapter provides the existing parties involved in medical waste management in Kathmandu.

Chapter three is about the literature review. This chapter describes the medical waste management around the world. The third chapter includes the types and characteristics of medical waste and how these are handled utilizing some processes and technologies. The chapter has a further emphasis on economic considerations and capacity building in the choice of technology. At last, the literature would end with a summary of the theoretical framework.

The fourth chapter is the empirical part of the research methodology. This chapter tells about the data collection process, challenges during the data collection periods, and data analysis. The data analysis narrates an overview of Nepal's medical waste treatment with specific emphasis on the Kathmandu. Also, the chapter describes the research reliability and validity of the research methodology process.

Chapter five is the last section of the thesis where summary and conclusions are drawn and presented along with key research findings, recommendations, and research limitations. Additionally, the fifth chapter advises on future research directions.

2 PROFILE: KATHMANDU, NEPAL

2.1 History and economic landscape of Nepal

Nepal is a landlocked country located between India and China. It borders China in the north and India to the south, west, and east. It has an area of 147 181 km^2. According to BBC (2018), the total population of Nepal is 31 million.

Geographically, Nepal is divided into three main zones: The mountains in the north, the Hills in the middle, and Tarai in the south (also known as lowland). Since the introduction of the new constitution, Nepal has been divided into 7 provinces and further subdivided into 77 districts, since 20th September 2015 (figure 1). Kathmandu is one of the districts and it is also the capital city of Nepal. The headquarters of Kathmandu district is called Kathmandu Metropolitan City (KMC). Kathmandu is a part of Kathmandu Valley which is made of three districts including Kathmandu, Lalitpur, and Bhaktapur (figure 2) which covers a total of 570 km^2 area that includes a population of 2,5 million (Urban Pathways n.d.). Out of this population, 1 million population live in Kathmandu. According to Urban Pathways (n.d.), the unofficial population in the valley could be about 3,5 million because of the annual growth rate in the valley is 4,63%. Kathmandu valley has a total of five main municipalities: Kathmandu Metropolitan City (KMC), Kirtipur Municipality (KRM), Lalitpur Sub-Metropolitan City (LSMC), Bhaktapur Municipality (BKM) and Madhyapur Thimi Municipality (MTM) (Government of Nepal & Japan International Cooperation Agency 2005).

Kathmandu valley is surrounded by four mountains: Phulchowki, Shivapuri, Nagarjun, and Chandragiri made as a bowl-shaped standing with a high of 1 400m. Nepal has 293, 6, and 11 are municipalities, metropolises, and sub-metropolises respectively (Kathmandu Post 2018). Nepal has the world's eighth highest mountains including Mount Everest (8 848 meters) which is also known as Sagarmatha or Chomolungma.

The Seti, Karnali, Mahakali, Koshi Gandaki, and Mechi are the significant rivers in the country. Nepal is the birthplace of Lord Gautama Buddha as well. According to the 2011 census the registered mother-tongue languages are about 123 in Nepal (World Bank Group 2018) and the majority in Hindu.

In figure 1 a map of Nepal is shown which divides the country into seven provinces and 77 districts where Kathmandu belongs to province number three. Similarly, the map in figure 2 demonstrates the Kathmandu district along with neighbouring districts.

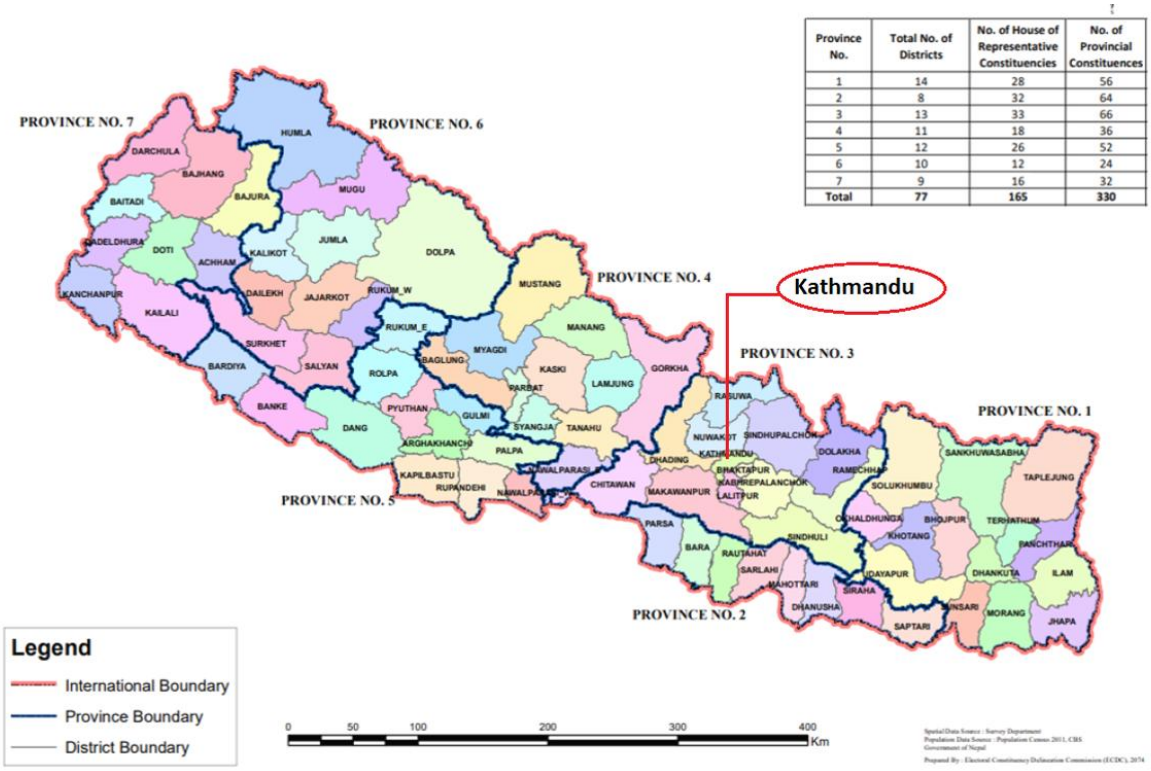


Figure 1. Map of Nepal with 7 provinces and 77 districts. Source: election.gov.np.

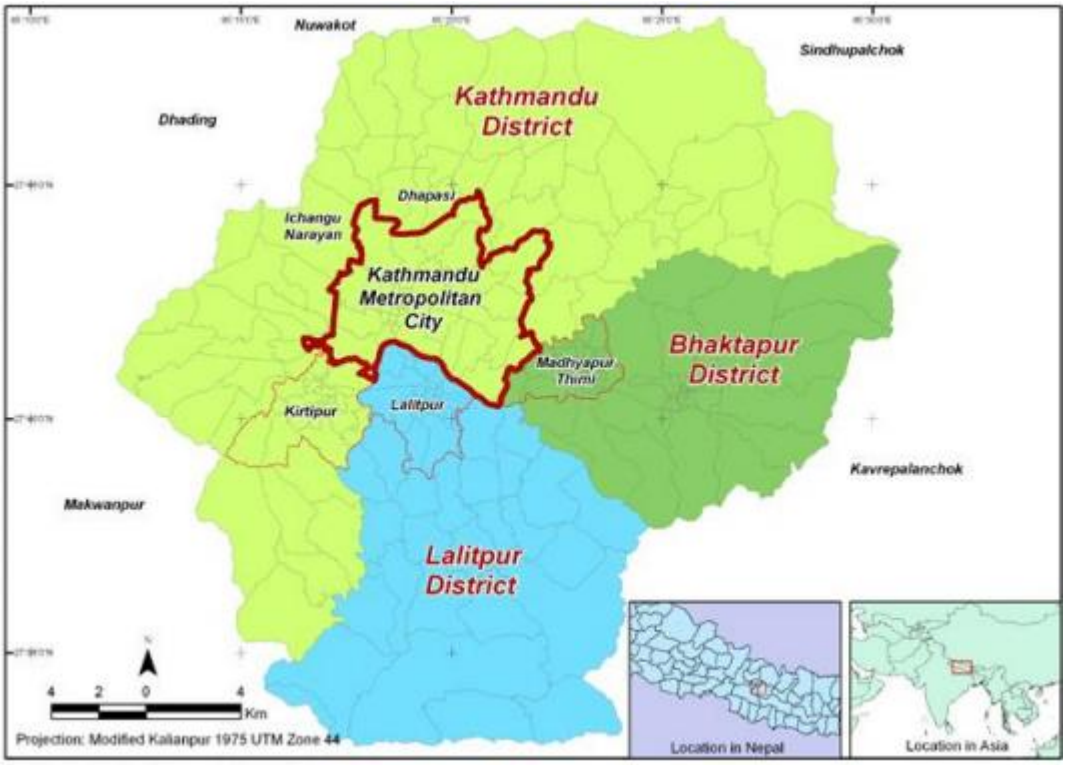


Figure 2. Map of Kathmandu District. Source: UDM 2015

In May 2008 Nepal's 240-year-old monarchy ended. Currently, Nepal is a Federal Democratic Republic (Government of Nepal n.d.). When the monarchy ended Nepal got its first President who is the head of the nation and the Prime Minister is leading the government.

Nepal’s main income originates from agriculture, which stands for almost 32 percent of the Gross Domestic Product (GDP) (Manandhar 2010). Table 1 presents an overview of the economic status of Nepal over five years periods from 2013 to 2018. This stable includes the population, GDP, Gross National Income (GNI), consumer index, and remittance income.

Table 1. Overview of Nepal's economic status.

Particulars	2013/14	2014/15	2015/16	2016/17	2017/18*
Population (million)	27.6	28	28.3	28.7	29.1
GDP (billion NPR, at current price)	1,965	2,130	2,253	2,642	3,007
GDP (at current price) growth rate (%)	15.9	8.4	5.8	17.3	13.8
GDP per Capita (USD)	725	766	748	866	1,004
GDP (At basic prices) (NPR Billion)	674	694	695	747	791
GNI per Capita (USD)	737	778	759	877	1012
Consumer Price Index (CPI) (%)	9.1	7.2	9.9	4.5	6.0
FDI net inflows (million USD)	30.4	51.9	55.8		
Remittance Income (In Billion NPR)	543	617	665	695	730
USD NPR Exchange Rate (Period Avg)	98.3	99.5	106.4	106.2	104.1

Source: Reanda Biz Serve 2019

Medical waste in Nepal

There is not much information available regarding healthcare waste management practices in Nepal. The WHO (2017a) mentioned that the "Health Care Waste Management Guideline 2014" has established as a country policy for the healthcare waste sector to manage and implement waste management according to the guidelines. However, only very few HCFs are implementing the guideline and separating their waste at the point of generating. In the current situation most of the HCFs (both government and private) are mixing their healthcare waste into municipality solid waste (Joshi 2013; Health Care Without Harm 2012). As per Joshi (2013), the majority of the cases, sweepers are transporting healthcare waste directly via plastic bags or waste bins containers to the deposit center. Only a few large HCFs use a trolley to transfer their waste.

According to WHO (2017a), the public does not have access to view the information regarding how much the health care waste is generated from each health care facility in Nepal. To take the data from each health care facility in the country, it is done by a direct visit to the hospital's facility. The ministry of health (MoH) and the department of health service (DoHS) are the main responsibility agency for taking care of the survey for HCFs in Nepal (WHO 2017a).

About 36 735 kg of medical waste is generated daily in Nepal (WHO 2017a). According to WHO there is generated about 1,35kg/person/day of health care waste. This amount was received from a survey done by the Ministry of Health in 2015. As per the United Nations Development Programme (UNDP), Nepal (2017), from a total of 274 hospitals, per year, hazardous and non-hazardous waste is generated 3 094 and 10 520 tons respectively.

Table 2 provides an overview of the healthcare facilities (HCFs) in Nepal that includes both bedded and non-bedded facilities.

Table 2. Overview of the healthcare facilities in Nepal.

Total number of health-care facilities in the country	5290
Government (all ministries) bedded and non-bedded	4122
Central hospitals (central, teaching and specialized)	16
Regional /zonal hospitals	16
District-level hospitals	84
Primary health care centers	201
Health posts	3805
Private (all health-care facilities)	1168
Total number of beds government (all ministries)	
Central hospitals	4229 beds
Regional hospitals	350 beds
Sub-regional hospitals	200 beds
Zonal hospitals	1494 beds
District-level hospitals	1802 beds
Medical colleges	5776 beds
Private	13360 beds
Total	27211 beds

Source: Adapted from WHO 2017a

The administration system of medical waste in Nepal

All the following health care activities: logistics, training, and administrative section are taken care of by the ministry of health and the department of health services (MoH 2004). The ministry of health is controlling all the central hospitals in Nepal (WHO 2017a). Correspondingly, in the village area, the initial access for health check-up point is the health post (HP) and primary health centers (PHC). District hospitals are taking

care of district-level health care which usually has 25 beds. All the health care facilities should have an environmental impact assessment (EIA) license if they are going to have more than 25 beds and if they generate radioactive and hazardous waste as stated in the environment protection rules 2054 (1997) (WHO 2017a).

2.2 Policy and regulation of medical waste in Nepal

Policy and regulation are playing a vital role in the management of medical waste in the country. Nepal has a Health Care Waste Management Guideline 2014 (WHO 2017a). There is also some type of policy for hazardous waste (Manandhar 2010). The Solid Waste Management Act of 2011 and the Solid Waste Management Regulation of 2013 which are made by the Government of Nepal, are the main supportive and relevant rules and regulations for the medical waste management sector (United Nations Development Programme 2017). Nepal does not have any training or guideline materials in case of emergency handling of healthcare waste and there is neither no mentioning of building quarantine places for disease control (WHO 2017a).

The ministry of health, ministry of federal affairs, local development, the ministry of population and environment (MoPE), the district public/health office, the regional health directorate office, village development committee (VDC), and municipality are the representative responsible persons to implementation the medical waste rules from their sectors (WHO 2017a).

The Health Care Waste Management Guidelines 2014 is providing guides and supporting all levels of health care facilities in Nepal to manage their waste systematically. There is no directly primary organization or department which is responsible for taking care of healthcare waste (Manandhar 2010). However, based on the Environmental Protection Act 1997, assigned the ministry of education science and technology (MOEST) to take care of health care waste (Manandhar 2010).

As per MoHP (2014), there are eight most existing national acts, policies, and regulations on the healthcare waste management (HCWM) sector. For more details on the legal documents, the information can be found from the secondary data; Health Care Waste Management Guideline 2014 (MoHP 2014), health care waste management practice in Nepal (Joshi 2013), and hazardous waste policy study in Nepal (Manandhar 2010). Next, some of the acts, policies, laws, and regulations will be shortly mentioned.

Solid Waste Management Act 2011 states about the HCWM regulations and legal information. The act discusses the hazardous waste at the local level and various punishment of not managing the waste in a proper way. The Environment Protection Act of 1997 and the Environment Protection Rules of 1997 dictates on the protection of the environment and emphasizes the permission which should be granted by the government in case industries open that are related to either chemicals or drugs. Yet, the overview of the various types of healthcare waste, classification, and way of handling the process have been stated on the Health Care Waste Management Guidelines 2008/2009. The Labor Act 1992, described the importance of a safe working environment for both workers and employees by using the appropriate protective gear. Additionally, the Solid Waste Management Rules, 2013 (2070 BS), Solid Waste Management Act, 2011 (2068 BS), Environment Protection Act, 1997 (2053 BS), Environment Protection Rules, 1998 (2054 BS) and Local Self-Governance Act, 1999 (2055 BS) are the Solid Waste Management Rules and Regulations for KMC and Solid Waste Management Technical Support Center (SWMTSC) (Urban Development Ministry 2015; MoHP 2014; Joshi 2013).

2.3 Medical waste management in Kathmandu

In Kathmandu district, a total of 1 072 various types of government and private healthcare facilities are registered on the government system as per table 3 (GoN - Health Management Information System 2019). Out of them, 123 are government, and 949 are privately owned healthcare facilities. In addition to this, it is estimated that

there could be still more healthcare facilities in function without a proper license in Kathmandu (Poudel 2019). Apart from this, the number of new HCFs are being opened all the time in Kathmandu. At the same pace, both hazardous and non-hazardous waste is being generated and increased from these healthcare facilities each day. Most of these healthcare facilities are still not handling the proper waste management system such as separation, collection and storage, transportation, treatment, and final disposal (MoHP 2014). Based on a survey, conducted by ENPHO, Kathmandu city produces daily one ton of estimated hazardous healthcare waste (Majumder et al. 2007).

Table 3. Total HCFs in Kathmandu district including both government and private HCFs.

Government healthcare facilities	
Healthcare facility types	**Total numbers**
General hospital	5
Urban health center	37
Health post	58
Primary health center	8
Institutional clinic	4
Specialized hospital	4
Laboratory	1
Other health facility	1
Teaching hospital	1
Central hospital	4
Total	**123**
Private healthcare facilities	
Healthcare facility types	**Total number**
Poly clinic	161
General hospital	76
Medical center	103
Specialized hospital	21
Other health facility	68

Teaching hospital	4
Health clinic	42
Diagnostic center	90
Dental clinic	205
NGO	12
Eye clinic	14
Laboratory	17
Nursing home	3
Medical clinic	79
Health center	51
Radiology	2
Aayurbed health clinic	1
Total	**949**

Source: Government of Nepal, Health Management Information System 2019

The government HCFs are operating with a non-profit purpose and provide the service to the country people and non-public HCFs are mostly for-profit purposes.

Dahal (2019) states that only non-hazardous waste is picked up from various HCFs such as medical shops, medical laboratories, hospitals, clinics, and household waste by Metrocity Waste Management. Nevertheless, they have found that the body parts have been mixed with general waste as well. The government sector requires healthcare facilities to disinfect healthcare waste by using the autoclave before its disposal (Poudel 2019). It also shows that some hospitals are having an agreement for collecting healthcare waste with the Kathmandu Metropolitan (Poudel 2019). The Kathmandu Municipality is officially responsible for collecting all non-hazardous (non-risk/harm) healthcare waste from healthcare facilities (WHO 2017a). Whereas any hazardous waste should be handled by healthcare facilities themselves. However, hidden private healthcare facilities in growing numbers are being operated without proper government permission. It has also been acknowledged that sometimes drug abusers are entering to the hospital premises to take items such as empty blood bags,

used syringes and saline bottles (Poudel 2019). These activities lead to the spread of various infectious diseases to the environment and are dangerous to public health. Each healthcare facility should be guarded and provided a safeguarding system at the entrance to prevent trespassing.

Kathmandu district along with other surrounding districts have only one waste collection and transfer station called Teku. From that waste is transferred to the Sisdol landfill located about 28 km away from Kathmandu (Environmental Management Centre 2007). It is reported that the Sisdol landfill is already running out of space (Lorch 2014). The government is already looking for an alternative solution for it. However, still, after many years ongoing Kathmandu along with Lalitpur, Bhaktapur, Kakani, and Banepa is disposing of their municipality waste of about 1 000 tons each day to Sisdol landfill (Rasaili 2019). Figure 3 shows the current condition of the waste transfer center Teku in Kathmandu. Also, figure 4 represents the roadside condition where waste was disposed of in Kathmandu, Nepal.

Figure 3. Municipality waste transfer center Teku, Kathmandu Nepal. Source: Menju 2019

Figure 4. Bridge side waste disposal view in Teku, Kathmandu, Nepal. Source: Menju 2019

In contrast, in the current context, many improvements steps have started such as 4R (reduce, reuse, recycle, and recover) principle. The principle and color-coding system have been taken into consideration by most of the healthcare facilities in Kathamndu (Dahal 2019). There is still a lack of enough practical knowledge of handling waste management with the health care staff (Health Care Foundation 2011). Besides, the government of Nepal has enforced those up running healthcare facilities who do not have a waste management system to upgrade their system. Otherwise, the ministry of health and the population will not give further permission for their operation (Development of Bureau 2014). Moreover, the government has made a law that all hospitals should meet the written standards otherwise hospitals license will not be issued to the HCFs (Himalayan News Service 2012). As per the healthcare waste management guideline, 2014 (MoHP 2014) below highlighted points are addressed for the appropriate healthcare waste management where the current situation has also described shortly:

Waste minimization: Waste minimization is a step to prevent or reduce waste as much as possible. The 4R principles (reduce, reuse, recycle, and recovery) could be the best choice of reducing healthcare waste in the context of Nepal (Manandhar 2010). According to Manandhar, all HCFs should implement the 4R principles. This means the replacement of process and methods, changing the practices in a way of working

or using more reusable and recyclable items. Presently the waste minimization concept is rising slowly among healthcare facilities.

Waste separation: In the present situation, most of the healthcare facilities are mixing all types of infectious and non-infectious waste and disposal to landfill directly (Chaudhary et al. 2015). Also, the various types of waste are treated together in the end even if the waste was separated at the waste origination (Onta et al. 2007). As per the ministry of health and population (2014), it is highly emphasized that all generated waste should be separated into different labeling color code bins. The color coding bins can be varied in each health care facility since there is no standardization of applying it (MoHP 2014). In this case, it is possible to use in different containers bins with correct visible hazardous signs and labeling. Despite this NGOs are inclined to make the standardize color-coding bins to all healthcare facilities. Figure 5 presents one example of healthcare waste separation at the Nepalese Army Hospital in Kathmandu by using the various color code labeling bins as their waste separation process.

Figure 5. Waste separation system at Shree Birendra Army Hospital (Nepalese Military Hospital), Kathmandu, Nepal. Source: Menju 2019

Waste collection and storage: The collection of health care waste (HCW) should be done each day. Hazardous and bio-degradable waste should only be held less than 24 hours (MoHP 2014). Most of the healthcare facilities even do not have own permanent storage place. Most of them are sending the HCW to the temporary storage places. Unfortunately, those are built either close to water supplies, within the healthcare area or near the municipality waste collection area for households (Joshi 2013).

Waste transportation: Waste transportation should be done in an efficient way so that no one can get infected. According to Onta et al. (2007) on-site transport is still done by the traditional way of working like manual carrying the waste without any trolley, wheeled containers nor carts support. For off-site transportation, the municipal must collect the non-risk healthcare waste from the healthcare facilities and transport to the municipality solid waste (WHO 2017a). Under current circumstances, hospitals should separate risk and non-risk generated waste before it is sent to the municipality. The WHO (2017a) claims that it often leads to mixing all types of waste because there is no stringent monitoring system. Conversely, some private companies have established to collect healthcare waste, but hospitals are not having to afford to contract them, and consequently dump their waste to municipal sites. The WHO (2017a) also states that some private companies illegally collect healthcare waste (HCW) and dump into the landfill.

Waste treatment and disposal: Waste treatment and disposal can vary from one healthcare facility to another (MoHP 2014). The local authority is obligated to pick up and safely dispose non-risk healthcare waste that is about 85% of total healthcare waste (WHO 2017a; Chaudhary et al. 2015). The WHO (2017a) urges that 15% of the waste that is hazardous should be taken care of by the healthcare facilities themselves. Primarily, there are no central treatment facilities, due to this most of the HCFs have built incineration within their healthcare premises increases costs for the individual HCFs (WHO 2017a). Apart from this, the systems are running without any proper observation sets for harmful emissions. The disposal methods of healthcare waste

either simply done by using the local hand made single-chambered incineration, sent to the municipality, or open burning. However, some of the HCFs recycle their medical waste products and disinfect before it sends the waste to a municipal landfill. However, that is only those who have a proper HCWM system (WHO 2017a).

Further, as per MoHP (2014), it is said that the following processes and technologies could be used in order to treat and dispose of medical waste in the context of Nepal. They are incineration, chemical disinfection, biological procedure, encapsulation, sanitary landfill, burial, septic/concrete vault, and Inertization. The biological procedure is used to treat biodegradable waste. Encapsulation methods used mostly to treat pharmaceutical and sharp objects waste.

Chemical disinfection: Healthcare facilities have received the instruction of how to use disinfection by the government and usually a 0,5% chlorine solution is applying in the hospitals. The common disinfection solution used by most of the hospitals is sodium hypochlorite and glutaraldehyde to disinfect surgical material (WHO 2017a).

Encapsulation: One of the hazardous waste disposal methods is encapsulation where containers are filled with waste along with an immobilizing material. Either cubic boxes of high-density polyethylene or metallic drums are employed in the process. Three-quarters is filled with sharps, chemical or pharmaceutical residues, or incinerator ash. The rest is filled up with a medium such as plastic foam, lime, cement mortar, bituminous sand, and or clay (MoHP 2014). The encapsulation process deters the unwanted garbage pickers to gain access to hazardous waste. (MoHP 2014).

Sanitary landfill: The sanitary landfill is modeled and built in a way that the waste does not expose to the Environment. Hence, soil, water surface, and groundwater should not be contaminated. Furthermore, the process should also limit air pollution, odour, and direct contact with people (MoHP 2014). The small amount of pharmaceutical and infectious healthcare waste is also permitted for this kind of process. As per the MoHP guideline, there are also procedures to follow before the sanitary landfill can be built.

Burial: A special pit can be made to bury healthcare hazardous waste. The burial process is more useful in those healthcare facilities where there is very limited access to healthcare waste management systems such as in temporary refugee camps or remote areas. The standard size of the bit is 2-5 m deep and 1-2 m wide (MoHP 2014).

Septic/concrete vault: This process is useful mostly particularly for syringes and sharp objects (MoHP 2014). The Healthcare Waste Management Guideline 2014 has written how to build a septic/concrete vault.

Presently, at least a few hospitals in Kathmandu are already making progress to their waste management handling system. The hospitals have been cooperating with various other national and international non-government organizations (NGOs) along the government to bring sustainable healthcare waste management to their healthcare facilities. NGOs are supporting and improving the current conditions and helping to bring the standard level of medical waste management system not only in Kathmandu but also in national wide. Some level of implementation has been seen in some hospitals e.g. Bir Hospital, the nation's oldest and biggest government hospital, that is located in the heart of Kathmandu. Bir Hospital has separate colorful containers for various types of waste such as hazardous, biodegradable, non-biodegradable, and degradable waste. Needles and syringes destroying machines have been placed in each ward. Hospital waste is being treated and disposed of on its premises within 24 hours and almost 34 percent of the total waste is being recycled (Health Care Foundation 2011). Bir Hospital has already been announced free of mercury. At the moment, Bir Hospital is being recognized as a model hospital among all other healthcare facilities in Kathmandu. Interestingly, other hospitals such as Civil Service Hospital, Shahid Gangalal National Heart Centre, Teaching hospital, and many more are also applying the healthcare waste management system (MoPH 2014). Nepal has banned the use and purchase of any mercury-containing devices in all healthcare facilities according to the Department of Health Services (2014) Instead, they should use other replacement devices. There is yet inadequate resources, coordination, method, and technologies (MoHP 2014) along with written specifications to treat medical waste.

There are various types of healthcare facilities that might not be necessary to require the same practices.

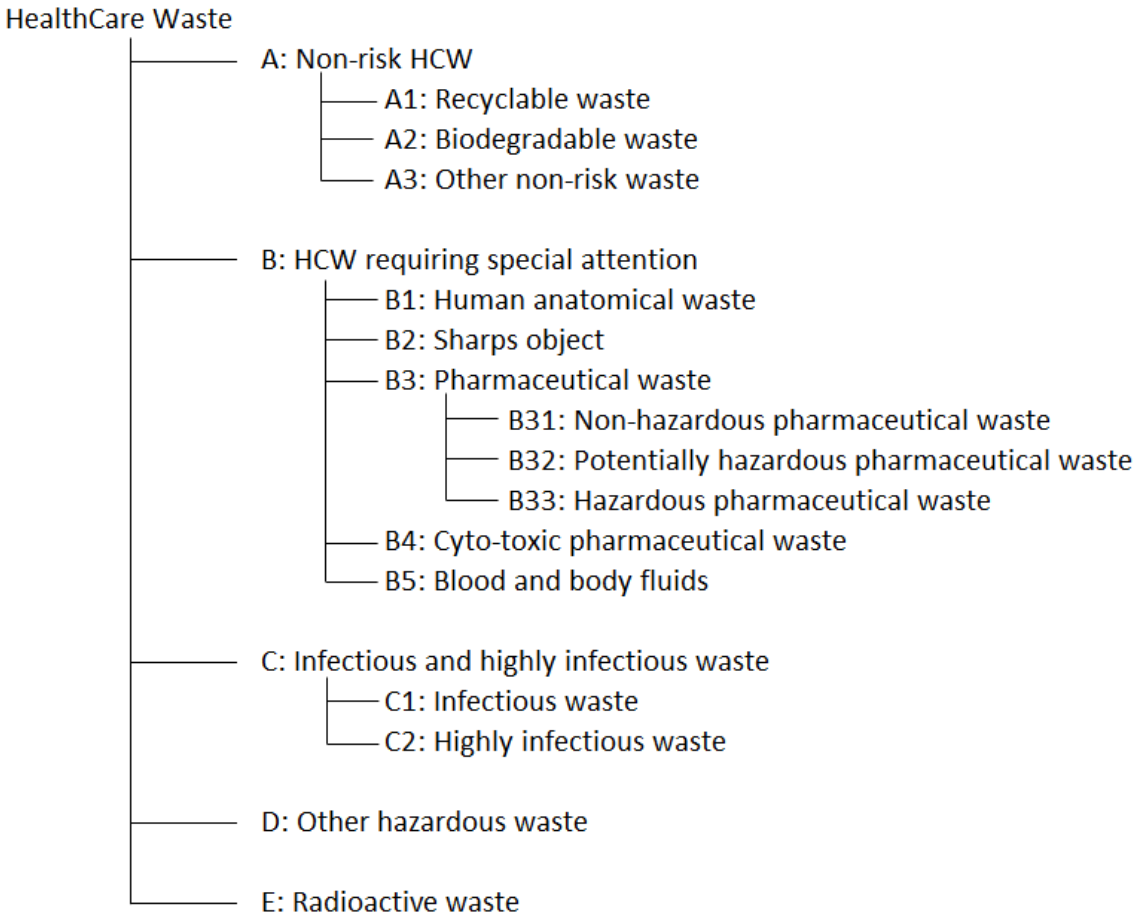
2.4 Types of medical waste in Kathmandu

According to the Ministry of Health and Population (2014), there are mainly two types of healthcare waste categorization: non-risk healthcare waste and risk health care waste. Non-risk (non-hazardous) healthcare waste has divided into two sub-group: bio-degradable and non-biodegradable. Correspondingly, risk (hazardous) HCW has been divided into six categories: pathological, sharp objects, infectious, cytotoxic, pharmaceutical waste, and other hazardous waste.

Further, MoHP (2014) and Joshi (2013) emphasizes that the standards approach for healthcare waste types and categories is to follow the standards from the United Nations Environment Programme / Secretariat of Basel Convention / World Health Organization (UNEP/SBC/WHO) standards which have divided healthcare waste into five main categories as shown in table 4.

Albeit, in the current context of Nepal, it has been recognized that it will be more complex if waste needs to be separated and managed based on UNEP/SBC/WHO standards (MoHP 2014). Because of HCWM practices in Kathmandu as well as the whole of Nepal, it is still in the very early stage of development. However, on the other hand, it is recommended to separate the waste according to standards as per table 4 as much as possible.

Table 4. Healthcare waste separation based on UNEP/SBC/WHO.



Source: Adapted from Joshi 2013

Non-risk healthcare waste: It includes biodegradable and non-biodegradable waste (MoHP 2014). Biodegradable waste is that type of waste that can be easily decomposed by biological processes or breaks down naturally and almost 25% of the total healthcare waste is biodegradable waste (Bharadwaj et al. 2015; HCWH n.d.). Since healthcare facilities produce a large amount of biodegradable waste many healthcare approach biogas plants in Kathmandu. Bir Hospital in Kathmandu used biogas plants to convert their biodegradable waste into energy, which was consumed for cooking foods and lighting purposes (Dahal 2019) until the earthquake in 2015. Similarly, some private hospitals e.g. Norvic International Hospital in Kathmandu has initiated a bio digestion plant to manage the pathological waste along with the hospital biodegradable waste (Global Green and Healthy Hospitals n.d.). However, in the long-term, pit dumping

biodegradable waste is not good because it affects the underground water system (Dahal 2019) which mentioned by HECAF director.

Non-biodegradable waste is a waste that cannot be decomposed. Recyclable waste is under the non-biodegradable waste. This kind of recyclable is saline bottles, syringes, masks, gauze and gloves, and cotton and they are counted at first risk waste. However, those could be a non-risk waste after sterilizing with the autoclave system before sending or selling them out (MoHP 2014).

Risk healthcare waste or infectious waste as follows:

Human anatomical waste: Human anatomical waste includes human body parts, tissues, organs, and unused blood products (WHO 2011). The anatomical waste is part of the pathological waste. The biological process has introduced to treat the pathological waste in the context of Nepal (WHO 2017a).

Sharp objects waste: Sharp objects waste includes needles, syringes, sharp tools, or knife in the healthcare facilities. Some HCFs are taking care of their sharp objects waste by separating the needle and encapsulate them as disposal methods (WHO 2017a). Also, some HCFs first disinfect sharp objects and send them for recycling purposes. On the other hand, the open burning and dumping system are considered as common practices of treatment and disposal of the waste (Onte et al. 2007). The authors add that without disinfection, sharps objects waste is disposed of either into the toilet or into the drainage system. Surprisingly, a large number of syringes are reused and commonly sold, while these syringes are supposed to be discarded (Uddin et al. 2017). By not mixing the infectious sharp objects with other waste would lead to less diseases and clean the environment (Chaudhary et al. 2015).

Pharmaceutical waste: Pharmaceutical waste is containing all kinds of expired medicines or medicines that are no longer in use. Nepal also does not have any official government guidelines to manage pharmaceutical waste (Paudel et al. 2019).

The author indicates that the Department of Drug Administration (DDA) in September 2017 proposed a preliminary draft for pharmaceutical waste management to target the pharmacy standard. However, the implementation part will take longer. The increasing new number of pharmacies from the private sectors, with some pharmacies being without registration, makes pharmaceutical waste more difficult to monitor and manage. There should be law from DDA to monitor and give permission to only those who meet the standard criteria for selling the products (Paudel et al. 2019). The HCWM guideline advises to dispose of the pharmaceutical waste by encapsulation methods or returns them to the supplier (MoHP 2014; WHO 2017a). With inadequate education, training, waste separation, color coding, and disposal pharmaceutical waste is hard to manage (Paudel et al. 2019). That means the pharmacies approach to open burning or sending the waste to municipality waste.

Cytotoxic waste: The waste that contains genotoxic properties called cytotoxic waste and also cytotoxic drugs used for cancer treatment (WHO 2018). Cytotoxic waste is emphasized also on the management of the pharmaceutical waste guideline which is developed through coordinating and cooperating between the WHO and the DDA (WHO 2017a).

Radioactive waste: All the materials that contain radionuclides substances is called radioactive waste (WHO 2017a). The materials could be solid, liquid, and gaseous e.g. liquid from laboratory research or radiotherapy, urine, sealed sources (WHO 2017a; UNEP 2012).

Chemical waste: Film developer, expired disinfectants, laboratory reagents are an example of chemical waste (WHO 2017b). By applying the waste minimization approach the chemical waste could be managed in a proper way such as substituting harmful chemicals with non-harmful products (UNEP 2012).

2.5 Existing parties involved in medical waste management in Kathmandu

The total registered Non-government organizations in Nepal during periods from 1977 to 2014 was 39 759 (Karkee & Comfort 2016). Over those periods, there were 189 of international non-governmental organizations (INGOs) from 26 different countries that have enrolled in Nepal to support in numerous sectors. Nevertheless, it is estimated that there are active NGOs and INGO which are 875 and 57 respectively (Nepal Public Health Foundation 2017). Among them WHO is the most known organization for Nepal and WHO is primarily supporting the health care waste management system (WHO 2017a). Other organizations are also playing the vital role to achieve the long-term sustainable goal in health care sectors such as Nepal Public Health Foundation (NPHF), Health Research and Social Development Forum (HERD), Nepal Health Research Council (NHRC), NGO-Federation of Nepal (NFN) and New ERA (Nepal Public Health Foundation 2017).

Table 5 presents some of the existing parties from the government, NGOs (national and international), and private sectors that are involving directly or indirectly in medical waste management along with municipalities waste in Kathmandu. As per secondary data, it shows that a big part of the healthcare waste is disposing to the municipality waste, and there are no specific assigned parties only for healthcare waste. Table 5 gives an overview of those parties involved in handling the waste of Kathmandu.

Private companies are mainly targeted to earn money from their services. It might happen that some private companies are not obeying the rules and regulations and are only following the minimum requirement that the government policy allows them. On the other hand, NGOs are non-profit organizations and work without any benefits purpose. Their main target is to help communities in various ways. They are helping to make the guidelines, policies, and establishing and upgrading the medical waste management system if necessary, with the cooperation of the government of Nepal. The government healthcare facilities provide the public with a minimum fee for the healthcare service.

Table 5. Involving parties (government, NGOs, and private companies) in medical waste management (MWM).

Involving parties (Ministries /NGOs/Private Companies)	**Functions**
Ministry of Local Development (MOLD)	Providing suitable landfills to dispose of waste from various cities.
Ministry of Kathmandu	Charge of medical waste management sector as well.
Nepal Health Research Council (NHRC)	Collaborating with WHO and published the health care waste management related documents. Also, published National Health Care Waste Management Guidelines in 2002 May.
Central for Public Health and Environmental Development (CEPHED)	Collaborating with WHO, focus on improving the public health and environment, mercury-free target to the entire country.
Health Care Foundation (HECAF)	Primarily taking care of healthcare waste management, support to install non-incineration technology, developed and implemented the health care waste management program to all levels of the health care facilities local to national wide, support sharp waste handling, autoclaving system and recycling process from health care.
Health Care Without Harm (HCWH)	Collaborating with various international organizations for supporting a better environment, health care, and reducing pollution. The main function is to establish the sustainable health care waste management system, replacement of mercury and other toxic chemicals, provide the technical support to HECAF for various health care waste activities.
Global Green and Healthy Hospitals (GGHH)	GGHH is a project of HCWH, to reduce the carbon from the environment, minimize the waste, and produce the energy from it.
World Health Organization (WHO)	Collaborating with the government of Nepal, providing the needs support, tools and direction to the national government, WHO is the main pillar for developing health care management by involving, encouraging and cooperating with various related institutions, parties, research, development and testing the new technologies as well as water consumer in the building, sanitation, environment impact, and hygiene. Also, the mercury-free zone is the main target for the organization.
Technical Cooperation of Germany (GTZ)	Supporting big projects in Nepal along with solid waste management, involving various projects more than in 60 districts across Nepal.
Japanese International Corporation (JICA)	Supporting big projects in Nepal along with solid waste management, run Sisdol landfill site, established the incinerator at Kathmandu teaching hospital, provide the funds to health post facilities for health care waste management system.

Asian Development Bank (ADB)	International financial support for the various sector in Nepal as well as in medical waste management projects. ADB has confirmed in Nepal for $592 million for a total of five projects in 2018 and $8,01million of technical assistance involving co-financing for $5,31 million which were loans and grants.
World Bank (WB)	International financial support for the various sector in Nepal as well as in medical waste management projects.
Nepwaste Pvt Ltd	Managing the solid waste in KMC along with 10 municipalities, joint venture of Finnish Compunication Oy, and Nepal's Organic Village. The company plan is to establish the landfill site to manage the various waste included hospital waste etc.
Clean Valley Company Pvt Ltd	A joint venture of Greenfield Waste Management Company, Kryss International, and BVG, mostly working for village development committees including other towns, associated with 2 million Nepalese Rupee investment with ISWMP (Integrated Solid Waste Management Project) KMC's pilot project.

Source: ADB 2019 Hakahaki 2018; WHO 2017; Chikanbanjar 2017; Himalayan news service 2016; Subedi 2016; WHO 2014; WHO 2011; HECAF 2011; MoH 2004 & CEPHED n.d.

3 LITERATURE REVIEW IN MEDICAL WASTE MANAGEMENT

This section gives an overview of information on the medical waste management sector and has been conducted by various researchers. The focus in this section is to explain the several types and characteristics of medical waste. This section will explain how medical waste is being treated by applying different processes and technologies around the world. Additionally, the section describes economic consideration and capacity building while choosing suitable technology. Furthermore, the final part is to summarize the theoretical framework.

To complete this chapter the required information has been obtained from various existing resources such as the government, NGOs' official websites, books, scientific journals, articles, online news, magazines.

3.1 Medical waste management

Worldwide, after radiation waste, healthcare waste is the most dangerous hazardous waste if it is not managed properly (Wafula et al. 2019). Most of the hazardous waste is produced during the research, testing, treatment, and diagnosis. The cultures, live vaccines, needles, syringes, pharmaceuticals, laboratory samples, and body fluids are some of the examples of hazardous waste.

The various types of healthcare facilities include: clinics, hospitals, research and teaching institutes, blood banks, animal houses, and veterinary institutes, dental clinics offices, laboratories, emergency services, drug addictions rehabilitation centers, nursing homes, tattoo, and cosmetic centers are the source of generating both hazardous and non-hazardous healthcare waste (UNEP 2012).

Presently, in both developed and non-developed countries inappropriate medical waste management is a vital issue and challenge (Reza et al. 2018). According to WHO (2018), developing countries produce less hazardous waste at the source than developed countries. The developed and developing countries generate 0,5kg/bed/day and 0,2 kg/bed/day respectively. However, low and middle-income countries in Asia, the Middle East, and Africa are facing challenges in healthcare waste management (UNEP 2012) along with a rapidly growing population. Hence, the importance of proper separation, storing, and disposing of various hazardous wastes such as biological and infectious wastes are highly considered (Manyele & Lyasenga 2010). Improper management of infectious waste raises the risk of spreading various diseases like hepatitis B, hepatitis C, HIV/AIDs, and cholera to name a few (Wilujeng et al. 2019; UNEP 2012; Abor 2007).

In most of the developed countries, waste is handled effectively from its source of waste generation to the final disposal center both for municipal solid waste and healthcare waste (Singh et al. 2015). Those developed countries have stringent regulations and policies to enforce producers for proper management of the waste all the way from the source to the final recycling phase.

Yearly, hospitals in the United States produces approximately 2 million tons of healthcare waste (Manasi 2017). As per the author, those healthcare waste remains a third national source of waste. From a total of 2,5 billion tons of waste that was produced in 2012 from 28 European Union countries around 4% was calculated to be a hazardous waste (European Environment Agency 2016). Each day about 5,24 kgs/bed healthcare waste is produced in a developed country. Tiwari & Kadu (2014) state that healthcare waste each day per bed is produced by the following countries as follows: the United Kingdom 3,3 kgs, France 2,5 kgs, Norway 3,9 kgs, Spain 4,4 kgs, Netherlands 4,2 kgs, USA 4,5 kgs, and Latin America 3,8 kgs. These countries recycle their recyclable waste or sell it at very low prices or even send it as a charity to other undeveloped countries (Manasi 2017).

Similarly, approximately each year India produces 0,33 million tons of healthcare waste which was estimated per day per bed to be 1 kg (Muduli & Barve 2012). The article also states that each day New Delhi, the capital of India, produces health care waste nearly 60 metric tons out of 40 000 beds. In India, most of the healthcare facilities do not comply with or do not have a waste management system except for a few healthcare facilities. The healthcare waste is openly dumped as normal waste along with infectious waste such as syringes, human tissues, bandages, and contaminated microorganisms either on the roadside or riverside without any treatment (Muduli & Barve 2012).

Each year approximately 250 000 tons of healthcare waste gets produced in Pakistan (Kumar et al. 2010). Kumar et al. (2010) conducted a survey in 2006 where they discovered that each day per bed waste was about 2 kg. There were approximately 92 000 beds in healthcare facilities in Pakistan. The author identifies that there is inadequate knowledge about health care separation, implementation of HCWM guidelines, needle destroying technique, and lack of bins. The waste is being sent directly to a municipal dumping area.

Most African countries have similar issues in properly handling healthcare waste. Sharp objects, needles, and other more infectious waste are the biggest risk for the countries (Manasi 2017; Globalization101 2010). Additionally, it is said that the boxes for sharps objects are too expensive for African healthcare facilities which lead to sharp objects being mixed in general waste. Manasi (2017) mentioned that in Africa over 1 000 incineration facilities are estimated to deal with its healthcare waste. However, the report found that incineration is either functioning with low standard conditions or not working.

Some countries do not even have any laws in healthcare waste management. These countries are namely Ghana, Lesotho, and Eritrea (Globalization101 2010). A study conducted by the WHO in 2012 revealed that among the 24 West Pacific area countries only the Republic of Korea and Japan had used the best available technologies to treat their healthcare waste (Datta et al. 2018). Apart from this, inadequate government

rules and regulations, an increasing number of healthcare facilities, and a lack of environmentally friendly technologies (United Nations 2011) lead to mismanagement of healthcare waste in most of the developing countries.

3.1.1 Types and characteristic of medical waste

As previously mentioned, according to WHO there are mainly two types of medical waste generated during diagnosis and treatment: hazardous and non-hazardous waste (WHO 2018; Baaki et al. 2017; WHO 2017b; UNEP 2012). Out of them, 85% of waste is non-hazardous and 15% of waste is hazardous waste that is produced in the healthcare facilities. The pie chart in figure 6 presents the types of healthcare waste in percentage that are generated in HCFs.

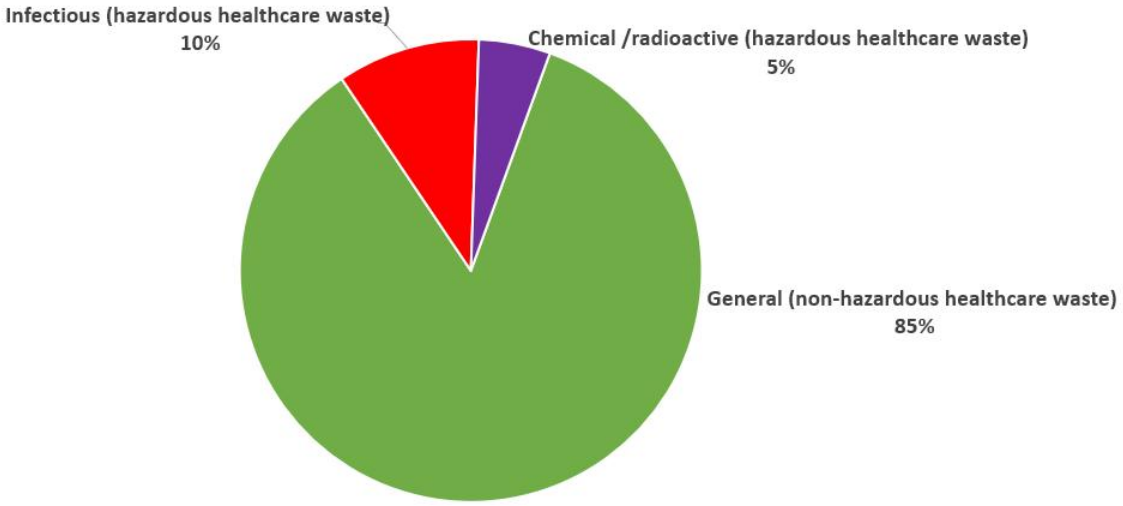


Figure 6. Types of healthcare waste. Source: Adapted from WHO 2017b

The World Health Organization has categories or classifies infectious (hazardous) and non-infectious (non-hazardous) healthcare waste as follows (WHO 2017b; UNEP 2012):

Infectious healthcare waste (hazardous healthcare waste):

Infectious waste: This kind of waste contains viruses, bacteria, fungi or parasites or any suspected transmission of disease to the human body or in the environment by waste such as body fluids, laboratory cultures, microbiological stocks, or any materials that touched with infectious patients (Chartier et al. 2014). In the case of Thailand, infectious waste is divided into two ways; sharp items (syringe, needles) and non-sharp items (body fluid of human and animal, and body parts from surgery or experiment) (WHO 2017a). Similarly, in Maldives majority of the HCFs, both infectious and non-infectious, waste is mixed after it is dispatched from the HCFs even if the waste was separated at waste generation (WHO 2017a).

Pathological waste: Pathological waste is such waste that requires special handling, treatment, and disposal since it contains highly infectious waste (Chartier et al. 2014). Some examples are: fluids, body parts, blood, post-mortem body, human fetuses, tissue organs, and also include animal carcasses (Chartier et al. 2014). Animal or human body parts in this category is called anatomical waste. In the country of Bhutan incineration and deep burial technic are used to treat the pathological waste (WHO 2017a).

Chemical waste: This kind of waste is physically either solid, liquid, or gaseous and holds chemical substances. Chemical waste can be both hazardous and non-hazardous (Chartier et al. 2014). Chemical waste is generated during the disinfection process, sterilization, photographic, housework cleaning products, mercury waste, diagnostic, cadmium waste from rejected batteries and also from experimental work (Ali et al. 2017; Hung et al. 2012). Additionally, chemical waste has properties that are described as toxic, flammable, reactive (either explosive, shock-sensitive, or waster reactive), corrosive, and oxidization (UNEP 2012).

In Indonesia, it is found that chlorine is a common method of disinfectant chemical waste. Liquid chemical waste is handled by HCFs themselves or by a third party (WHO 2017a). The WHO added that in Myanmar there is a special policy on chemical waste

with a focus on disinfectants. For the basic chemical waste, they just disposed it into drains or mix it with municipality waste. For developing countries, the draining system is the most common way to dispose of chemical waste (Ali et al. 2017). The authors state that chemical waste enters the eco-system through the water supply. The chemical waste can be minimized by applying some of the following approaches: use limited amounts, replace with less harmful products for the environment, build good draining systems, and or good inventory (Chartier et al. 2014).

Pharmaceutical waste: Pharmaceutical waste consists of all unused, expired, poisonous substance medicines, and drugs or vaccines that are not used any more (UNEP 2012). Other materials such as gloves, masks, boxes, bottles, or container that has used or hold liquid medicines are also included (Chartier et al. 2014). From the total healthcare waste, pharmaceutical and chemical waste is less than 3% (HCWH 2011).

Improper disposal of pharmaceutical waste may raise various issues such as the growth of microorganism, effects on the environment, decreased fertility in fish and wildlife (European Commission 2019) as well as it affects water, soil, and thyroid issues (Kadam et al. 2016). Kadam et.al (2016) state that round the world, there are about 123 761 pharmaceutical cases that relate to issue in the environment. These might be because most human beings dispose of their pharmaceutical waste either to the toilet, dustbins, sink, or even open fields.

Most of the developed countries return expired medicine back to their pharmacies (Tong et al. 2011). In contrast, many developing countries in South East Asian are handling pharmaceutical waste poorly and some countries even do not have government guidelines for managing pharmaceutical waste (Paudel et al. 2019). Most of them dispose of pharmaceutical waste openly outside (Kadam et al. 2016). In the case of India, all pharmaceutical waste is disposed of either directly to a landfill or burned or disposed to some separate place (Mani & Thawani 2019). In Myanmar, the municipality is taking care of all the pharmaceutical waste on the central level (WHO

2017a). The country uses either incineration or a deep-buried system to disposal the pharmaceutical waste.

Healthcare facilities should take responsibility for writing pharmaceutical prescriptions only in limited amounts (Global Green and Healthy Hospitals, n.d.). Besides, staff working around pharmaceutical wastes should speak openly about the issue to their own healthcare waste management team and at a government level. Yet, it is indispensable to advise the patient on how to dispose of the pharmaceutical waste (HCWH n.d.), because patients are playing the main role to prevent the pharmaceutical waste amount. Hospitals should also have an agreement with the supplier to return unused and expired medicines (HCWH n.d.). This is because according to HCWH (2011) manufacturers know their products and know-how to destroy them. Good inventories and monitoring systems are other forms that could help to minimize pharmaceutical waste.

Cytotoxic waste: Cytotoxic waste is also called genotoxic chemotherapeutic or antineoplastic drugs. The chemotherapy drugs are used for cancer treatment. The use of cytotoxic drugs even prevents growth or kills the active cells (Chartier et al. 2014). The urine, chemical compounds, radioactive materials, and vomit are examples of genotoxic waste (Hung et al. 2012). Pharmaceutical waste is included in cytotoxic waste as one category (WHO 2017b).

Sharps object waste: Sharps object waste consists of all the needles, syringes, knives, blades, saws, broken glass, or pipettes either used or unused (Chartier et al. 2014). The authors describe that several diseases are transferred not only between co-workers and healthcare handlers but also to the public by mismanagement of sharp objects. There were HIV, Hepatitis C and B infected about 1000, 16000, and 66000 respectively in the year 2000 which were caused by not having proper management of sharp objects (UNEP 2012). The UNEP also added that each year there are about two million healthcare workers who directly or indirectly get infected by contaminated sharp objects. Many developing countries mix sharp objects with other normal healthcare

waste and send them to municipality waste without any pre-treatment. On table 6 there is an example of some disposal methods for India and Ukraine regarding sharp objects.

Table 6. Examples of disposal methods for sharp objects.

Country	Methods for disposing of the sharps objects
India	Uses Incineration technology to destroy the sharp object. They use the first safety cardboard to collect the used sharp object. They also apply autoclave as a non-incineration technology to minimize air pollution.
Ukraine	Uses autoclave and separate first both plastic and needle parts before they are sent out. Plastic parts are sent for recycling and needle parts are send to either be melted or buried.

Source: Chartier et al. 2014; HCWH 2011

Radioactive waste: Radioactive waste includes radioactive substance materials in the following forms: solid, liquid, or gaseous (UNEP 2012). All health care facilities do not have radioactive waste. However, some equipment might contain radioactive substances, or radioactivity can be caused by some treatment. The microwave or wet thermal is not a proper process to disinfect the radioactive solid waste (Chartier et al. 2014). To avoid reuse, the authors have provided the recommendation to damage the bottles, glassware, or containers which have solid radioactive substances.

Non-hazardous or non-risk waste

Non-hazardous waste is a waste that is not physically in contact with any other infectious materials or is not a harmful substance (UNEP 2012). The UNEP states that the non-hazardous waste amount is about 85% in total healthcare waste and this type of waste has divided further into three categories namely; recyclable, compostable (bio-degradable) and non-recyclable waste. UNEP (2012) states that cardboard, paper, aluminum beverage cans, aluminum containers, foods tin cans, metal containers, and plastic bottles that have polyethylene terephthalate (PET or PETE), saline (but need sterilization), glass and wood all are counted as recyclable non-hazardous medical waste. Bio-degradable medical waste includes garden waste, kitchen foods, and flowers

which contains almost 25% of healthcare waste (HCWH n.d.). By the use of biological processes, the bio-degradable waste can decompose (Bharadwaj et al. 2015). Also, by applying the anaerobic digester to produce renewable energy from biogas, in developing countries like Nepal, could be used for the daily purpose for cooking or lighting (UNEP 2012). Common techniques for many municipalities' biodegradable waste is applying the vermicomposting to their municipality solid waste by using worms for biodegradable waste (UNEP 2012). According to UNEP, one of Sri Lanka's hospitals produces over 50% biodegradable waste of the total hospital waste. The non-recyclable waste cannot be either biodegradable or recyclable. healthcare waste in most of the developing countries.

3.1.2 Handling of medical waste: processes and technologies

The waste separation along with environmentally friendly, accessible technologies and processes are the essential key components for healthcare waste management (UNEP 2012). Additionally, other factors also play vital roles in healthcare waste management namely: waste classification, waste minimization, labeling and color-coding, handling, transport, storage and, treatment and disposal. The budget, government rules and regulations, planning and implementing, training, awareness, coaching, and monitoring are also important keys factors (UNEP 2012). Below are more detailed steps for medical waste management:

Health care waste classification: Health care waste classification can vary from country to country (UNEP 2012) or even at the local level based on various factors. According to UNEP (2012), most of the health care facilities around the world follow WHO guidelines for the classification of their healthcare waste. Each healthcare facility should identify the waste type at waste generation and separate them as per classification.

Waste minimization: Waste minimization refers to produce less waste as much as possible at the source (UNEP 2012). UNEP added, by separation, product substitution, use of environmentally friendly technology and process replacement, recovery, reuse, and recycling all are part of waste minimization. For example: replace the mercury thermometer with another electric or digital thermometer.

The 4R's principle (reduce, reuse, recycle, and recover) is the best approach of waste minimization (Bhat et al. 2019). Reduce mean generate less waste and use an environmentally friendly product. Reuse refers to using the product multiple times either for the same purpose or other aims, and obviously, disinfection and sterilization should be followed well. By recycling, waste new products can be created once the products have been used. Recover stand for the use of healthcare products that could be converting to special resources (Bhat et al. 2019) such as electricity, heat fuel.

Waste Separation: The waste separation process in developed countries for healthcare waste is undertaken properly by using the color coding and labeling bags system at the source of generating (Ali et al. 2017). However, in developing countries separation systems by using the color coding, labeling bags, or container are not fully implemented and standardized within-countries and region to region. Some of the reasons could be inadequate practical knowledge for separation, color coding, inadequate awareness, and monitoring (Ali et al. 2017). The authors emphasize the consequence of mixing infectious waste such as radioactive or human organs with other general municipality waste carelessly conducted by healthcare staff. They also found that some healthcare facilities separated only sharp objects as infectious waste.

Waste Color coding: Color coding is used for various types of health care waste to identify and keep the waste in the correct container. The standard color coding for infectious waste uses red and yellow in most of the countries (UNEP 2012). Similarly, black or clear bags are used for general waste. It is required to use the international level of the biohazardous symbol with a unique color when handling infectious waste.

Table 7 provides international recommendations for color coding and symbol, and container types that have proved by WHO/UNEP/SBC (International Committee of the Red Cross (ICRC) 2011).

Table 7. International recommendation color coding.

Types of waste	Colour coding - a symbol	Types of container
1. Household refuse	Black	Plastic bag
2. Sharps	Yellow and 	Sharps container
2a. Waste entailing a risk of contamination 2b. Anatomical waste	Yellow and 	Plastic bag or container
2c. Infectious waste	Yellow marked "highly infectious" and 	Plastic bag or container which can be autoclaved
3. Chemical and pharmaceutical waste	Brown marked with a suitable symbol e.g. 	Plastic bag, container

Source: Adapted from ICRC 2011

Waste Labelling: Labelling each waste category in the container is important. Color containers vary from country to country or even at a local level, so it is mandatory to use the correct labeling to clear recognition of the waste types and categories to prevent the mixture of waste. Furthermore, Ali et al. (2017) mentioned that the suitable labeling for containers and bins are missing along with storeroom in some healthcare facilities.

Waste transportation: Infectious waste transportation rules vary between Europe, developed, and undeveloped countries (WHO 2015). In Europe, 28 countries are following the "*International of the Carriage of Dangerous Goods by Road (ADR)"*

regulation to control the transportation for hazardous waste (Ali et al. 2017). Furthermore, the authors added, many developed countries have developed online apps to track their medical waste transportation. Yet authors describe that some countries have made a rule that a driver must have an authorized license to drive vehicles with infectious waste. Furthermore, waste transportation is carried out in two ways in developing countries; on-site and off-site transportation. The on-site transportation takes place within healthcare premises by internal healthcare handling staff and off-site takes place outside of healthcare facilities (Ali et al. 2017). However, some countries use either a municipality or private agency. The authors explain that inadequate carts, trolleys, personal protective equipment (PPEs), and improper vehicles that have leaked or not built for waste transportation are the main challenges for healthcare waste transportation mostly in developing countries.

Waste storage: Storage should be built and maintained in a way that meets standard criteria to handle all kinds of waste such as anatomical waste (Hung et al. 2012). This waste should be stored below 4 degrees Celsius. The waste storage areas should be well ventilated to pass the air in and out, have adequate lighting, have water drainage areas, and separate containers for different types of waste with mark and written text (Hung et al. 2012). In developed countries, healthcare waste is separated immediately at source generation and stored according to the standard requirements. In developing countries, some healthcare facilities do not even have their storage area on their premises (Ali et al. 2017). Therefore, waste is openly dumped into either road or riverside. The authors added that some healthcare facilities are using their storage place for other purposes and some healthcare facilities are not applying disinfection while sending their infectious waste out from the premises of the healthcare facilities.

Waste treatment and final disposal: The correct treatment methods and technologies are depending on various elements (Hung et al. 2012) and vary from country to country. The treatment should improve public health and the environment. There are various processes and technologies which are used in the healthcare waste treatment by many developed countries such as thermal, chemical, mechanical, irradiative and biological

processes, where autoclaving, incineration, landfilling (Ali et al. 2017). The most common and dated method for waste treatment is incineration (UNEP 2012). However, inadequate temperature may lead to the release of toxic gases or hazardous air pollutants. Because of its drawbacks, many developed countries are inclined to use non-incineration, to reduce incineration technology or find alternative technologies (Ali et al. 2017). However, for developing countries incineration is one of the main disposal methods. For instance, China's biggest disposal technology is incineration (Yang et al. 2009). However, the country is moving more towards non-incineration technologies. In developing countries, the waste disposal process can be varying within the same region (Ali et al. 2017). The authors mentioned some countries or regions dispose of the healthcare waste with the municipality, hire private companies, use landfill sites, chemical disinfection, autoclave or open burning outside. The authors claimed that some of the infectious waste such as chemical and pharmaceutical waste commonly gets disposed into the water supply.

Moreover, establishing a waste management team within a healthcare facility is playing a vital role to develop and implement waste in a proper way (UNEP 2012). Each healthcare facility should form its organization and divide the work within the team. Financial support is required for sustainable and safe healthcare waste management activities and this is the main theme in WHO (UNEP 2012). Budgeting is another factor affecting healthcare waste management in the facilities. Inadequate budget leads to poor waste management. In many developing countries the budget system is not separately calculating healthcare waste management which leads to poor waste management systems (Ali et al. 2017).

According to ICRC (2011) there is no common worldwide healthcare waste recommendation or resolution. The processes and technologies that are applied should take into consideration conditions that minimize the harmful hazardous effects on both the public and the environment. There are mainly five types of healthcare waste treatment: thermal, chemical, irradiative, biological, and mechanical processes (Chartier et al. 2014). Nevertheless, in this research, it narrows down to focus only on

thermal and chemical processes, and under the thermal process, three technologies will be discussed: autoclave, microwave, and incineration. A chemical treatment technology under the chemical process will also be discussed. According to ICRC (2011) various parameters are determined for choosing the healthcare waste treatment processes and technologies e.g. waste quantity and type, existing treatment technologies, space, transportation, national polices, safety, weather, groundwater situation, material, human capitals, geographical and economic factors.

3.1.2.1 Thermal processes

Thermal processes are part of the process using either incineration or disinfection in medical waste. The thermal processes are the most common healthcare treatment processes worldwide (UNEP 2012). The processes use low to high heat technologies in either disinfecting, microwaving, autoclaving, or incinerating medical waste materials as shown in table 8.

Table 8. Thermal processes low to high heat technologies and some examples.

Technology range	Temperature range	Example of technologies and processes
Low heat temperature technologies	From 93°C to 177 °C	Autoclave, hybrid autoclave system, continuous steam treatment systems, microwave, and retorts
Medium-heat temperature technologies	From 177°C to 540°C	Reverse polymerization and thermal depolymerization
High-heat temperature technologies	from 540°C to 8300°C	Incineration and plasma pyrolysis

Source: Datta et al. 2018; Hung et al. 2012

Thermal is not a technology but uses technology to do a process. Heat is used to destroy any virus, bacterium, or microorganism from the healthcare waste in the thermal

processes (UNEP 2012). Below is the explanation of three technologies that are under the thermal processes: autoclave, microwave, and incineration.

Autoclave

The autoclave is the latest process based on sterilizing medical devices to their reuse purpose and treating healthcare waste (Ferdowsi et al. 2013). The autoclave is the best choice because it is an ecologically safe technology. The low heat treatment technology is used in an autoclave. The various types of infectious waste for treating are acceptable in the autoclave such as sharp objects, blood, fluids that contain in the materials, cultures, and stocks, laboratory waste, bandages, drapes, gowns and bedding, surgery waste but except for chemical waste (Chartier et al. 2014; UNEP 2012). According to Chartier et al. (2014) by considering the country's cultural, religious, or other legal aspects the small amount of human tissue is also able to be handled via autoclave. Besides the healthcare facilities, autoclave technology is used equally in other places such as parlor, funeral homes, and tattoo sectors (Sarokin 2018). There are principally four parameters required to handle the autoclave process: steam, pressure, temperature, and time (Centers for Disease Control and Prevention n.d.).

An autoclave is made of metal vessels with a sealed door where pipes and valves are placed for passing and removing the steam from the vessel (Chartier et al. 2014). The authors added, it is designed in the way that a vessel should stand with high pressures. Some autoclaves can be designed another way by adding the new layer outside the vessel with a steam jacket. While applying the process, the steam is passed into both areas inside the chamber and outside jacket which helps to reduce the moisture inside the chamber by applying the heat in the outside jacket. This system means that the process can be run with lower steam temperatures inside the chamber. The author states further that an autoclave can be named sometimes “retort” if it uses without a steam jacket. The retort process can be built for those who have a low budget in their healthcare facilities and for covering in a large area. Air is an important element

playing the vital role releasing of pathogenic aerosols in-stream treatment. The heat processes into the waste by removing the air from the autoclave (Chartier et al. 2014).

Autoclave process is not a continuous process, but it runs only as a batch system and can be found from 20 liters to above 20 000 liters per cycle capacity range (UNEP 2012). The normal processing time of autoclaving is between 15-30 minutes with temperatures of 121-degree centigrade (Hung et al. 2012). In contrast, the amount of time and temperature can vary from other factors such as packing size, types of container bags, load size, air pressure in the chamber, and so forth. Because of the by-product of toxic emissions, autoclaves are not suitable in case of chemicals and infectious waste. Odious also rises in case of not inadequate ventilation (Datta et al. 2018; UNEP 2012). Figure 7 is an example of autoclave technology in healthcare waste treatment.

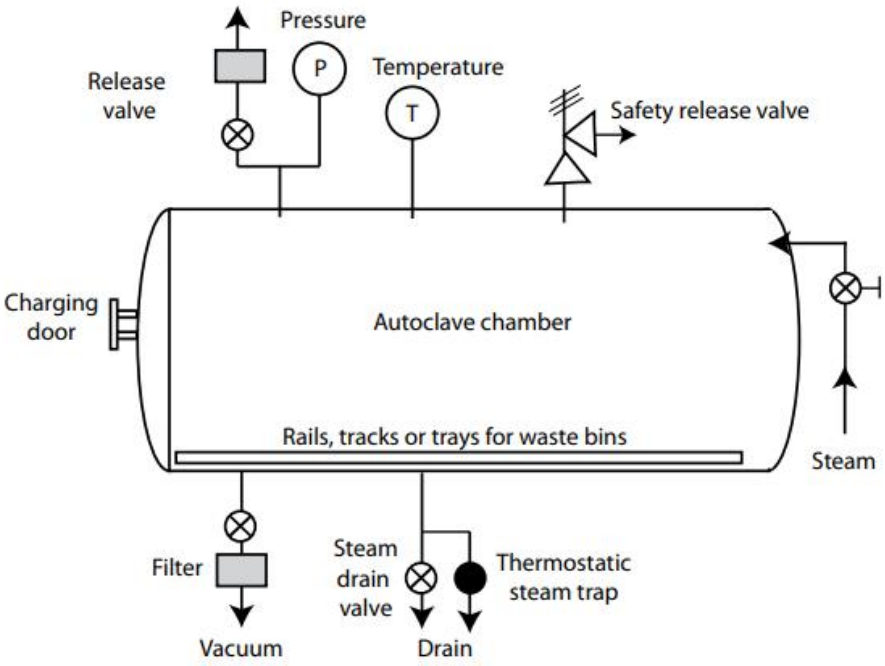


Figure 7. Autoclave for healthcare waste treatment. Source: Chartier et al. 2014

Microwave

Microwave is a stream-based process (Chartier et al. 2014) that uses low heat technology for infectious waste which are treated in a microwave. By using microwave energy, steam is generated with an act of wet heat where the treatment process starts

(Chartier et al. 2014). The units of the performance frequency and wavelength of the microwave are 2450 MHz and 12.24 cm respectively (UNEP 2012) to destroy the microorganism. Waste that is used in the microwave is laboratory waste, soft waste, sharp objects, and human waste (Datta et al. 2018). Pathological waste from animal tissues are also used in a microwave. However, some medical waste should not be treated in microwave e.g. radiological, hazardous chemical, mercury, chemotherapeutic waste, and volatile and semi-volatile organic compounds that need a higher temperature (Chartier et al. 2014; Datta et al. 2018). There are two types of systems operating in microwave technologies: batch microwave and continuous microwave (UNEP 2012).

To cover the smaller area, the batch microwave technology is used. The microwave is usually designed with a capacity of 30 to 100 liters of waste at once slot (Chartier et al. 2014). The processing time of waste is between half an hour to one hour depending on its cycle periods. Continue microwave technology is suitable especially for large hospitals or central treatment facilities. The system can handle per hour 250kg of health care waste which is equivalent to 3000 tons per year (Chartier et al. 2014). Figure 8 shows batch and continuous microwave technologies.

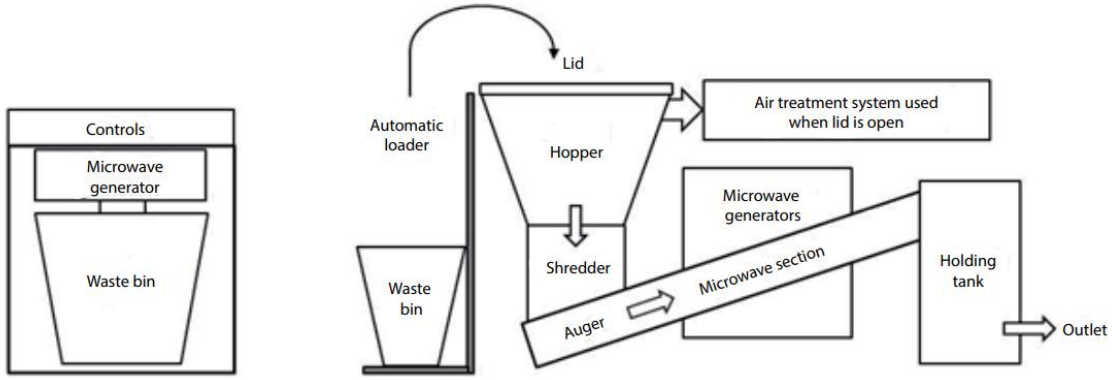


Figure 8. Batch and continuous microwave technologies. Source: Chartier et al. 2014

Incineration

Incineration is a high heat temperature technology where the waste is burnt into ash in a kiln temperature between 540°C and 8300 degree centigrade (Datta et al., 2018; Voudrias 2016; Hung et al. 2012). The process decreases waste mass, volume, and weight and when reduced wastes are not anymore recycled, nor reused, it can easily be disposed of in the permitted landfill (Hung et al. 2012). The incineration process is appropriate for sharp objects, pathological waste, large anatomical body parts, organs, tissues, and infectious waste, laboratory waste, cultures, and stocks. The waste that should be 60 percent of burnable substances to treat them in incineration (Shareefdeen 2012). The author emphasizes that sharp, hazardous, and pathological waste is proper for incineration.

Furthermore, incinerators that have a temperature of more than 1200 °C are used mainly for chemical waste. The incinerators with highly equipped air control devices along 1200 °C can treat hazardous chemical, pharmaceutical, halogenated waste including plastic Polyvinyl Chloride (PVC) materials and chemotherapeutic waste (UNEP 2012). Incineration helps to decrease waste capacity by 50 to 400 times. However, when waste is burned in less than 800 °C temperature or waste substances contain PVC, that produces various gas such as dioxins, furans, or toxic air (ICRC 2011). All waste that comes from the incineration process becomes flue gas, ash, and heat (Bajaj 2017). There are mainly three types of incineration technology that are used in the healthcare waste management sector namely dual-chamber starved air, multiple chambers, and rotary kilns or single chamber. This is because all medical waste cannot be treated with the same level of temperature (Hung et al. 2012). Figure 9 represents the general chart flow of the incineration process.

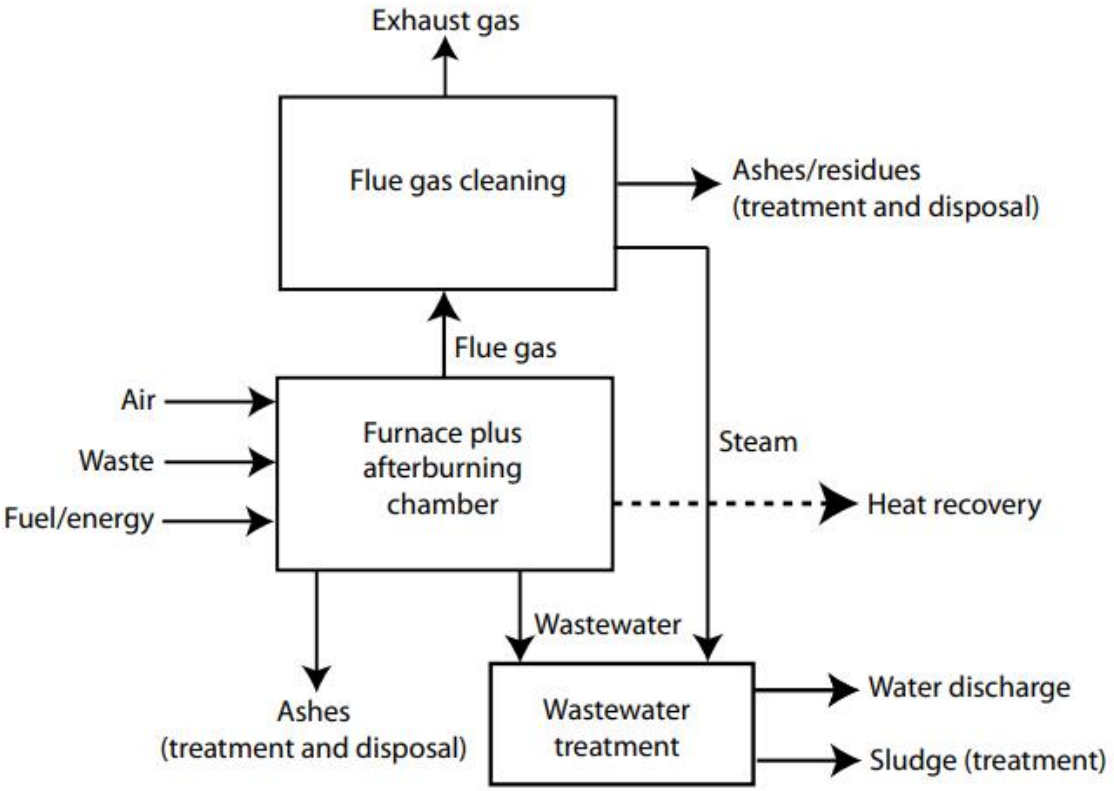


Figure 9. Incineration process. Source: Chartier et al. 2014

3.1.2.2 Chemical processes

Chemical treatment process or chemical-based technology is applied to disinfect healthcare waste and medical equipment to kill macro-organisms by applying the various chemical solutions such as chlorine dioxide, peracetic acid, bleach (sodium hypochlorite), ozone gas or day inorganic chemicals (e.g. calcium oxide power) or lime solution (Chartier et al. 2014). The authors noted that sharp objects, microbiological cultures, human waste, laboratory waste, gauze, bandages, and gowns are acceptable healthcare waste through chemical solutions. Despite that, some healthcare waste should not be treated via chemical processes such as mercury, radiological, volatile, semi-volatile organic compounds (Datta et al. 2018). Mostly liquid infectious wastes are suitable for chemical disinfection treatment such as urine, feces, hospital sewage,

or blood (Chartier et al. 2014). Chemical base technology can quickly break down the tissues, anatomical parts, animal carcasses, and pathological waste when hot alkali is applied inside the closed steel tanks (Datta et al. 2018; Chartier et al. 2014). Grinding, shredding, or mixing the waste with chemical substances speed up the process in an efficient way (ICRC 2011). The main benefit of the chemical process is that the method is very cheap and simple to use. Before using chemical disinfection, caution is essential because of harmful substances (ICRC 2011).

Table 9 demonstrated each example on the autoclave, microwave, incineration, and chemical treatment technology and process where a certain parameter has been taken to make a comparison between them.

Table 9. Examples of autoclave, microwave, incineration, and chemical treatment technologies and process.

Parameter	**Name of the Technologies and process**			
	Autoclave: Vacuum autoclave	Microwave: Continuous microwave	Incineration: Dual chamber pyrolytic incineration	Chemical treatment: Positive Impact Waste Solutions (PIWS) - 3000
Waste type	Blood and body fluids, cultures and stocks, surgery waste, sharps object, laboratory waste (not chemical waste), soft waste from the patient including bandages, drapes, gauze, bedding, and gowns, and also a small size of human tissue but not a large body part	Human and animal tissues, all blood products, dialysis waste, animal carcasses, body parts, needles, syringes, biological waste, laboratory waste, surgery waste, research waste, contaminated with HIV/AIDS and hepatitis waste, pathology and histology waste, gloves gowns, cultures, waste substance that has chemotherapeutic elements	Pathology waste (large body parts, tissues, organs, and animal carcasses), sharp objects, infectious waste, pharmaceutical waste, genotoxic waste, low effect radioactive waste, chemical waste, cultures, body fluids, surgery waste, laboratory waste, soft waste (include gauze, drapes, gowns, bandages, and bedding). More, PVC materials, chemotherapeutic waste, thermally stable pharmaceutical waste and laboratory chemical waste can use especial air pollution control devices along with temperature that is higher than 1200℃	Liquid waste including the blood, urine, hospital sewage and stools, and infectious healthcare such as cultures, sharp objects and microbiological
Waste that should not be treated	No large body part, hazardous chemical, a heavy metal such as mercury, other laboratory dissolving polluting substance	Radiological waste, hazardous chemical waste, mercury, chemotherapeutic waste, and volatile and semi-volatile organic compounds	A large amount of chemical waste, radiographic waste, mercury, silver salts and photographic, cadmium and metal devices such as thermometers, batteries and lead, radioactive materials, sealed ampoules or vials, and waste require 60% fire catch, less than 5% non-fire and 30% moisture content	

Reduction of waste /inactivation microorganisms	30 to 40% / 99,9999%	80% / 99,99999	Reduce waste to ash and remove pathogens from waste	70% / 99,9999
Capacity	1kg/cycle to 110 kg/cycle or volume 20/l to 1200/l	810 kg/hr	5 to 1000 kg/hr	900 to 180 kg/hr
Emissions	No emission limits	Minimum emissions amount and a HEPA filter to prevent the aerosols	EU emission limits for gas cleaning system	HEPA or another kind of filters has used to pass the gases by exhaust
Odor	Odor problem if not proper ventilation	A very little amount of odor reduce the only unit area		
Maintenance	Daily to annual	15 minutes daily outlook checking, yearly basic inspection	Daily to annual	5 to 10 minutes each day and weekly
Range of capacities / range of operating costs	2 to 3600 kg/hr / 0,14 to 0,33 USD/kg	100 to 810 kg/hr / 0,07 to 0,11 USD/kg	5 to 3500 kg/hr / 0,27 to 1,66 USD/kg	23 to 410 kg/hr / 0,12 to 0,52 USD/kg

Source: UNEP 2012

3.2 Economic considerations and capacity in choice of technology

To develop a medical waste treatment center or thinking of how to dispose of health care waste in a country one must consider the economics of that specific country, whether they have the needed resources to be able to take care of the existing issues. As part of these, by understanding the economics that they have, it must be thought how to build the capacity from one unit to multiple units across the country. One would also need to decide on the choice of technology to be used for treatment facilities to be able to handle medical waste. For this research, the focus would be to understand macroeconomics because it studies a large scale of the national economy. It is mandatory to talk about economic considerations (Auffhammer et al. 2016) on macroeconomics aspect, while building the treatment center for medical waste because various types of resources are required on the global level, government policies, budget, national income, investment, and GDP to name a few (Getsmarter 2019; Gujrati 2019; Boundless 2019; Essays, UK 2018).

Along with taking into consideration economic aspects, when establishing treatment facilities, capacity building plays a prominent role to achieve long term sustainability. Also, by managing and involving various stakeholders from the higher-level government sector to individual parties whether they have an organization structure, competencies, adequate resources, and so on (Whittle et.al 2012; UNEP 2012). A sustainable healthcare waste management system fully relies on the choice of medical waste technology (MWT) and final activities after the treatment of waste (UNEP 2012). While choosing medical waste technology the stakeholders should understand the types of competencies and expertise that the country has when adapting to a certain type of MWT. Because chosen MWT should improve the environment, public health, creates jobs, and social acceptance (UNEP 2012; Pandian 2010).

By knowing the HCFs, in order to build capacity, the government should start from the public sector and even allow the private sectors to contribute to building such treatment facilities. In the case of inadequate expertise and competence of handling

the specific technology, there should be some kind of training package that would be ruled out by the government, individual stakeholders, and NGOs so they can promote the knowledge on how to properly handle medical waste via technology.

In the context of the healthcare waste management sector, there are neither specific policies, rules, regulations, except HCWM guidelines 2014, nor any standardized technologies for medical waste treatment in Nepal (WHO 2011).

The government does not have any dedicated budget system to handle the systematical healthcare waste management (Onta et al. 2007). However, according to the WHO (2017a), 15% of the total budget from "District Hospital quality and service strengthening" (DoHS) has during the past three years been budgeted to health care waste management. Similarly, 16% of the total "*Primary health centers quality and service strengthening*" budget that the Primary health centers are getting from 2016. The Ministry of Health also assigns the budget which also means for health care waste management to various types of healthcare facilities namely central, zonal regional, and sub-regional. However, the fund is not enough to handle the complete healthcare waste management system as per MoH and DoHS (WHO 2017a).

There is no one responsible for healthcare waste management and even the Ministry of Local Development has indicated that there should be someone responsible (Development Bureau 2014). Additionally, no one has calculated the costs of handling healthcare waste management. Since the last two years, the monitoring system has not been done from the government side to healthcare facilities because of inadequate budget and human resources personnel (Poudel 2019).

According to the WHO (2017a) establishing a cost-effective and ecologically sustainable appropriate treatment technology, giving standards or checking the validation for the technology the main parties need to cooperate and coordinate to control and provide the permission. The main parties are the following: the Ministry of Health, Ministry of Population and Environment, municipalities local bodies, and pollution control

boards. Nevertheless, local NGOs and international NGOs are playing a vital role and cooperating with the government of Nepal for various activities in healthcare waste management. These include making the policies, technology validation, validating standards, prepare the guideline, or provides funds.

The HCWM guidelines 2014 emphasize that there should be a common healthcare treatment facility in Nepal because of many constraints such as HCFs are facing the issue of managing their HCW and also many private collectors dump collected HCW illegally to the landfill (WHO 2017a) which creates environmental and public health issues.

The international NGOs and partners, such as WHO, JICA, are funding and cooperating to run some of the local NGOs such as the Health Care Foundation (HECAF) and the Centre of Public Health and Environment Development (CEPHED) which are mainly working in healthcare waste management (WHO 2017a). Almost none of the healthcare facilities receive the fund from the government. Instead of healthcare facilities either use own their funds or get support from WHO and HECAF for waste management infrastructure to their premises (WHO 2017a).

Figure 10 shows various involving parties in the waste management system. The Ministry of Local Development (MOLD), various line ministries, and Solid Waste Management Technical Support Center (SWMTSC before it called Solid Waste Management and Resource Mobilization Center (SWMRMC)) play a crucial role and take responsibility together with KMC. The parties coordinate and part of the establishment from policy to operation level.

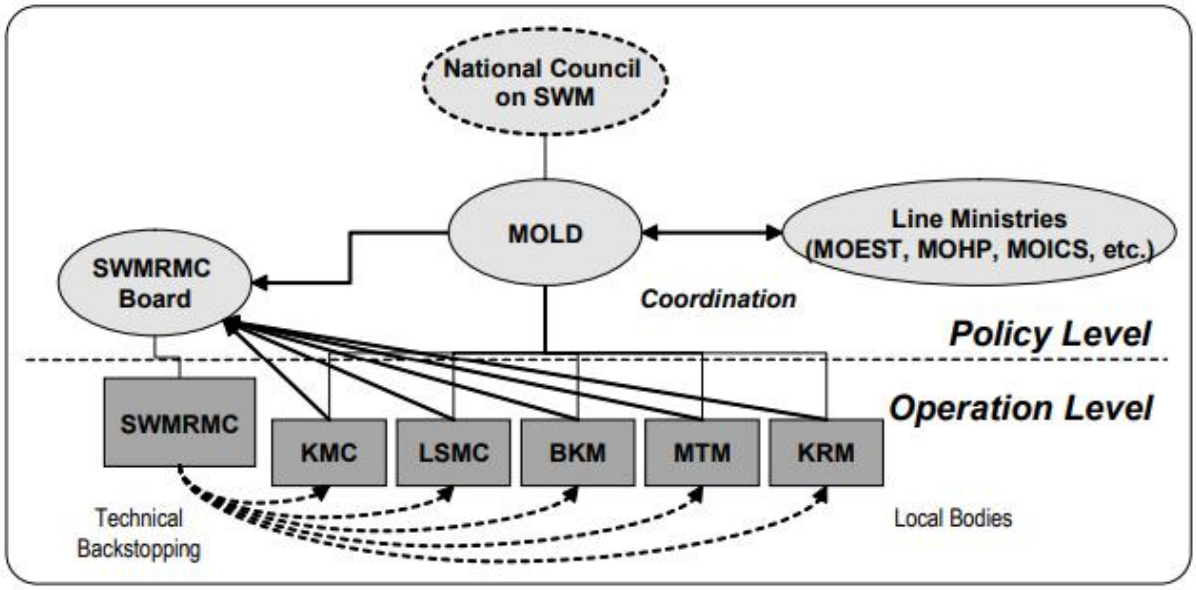


Figure 10. Involved parties in solid waste management in Kathmandu Valley. Source: JICA 2005

Kathmandu municipality spends about 10% of its municipality budget to handle and manage the municipality waste (ADB 2013). Of that, the spending, about 60 to 70% and 20 to 30% are used to sweep streets, and collection and transportation respectively. Other remaining spending goes to the final landfill site.

In the fiscal year 2003/2004 the national level budget allocated 4,8 billion Nepalese Rupees and in 2004/2005 6,2 billion Nepalese Rupees to MOLD that has the responsibility for implementing the local development area in the waste management sector (JICA 2005). This accounts for a bit over 5 % of total government expenditures for both fiscal years. From the MOLD budget in fiscal year 2004/2005 SWMRMC was assigned 85 million Nepalese Rupees for solid waste management at a national level. It clearly shows that a large portion of the budget is allocated for the municipality waste management each year. It seems that the government is inadequate to plan sustainably.

Kathmandu municipality city employed over 1 000 persons including drivers, sweepers, helpers, technical persons, supervisors as well as other necessary skilled people (more details can be seen from Appendix 3 as per JICA 2005 report) (Hakahaki 2018).

According to the author, the Kathmandu valley's waste is being collected by 70 private companies. Approximately, only 40% to 50% of the city's produced garbage is taken to the site, with remaining garbage is being left in the streets or rivers side, where near 60% of that garbage is organic (Lorch 2014).

Additionally, as described by Aryal (2009) at KMC, there could be more privates, individuals, and NGOs which are not registered officially but still actively collecting the waste in Kathmandu and Lalitpur. Besides this, there is a total of 26 individuals and organizations authorized at KMC and Solid Waste Management and Resource Mobilization Center (Aryal 2009). These individual organizations can earn per month about 2 million Nepalese rupees by charging each household from 500 to 15 000 rupees. If this was regulated by the district than these would create more job opportunities for the communities and take care of these waste management in a realistic way. Also, that money could be used for some development areas such as building treatment facilities. On top of that, each year approximately USD 2 million which equivalent to 149 million Nepalese Rupees are spent by KMC for managing the municipality waste (Environmental Management Centre 2007). Additionally, it said also that each month about 2 million Nepalese Rupee is spent to operate the landfilling site for the collected waste (located in KMC) which has been operating since 2000 for managing the waste for KMC along with other municipalities. The total collected daily waste estimated for landfilling is about 250 tons (Environmental Management Centre 2007).

Decent health care waste treatment could be managed with about 2 million Nepalese Rupees according to the Solid Waste Management Technical Support Center (Development Bureau 2014). Furthermore, it notes that a central treatment facility is a better approach for sustainable solutions than establishing individual treatment centers for each healthcare facility. However, according to the development bureau (2014) action should start from the government side because of the voluntary approach to manage waste is not considered to be effective for healthcare facilities. Additionally, about 50% of recycling products from healthcare waste is selling to India because there are no such recyclable factories in Kathmandu (Dahal 2019).

Every month recyclable products from Kathmandu valley, which is equivalent to 3 000 tons, go outside the country. That exported materials generated about 371 million Nepalese Rupee income for the country (Environmental Management Centre 2007). If Nepal could recycle internally the recyclable items could be utilized economically better inside Nepal.

In the context of Kathmandu or entire Nepal, the priority should be on the capacity building of the healthcare waste management sector for sustainable improvement (Marlon 2016). The author highlights that there should be a clear guideline for the policy, law, and regulation on this sector and recognize an environmentally friendly safe disposal location.

3.3 Summary of the theoretical framework

The theoretical framework in figure 11 summarizes both the background analysis of the case country and the literature which can be divided into four mainstreams. These four main parts included: the stakeholders' activities, types of medical waste, management of the waste, and the economic and capacity building in choice of technologies and processes. The stakeholders include the government, investors, NGOs (both national and international NGOs), private sectors, and communities. They are involved in the budget allocation, rules, and regulations that govern the collection and management of waste. Regarding the type of waste, the literature and this thesis have identified either hazardous or non-hazardous sometimes it refers them to as infectious or non-infectious waste. E.g. sharp objects, pharmaceutical and chemical waste is under the name of infectious waste and bio-degradable waste is under non-infectious waste. Further, the waste management (WM) team includes a team of the management committee and they are planning, monitoring and evaluating, and also training, coaching, and creates awareness.

These include also collection and storage as well as the transportation and treatment of the waste either on-site or off-site. The last part is the economical, technological processes, and capacity that involves identifying the type of technology and chemical processes to determine the type of capacity to build and help in the management of medical waste. Under the thermal process, there are three types of technologies: autoclave, microwave, and incinerator and these have been considered further and the various chemical solution discuss can be found under the chemical process.

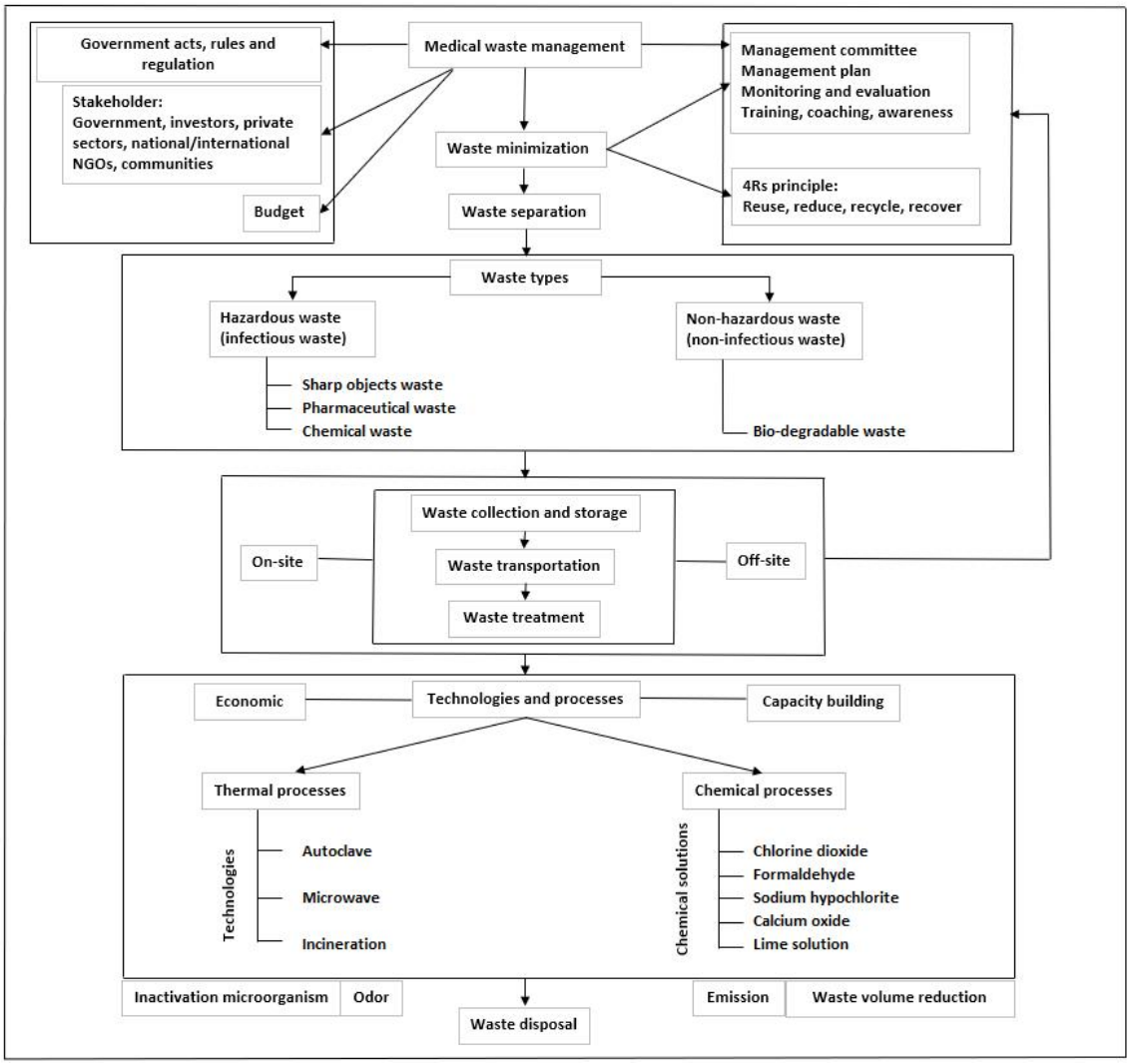


Figure 11. Theoretical framework

4 METHODOLOGY

4.1 Description of methodology process

The main purpose of this chapter is to explain in detail the research methodology which includes methods and procedures of collecting and analysing the data to obtain the research objectives. The quantitative method has been carried out to collect the data in this research. The quantitative research method is about numbers or quantities from a given variable, it is analysed by specific statistical techniques to obtain the research results by answering questions such as "*who, how much, what, where, when, how many, and how"* (Apuke 2017). The author added that collected data gives more insight into the current situation and the research topic and can later be used to analyse them with statistical techniques.

The tool used to collect the data was an online survey questionnaire. The online survey questionnaire was created via Google form and sent by email to all types of the representative of the healthcare facilities which are in Kathmandu, Nepal. The purpose of a survey is to reveal the amass of valuable current information on research topics from the targeted population (Briggs et al. 2012). The main research question is "what are the factors enabling the development of medical waste treatment in Kathmandu, Nepal?"

4.2 Data collection

This section describes an in-depth process of collecting and measuring the data to analyse the output by using the various types of procedures or tools. Both primary and secondary data were used in this study. The primary data were collected directly from the online survey questionnaire. Similarly, the secondary data were collected from the Profile: Kathmandu, Nepal, and literature review where information is taken from

such as various existing government websites, newspapers, scientific articles, journals, and books. The secondary data provides an understanding of the overall situation of the medical waste management sectors in the Kathmandu district and entire Nepal.

A set of questionnaires was developed in a way that would cover all types of healthcare facilities in the Kathmandu district. No personal details or specific health facility names were asked in the survey questionnaire which allowed the respondents to feel more comfortable. The survey questionnaires were designed based on the knowledge obtained from the secondary data and represent the current waste management issue. It is broken down into major parameters such as types and categories, volume, process, and technologies of the medical waste by covering the research objectives on the questionnaires. The questionnaires were then checked and approved by the supervisor and the survey questionnaire was created by using an online Google form. There were 15 questions and most of them were multiple-choice questions and short text answers. Due to inadequate resources, the researcher decided to execute a survey in a specific format such as sending a survey via e-mail, making phone calls directly from Finland to Nepal, and used a third party when necessary.

Before sending an e-mail with a survey questionnaire to the representative of the facilities in Kathmandu, the total population has been identified from the target research area as shown in table 10 and table 11. Afterward, the sampling size has been designed and taken from those populations. The sample size was random sampling size because every single population should have had an equal chance of selecting a survey questionnaire without any bias. On top of that, the sample size has been taken according to the research goal.

Once the survey questionnaire was ready, emails were sent to those selected health facilities. The phone calls were also made directly from Finland to Nepal after immediately sending emails to ensure that the right person has received and completed the survey questionnaire. Sending one email and making one call was not adequate to survey so additional phone calls were made to those selected facilities.

The researcher faced numerous challenges during the data collection which are explained below in this section. More importantly, to avoid misuse by any third person, the survey link was not shared on any online or social media. It was solely emailed with the survey link, phone calls, and third party which was used during the data collection. The third-party was used to collect the data by a printed paper version and supported by forwarding the email to reach more HCFs. One of the reasons to use the printed paper was some facilities did not have access to email. On top of that, at the beginning of the survey, a few health facilities had requested a separate official invitation paper from the University in order to complete the survey. I informed my supervisor and he did the invitation letter immediately.

In the Kathmandu district, the total population of HCFs is 1 072 and includes both government (123) and private (949) actors that are registered in the government system (chapter 2, table 3). Out of the total population, the representative government and private HCFs have been chosen for the survey as an overview of HCFs types and its population shown in table 10 and 11.

Both tables 10 and 11 demonstrate the chosen representative HCFs type and its population, a sample size that survey has sent, and the total achieved survey in the last column by both government and private HCFs in the Kathmandu district. Further, a total of five main categories has been divided to analyse the data. From table 10 under the main category of the general hospital, the other two hospitals included are general and central hospital. From table 11 for the private sector health facilities, the general hospital, polyclinic, medical center, and health center are included as one category called the general hospital. Moreover, the pharmacy is part of the laboratory. Both laboratory (pharmacy) and diagnostic centers are included under the main laboratory category.

Table 10. Representative government HCFs type, population, and total surveys achieved.

Health facility types	General population	Sample size	Total survey achieved
General hospital (general hospital and central hospital)	5+4 = 9	4+3 = 7	1+2 = 3
Healthpost	58	14	5
Specialized hospital	4	3	1
Laboratory	1	1	1
Teaching hospital	1	1	1
Total	73	26	11

Table 11. Representative private HCFs type, population, and total survey achieved.

Health facility types	General population	Sample size	Total survey achieved
General hospital (general hospital, poly clinic, medical center and health center)	76+161+103+51 = 391	26+59+42+20 = 147	8+8+6+1 = 23
Specialized hospital	21	8	4
Laboratory (Laboratory (pharmacy) and diagnostic center)	17+90 = 107	(2+(7)) +24 = 33	9 +5 =13
Teaching hospital	4	3	1
NGOs	12	5	2
Total	535	196	43

The research objectives are as follows:

- *To find categories, characteristics, and volume of healthcare waste generated in Kathmandu, Nepal.*
- *To research the present situation of healthcare waste management in Kathmandu, Nepal.*
- *To recommend suitable technology in Kathmandu, Nepal.*

Challenges of the data collection process

A very few counted representatives of the health facilities agreed to do the complete survey and made their action accordingly by just one email and a phone call. However, the rest of the data collection was very challenging. On the other hand, it gave an opportunity to study and understand even in a better way the current situation of the medical waste management system in the Kathmandu district. It is worth mentioning that the use of an online survey is not very common in Nepal. Normally, the common process of the survey is in a paper format where correspondent(s) is physically present, which makes the respondent comfortable and builds trust.

The survey begins by sending an email to those representatives of the health facilities. Firstly, emails and phone numbers were taken from their health care facilities web site. The emails were generic for the premises which might not be picked up immediately or never responded or forwarded to the person in charge of handling medical waste. That's why immediate phone calls were necessary from Finland to Nepal as a follow-up. Once an email with the survey link was sent to the responsible person, a few phone calls were required to explain in detail and make sure that he or she was taking part in the survey. That also gave reliability and validity of the data. However, sending the email(s) were also big challenges at first in some cases: because of the invalid email address which led to email failure to delivery. Some phone numbers were also invalid or went to some other offices or personal. In a few cases, the email went to the information technology (IT) or administration team and from there they were supposed to forward it to the right team. It was not possible to speak directly to any person in handling healthcare waste or team members. Each time calling should transfer or go through a reception channel. In this case, many calls were failed because sometimes the phone was busy. Sometimes there was phone transfer, but the person was busy and could not pick up. In some cases, the contact person was in the field or in a meeting. In some cases, few phone calls were required to convince the person in charge of the waste management of some health facilities to take part in the survey.

The first round of emails sent was to get a connection with the HCFs. Hence, in order to receive a survey from the right person, firstly the researcher needed to call the reception and then needed to explain everything, and after that only reception forwarded the phone call to the right person. After being forwarded to the correct person the person was either too busy, not at the office, went for lunch, or was in the meeting. It was also challenging to reach them. The researcher needs to call another time and another receptionist picks up the phone and again the researcher needs to explain from the beginning about the research survey. Once they feel comfortable and trust the researcher, they then forward the phone call to the right person. This required many phone calls and become more expensive. So, in some cases, it required to follow up two weeks continuously to do one survey. However, in some cases despite repeated follow-ups, there was no response from the sent survey. Once the right person was reached everything had again to be explained in detail to build the trust and give a word to protect their privacy by referring to the official attached documents from the university and so on by phone. Sometimes, lack of power supply to specific towns prevented internet access and thus non-accessibility to emails. Furthermore, busy schedules of personnel in these health centers made it is difficult for them to respond to inquiries. Some places had no internet connection, so the researcher had to wait a few days in order to get arranged contact by phone. Some of the health facilities require approval from human resources (HR) before they can conduct a survey. In order not to get delayed the researcher needed to call and make a request to them to do the process faster because of the dateline. Another issue was due to the time zone between Nepal and Finland. Nepal's time is about four hours forward compared to Finland during the winter when the survey was carried out.

More challenging was to convince smaller health facilities to participate in the survey as they were reluctant to complete the survey without consent from the higher level. Many health facilities were not interested in the survey. Even though in some cases the third party forwarded the email and talked directly to representative HCFs. But most of them were not interested to participate in the survey as well. This might be because most of the health facilities did not have a proper health waste management system

in place and afraid of disclosing the status to the third party. Some health care representative person requires fees for the survey which was very high compared to the amount of time they need to spend on the survey or also it was not clear in which circumstance the price has set. Furthermore, some representatives expressed on the phone that they do not want to give an interview by phone or take part in the survey via email for their healthcare waste information. The emphasis was to visit physically for the survey.

Because of all these challenges, the researcher got only a smaller number of respondents. Nevertheless, information obtained from the respondents was representative information that could represent the whole HCFs current situation such as hazardous and non-hazardous waste collection and how it is handled in Kathmandu.

4.3 Data analysis

The data analysis part is done by using the Microsoft Excel Spreadsheet, frequency table, percentage, pie charts, and bar diagram have been used to demonstrate the results. The core aim of the data analysis section is to glean all the three main research objectives. The first objective is to find the categories, characteristics, and volume of healthcare waste generated in Kathmandu, the second objective is to research the current situation of the waste management system in Kathmandu and the last one is to recommend suitable technology in Kathmandu, Nepal.

There were fifteen (15) survey questionnaires mostly multiple-choice and short text answers. However, some of the respondents gave very valuable supplementary information, which could contribute to a better understanding of the medical waste management issue in the district. Each question in the analysis part is garnered both from the government and private sectors in various types of HCFs representative in the Kathmandu district.

Question number one was about the role or position in the facility of the respondents. The pie chart in figure 12 demonstrates that different types of health professionals such as waste management officers, a nursing officer in charge, housekeeping managers, and so on were directly engrossed in the management of medical waste in their HCFs and completed the survey. The researcher had spoken via telephone representative prior to the survey in order to ensure the reliability and validity of the data accuracy.

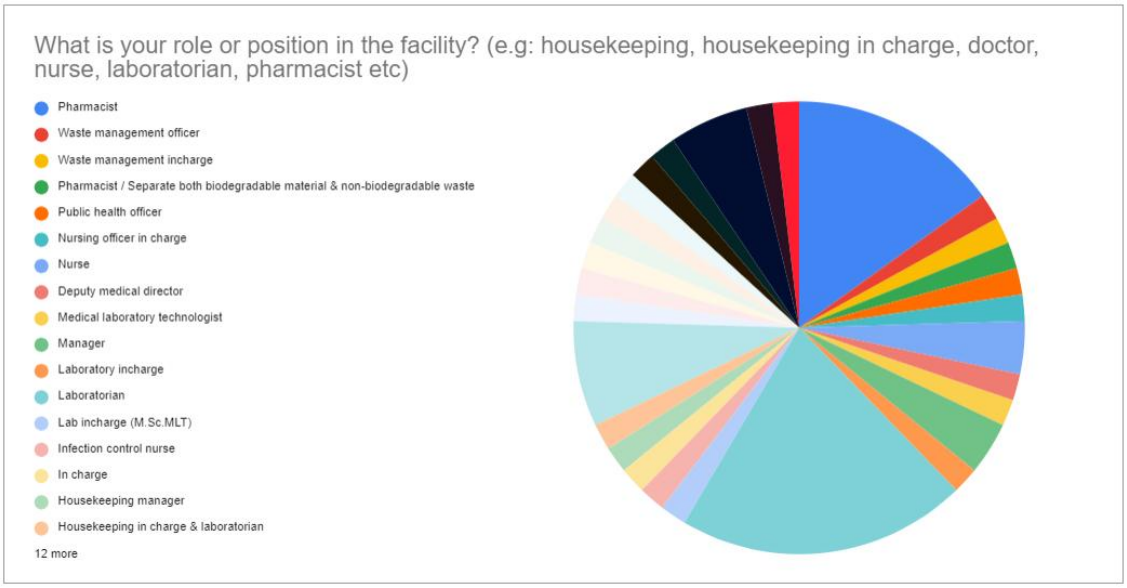


Figure 12. Respondent(s) various roles and positions in the facilities.

Question number two was about the respondent(s)'s healthcare facility type. This question provides the reader to an understand what types of representative facilities sample size has taken from the population. In section 4.2 tables 10 and 11 present the respondent's HCFs name from both government and private HCFs. The researcher was able to conduct a survey questionnaire for most of the important health facilities that could represent the whole population that are in the Kathmandu district.

Question number three was about the amount of hazardous (infectious) waste that was generated per day from the healthcare facilities. The question was not asked separately for each different type of hazardous waste quantity, but instead, as one bundle and same for question number four. Table 12 displays the total hazardous waste that was

generated in kilograms per day from various types of healthcare facilities in Kathmandu as per survey respondents. Tables 12 and 13 presents only the total sum from those healthcare facilities which has referred to their hazardous and non-hazardous waste amount in number format. Also, those who have provided their waste amount weekly, monthly, and yearly have been converted into daily amounts. Aside from this, hazardous and non-hazardous waste quantity has not been counted if responses have written only some "text" with additional information instead of quantity (even though respondents have provided valuable information) and also quantity amount in different measurement unit (s) which has not been recognized by the researcher. Table 12 present the total amount of hazardous waste generated from both government and private HCFs in Kathmandu district.

Table 12. Hazardous waste generated kg/day in Kathmandu.

Health facility type	Hazardous waste generated kg/day
Government HCFs	192,1 kg/day
Private HCFs	377,8 kg/day

Overall, from the government HCFs sector, as per table 10 from section 4.2 total of 11 surveys received and out of that only 6 respondents have mentioned the amount for hazardous waste that was generated to their HCFs which is equivalent to 192,1 kg/day (shown on above table 12). Two other respondents have written the text with valuable information. From the two, one respondent from a big hospital said that due to inadequate manpower, they have not measured the generated hazardous waste amount until now while another respondent from the laboratory stated that they have not documented it so far. Furthermore, two of the other healthcare facilities inserted the text named sharps and pathological waste but they did not provide any specific measurement for it. That reveals at least they do produce hazardous waste. Besides these, only one answer field was empty out of 11 surveys that were collected.

From the private healthcare facilities sector, the survey received in total 43 (as seen in table 11), and out of that 23 respondents were given the amount of hazardous waste that produced to their healthcare facilities. The total amount was 377, 8 kg/day as shown in table 12. Some of the respondents have provided separately the amount for infectious, sharp objects, pharmaceutical, radioactive, and pathological waste which can see a very well-organized waste management system to their healthcare facilities. Those amounts were included as one bundle as a hazardous waste. Three respondents have given genuinely valuable information about their waste amount of quantity generated. However, those were not counted in Table 12, because the quantity measurement unit was not specified. For instance, one respondent mentioned that 1 cardboard sharp object generated weekly and 1 to 2 plastic bags infectious waste generated per day. The information provided does not specify what is the measurement for one full sharp cardboard or how many sharps fit into one cardboard. Furthermore, those bag sizes are unknown. Another respondent mentioned that 70 kg per day both hazardous and non-hazardous waste produces but this does not give an exact amount of hazardous waste. Further, one respondent indicated that 20-30 specimens per day hazardous waste are generated. Regardless, all information was extremely important which allow the researcher to know the current situation even more in detail. Besides that, there were fourteen important texts inserted by respondents such as chemical waste, infectious waste, sharp, pathological waste weekly, pharmaceuticals, 4 waste materials, radioactive waste monthly, small buckets per week, and so on. From the aforementioned information, they do generate various types of hazardous waste, but they did not give the measurement units. And only three fields for this question were empty so far from a total of 43 surveys.

Question number four was about the amount of non-risk (non-hazardous) waste that is produced per day. Table 13 exemplifies the total amount of non-hazardous waste that was generated from both government and private various healthcare facilities in Kathmandu. It shows that private HCFs produce 801,3 kg/day more non-hazardous waste compare to government HCFs 576,4 kg/day.

Table 13. Non-hazardous waste generated kg/day in Kathmandu.

Health facility type	Non-hazardous waste generated kg/day
Government HCFs	576,4 kg/day
Private HCFs	801,3 kg/day

From the government side, five out of eleven respondents have provided their waste quantity amount which was converted into kilograms per day as well. One specialized hospital additionally added a remarkable text such as that the researcher should also have a survey question where it asked *on the collection of revenue from selling waste*. The other three respondents have provided impressive information instead of quantity, for example, one of the biggest hospitals has not measured non-hazardous waste until now because of inadequate resources. Another big healthcare facility mentioned that they do not have any document for it whereas one of the health-post said no measurement. Moreover, two healthcare facilities have provided information such as 85% non-hazardous 15% hazardous, and other mentioned non-biodegradable waste as a text format. From this information, researchers do not know exactly the measurement unit, so it has not been added to the total amount as shown in table 13. At least from this type of information, it can be concluded that they are producing non-hazardous waste in their HCFs. One respondent out of the total eleven surveys has not given any answer.

In the private sector, from a total of 42 respondents, 24 respondents have provided the non-hazardous waste quantity amount which sums 801, 3 kg/day as per table 13. The other fifteen have written their precious information such as one big bucket per week, non-risk waste per day, weekly, 13 non-hazardous waste, bio-degradable waste weekly, generally 1 to 2 buckets weekly, and 70 kg/day including hazardous and non-hazardous waste. Looking at all this information it embodies that these HCFs produce non-hazardous waste daily. However, the researcher does not know their measurement unit clearly, for that reason these fifteen have not been included and counted in the total sum. Besides all, only four were empty regarding the non-hazardous waste quantity from the respondents.

Question number five was about the current processes and technologies that have been used to handle and treat their medical waste. Based on 54 responses the bar graph in figure 13 shows undoubtedly autoclave (81,5%) is the most popular and common current technology that has been used by both government and private HCFs in Kathmandu. Besides autoclave, chemical disinfection and incineration are in second and third place with 42,6% and 31,5% respectively and other more information can be seen from below figure 13. The data analysis shows that the majority of the HCFs as per respondents' answers are managing their healthcare waste by a combination of both technology and process. Further, figure 13 also shows clearly that open burning and discards to the municipality are also the way of disposing of healthcare waste and some respondents informed that they handed it to waste collectors as well.

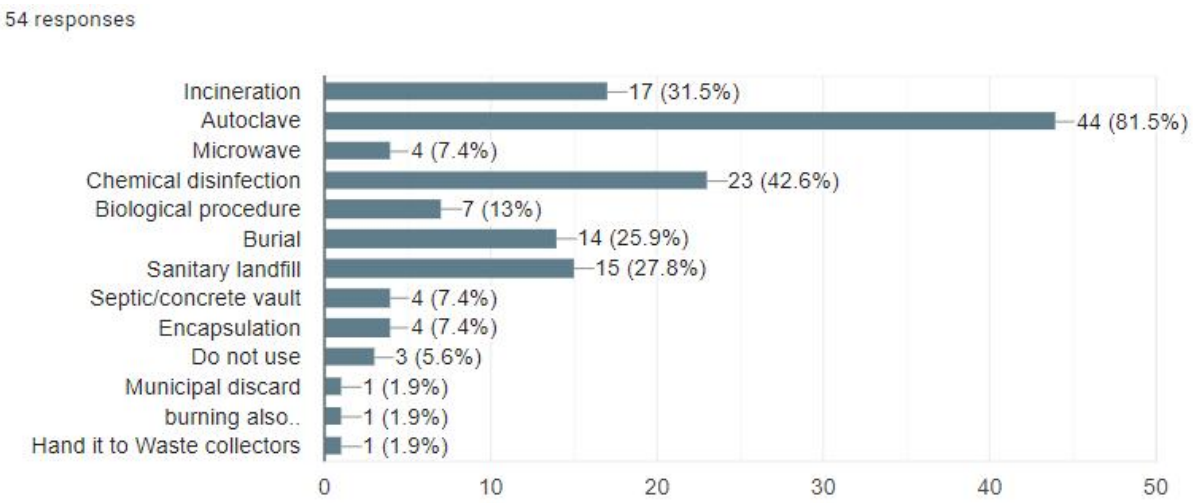


Figure 13. Popular medical waste treatment processes and technologies in Kathmandu.

Question number six was about the capacity of the current process and technologies that are used by both government and private HCFs in Kathmandu district. Most of the healthcare facilities are using 20kg capacity of the autoclave. Besides, the result shows that some health facilities deploy the autoclave which has capacity about 30-40 gallons/day, 50kg, and even 175+175 liter. However, some respondents mentioned that their waste is taken by the municipality. Adding more, one respondent responded with valuable comments such as "*Encapsulation technique and chemical disinfection is much preferred. Chemical disinfection has a high antimicrobial capacity and decreases the*

environment pollution and encapsulation also decreases environmental hazards". Another representative healthcare waste management respondent added that they use "*chemical disinfection and autoclave for blood samples in the laboratory and non-hazardous waste is applied by incineration technology"*. Some were saying with text either sufficient, moderately sufficient, or unknown about their process and technology's capacity. Additionally, one respondent mentioned that incineration and chemical disinfection have a capacity that could hold for one month whereas autoclave and microwave have a capacity for holding a week's medical waste.

The sub-question number six (a) as if the selected process and technology have sufficient capacity. The below pie chart figure 14 demonstrates that the highest number (88,2%) of respondents have agreed that they can manage their medical waste from their existing available process and technology. On the other hand, only 11,8 percent of the respondents indicated that they do not have enough capacity for handling and treating their medical waste.

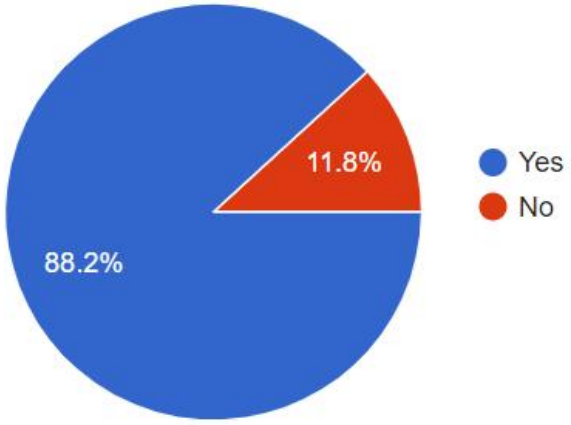


Figure 14. The capacity of processes and technologies.

Question number seven was about who is the assigned organization that collects medical waste from both government and private HCFs in Kathmandu. Table 14 is the frequency table with percentage for medical waste collectors from total respondents and the pie chart in figure 15 is the results. Out of a total of 54 responses, the majority of 26 (48,1%) of the respondents confirmed from both private and government HCFs that they use the private utility to collect their medical waste. Similarly, 21 (38,9%)

responses through public utility. However, the result revealed also that nearly 7,4% of the health facilities openly burned their medical waste on the site. Besides that, some respondents confirmed to collect either themselves (self-collection), use separate biomedical waste, or buries the waste safely. The overview clearly shows that most of the HCFs have some sort of system in place for the disposal of their medical waste.

Table 14. Medical waste collection parties.

Collector	Frequency	Percentage
Public utility	21	38,9
Private utility	26	48,1
Burning openly	4	7,4
Self-collection	1	1,9
Biomedical waste organization	1	1,9
Infectious waste is buried safely	1	1,9
Total	54	100

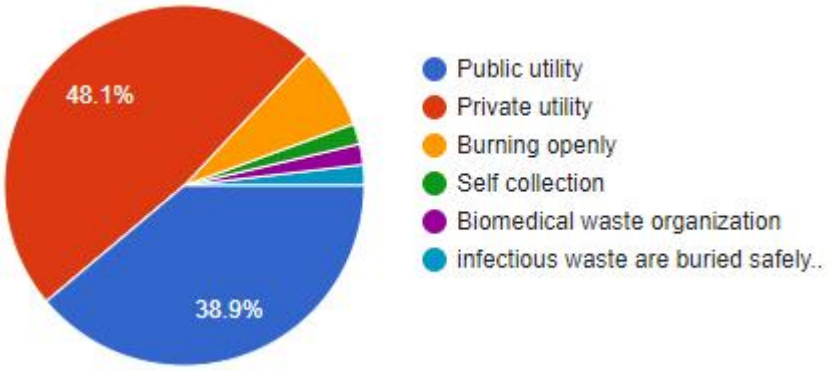


Figure 15. Medical waste collection system in Kathmandu.

Further, when the researcher had an opportunity to survey via the third party in the printed version, one of the bigger government hospitals added valuable information for this question that the public utility collects their treated waste and private utility collects plastics and bottles.

Question number eight was about whether the separation of medical waste takes place when the waste is generated or not from both government and private HCFs in Kathmandu. Table 15 illustrates the total frequency and percentage responses and the pie chart in figure 16 is the result. The highest amount of 43 (81,1%) of the responses agreed that they do separate their generated medical waste at the source of the

generating point. In contrast, 9 (17%) of the respondents stated that they do not separate their medical waste at the source of generating point and one respondent addressed that they dispose of everything together at the end even though waste was separated at first.

Table 15. Medical waste separation system.

Medical waste separation	Frequency	Percentage
Yes	43	81,1
No	9	17
But disposed together	1	1,9
Total	53	100

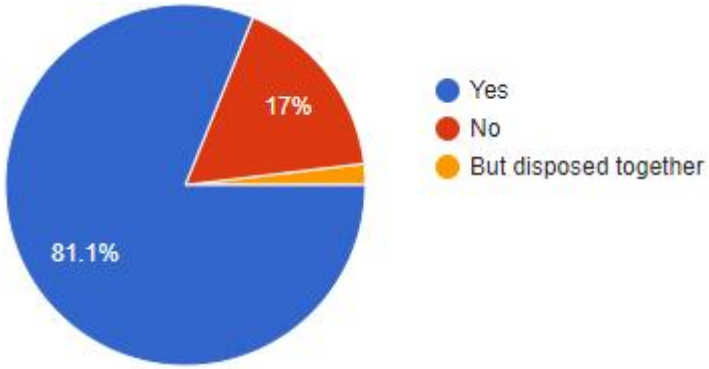


Figure 16. Separation of the medical waste at the source of generating point in Kathmandu.

Question number nine was inquiring if both government and private HCFs have sufficient budgets to handle their medical waste. Table 16 shows the distribution frequency of the responses with the percentage and pie chart form in figure 17 present the table results. A total of 54 responses to the majority 33 (61,1%) verified that they have a sufficient budget for managing and handling their medical waste. The other 15 (27,8%) responses report an inadequate budget for handling their medical waste. Conversely, 11,1% of the responses were uncertain whether the budget is enough or not to handle their medical waste.

Table 16. Budget to handle medical waste.

Enough budget	Frequency	Percentage
Yes	33	61,1
No	15	27,8
Uncertain	6	11,1
Total	54	100

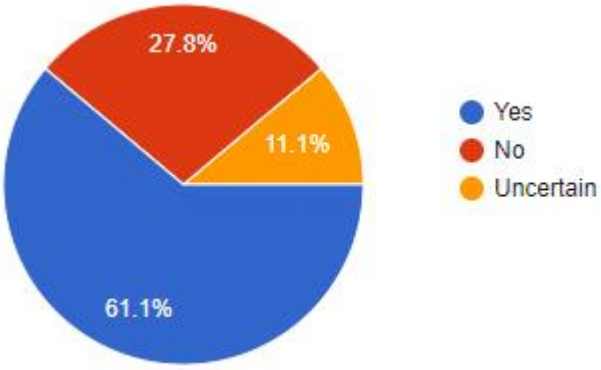


Figure 17. Budget for medical waste management.

In question number ten the question asked were if any government and private HCFs are receiving national or international NGOs' support for handling their medical waste system. Table 17 present the frequency and percentage, and the results are shown on the pie chart in figure 18. The pie chart highlighted that the majority of the responses 83,3% said they do not receive any support for handling their medical waste management system from any national or international NGOs. Undoubtedly, 16,7% mentioned that they do receive some support from them.

Table 17. Support for the HCWM from NGOs.

Support from NGOs for HCWM	Frequency	Percentage
Yes	9	16,7
No	45	83,3
Total	54	100

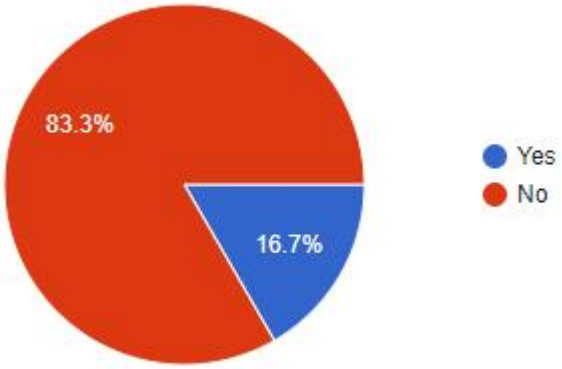


Figure 18. Support received from NGOs on the healthcare waste management system.

Question number eleven asked whether the HCFs (government and private HCFs) receive medical waste management training on their premises or not. Table 18 shows the clear responses answers with percentages and results in pie chart figure 19. From the total 54 responses, the majority, 24 (44,4%) of the respondents said they did not receive any waste management training and 21 (38,9%) of the respondents mentioned that they received once a year healthcare waste management training. Very few responded that medical training was received twice a year, three times a year, and more. Also, the researcher had a chance to collect the data through a printed version via a third party from one of the larger national hospitals in Kathmandu. The survey answered showed that the hospital received the training but not yearly and they have not had the training for the last three years.

Table 18. Medical waste management training on HCFs premises.

Medical waste management training	Frequency	Percentage
Every year	21	38,9
Twice a year	4	7,4
Three times a year	3	5,6
More	2	3,7
No	24	44,4
Total	54	100

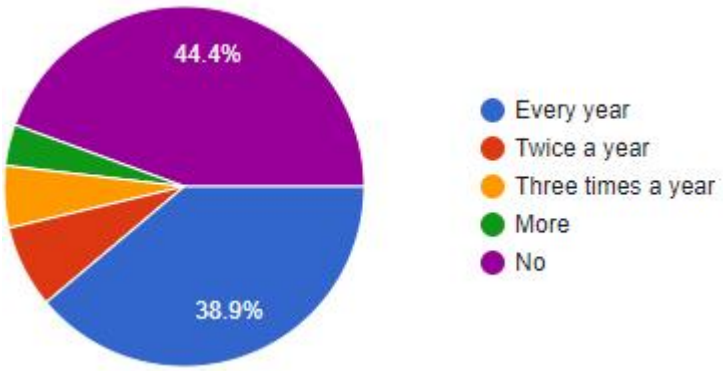


Figure 19. Medical waste management training.

Question number twelve was about whether HCFs (both the government and private) are recording the injury-related medical waste or not. If respondents answered yes, then how often recording is addressed in the system. Table 19 shows distribution frequency and percentage on the next column based on responses answers where the pie chart in figure 20 is the results of it. Most of the responses (71,7%) show clearly that their HCFs do not have any recording system related to an injury on medical waste. And 22,6% HCFs as per responses address that they do record injury related to medical waste from 1 to 5 each day and very few responses said that they do record their injury which occurs 5-10 times each day. More details can be seen from the pie chart in figure 20.

Table 19. Injury record on medical waste.

Injury record	Frequency	Percentage
1-5 each day	12	22,6
5-10 each day	3	5,7
11-15 each day		
Over 16		
Not recorded	38	71,7
Total	53	100

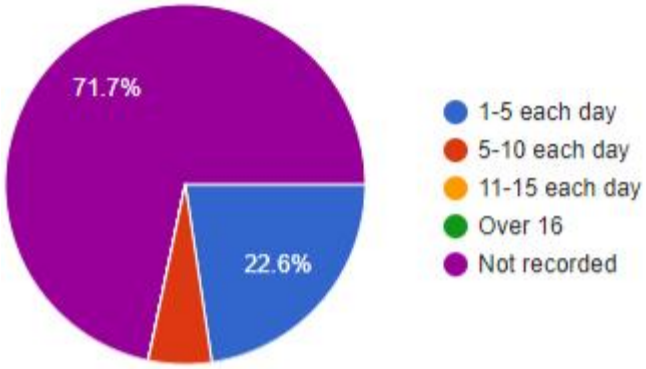


Figure 20. Injury record on medical waste.

Question number thirteen asked whether the government and private HCFs in the Kathmandu district are following the Healthcare Waste Management Guideline 2014. Table 20 illustrates the frequency and percentage from the responses and pie chart figure 21 is the result of the responses. The results describe that the majority 77,4% of respondents replied that they do follow the Healthcare Waste Management Guideline 2014 and the other 22,6% referred that they do not follow any guidelines for handling their medical waste.

Table 20. Health care waste management guideline 2014 follow up.

Follow HCWM guideline 2014	Frequency	Percentage
Yes	41	77,4
No	12	22,6
Total	53	100

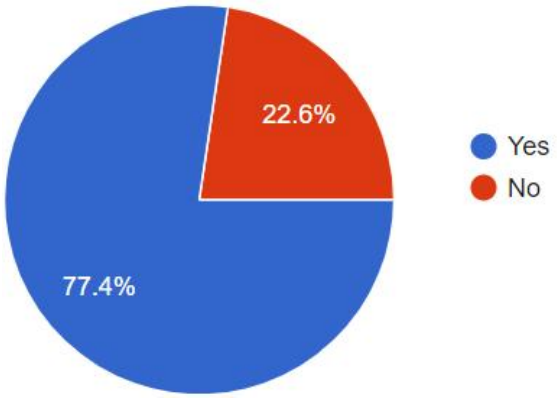


Figure 21. Following the health care waste management guideline 2014.

Question number fourteen was about the opinion of respondents if they prefer to have a healthcare waste treatment center outside of their facility premises. Table 21 present the frequency with percentage and pie diagram figure 22 shows the result of the table. The majority 75,5% (included 41,5% agree and 34% strongly agree) of the responses prefer to have a healthcare waste treatment center outside their facility premise. The other 17% of the responses were indifferent about having a treatment center within their own facility or outside the own facility premises. Also, 5,7% and 1,9% were disagreeing and strongly disagreeing respectively.

Table 21. Establishment of the medical waste treatment facility.

Establishment of the medical waste treatment facility	Frequency	Percentage
Strongly agree (5)	18	34
Agree (4)	22	41,5
Neither agree or disagree (3)	9	17
Disagree (2)	3	5,7
Strongly disagree (1)	1	1,9
Total	53	100

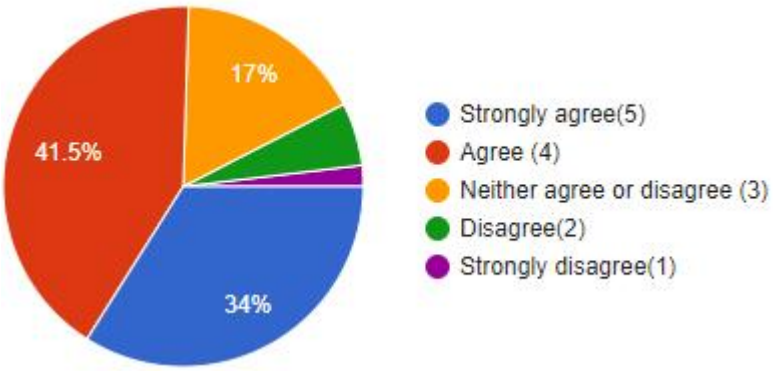


Figure 22. Medical waste treatment facility center.

The last question asked whether the respondents would like to get a summary of the results from the researcher. The results of the analysis overall were that most of the responses from both government and private HCFs are willing to know the current situation of the healthcare waste management system in the Kathmandu district.

4.4 Research reliability and validity

The quality of the research is based on the two features; validity and reliability (Middleton 2019). The research is reliable if the same phenomena, methods, and tools are repeated by another researcher and that the conclusion should be similar or the same tells that the research is reliable (Briggs et al. 2012). The online survey questionnaire instrument or techniques was applied as the reliability of data collection to gather accurate information. The point is each time the reliable instrument delivers exactly or similar results (Briggs et al. 2012).

The researcher has directly interacted and discussed with each representative of the HCFs by phone from Finland to Nepal before the survey was conducted and followed by the next round email. The aim was to verify and ensure the right person of that HCFs premises completed it. All the surveys are conducted only by representative respondents which can be seen from the pie chart in figure 12 in section 4.3 in question number one. The direct contact procedure helps to minimize the errors and bias in the data collection process (Briggs et al. 2012). In this case, the reliability of the research was very high.

Validity refers that the research field that measures all the information that it should be measuring (Taherdoost 2016). The author added further that validity is defined as the mandatory information that is supposed to measure from the targeted research field via the data collection method. Additionally, the idea of validity is to evaluate if the study precisely outlines the phenomenon that it is meant to outline (Briggs et al. 2012). A preliminary survey was carried out via telephone to make the respondents understand the purpose of the research and define some parameters such as medical waste, medical waste management, and technologies. Every single question has been described clearly so respondents give the correct measurement to fulfil objectives of the research. This phenomenon verifies that the researcher has surveyed with high validity.

5 SUMMARY AND CONCLUSIONS

This chapter of the research demonstrates the summary and conclusions of the research. Primarily, this chapter emphasizes the research's main question and objectives. Then the key research findings and research recommendations are presented based on the survey's outcome. Additionally, research limitations are highlighted, and future research directions will be suggested.

The main question was outlined as a guide for the research:

What are the factors enabling the development of medical waste treatment in Kathmandu, Nepal?

In order to determine the factors enabling the creation of medical waste treatment centers, the three main objectives of this research were laid down as follows:

- *To find categories, characteristics, and volume of healthcare waste generated in Kathmandu, Nepal.*
- *To research the present situation of healthcare waste management in Kathmandu, Nepal.*
- *To recommend suitable technology in Kathmandu, Nepal.*

5.1 Key research findings

The research revealed as shown in table 22 the three most popular technologies and processes used by both government and private HCFs in the Kathmandu district where among them autoclave is the most popular technology.

Table 22. Top three most popular HCWM technologies and the process in Kathmandu.

Technology/process	Percentage (%)
Autoclave	81,5%
Chemical disinfection	42,6%
Incineration	31,5%

Further, the research revealed that the total approximately quantity of hazardous and non-hazardous waste is generated by both government and private HCFs is 11 315,55 kg/day and 27 350,1 kg/day respectively, with a total sum of 38 665,65 kg/day in the Kathmandu district (as per below table 23).

Table 23. Total generated hazardous and non-hazardous medical waste in Kathmandu.

Waste type	Medical waste generated kg/day from both government and private HCFs as per 54 survey	Medical waste generated kg/day from both government and private 1 072 HCFs
Hazardous waste	570 kg/day	11 315,55 kg/day
Non-hazardous waste	1 377,71 kg/day	27 350,1 kg/day
Total	1 947,71 kg/day	38 665,65 kg/day

Hints:

From 54 government and private HCFs generated hazardous waste = 570 kg/day
So, a total of 1 072 HCFs generated hazardous waste = 570*1 072/54 kg/day
Total hazardous waste = 11 315,55 kg/day

From 54 government and private HCFs generated non-hazardous waste = 1 377,71 kg/day
So, a total of 1 072 HCFs generated non-hazardous waste = 1 377,71*1 072/54 kg/day
Total non-hazardous waste = 27 350,1 kg/day

Total hazardous + non-hazardous waste from 1 072 HCFs = 11 315,55 kg/day + 27 350,1 kg/day
= 38 665,65 kg/day

The majority of the HCFs, both government and private, used private collectors to collect their medical waste. Yet, more than 70% of the responses said that they do not have any record related to injury to medical waste. Further, the research identified that some of the HCFs are burning openly their healthcare waste. It was further found out that some of the bigger hospitals generated their healthcare waste but did not calculate it until as per data collection time because of inadequate resources. Also, others indicated that there are no documents inserted in their system regarding how

much the healthcare waste amount is generated. Lastly, the result revealed that most of the respondents prefer to have a healthcare waste treatment center outside of their healthcare facility premises.

5.2 Research recommendations

Many challenges are being faced by HCFs in the medical waste management sector in the Kathmandu district. Medical waste management is nothing new rather it is a less researched area in Nepal. Thus, stakeholders are not fully aware of the health implication of improper medical waste management as well as the environmental impact. The adaption of modern waste management technology is slow in Kathmandu.

Firstly, this section recommends a suitable choice of technology in healthcare waste management to manage the HCF's waste in the Kathmandu district. Based on the secondary data and primary data analysis researcher recommends the suitable technology could be the autoclave for the Kathmandu district. The capacity of the autoclave that should handle approximately 11 315, 55 kg/day of hazardous waste as shown in table 23.

There are a few main reasons for choosing the autoclave as a suitable technology. The first reason, as per survey results, it is currently the most popular technology that is used by both government and private HCFs. Second, in the current context of Kathmandu and Nepal as a whole, incineration is not promoted by the government instead the emphasis is to use other non-burning technology such as an autoclave. Third, by applying the autoclave most of the HCFs can re-generate the extra income by sending their re-usable healthcare waste products to recycling facilities abroad. Further, by looking at the result, autoclave seems to be more affordable to most of the HCFs on a small scale by themselves, since almost no HCFs received the funds from the government, except using their facilities own funds or get some support or help from

the national or international NGOs. This scenario could be similar all over Nepal. That's why the same technology could be suggested to across the whole of Nepal.

Secondly, the empirical part for collecting the data should have more options mainly field visits including interviews and or printed copy as per HCFs requirement. These options would allow the researcher to understand and receive more information about ongoing issues in this area.

Thirdly, there should be a policy, law, rules, and regulation particularly addressing the medical waste management system. Also, the law should emphasis on the bookkeeping system for injury-related accidents and provide the waste handler good health care system. On top of that, the government should have clear rules and regulations for assigning the organization for collecting the HCW and how to dispose of them properly.

Fourthly, monitoring and training should emphasize frequently to improve the healthcare waste management system. Apart from this, some opportunities such as job rotation which will help to learn and teach others. Also, awareness, education, advertisement, or news can be spread around the public sector and/or teach it already from the school level.

The last important recommendation is that the government should focus on managing the issue of the medical waste system by establishing a medical waste treatment center, not only for public HCFs but also to bring on board the private HCFs by involving the various stakeholders. Also, by identifying the country's economy and the capacity in choice of technology, the same capacity treatment centers should be installed across Nepal. This triggers a sustainable medical waste management system, generate jobs, protects the public health and the environment not only in the Kathmandu city but also across the whole of Nepal.

5.3 Research limitations

This section demonstrates some limitations that were found by the researcher during the data collection and analysis process.

Firstly, one limitation was the problem of covering a big scale of data from various types of HCFs in the Kathmandu district because of many challenges as stated in chapter 4. Importantly, a physical visit would be mandatory for the next research to collect the data on a big scale in the context of Kathmandu or the whole of Nepal.

Secondary, due to limited resources, as a result of self-financing the process of collecting the primary data led to the loss of some potential respondents who prefer face to face interaction, due to confidentiality. Therefore, this was a contributing factor to the low response rate.

Thirdly, survey questions should have more options and text fields to allow the respondents to choose more options and to write it if they require it. This was realized during the data analysis periods when some of the respondents have provided very valuable information on the printed version.

Finally, there should have been face to face interviews, with both government and private sector medical waste handling representatives to discuss more in detail about medical waste and its management and how this could be improved.

5.4 Future research directions

There is a gap in the medical waste management sector in Kathmandu and overall Nepal. Because medical waste management has less research implemented to the system in the context of Nepal. Here are some suggestions for future research to fulfill the gap.

1. In the future, there should be individual questions asked about the quantity of each type of medical waste that is generated from each HCFs. This will help to identify the types of medical waste and subsequently what types of equipment are needed for hazardous waste and how big the equipment is required to treat the quantity.
2. Are those existing technologies and processes adequate to handle their medical waste and how often are they monitored and maintained? This helps to understand the HCFs' way of handling and treating medical waste. The monitoring and maintenance activities provide to improve safety as well as protect the environment.
3. Every single step of handling the medical waste management system should be investigated. This will help to understand each step and how HCFs are taking care of their medical waste that includes minimization, separation at the source of generating point, collection, storage, transport, treatment, and disposal properly with valid criteria.
4. What kind of resources do waste handlers receive from their HCF e.g. health protection equipment, health insurance, and the vaccine? Waste handlers are the main responsible person in taking care of medical waste and the resources provided support and encourage the worker to work more efficiently.
5. Future research should examine whether that collected waste is disinfected before it is dispatched from the HCFs. Most of the HCFs medical waste is collected by a private and public utility and some other biomedical waste organization.
6. It would be valuable research for the economy if research examines ways of producing energy of health care waste.
7. The possible impact of uncontrolled medical waste generated from HCFs on public health, as well as the impact on the environment, needs to be investigated.
8. Also, future research would be valuable if the Health Care Waste Management Guideline 2014 has precisely been followed by all the HCFs. Also, examining if the budget is enough for taking care of the healthcare waste themselves.

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APPENDICES

APPENDIX 1. Invitation Letter from the University

Vaasan yliopisto
UNIVERSITY OF VAASA

To whom it may concern

Subject: Official Invitation to Answer a Survey Questionnaire

Dear Sir/Madam,

On behalf of the University of Vaasa, Finland, I am supervising Menju Karki on her master's research on the management of medical waste in the Kathmandu region.

I would appreciate it if you could spare some minutes of your tight schedule to answer the research survey questionnaire. I would like to assure you that all the answers collected are processed and utilized with the strictest confidentiality. Please, find attached in a separate document, the detailed information and questionnaire also approved by me.

I look forward to receiving your valuable support for Karki's survey for her research.

Thank you in advance.

Sincerely,

Emmanuel Ndzibah
Assistant Professor
Program Manager – Industrial Systems Analytics
School of Technology and Innovations
Wolffintie 34, 652000 Vaasa - Finland

APPENDIX 2. Research Questionnaire Letter

Research Questionnaire

Dear Sir/Madam,

First of all, I would like to thank you for your interest in reading my request.

I am conducting a survey for my master's research at the University of Vaasa, Finland on the management of medical waste in Kathmandu district. The same survey questionnaire will be distributed to all types of medical facilities and laboratories in Kathmandu district. Your participation is valuable for the data collection process. The aim of this survey is to fulfil the following research objectives:

- *To find categories, characteristics, and volume of healthcare waste generated in Kathmandu, Nepal.*
- *To understand the present situation of healthcare waste management in Kathmandu, Nepal.*
- *To recommend suitable technology in Kathmandu, Nepal.*

I would very much appreciate it if you could spend some 5-10 minutes to attempt the questionnaire. There are 15 questions and most of them are multiple-choice questions.

All given answer will be kept confidentially. Only summarized results will be utilized. The survey results could be useful for investors in medical equipment, waste-to-energy companies, and policy decision makers to further address this current phenomenon in the district.

I would much appreciate if you could send back the completed questionnaires at your earliest convenience.

Thank you in advance for your time and co-operation.

Yours faithfully,

Menju Karki (Msc Candidate)
University of Vaasa
School of Technology and Innovations
Dept. of Industrial Management
Vaasa, Finland
Email: menju.karki@student.uwasa.fi; menju101@hotmail.com

APPENDIX 3. Additional information on SWM resources, types and quantity, and budget.

Involved human resource in 2014 for SWM in the KMC

Post	**Number**
Department Chief	1
Division Chief	2
Engineer	5
Section Officer	3
Administrative Personnel	36
Junior Engineer	3
Municipal Police	19
Driver	135
Sweeper	828
Other	79
Total	**1111**

Source: UDM 2015

Daily collection waste types and quantity in the KMC

Types of waste	**Quantity in ton**
Organic waste	326,22
Plastic	55,72
Paper	46,54
Glass	27,96
Construction and demolition waste	23,22
Textile	11,87
Rubber	6,19
Metals	2,17
Others	16,07
Daily waste collection	**516**

Source: UDM 2015

Budget (Nepalese Rupee) allocation and expenditure on SWM at Kathmandu valley

Fiscal Year	**The KMC**		**The SWMTSC**	
	Budget	**Expenditure**	**Budget**	**Expenditure**
2068/69 (2011/12)	462 600	399 990	73 459	67 058
2069/70 (2012/13)	482 960	398 542	60 704	57 799
2070/71 (2013/14)	621 700	403 023	122 786	111 617

Source: UDM 2015

APPENDIX 4. Macroeconomic key elements of Nepal.

Indicator	Annual Percentage Change							
	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18[R]	2018/19[P]
Real GDP at Producers' Price	4.8	4.1	6.0	3.3	0.6	8.2	6.7	7.1
Real GDP at Basic Price	4.6	3.8	5.7	3.0	0.2	7.7	6.3	6.8
Nominal GDP at Producers' Price	11.7	11.0	15.9	8.4	5.8	18.7	13.3	14.3
Nominal GDP at Basic Price	11.1	9.9	15.3	8.0	5.0	17.4	11.7	12.3
GNI at Current Price	12.0	10.9	16.9	8.4	5.7	18.3	12.9	14.8
Gross National Disposable Income	16.6	12.4	19.2	9.3	6.6	16.0	10.1	16.6
National Consumer Price Index	8.3	9.9	9.1	7.2	9.9	4.5	4.2	4.6
National Wholesale Price Index	6.4	9.0	8.3	6.1	6.3	2.7	1.7	6.2
National Salary and Wage Rate Index	27.4	9.2	13.7	8.4	5.8	14.4	6.2	9.3
Broad Money (M2)	22.7	16.4	19.1	19.9	19.5	15.5	19.4	15.8
Narrow Money (M1)	18.6	14.4	17.7	19.7	18.5	13.1	17.6	8.6
Domestic Credit	9.3	17.2	12.7	16.2	18.2	20.6	26.5	21.4
Domestic Credit to Private Sector	11.3	20.2	18.3	19.4	23.2	18.0	22.3	19.1
Time Deposits	14.1	14.3	11.8	15.1	21.6	58.8	25.5	22.4
Total Exports	15.4	3.6	19.6	-7.3	-17.8	4.2	11.4	19.4
Total Imports	16.5	20.6	28.3	8.4	-0.1	28.0	25.8	13.9
Gross Forex Reserves	61.5	21.4	24.8	23.8	26.1	3.9	2.1	-5.8
Government Revenue	22.3	21.1	20.5	13.8	18.8	26.4	19.3	19.1
Government Expenditure	15.2	12.3	16.3	22.0	14.2	40.2	30.7	0.1
	As % of Nominal GDP at Producers' Prices							
Gross National Disposable Income	128.5	130.1	133.8	134.9	136.0	133.0	129.3	131.9
Broad Money (M2)	74.0	77.6	79.7	88.2	99.6	96.9	102.1	103.4
Narrow Money (M1)	17.3	17.8	18.1	19.9	22.3	21.3	22.1	21.0
Domestic Credit	65.1	68.8	66.9	71.7	80.1	81.4	90.9	96.6
Domestic Credit to Private Sector	53.0	57.4	58.6	64.5	75.1	74.7	80.6	84.0
Time Deposits	22.3	23.0	22.2	23.6	27.1	36.2	40.1	43.0
Total Exports	4.9	4.5	4.7	4.0	3.1	2.7	2.7	2.8
Total Imports	30.2	32.8	36.4	36.4	34.3	37.0	41.1	40.9
Trade Deficit	25.4	28.3	31.7	32.4	31.2	34.3	38.4	38.1
Current Account Balance	5.0	3.4	4.6	5.1	6.2	-0.4	-8.2	-7.7
Gross Forex Reserves	28.8	31.5	33.9	38.7	46.1	40.4	36.4	30.0
Government Revenue	16.0	17.5	18.2	19.1	21.4	23.0	24.0	25.0
Government Expenditure	20.9	21.2	21.3	23.9	25.8	30.9	35.2	30.8
Government Budgetary Deficit (Gross)	-1.9	-2.2	-0.9	-3.2	-2.5	-7.1	-10.1	-5.4
Gross Domestic Borrowing	2.4	1.1	1.0	2.0	3.9	3.3	4.8	2.8
Net Domestic Borrowing	2.0	-0.1	-0.3	-0.2	1.7	1.9	3.5	1.8
Gross External Borrowing	0.7	0.7	0.9	1.2	2.6	2.2	3.0	2.4
Net External Borrowing	-0.2	-0.1	0.1	0.4	1.6	1.4	2.4	1.8
Outstanding Domestic Debt	13.7	12.2	10.3	9.2	10.4	10.7	12.9	13.1
Outstanding External Debt	20.3	19.7	17.7	16.1	17.0	15.7	17.3	17.2

Source: GoN - Nepal Rastra Bank 2019

APPENDIX 5. Additional information on MWT capacity.

An example: Capacity of vacuum autoclave technology

Model	Volume (liters)	Capacity (kg per cycle)
Hazclave mini	20	1
	35	3
	75	7
Hazclave mega	180	12
	350	20
	450	45
	650	65
	900	90
	1200	110

Source: Adapted from UNEP 2012

An example: Capacity of dual-chamber, pyrolytic incineration

Model	Capacity (kg per hour)
CP5	5
CP10	10
CP15	15-20
CP30	30-40
CP50	50-60
CP100	100-120
HP500	150
HP750	200
HP1000	250
HP1250	350
HP1500	500

Source: Adapted from UNEP 2012

APPENDIX 6. Survey Questionnaire

1. What is your role or position in the facility? (e.g: housekeeping, housekeeping in charge, doctor, nurse, laboratorian, pharmacist etc)

   Short answer text
   ---

2. What is the name of your facility? (e.g: government hospital, central hospital, private hospital, general hospital, specialized hospital, diagnostic center, ayurbed health clinic, primary health center, health post, pharmacy, laboratory, NGOs, nursing home, medical clinic, dental clinic, poly clinic, eye clinic, teaching hospitals etc)

   Short answer text
   ---

3. What is the amount of hazardous (infectious) waste that is generated per day? (e.g: infectious, sharp object, pharmaceutical, chemical, radioactive, cytotoxic, pathological waste etc. Also, where there is no information about per day waste, please consider weekly, monthly or annually)

   Short answer text
   ---

4. What is the amount of non-risk (non-hazardous) waste that is produced per day? (e.g: bio-degradable, non-biodegradable waste etc. Also, where there is no information about the non-risk waste per day, please consider weekly, monthly or annually)

   Short answer text
   ---

5. What kind of process and technology that your facility use to treat medical waste? Note: possible to select more than one option.

- [ ] Incineration
- [ ] Autoclave
- [ ] Microwave
- [ ] Chemical disinfection
- [ ] Biological procedure
- [ ] Burial
- [ ] Sanitary landfill
- [ ] Septic / concrete vault
- [ ] Encapsulation
- [ ] Do not sue
- [ ] Other…

6. What is the capacity of above mentioned process and technology?

Short answer text

6a. Is the capacity enough?

- ◯ Yes
- ◯ No

7. Who collect your medical waste?

- ◯ Public utility
- ◯ Private utility
- ◯ Burning openly
- ◯ Other…

8. Does your facility separate medical waste at the waste generating point?

- ◯ Yes
- ◯ No
- ◯ Other…

9. Does facility have enough budget to handle the medical waste?

- ◯ Yes
- ◯ No
- ◯ Uncertain

10. Does national or international NGOs support the handling of medical waste?

- ◯ Yes
- ◯ No

11. Does your facility get any waste management training?

- ◯ Every year
- ◯ Twice a year
- ◯ Three times a year
- ◯ More
- ◯ No

12. How often does your facility record injury related to medical waste?

- ◯ 1-5 each day
- ◯ 5-10 each day
- ◯ 11-15 each day
- ◯ Over 16
- ◯ Not recorded

13. Does your facility follow the Healthcare Waste Management Guideline 2014?

- ◯ Yes
- ◯ No

14. Do you prefer to have a healthcare waste treatment center outside of your own facility premises?

- ◯ Strongly agree (5)
- ◯ Agree (4)
- ◯ Neither agree or disagree (3)
- ◯ Disagree (2)
- ◯ Strongly disagree (1)

15. If you wish to receive a summary of the result please provide your email address.

Short answer text
