



**HEALTHCARE SOLID WASTE GENERATION AND ITS MANAGEMENT
SYSTEM: THE CASE OF KELLE PRIMARY HOSPITAL, KOORE ZONE, SOUTH
ETHIOPIA REGION, ETHIOPIA**

M.Sc. THESIS

ABREHALIGN ASHENAFI

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

OCTOBER 2024

**HEALTHCARE SOLID WASTE GENERATION AND ITS MANAGEMENT SYSTEM:
THE CASE OF KELLE PRIMARY HOSPITAL, KOORE ZONE, SOUTH ETHIOPIA
REGION, ETHIOPIA**

ABREHALIGN ASHENAFI

**A THESIS SUBMITTED TO THE DEPARTMENT OF BIOLOGY, COLLEGE OF
NATURAL AND COMPUTATIONAL SCIENCES, SCHOOL OF GRADUATE
STUDIES HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN ECOTOXICOLOGY AND ENVIRONMENTAL HEALTH**

OCTOBER 2024

SCHOOL OF GRADUATE STUDIES
HAWASSA UNIVERSITY
ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled “**HEALTHCARE SOLID WASTE GENERATION AND ITS MANAGEMENT SYSTEM: THE CASE OF KELLE PRIMARY HOSPITAL, KOORE ZONE, SOUTH ETHIOPIA REGION, ETHIOPIA**” submitted in partial fulfillment of the requirements for the degree of **Master’s** with Specialization in Ecotoxicology and Environmental Health, the Graduate Program of the **Department of Biology**, and has been carried out by *Abrehalign Ashenafi ID N^o GPEcEHR/0001/15*, under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the Department.

Mekuria Teshome (Ph.D.)

Advisor

Signature

Date

SCHOOL OF GRADUATE STUDIES
HAWASSA UNIVERSITY
EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by **Abrehalign Ashenafi** have read and evaluated his/her thesis entitled” **HEALTHCARE SOLID WASTE GENERATION AND ITS MANAGEMENT SYSTEM: THE CASE OF KELLE PRIMARY HOSPITAL, KOORE ZONE, SOUTH ETHIOPIA REGION, ETHIOPIA**”, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Ecotoxicology and Environmental Health.

<u>Firew Kebede (Ph.D.)</u>	_____	_____
Name of the Chairperson	Signature	Date
<u>Mekuria Teshome (Ph.D.)</u>	_____	_____
Name of Major Advisor	Signature	Date
<u>Daniel Fitamo (Ph.D.)</u>	_____	_____
Name of Internal Examiner	Signature	Date
<u>Ermias Deribe (Ph.D.)</u>	_____	_____
Name of External examiner	Signature	Date
SGS Approval	_____	_____

ACKNOWLEDGEMENTS

Above all, I would like to express my deepest thanks to the Almighty God for his inexpressible support starting from my creation in the womb to the moment. Next, I am very thankful to Hawassa University, College of Natural and Computational Sciences and School of graduate Studies for giving me this chance.

My sincere gratitude felt to my humble advisor Mekuria Teshome (Ph.D., Assistant Professor) who stands beside me without saying tired and bored by giving me helpful advice and encouragement.

Finally, I am greatly indebted to Kelle Primary Hospital Management staff members specially Mr. Teferi Aliqa, Dr. Yonatan Worede, all my friends and families who supported me, by giving support and encouragement.

DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis / dissertation have been duly acknowledged.

Name: _____

Signature: _____

This MSc thesis has been submitted for examination with my approval as thesis advisor.

Name: _____

Signature: _____

Place and Date of Submission: _____

TABLE OF CONTENTS

Content	Page
ADVISORS' APPROVAL SHEET.....	I
EXAMINERS' APPROVAL SHEET	II
ACKNOWLEDGEMENTS.....	III
DECLARATION	IV
TABLE OF CONTENTS.....	V
LIST OF TABLES.....	IX
LIST OF FIGURES	X
LIST OF APPENDICES.....	XII
ABBREVIATIONS AND ACRONYMS	XIII
ABSTRACT.....	XV
1. INTRODUCTION	1
1.1 Background of the Study.....	1
1.2 Statement of the Problem	3
1.3 Objectives of the Study	6
1.3.1 General Objective	6
1.3.2 Specific Objectives	6
1.4 Research Questions	6

1.5	Significance of the Study	7
1.6	Scope of the Study	7
1.7	Limitation of the Study	8
2.	LITERATURE REVIEW	9
2.1	Definition of Concepts and Terms	9
2.2	Categories of Healthcare Waste	10
2.2.1	Non-Hazardous Waste	11
2.2.2	Hazardous Waste	12
2.3	Sources of Healthcare Waste	14
2.4	Healthcare Waste Generation Rate	15
2.5	Healthcare Waste Management System.....	20
2.5.1	Segregation	21
2.5.2	Collection.....	24
2.5.3	On-Site Storage.....	25
2.5.4	Transportation.....	26
2.5.5	Treatment and Disposal Technologies.....	27
2.6	Health and Environmental Impacts of Healthcare Waste	34
2.7	Conceptual Framework	36
3.	MATERIALS AND METHODS.....	38
3.1	Study Area and Period	38

3.2	Study Design	39
3.3	Sample Size and Sampling Technique	39
3.4	Inclusion and Exclusion Criteria	40
3.4.1	Inclusion Criteria	40
3.4.2	Exclusion Criteria	40
3.5	Data Collection Tools and Procedure	40
3.5.1	Measurement of healthcare solid waste generation rate	40
3.5.2	Evaluation of Healthcare Solid Waste Management System	42
3.6	Study Variables	42
3.6.1	Dependent Variables.....	42
3.6.2	Independent Variables	43
3.7	Data Processing and Analysis	43
3.8	Data Quality Assurance.....	44
3.9	Ethical Consideration	44
3.10	Dissemination Plan of the Study Findings	44
4.	RESULT	45
4.1	Patient flow in Kelle Primary Hospital	45
4.2	Healthcare waste generation rate	45
4.3	Healthcare waste generation rate in different wards	47
4.4	Healthcare solid waste generation rate by types of waste.....	51

4.5	Comparison of Daily Healthcare Solid Waste Generation Rate and Patient Flow	52
4.6	Healthcare solid waste management system	53
4.6.1	Segregation of Healthcare Waste Management System	53
4.6.2	Collection, storage and transportation of healthcare solid waste.....	54
4.6.3	Treatment and Disposal Practice	57
4.6.4	Incinerator ash generation and management practice.....	58
4.6.5	Waste management guideline, instruction and minimization practices.....	59
4.6.6	Training and safety devices	60
5.	DISCUSSION	63
6.	CONCLUSION AND RECOMMENDATION.....	67
6.1	Conclusion.....	67
6.2	Recommendation.....	68
7.	REFERENCES	69
	APPENDICES	83

LIST OF TABLES

Table	Page
Table 1: Categories of healthcare waste. After Rae and Hirani (2014).....	13
Table 2: Table shows categories/classification of healthcare waste and their treatment and Disposal sites from Rae and Hirani, (2014).....	29
Table 3: Average daily healthcare solid waste generation by types of waste in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024	46
Table 4: Total Healthcare waste generated in different wards by types of waste in the given seven days of data collection time in Kelle Primary Hospital, Koore Zone, South Ethiopia region, 2024	48
Table 5: Comparison of General waste generation rates in different wards using Post- Hoc test in One-Way ANOVA in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024	49
Table 6: Comparison of Hazardous waste generation rates in different wards using Post-Hoc test in One-Way ANOVA in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024	50
Table 7: Spearman’s Correlation Matrix (r_s) Hazardous waste, Total Healthcare waste and Patients Flow in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024.....	51
Table 8: Participants' response on the waste collection, treatment and disposal practice in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024	62

LIST OF FIGURES

Figure	Page
Figure 1: Standard waste composition in healthcare facilities, source from Janik-Karpinska <i>et al.</i> , (2023).....	11
Figure 2: Figure shows the source of healthcare wastes (The Gazette of India, 2021).....	14
Figure 3: A color-coding for healthcare waste segregation also treatment and discarding system of the wastes, Source Nandy <i>et al.</i> , (2022).	22
Figure 4: Conceptual framework of factors affecting healthcare solid waste generation rate; and current waste managing system	37
Figure 5: Map of Kelle Primary Hospital (Google Earth Pro, 2024)	39
Figure 6: The daily distribution of total amount of healthcare waste generation in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, February 2024.....	47
Figure 7: The percentage of healthcare waste generation rate by types of waste in Kelle Primary Hospital, Koore Zone, South Ethiopia region, February 2024.	52
Figure 8: Scatter plot of daily variation in total healthcare waste generation versus total number of patients visited Kelle Primary Hospital, February 2024.	53
Figure 9: Photo shows, healthcare waste segregation practice at point of generation (figure A), placement of bucket at which sharp waste deposited (figure B), in Kelle Primary Hospital, February 2024	54
Figure 10: The Photo shows, healthcare waste collection (figure A), transportation by open plastic bin (figure B) and scattered waste on roads and areas (figures C and D) in Kelle Primary Hospital, February 2024	56

Figure 11: Photo shows the incinerator site (figure A), firing the waste loaded to the incinerator and smoke emission (figure B), in Kelle Primary Hospital, February 2024 57

Figure 12: Photo shows, dumping of waste in old brick incinerator (figure A), open and unsecured placenta pit (figure B) in Kelle Primary Hospital, February 2024 58

Figure 13: Photo shows uncovered ash pit (figure A), platted land and growing vegetable near the ash pit (figure B) in Kelle Primary Hospital, February 2024 59

Figure 14: Photo shows the healthcare waste handler using latex glove as protective equipment (figure A) and a person operating the incinerator without using any protective equipment (figure B), in Kelle Primary Hospital, February, 2024..... 61

LIST OF APPENDICES

Appendix	Page
Appendix I: Verbal Consent sheet, Observational Checklist and Interview Questionnaires.....	84
Appendix II: Parts of National Healthcare Waste Management Guideline (2008).....	93
Appendix III: Photos showing solid healthcare waste management practice in Kelle Primary Hospital.....	95

ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ART	Antiretroviral Treatment
BMW	Biomedical Waste
CO	Carbon Dioxide
DEP	Department of Environmental Program
EFMHCA	Ethiopian Food, Medicine and Healthcare Administrative and Control Authority
FMoH	Federal Minister of Health
GDP	Gross Domestic Product
GNI	Gross National Income
GW	General Waste
HCF	HealthCare Facilities
HCWM	Healthcare Waste Management
HSW	Hospital Solid Waste
HSDP	Health Sector Development Program
HW	Hazardous Waste
ICU	Intensive Care Unit
MCH	Mother-Child Health

MD	Mean Difference
MDGs	Millennium Development Goals
MMIS	Making Medical Injections Safer
NICU	Neonatal Intensive Care Unit
NO _x	Compounds of Nitrogen
OPD	Outpatient Department
PCB	Polychlorinated Biphenyl
PVC	Polyvinyl Chloride
PM	Particulate Matter
PPE	Personal Protective Equipment
SD	Standard Deviation
SDG	Sustainable Development Goal
SOP	Standard Operating Procedure
TB	Tuberculosis
UNEP	United Nation Environmental Program
UNICEF	United Nations International Children's Emergency Fund
UNSD	United Nation Statistics Division
WHO	World Health Organization

ABSTRACT

Healthcare facilities generate healthcare wastes that can endanger the health of human being and environment. Healthcare Waste refers to waste that is produced during treatment, diagnosis and related activities. It needs special and suitable handling before disposal. This study is aimed to assess the healthcare waste management system in Kelle Primary Hospital, Koore Zone, South Ethiopia region, Ethiopia. A cross-sectional study design involving Direct Observation, Key Informant Interview and weighing scale was used to evaluate the healthcare solid waste management system. Analysis of variance was used to compare the mean waste generation rate among wards. The average daily healthcare waste generation rate was determined to be 0.84 kg/bed/day and 0.65 kg/patient/day. Of the total solid waste generated, over half (52.16%) constitutes general waste and the remaining 47.84% was hazardous waste. There were significant variation between different wards regarding GW and HW. Regarding GW (OPD and radiological ward (MD=7.43, P<0.001)) was the highest and regarding HW (Delivery ward and Pharmacy (MD=7.61, P<0.001)) was the highest. Besides, there was limited segregation of healthcare waste by type at the point of generation. Healthcare waste was collected and transported using a cracked sub-standard open plastic bins. Moreover, the brick incinerator performs at low temperature. The average hazardous healthcare waste generation rate is above the threshold value set by WHO, of hazardous HCW generation rate in low-income countries. Therefore, proper application of the principle of waste segregation based on international and national guideline have to be applied in the Hospital.

Key Words: *Healthcare waste, Generation rate, Management system, Kelle Primary Hospital*

1. INTRODUCTION

1.1 Background of the Study

Healthcare facilities are essential institutions, dedicated to minimizing health issues and eliminating immediate threats to people's well-being (Patil and Pokhrel, 2005). The global healthcare system has significantly grown in numerous industrialized and developing countries during the past few decades and this allows for expanding of healthcare services to a larger population across vast geographical regions (Faiza and Artika, 2019). Unfortunately, advancements in healthcare can result in the production of a continuously increasing volume of waste that is not being adequately managed (Shalini and Harsh, 2012).

Healthcare facilities include clinics, Hospitals, dentist's offices, doctor's offices, blood banks, urgent care facilities, medical research institutions and medical laboratories (Ben, 2020). Each of these healthcare facilities generates waste, which is growing in both quantity and complexity because of technological advancements, and is having an impact (Srivastav and Mahajan, 2016). Hospitals are comprehensive institutions that are visited by individuals from every community of society, irrespective of age, gender, ethnicity, or religious affiliation (Col *et al.*, 2003). Urban and rural Hospitals and clinics in developing countries dispose their healthcare waste in a manner that pose a risk of diseases among populations (WHO, 2004a).

According to Ethiopian Food, Medicine and Healthcare Administrative and Control Authority, Healthcare Waste Management directive, 2005 "*Healthcare Waste*" refers to waste that is produced during the treatment, diagnosis or immunization of human beings or in related research and laboratory activities (EFMHACA, 2005), which includes different types of

hazardous wastes such as infectious wastes, pathological wastes, sharps, pharmaceutical wastes including chemical waste and radioactive waste (WHO, 2017).

Majority of these waste produced in healthcare facilities are non-hazardous(WHO, 2015b). According to World Health Organization report in 2017, about 85% of the waste generated in health-care facility is identical to domestic waste and generally called “*general healthcare waste*”. It mostly comes from the administrative, kitchen and housekeeping functions of healthcare facilities and may include packaging waste and waste generated during construction and maintenance of health-care buildings whereas, the remaining 15% wastes generated in health-care facility, are hazardous (WHO, 2017), and regarded as ‘*healthcare waste*’ which could present many health and environmental risks (Sharma *et al.*, 2013)

Healthcare waste constitutes around 1–2% of municipal wastes, this is a significant public health issue as it poses risks to both human and environmental health (Belhadi *et al.*, 2020). Following healthcare waste from healthcare facilities in most of developing and developed nations has created several concerns due to the fact that there are still inappropriate techniques for the management of those wastes(Diaz *et al.*, 2008). Poor management of healthcare waste threatens healthcare professionals, those who handle waste and community members to illnesses, harmful effects and fatalities (WHO, 2015b). Hence, healthcare waste generated in Healthcare facilities require special attention and adequate and safe management mechanisms before final disposal, including all activities involved in waste generation, segregation, collection, storage, transportation, treatment, and final disposal (Meleko *et al.*, 2018).

1.2 Statement of the Problem

Around the world, the health sector has seen significant improvement. Nevertheless, the proportion of waste produced at healthcare facilities has not received equivalent attention as other categories of waste(Coad, 2004). Generation and discarding of healthcare wastes have become emerging problems worldwide(Yazie *et al.*, 2018). Improper management of health care wastes poses environmental, occupational, and public health threats to at least half of the world's population, according to a systematic review of 150 studies published since 2015 (Caniato and Tudor, 2015).

Inadequate management of healthcare waste can lead to various issues such as accidental exposure to infectious materials, increasing concerns about potential harm caused by sharp instruments, transmission of diseases from infectious agents to humans, and contamination of the environment with infectious and hazardous chemicals(Jang, 2011).

Every year, it is estimated that over 16 billion injections are given all over the world; however, not all of the syringes and needles are discarded of in an appropriate manner after use, which results in the possibility of damage, infection, and the possibility of reuse (WHO, 2016). In 2010, WHO assessed that injections with contaminated syringes and needles were still accountable for about, 33,800 Human immunodeficiency virus cases, 1.7 million Hepatitis B virus infections and 315,000 Hepatitis C virus infections in low and middle-income countries(WHO, 2015b).

Regardless of its adverse impact on the surrounding public health and environment in broad, proper handling and management of healthcare waste is still substantially undermined in many developing countries(Emmanuel *et al.*, 2014). The findings of a WHO evaluation was found

that between 20% and 60% of health care institutions in 22 developing countries do not have proper health care waste management systems(WHO, 2016). In 2015, a joint WHO/UNICEF study indicated that slightly more than half (58%) of examined healthcare institutions from 24 countries had suitable processes in place for proper disposal of healthcare waste (WHO/UNICEF, 2015). A new global report of joint WHO/UNICEF in 2019, indicated that there is no or very inadequate safe management of healthcare waste in least the developed countries, only 27% of healthcare institutions had basic healthcare waste management services. Furthermore, there is a significant lack of reliable information on aspects such as waste generation and waste properties, making it difficult to establish viable and sustainable management alternatives (Caniato and Tudor, 2015). This is evidenced by a recent joint WHO/UNICEF report indicating that, only three out of eight Sustainable Development Goals regions have data on waste management services in HCFs(WHO/UNICEF, 2019).

In Ethiopia, as in several developing nations medical waste generation is risen dramatically in recent years due to fast population growth(Abebe, 2017) and thus increasing demand for health service. Particularly after global declaration of United Nation Millennium Development Goal, the country implemented the fourth health sector development program in 2010: to address the basic health needs of the society and to achieve the health related MDGs, in this program, the expansion of health facilities was one of the program's pillars (HSDP IV, 2014). These combined trends increase the amount of healthcare waste produced in the country(Abebe, 2017). Nevertheless, waste management throughout health facilities is still not adequate and has gotten less attention(Yazie *et al.*, 2019). There was lack of nationally or locally adapted standards and guidelines(Tesfahun, 2015).

Information on waste management system is scanty; at best, the available ones lack details and comprehensiveness. Most HCFs do not have annual waste management plan. They do not know the quantity of waste generated from their facilities which makes the management system complicated and difficult(Deneke *et al.*, 2011). The kind and amount of waste produced as well as institutional procedures with regard to the sustainable handling of healthcare waste is inadequately investigated and recorded in healthcare institutions(Tesfahun, 2015).

Furthermore, A review conducted by Sharma *et al.*, 2013, concluded that the high air pollution levels in areas near incinerators were associated with a detrimental effect on respiratory system: lung function in children and another study also pointed out a small increased risk of liver cancer associated with people living within 1 kilometer of an incinerator. Thus, to reduce and manage the risks that are associated with improper handling of healthcare wastes; it is necessary to plan and implement evidence-based strategies for intervention (Meleko *et al.*, 2018).

However, Kelle primary Hospital is the only hospital that is found in Koore Zone and the customers flow in the hospital from the urban, rural areas of the zone and from the neighbor woredas of East Guji zone is high and it may be related to high generation of healthcare waste and different nosocomial infections related to the healthcare waste in the Hospital. In addition, the amount of healthcare solid waste generated and the existing healthcare waste management system practiced in Kelle Primary Hospital has not yet been examined. Therefore, this study aimed to address this gap by giving information on healthcare solid waste generation rate, and current management implemented in Kelle Primary Hospital.

1.3 Objectives of the Study

1.3.1 General Objective

- To assess healthcare solid waste type, generation rate, and management system in Kelle Primary Hospital.

1.3.2 Specific Objectives

- ☞ To assess the existing healthcare solid waste management system.
- ☞ To assess the healthcare waste types.
- ☞ To determine the healthcare solid waste generation rate.
- ☞ To assess the factors associated with the Hospital solid waste management system.

1.4 Research Questions

1. What are the quantities and types of healthcare solid waste generated at Kelle Primary Hospital and how effective is the current waste management system?
2. What are the challenges and opportunities in the healthcare solid waste management system at Kelle Primary Hospital?
3. How does the healthcare solid waste management system at Kelle primary Hospital comply with national and international standards?
4. What are the environmental and health impacts of healthcare solid waste management practices at Kelle Primary Hospital?

1.5 Significance of the Study

The major importance of the study is:

- ✎ Providing important information on the amount of healthcare solid waste generated in Kelle Primary Hospital.
- ✎ Evaluating the existing healthcare solid waste management system and then forward appropriate intervention that optimize the waste management system.
- ✎ Furthermore, the outcome of the study will be used as base line data for planning and implementation activities for Kelle Primary Hospital and other Primary Hospitals.
- ✎ It will also help the policy makers, the researchers and other concerned bodies to develop effective healthcare solid waste management system in Kelle Primary Hospital and the country as a whole.

1.6 Scope of the Study

This research focused on the healthcare solid waste generation and its management system in Kelle Primary Hospital. The study was limited to Kelle Primary Hospital, including all departments and units responsible for generating solid healthcare waste. The study focused on solid waste only, which included General Healthcare Waste, Infectious Waste, Pathological Waste, Sharps, Pharmaceutical waste and Radiological wastes.

The study also covered waste generation patterns like quantity of waste: - quantify the solid waste produced per day and per patient. Similarly, the study covered waste management practices in the hospital such as evaluated the hospitals practice in sorting solid healthcare wastes at the source, analyzed how solid healthcare waste was stored and moved within the

hospitals before final disposal, investigated methods used for treating and disposing different types of solid healthcare wastes.

In addition, the study covered the hospitals adherence to national and international healthcare waste management regulations and standards, such as WHO guidelines or national regulation and standards and investigated challenges faced by Kelle Primary Hospital in managing solid waste, such as lack of resources, inadequate staff training, or insufficient infrastructure for handling the wastes. It also proposed practical recommendations for enhancing solid healthcare waste management practices, including better segregation, waste reduction strategies, improved staff training, and potential infrastructural upgrades.

1.7 Limitation of the Study

While this study aimed to provide valuable insights, it is important to acknowledge some potential limitations. One of the limitations in this research was that the study did not consider the seasonal variation when determining healthcare waste generation rate in the hospital. Additionally, Measurement results in this study represent only the time when the data was collected for seven consecutive days (a week) in a specific month, which may be different result if taken in different weeks, and different months.

2. LITERATURE REVIEW

2.1 Definition of Concepts and Terms

There are currently several terms used to indicate the healthcare waste generated by healthcare establishments. These are clinical waste, hazardous healthcare waste and medical waste are typically encountered (Hossain *et al.*, 2011). However, ‘Healthcare waste’ is the most often used term in most articles (Rajan *et al.*, 2018). It is defined and used interchangeably in different parts of the world (Hossain *et al.*, 2011). In India, according to Healthcare Waste (Management and Handling) Rules, 2016 ‘**Healthcare waste**’ is defined as “Any waste which is produced during the treatment, diagnosis or vaccination of human beings or animals or in research activities pertaining thereto or in the production or testing of biological or in health camps (Rajan *et al.*, 2018). Ethiopian Food, Medicine and Healthcare Administration and Control Authority (EFMHACA) defined healthcare waste as ‘the waste produced during the treatment, diagnosis or immunization of human beings’ (EFMHACA, 2005). There are also another important terms. Those are - **Basic service**: - Healthcare waste is safely segregated into at least three bins, and sharps and infectious waste are treated and disposed of safely.

Limited service: - There is limited segregation and or treatment and disposal of infectious waste and sharps, but not all requirement for basic services are met.

No service: - There are no separate bins for sharps, and infectious waste and or infectious waste are not treated/disposed of safely.

Source: JMP (Joint Monitoring Program of WHO/UNICEF) service ladders for monitoring basic waste management services in healthcare facilities (WHO/UNICEF, 2019).

2.2 Categories of Healthcare Waste

A categorization system should clearly distinguish between the many types of waste. For example, General waste or non-hazardous waste comprises a significant portion of healthcare waste which is recyclable (paper, glass, aluminum, packaging material, etc.) or compostable (Hospital kitchen waste, yard waste, etc.)(Emmanuel, 2007a). Infectious waste is likely to contain pathogenic organisms (bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts and it generally includes waste contaminated with body fluids or blood, biological cultures and stocks, and anatomical or pathological waste (body parts, tissues, etc.) (Mandal and Dutta, 2009). Pathological wastes Human or animal pathological wastes, including tissues, blood, organs, pus and body parts and fluids that are removed during autopsy and surgery or other medical procedures (Jang, 2011). Sharps are materials that could cause puncture or cuts wounds, including hypodermic needles, needles, scalpel and other blades, infusion sets, saws, knives, broken glass, and nails. Pharmaceutical waste- Waste containing pharmaceuticals; e.g., pharmaceuticals that are outdated or not anymore needed, goods contaminated by or having pharmaceuticals in bottles, boxes (Joy *et al.*, 2022). Chemical hazardous waste include cytotoxic or chemotherapeutic waste, mercury waste, spent laboratory solvents, cleaners and oils from maintenance, disinfectants, and expired pharmaceutical waste (Chartier, 2014). Tertiary health-care institutions also generate low-level radioactive waste which including radioactive substances; e.g., urine and stool from patients dealt with or tested with uncapped radionuclides, leftover liquids from radiation or laboratory research, packaging or absorbent paper, infected glassware, and sealed sources (Hassan *et al.*, 2018).

Approximately 85% of healthcare waste is classified as nonhazardous and poses no significant threat, similar to regular municipal garbage. The other 15% is classified as hazardous, posing a risk of harm to both humans and animals, as well as having a detrimental effect on the environment (WHO, 2017). It is vital to realize that if both these types are mixed together then the whole waste becomes harmful (Pasupathi *et al.*, 2015).

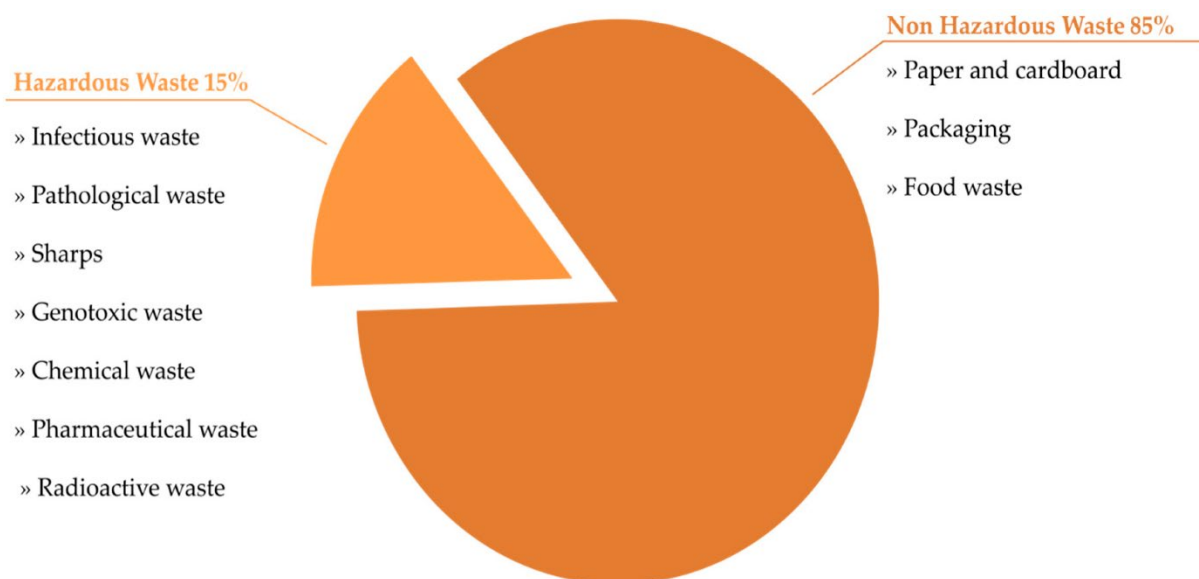


Figure 1: Standard waste composition in healthcare facilities, source from Janik-Karpinska *et al.*, (2023)

2.2.1 Non-Hazardous Waste

Also known as, General waste it consists of all the waste other than hazardous waste and which has not been in contact with any hazardous or infectious, chemical or biological secretions and does not include any waste sharps. This constitutes about 85% of the waste generated in most healthcare set-ups. This includes waste consisting of fruit peels, food remnants, wash water, packaging material, paper cartons, Plastic water bottles, Cans made of aluminum of soft beverages, building and Demolition wastes etc.(Pasupathi *et al.*, 2015).

2.2.2 Hazardous Waste

Hazardous waste implies any wastes, which is produced during the treatment, diagnosis or vaccination of human beings, which comprises all the waste produced from the Healthcare institutions, which can cause any negative impact to the well-being of a person or to the natural environment as a whole if not disposed adequately. It is also called biohazards, and they are biological substances that are harmful to living things, mostly people (Capoor and Bhowmik, 2017). This may encompass medical waste or samples of a microbe, virus or toxin (from a source that is biological in origin) that can influence human health. It can also comprise compounds detrimental to animals (Shannon and Woolridge, 2011). The word and its related symbol is often used as a warning, so that anyone possibly exposed to the materials will know to take precautions (Pasupathi *et al.*, 2015).

Table 1: Categories of healthcare waste. After Rae and Hirani (2014)

S.No	Waste categories	Description and Examples
1	Non-Hazardous/General wastes	Largely composed of domestic or household type waste. It is non-hazardous to human beings, E.g. packaging material, kitchen waste, wrappers, paper, and plastics.
2	Infectious waste	The wastes include a significant concentration or amount of germs that have the capacity to cause diseases. The collection comprises stocks and cultures of infectious agents obtained from laboratories, as well as trash generated during surgical procedures and garbage originating from patients with infectious diseases.
3	Pathological waste	Human body parts, tissues and organs.
4	Sharps	Healthcare waste that poses a physical hazard, such as needles, shattered glass, saws, nails, blades, and scalpels.
5	Pharmaceutical waste	Pharmaceutical products and Drugs that are contaminated outdated or have been spilled.
6	Chemical waste	Chemicals disposed in cleaning, housekeeping, and disinfecting.
7	Radioactive waste	Consists solid, liquid, and gaseous waste, which is contaminated with radionuclides, produced from fluid and in-vitro analysis of body tissues, in-vivo body organ imaging and tumor localization and therapeutic procedures.

2.3 Sources of Healthcare Waste

Healthcare solid waste can be the solid waste stream that is generated from healthcare establishments, health-related research facilities, and laboratories. Hospitals, medical research centers, clinics, laboratories, pharmacies, blood banks, pharmaceutical manufacturing plants, home healthcare activities and veterinary health care centers, are some of the producers of healthcare waste regardless of characteristics, volumes, and composition (Derso *et al.*, 2018).

Medical centers and Hospitals produce the most healthcare waste. This includes Hospitals and medical centers that do surgery, intensive care, maternity wards, accident and emergency rooms, mortuaries, pharmacies, isolation wards, pathology labs, and other research facilities (Bendjoudi *et al.*, 2009).

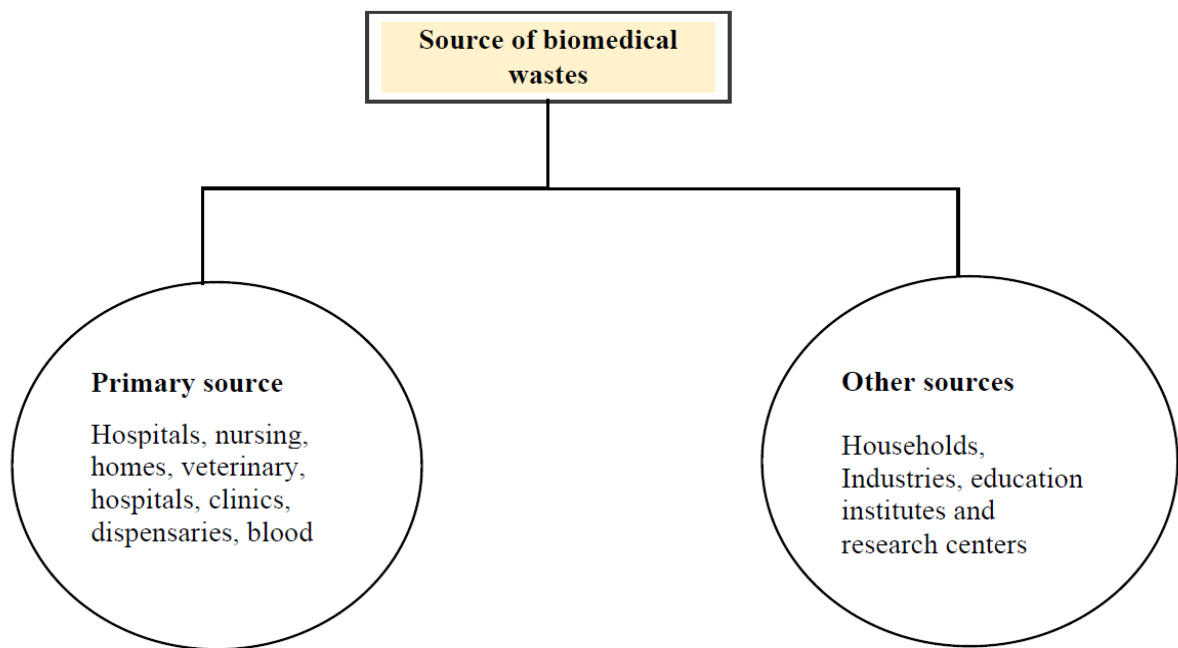


Figure 2: Figure shows the source of healthcare wastes (The Gazette of India, 2021)

2.4 Healthcare Waste Generation Rate

Knowing the quantities and kinds of waste produced in a health-care facility is an important first step in safe disposal (Chartier, 2014). Waste-generation data are used in estimating the required capacities for containers, storage areas, and transportation and treatment technologies (Korhonen and Kaila, 2015). Waste-generation data can be utilized to establish baseline data on rates of production in different medical areas and for procurement specifications, planning, budgeting, optimization of waste management systems, and environmental impact assessments (Emmanuel, 2007a).

HCW generation in healthcare facilities depends on various aspects such as Hospital specialization, Hospital bed capacity, healthcare facility types, accessible waste separation/segregation options, seasonal fluctuation, and proportion of patients treated on a daily basis (Debere *et al.*, 2013).

Globally, it is predicted that 0.5-2.0 kg of healthcare waste is generated per bed per day (WHO, 2016). However, the range of values for countries of similar income levels is probably as wide in high-income countries as in less wealthy countries (Chercos *et al.*, 2017). A study conducted on changing assessment of the economic and environmental sustainability indicator and production, structure, environmental and human health concerns of Hospital solid waste in developing countries showed that the Healthcare solid waste generation rate in healthcare facilities varies from nation to nation depending upon national income and available waste treatment facilities (Ansari *et al.*, 2019).

In United States of America, daily 10.7 kg of HCW is produced by a patient only in major Hospitals in which 2.79 kg/bed/day is infected waste (Sepetis *et al.*, 2022). Those types of

financially wealthy nations are generating waste generally 4–9 kg/bed/day, whilst moderated and lower income countries contribute 0.5– 6 kg and 0.5–4 kg per each person of its population (Attrah *et al.*, 2022). As an example, The African nation Tanzania is generates roughly 0.3 kilograms of Hospital solid waste per bed every day as well as Vietnam, Mongolia, Ecuador and Peru are also generating waste as per increasing order of per capita gross national income (GNI) (Kagonji and Manyele, 2011).

In India, the principle of per bed/day HCW generation differs on the kind of Hospital and its locale as government Hospitals create 5–7 kg while private healthcare facilities produce 2–4 kg in southern India. In western India, the Hospital solid waste is around 1– 3 kg/bed/day (Banerjee *et al.*, 2019). Data from WHO also reveal that the United States of America produces 2.79 kg of healthcare waste per occupied bed/day (Emmanuel *et al.*, 2014). The study revealed in the Kingdom of Bahrain demonstrated that the range of healthcare waste production varies from 0.038 kg/patient-day (for a small Hospital with 10 beds) to 1.177 kg/patient/day (for extremely large complex Hospital with 882 beds)(Mohamed *et al.*, 2009). The greater overall healthcare waste generation rate in industrialized countries may be linked to the higher the per capita gross domestic product (GDP), the higher quantity of healthcare waste that is related to the high supply and provision of healthcare services (Emmanuel *et al.*, 2014, Windfeld and Brooks, 2015). whereas South Africa produces 1.24 kg of healthcare waste per occupied bed/day (Caniato and Tudor, 2015).

In less developed countries, the amount of healthcare waste has sharply risen in recent years because of rapid population growth and thus increasing demand for health services (Nor Faiza *et al.*, 2019). Particularly, in Ethiopia, the number of health institutions has been considerably

highlighted since the starting of the health sector development program IV in 2010; in this initiative, the growth of healthcare institutions was one of the program's pillars (Lemma *et al.*, 2021). Because to this and other associated considerations, the kinds and amounts of disposable healthcare equipment and supplies are expanding and may eventually end in a higher rate of healthcare waste generation in the country (Derso *et al.*, 2018).

The amount of waste generation rate also depends on type and size of the healthcare institutions, number of patients who visit the Hospitals and type of services provided (Hossain *et al.*, 2011). For instance, the study done at three distinct tiers of healthcare institution in Ghana, revealed that the clinical waste generated was computed to be 0.26 kg/patient/day, 0.39 kg/patient/day, and 0.58 kg/patient/day respectively (Wiafe *et al.*, 2015). Another study that was conducted in rural selected healthcare facilities in Vhembe District, Limpopo province, South Africa showed that the mean waste production rate was 0.33 kg/patient/day (Olaniyi *et al.*, 2019). A study Carried out in Mauritius by Bokhoree *et al.*, (2014) showed that the average healthcare waste generation rate in private clinics was 2 kg per/bed on a daily basis (Bokhoree *et al.*, 2014). Another study Carried out in 12 Healthcare centers in Bujumbura, Burundi reported that the average solid healthcare waste generation rate per patient was 0.27 ± 0.17 kg/patient/day in all of the HCFs, and among those, private HCFs generate 0.29 ± 0.21 kg/patient/day, and public HCFs generate 0.22 ± 0.11 kg/patient/day (Niyongabo *et al.*, 2019). There is another study that was done in Nigeria by Abah and Ohimain, (2011) that showed the predicted waste generation rate is within 0.562 to 0.670 kg/bed/day and as high as 1.68 kg/bed/day (Abah and Ohimain, 2011). In addition, there was another study conducted by Longe, (2012) in particular healthcare facilities in two cities (Ikorodu and Lagos) of Nigeria that revealed the averaged waste generation was 0.631 kg/bed/day (Longe, 2012). In addition, a study done in southwest region

of Cameroon showed that the average healthcare waste production rate was 0.55 kg/bed/day (Manga *et al.*, 2011).

A study done by Hassan *et al.*, (2018) in Sudan showed that the estimated average generated rate of HCW ranged from 0.38 to 0.87 kg/bed/day in 2009 and 2012, respectively (Hassan *et al.*, 2018). On other hand a mini-reviewed by Ali *et al.*, (2017) on Hospital waste management in poor nations found that the mean waste production rate in Sudan (Khartoum) from eight healthcare facilities was 0.85 kg/bed/day, in Nigeria(Lagos) from 4 facilities was 0.57 kg/bed/day and in Mauritius (Port Louis/North) from 3 facilities was 0.37-0.4 kg/bed/day (Ali *et al.*, 2017).

A study carried out in Dares Salaam, Tanzania which included 47 Hospitals showed that the overall amount of HCW was 0.134 kg/patient/day (0.076 kg/patient/day was hazardous waste and 0.058 kg/patient/day non-hazardous waste (Manyele, 2017). Another similar study was done in Dares Salaam, Tanzania that involved four Hospitals that showed the average healthcare waste generation rate ranges from 0.3-1.8 kg/patient/day (Olaniyi *et al.*, 2019). Study carried out in Ethiopia revealed the mean standard deviation (\pm SD) of healthcare waste generation rate was 1.79 ± 0.57 kg/patient/day. Of which 0.93 ± 0.3 kg/patient/day were general or non-hazardous and 0.86 ± 0.33 kg/patient/day were hazardous waste (Azage and Kumie, 2002).

Another study done in the Hospital of Addis Ababa, Ethiopia revealed the average healthcare waste produced were 0.5 kg/patient/day and 1.6 kg/bed/day (Haile *et al.*, 2008). A study done in two Hospitals in shashemene (Elie *et al.*, 2023) town showed that the mean generation rates of HCW were 45.2 ± 5.8 kg/day (0.20kg/bed/day) and 20 ± 2.4 kg/day (0.19kg/bed/day) from Government Hospital and Private Hospital, respectively. Of the total solid waste generated, over

half (Government Hospital: 53.3%; Private Hospital: 57.1%) constituted nonhazardous waste, and the left (Government Hospital: 46.7%; Private Hospital: 42.9%) comprised hazardous waste. A study done in Gondar University Teaching Hospital reported that the average production rate of solid healthcare waste estimated based on the number of inpatient was 0.95 kg/bed/day and 0.142 kg/outpatient/day. There were statistically significant correlation between patient flow and the production rate of healthcare waste (Tesfahun, 2015).

Among the studies conducted locally, the study carried out in Mizan Tepi University Specialized Hospital revealed that the total mean production rate of healthcare waste was 0.164 kg/bed/day of which 0.091 kg/bed/day(55.5%) was nonhazardous waste and the left 0.073 kg/bed/day (44.5%) was hazardous waste (Meleko *et al.*, 2018), and in Gondar teaching Hospital 0.37 kg/patient/day of the overall healthcare waste produced was hazardous, as mentioned in (Tesfahun, 2015). A study conducted by Lemma *et al.*, (2021) in Jimma medical center showed that the average daily healthcare waste generation rate was identified to be 0.92 kg/bed/day or 0.75 kg/patient/day (Lemma *et al.*, 2021). There is also study conducted in Tepi General Hospital revealed that the total average healthcare waste generation rate was 0.65 kg/patient/day (Mekonnen *et al.*, 2021). Another similar study was done among Health centers in Bench Maji Zone and showed that the average healthcare waste production rate was 0.02 kg/patient/day (Meleko *et al.*, 2018). A study carried out in West Gojjam Zone, Amhara region among 10 health centers showed that the mean waste production rate was 0.035 ± 0.05 kg/patient/day(Azage and Kumie, 2002).

Another study carried out in Addis Ababa city government health centers showed that the mean (\pm SD) healthcare waste production rate was 9.61 ± 3.28 kg/day of which (38%) 3.64 ± 1.45

kg/day was non-hazardous or general waste and (62%) 5.97 ± 2.31 kg/day was hazardous (Tadesse and Kumie, 2014). A study carried out in selected public and private healthcare centers in Ethiopia showed that the total generation rate of healthcare wastes of Hospitals ranged from 0.25 kg/bed/day to 2.77 kg/bed/day with a median value of 1.67 kg/bed/day for inpatients to 0.21–0.65 in kg/patient/day with a median value of 0.31 kg/patient/day for outpatients (Tesfahun *et al.*, 2014). A study carried out in Addis Ababa, Ethiopia (2011) showed that the mean waste production rate was found to be from 0.361 kg/bed/day to 0.669 kg/patient/day, consisting of 58.69% general or non-hazardous and 41.31% hazardous wastes. from the total hazardous healthcare waste, the majority of which was infectious 13.29%, pathological waste 10.99%, and pharmaceutical and sharp waste 8.74%, and 6.14%, respectively (Debere *et al.*, 2011).

2.5 Healthcare Waste Management System

Medical care is essential for our life and health, but the lack of proper management of healthcare waste causes a serious health impact and damages the ecosystem including flora and fauna. Healthcare waste management is a vital aspect of traditional and contemporary system of health care. Waste management covers every step and action needed to manage waste from starting point to its final disposal (UNSD, 2020). Waste generated during the course of health care activities holds a higher potential for infection and damage than any other sort of waste can cause. It is crucial that all healthcare waste materials are separated at the point and time of generation, adequately handled and discarded of safely (WHO, 2015a).

Worldwide, the handling of hazardous wastes has received many much attention since the early1980s due to its toxicity and infectious nature (Yazie *et al.*, 2019).

Healthcare waste management is a properly designed route activities started from their point/source of generation to their final disposal. This stream mentioned above is made up of several stages that include: generation, segregation/separation, collection, on-site transportation, on-site storage, offsite transportation (optional), treatment and disposal (Jindal *et al.*, 2011).

2.5.1 Segregation

Standardization of waste segregation procedures is necessary nationwide and should be informed by national guidelines/legislation for healthcare waste management. Such waste segregation systems should rely on a uniform color coding system which gives a visual indicator of the potential risk caused by the waste in that container and makes it easier to put waste materials into the right kind of container and to maintain segregation during transport, storage, treatment and disposal (Hossain *et al.*, 2011). Segregation should always be the duty of the waste producer, should take place as close as feasible to where waste is generated (Emmanuel *et al.*, 2014).

The bags and containers should be labeled with the international symbol and it should be leak proof bags of plastic and containers. To handle sharps the container should be tough and watertight so that they safely hold not only the sharps but also additionally any remaining liquids from syringes. There is no color marking for radioactive waste container but as a specification, it should be Lead box, labeled with the radioactive symbol. The lead box will protect the emission of radioactive materials (WHO, 2017).

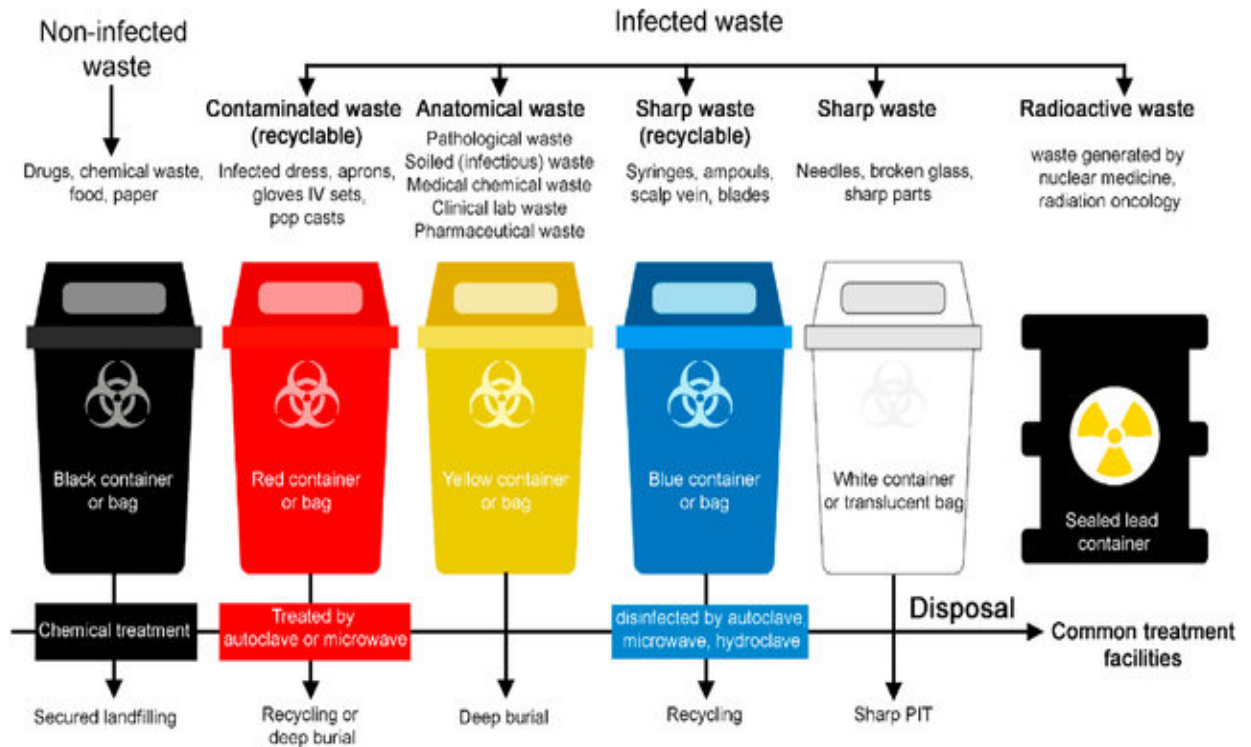


Figure 3: A color-coding for healthcare waste segregation also treatment and discarding system of the wastes, Source Nandy *et al.*, (2022).

In a developed country, healthcare waste is separated/segregated into color coded and labeled bags or containers (Vitale, 2008). Standards require source segregation of different waste streams into labeled and color-coded waste bags/containers. The study of healthcare waste management system carried out in different Hospitals of United States of America, reported that almost beyond half The Hospitals are separating infectious waste from ordinary medical waste (Klangsin and Harding, 2011). However, the implementation of the standards varies from one place to another. Pertinent issues include lack of proper source segregation, the study done in eight educational Hospitals of Iran University that neither of the Hospitals routinely segregated general and medical wastes storage system at the Hospital (Ali *et al.*, 2017). Whereas, in most developing countries, healthcare solid waste has been handled and disposed together with the

general waste, which is creating inevitable risks to the health care workers, publics and the environment (Vitale, 2008). A study done at the different level of five Hospitals in Dakar, Senegal, in 2012, by Dieng *et al.*, indicated that segregation/separation of healthcare waste was inadequate in 53.5% of the services and the implementation of the color-coding system is effective in only 31.4 % of the facilities (Ndiaye *et al.*, 2012). at furthermore, medical waste separating and management methods at 5 Hospitals in Ghana further reveal that although infected sharps were separated in brown safety boxes, adherence to color-coding of other pathogenic waste containers was variable throughout the health facilities (Adu *et al.*, 2020). In health facilities in northern Cameroon, or in the suburbs of Dakar in Senegal, the sorting of solid healthcare waste was also inadequate and the use of the color-coding system is non-existent in health facilities (Mbog *et al.*, 2020; Ndiaye *et al.*, 2020). In a meta-analysis conducted on healthcare and medical waste handling techniques in 2021 in 78 countries including 23 in Africa, 18 in Europe, 19 in Asia, 10 in the Middle East, 2 in North America and 6 in Latin America, on average only 38.9% of healthcare waste is sorted (Singh *et al.*, 2021).

Healthcare waste management studies conducted in Amhara region health facilities, Ethiopia, showed absence of segregation practices in 75% of the HCFs and mixing of hazardous HCW with other wastes in healthcare facilities, moreover the wastes were distributed on the road around treatment sites because of the use of sub-standard waste containers during transportation (Tesfahun, 2015). A study done in Addis Ababa by Debere *et al.*, (2011) revealed that basically in all of the Hospitals there was no separation of waste into pathological and pharmaceutical, infectious, and had no distinct containers for the collection of infectious waste. Non-Hazardous healthcare waste was commonly mixed with infectious waste (Debere *et al.*, 2011). Another study carried out in referral Hospital of Hawassa University by Sisay, (2017), and Mizan Tepi

University specialized Hospital reported that the waste segregation or separation was not practiced at source of production (Meleko *et al.*, 2018). Another study carried out in Hawassa town showed that most (67%) of the healthcare institutions had no separation or segregation of healthcare waste at their facility by using a comprehensive color coding system (yellow puncture-proof plastic container for infectious waste, black for general waste and puncture-proof safety box for sharps waste) (Deneke *et al.*, 2011).

2.5.2 Collection

Healthcare waste, segregated at the source of production and then collected, must often be stored prior to transport for final treatment and/or disposal off site (Emmanuel, 2007b). In order to avert the accumulation of the waste, it is useful to be collected on a fixed basis and transferred to a central storage facility within the HCF before its treatment or removal (Secretary of the Basel Convention/WHO, 2021). The collection must follow certain routes through the HCF in order to minimize the passing of laden carts into wards and other neat places. Considering the management of healthcare waste great care should be given by the Hospital staff to protect occupational hazard. The most important risks are linked with the injuries that sharps can produce. When handling healthcare waste, sanitary staff and cleaners should always wear protective clothing including, as minimum, overalls or industrial aprons, boots and heavy duty (WHO, 2004b).

Collection need to begin from the most properly vulnerable medical regions (e.g. intensive care, dialysis, operating theatres) and follow a regular way around additional medical sections and intermediate storage locations. The frequency of collection should be refined through experience to ensure that there are no overflowing waste containers at any time (WHO, 2017).

Collection periods should be defined and proportionate to the amount of waste generated at each location of the healthcare institution. General waste must not be picked at the same time, or in the same cart, as infectious or other hazardous wastes (WHO, 2017). However, a study done in Addis Ababa City showed that the city administration has a Primary and secondary mixed solid waste collection system (Debalkie and Kumie, 2017). There is no separate hazardous healthcare waste collection, transportation and disposal systems and technologies. The waste in the Hospitals was stored in Black, yellow and red Primary storage containers (Abebe, 2017). The study carried out in Menellik-II referral Hospital indicated that the healthcare waste was gathered daily in the morning at 8:00 AM (Debalkie and Kumie, 2017).

2.5.3 On-Site Storage

After collection of healthcare waste is performed on each ward, different sections of the healthcare institution there should be well-designed temporary storage place in the compound, having the size according to the volume of waste generated also the frequency of collection. A storage location for healthcare waste should be designated inside the healthcare facility (WHO, 2016). Space for storing wastes should be incorporated into a building design when new construction is undertaken and these storage areas should be sized according to the amounts of waste produced and the frequency of collection (WHO, 2017). The study carried out in referral Hospital of Hawassa University by Sisay *et al.*, (2017) has been found from the study that, with the exception of few wards the majority of departments (units) did not have temporary storage. Because of, when storage containers (buckets) grow full, patient attendants just store or put wastes on the ground or on the floor. There had not been containers for storage put outside of the facility for health care waste patient caregivers and others. There was also no reserve containers when the filled containers are hauled to the dumping site (Sisay *et al.*, 2017).

These areas must be totally enclosed and separate from supply rooms or food preparation areas. Only authorized staff should have the authority to access the waste storage areas. Loading docks, space for compactors and balers for cardboard, staging areas for sharps boxes, recycling containers and secure storage for hazardous items such as batteries should all be provided (WHO, 2017). The facility should not be situated near to food stores or food preparation areas and its access should always be limited to authorize personnel unless a refrigerated storage room is available, Cytotoxic waste should be kept separately from other health-care wastes in a designated secure location (Emmanuel *et al.*, 2014).

2.5.4 Transportation

Healthcare waste should be carried throughout the Hospital or other institution by use of containers, wheeled trolleys, or trolleys that are not utilized for any other waste transporting purpose. The carts should be: easy and suitable to loading and unloading, have no sharp edges that could damage waste bags or containers and easy to clean (Emmanuel *et al.*, 2014). However, the study conducted of public healthcare institutions in the city of Adama found that in all studied healthcare facilities, majority of the equipment used for on-site transfer of HCW were open or unprotected (Fikadu, 2016).

Another study done in Menellik-II referral Hospital also revealed that most of the devices utilized for onsite transportation of HCW were closed bin with wheel. The waste on municipal waste tank (completely infectious) was kept for minimum of a week and maximum of three weeks and transferred by out sourced privately owned business in to the city municipal dumping site (Debalkie and Kumie, 2017). And the study carried out in Addis Ababa city and Hawassa town healthcare facilities revealed that most of the solid waste at the HCFs was discovered to

be collected in punctured plastic containers that are designed for usage in areas of administration only and transported largely in open containers of plastic from the point of generation to the treatment site(Deneke *et al.*, 2011; Debere *et al.*, 2011).

2.5.5 Treatment and Disposal Technologies

In selecting healthcare waste management technologies, the terms ‘treatment’ and ‘disposal’ are often wrongly used interchangeably (Alagöz and Kocasoy, 2007), clarify ‘treatment’ as an alteration of a waste stream or contaminated site in order to eliminate, reduce or immobilize hazardous constituents, while ‘disposal’ implies disregard for return, and is thus considered to be permanent storage or release. As per the clarifications of the two terms, examples of treatment technologies include incineration and pyrolysis, microwave and autoclave sterilization and disinfection with chemicals. Disposal technologies in contrast include the utilize of landfills and other surface impoundment techniques (Ikome and Mochungong, 2011). It is found from literatures that the most common disposal technique of healthcare solid waste, especially in less developed countries, are open dumping, landfill or incineration (Hossain *et al.*, 2011). Pathogenic health care waste presents an enormous risk to health and should be treated prior to disposal; a number of different options are available, including chemical treatment, incineration, microwaving, autoclaving and shredding/compacting (WHO, 2004b).

The choice of healthcare waste treatment as well as disposal techniques depends on various parameters: the amount and kind of wastes produced, whether or not there is waste treatment station near the Hospital, the cultural acceptance of treatment methods, the accessibility of efficient means of transport whether there is enough space around the Hospital, the availability of financial, material and human resources, the availability of a steady supply of electricity,

whether or not there is national law and legislation on the subject, the climate, groundwater level, etc. The method must be selected with an objective to minimizing negative impacts on the well-being of human beings and the environment. There is no worldwide solution for waste treatment. The option chosen can only be a compromise that depends on local circumstances (ICRC, 2011).

Treatment technologies should comply with national standards and international conventions including the Stockholm Convention and the Basel Convention (for those countries that have ratified or acceded to the Convention). With regards to environmental and occupational safety, the recommendations in the WHO policy paper on healthcare waste management, the Basel Convention Technical Guidelines for Environmentally Appropriate Management of Healthcare and Health care Wastes, and the Stockholm Convention Guidelines on Best Existing Techniques and Preliminary Guidance on The most effective Environmental should be considered into account (UNEP, 2008).

In some very low resource settings, it may be tough to meet international conventions and/or national standards, especially for waste destruction. In such instances, every effort should be taken to incrementally improve how waste is managed and destroyed to reduce, as much as possible, dangers to human being and environmental health. A plan must be put in place to ensure that over time, capacities and resources are available to meet national standards and international safeguards (WHO, 2019).

According to new global data released by joint WHO/UNICEF in 2019, ladder of technology for the management of dangerous and sharp waste from healthcare establishments, technologies should be selected according to the economic, environmental and social context (WHO, 2019).

Table 2: Table shows categories/classification of healthcare waste and their treatment and Disposal sites from Rae and Hirani, (2014).

Option	Waste category	Treatment and Disposal
Category No. 1	Human Anatomical Waste	Incineration/deep burial
Category No. 2	Animal Waste	Incineration/deep burial
Category No. 3	Biotechnology and Microbiology Waste	local autoclaving / micro-waving / incineration
Category No. 4	Waste sharps disinfection	(chemical treatment/ autoclaving/ micro- waving and mutilation/ shredding
Category No. 5	Discarded Medicines and Cytotoxic drugs	Incineration /destruction and drugs disposal in secured landfills
Category No. 6	Solid Waste	Incineration autoclaving / micro-waving
Category No. 7	Solid Waste	Disinfection by chemical treatment autoclaving/ micro-waving and mutilation/ shredding
Category No. 8	Liquid Waste	Disinfection by chemical treatment and release into drains.
Category No. 9	Incineration Ash	Discarded in municipal landfill
Category No. 10	Chemical Waste	Chemical treatment and release into drains for liquids and a protected burial for solids

2.5.5.1 Incineration

Incineration is a high-temperature (850°C to 1100°C) dry oxidation process that reduces organic and combustible waste to inorganic, non-combustible substance and results in a very significant decrease of waste weight and volume. Incineration is among the most often used treatment process for medical waste (WHO, 2019). Properly constructed and functioned, the incinerator will eliminate all chemically and biologically harmful materials and will decrease the volume of garbage demanding final disposal to around 10% of its original value. The technique has the important additional advantage of rendering hypodermic syringes ("sharps") unusable by melting and/or deforming them and then oxidizing them into the ash. Based on the requirements for final disposition of the products of any waste treatment process and the kinds of waste which may be categorized as infectious, it appears that incineration is an environmentally responsible option for volume reduction, cost and convenience of handling the final product, and assurance of permanent disposal of materials that are potentially biologically hazardous (Ferraz *et al.*, 2011).

Healthcare waste incinerators are classified into three groups based on waste incineration process: there are three main types of incinerators used: excess air, controlled air and rotary kiln (UNEP, 2012). Controlled burning at high temperatures (over 1000°C) is one of the rarest technologies with which all types of healthcare waste can be treated properly and it has the benefit of crucially decreasing the weight and volume of the wastes that is being treated (ICRC, 2011).

Controlled air incinerator comprises two furnace chambers, which are Primary and secondary (Hossain *et al.*, 2011). In the surplus air incinerators, waste is ignited in the Primary

compartment and the secondary compartment supplies the residence duration, temperature and supplemental fuel for burning of the not burned organics. The incinerator has several internal baffles to channel the combustion gasses through 90° rotations in both horizontal and vertical directions. At each revolution, ash descends from the gas stream. The air is fed into the Primary and secondary combustion chambers by the supplementary fuel burners (Singh and Prakash, 2007; UNEP, 2012).

The rotary kiln is a horizontal refractory lined cylinder that revolves about horizontal axis. Waste is imposed straight into the kiln. Air, often in addition of the balanced need, is provided to the kiln to ignite the waste. A secondary chamber for combustion makes up component of the kiln system. Off-gas from the kiln comprises volatiles from the trash that have not burnt out and their combustion is completed in secondary chamber (Singh and Prakash, 2007)

The incineration process must be properly controlled (temperature, residence time, and turbulence). Standard incineration techniques are being superseded by “controlled-air” combustion systems. Such systems have benefits of fewer pollution hazards and smaller operation costs along with easier maintenance of high temperatures. Controlled-air high temperature incinerators are equipped with two chambers. The first one operates at temperatures of about at or above 850 °C. while the operation temperature of the second chamber should be never below 1100 – 1200 °C (WHO, 2019). (Portuguese legislation establishes 1100 °C as the minimum temperature for cytotoxic incineration and two seconds as the minimum residence time (Ferraz *et al.*, 2011). For an incinerator with minimal controls, a well-trained operator must monitor and adjust Primary and secondary chamber temperatures, charging rate, and air levels in the Primary and secondary combustion chambers (WHO, 2019).

Similarly, in Ethiopia all health facilities have chosen incineration to treat HCW. However, a study carried out by Making Medical Injections Safer (MMIS) project in District health institutions in Ethiopia found that the most common ways of healthcare waste disposal were open burning in a pit 54%, low-temperature incineration 52% and open air burning on the surface 18% (Habtetsion *et al.*, 2009). In addition, another study also founds, improper use of incinerators was observed or the incinerators were not working to their full capacity. Some of the reasons include lack of know-how on the part of incinerator operators, poor maintenance and location issues (Kasahun, 2014)..

2.5.5.2 Autoclaving

Autoclave of healthcare waste is seen as a possible replacement technology of the incinerator, but it is considered as a more costly approach than incineration (Jang *et al.*, 2006). It is because, autoclaving is the double treatment alternative of healthcare solid waste and since autoclaving, and wastes demand another treatment process for final disposal. In addition, it cannot handle large amounts of hazardous waste. Besides, autoclave cannot treat a variety of hazardous substances and chemicals such as wastes from volatile and semi-volatile organic compounds, mercury, chemotherapy treatment, radioactive wastes, and other hazardous chemical wastes(UNEP, 2012). It is not appropriate to treating huge body parts, animal corpses, or other large materials that, because of their mass and other qualities, which make it challenging or time consuming for the entire material to achieve the necessary temperatures (Emmanuel *et al.*, 2014).

2.5.5.3 Microwaves

Microwaves are electromagnetic waves with frequencies between radio waves and infrared waves. It is vital if the waste is wet, whether because of naturally occurring moisture or by the addition of the gas steam, in order to establish the thermal process. Some treatment processes utilize microwaves to heat the water to form steam, which is then used to the clinical waste stream. Some systems apply low frequency radio waves to inactivate microorganisms contained within the waste. The microwaves can heat the healthcare waste from the interior of the materials onto their outer surfaces. However, microwaving healthcare waste might be economically competitive compared to the incinerator. Nevertheless, microwave technology is not appropriate for large-scale treatment. The treatment cost is also expensive and is not affordable for the less developed countries. Surveys also reported that microwaving of clinical waste refers inadequate microorganism sterilization capability (WHO, 2019).

2.5.5.4 Open dump and Open Burning

Open dump is the most popular healthcare waste disposal method in developing countries. This is probably less expensive and no other alternative methods are available at this reasonable cost. However, this method also is the least expensive alternative, but open dumping has long been recognized as a possible major source of public health concerns and environmental pollution. It is uncontrolled and inadequate disposal option of healthcare waste, since the waste accessible to scavengers and animals (WHO, 2019). Therefore, healthcare waste must not be deposited on or around open dumps. This is Due to this unregulated healthcare waste distributes contagious disease causing microorganisms to the surroundings either via direct contact through wounds,

ingestion or, inhalation, or indirect contact through the food chains or a pathogenic host organism(Emmanuel *et al.*, 2014).

2.6 Health and Environmental Impacts of Healthcare Waste

Health-care activities will contribute to the generation of wastes that could give rise to undesirable and deleterious health effects. Infectious components in healthcare waste like contaminated sharps and syringes pose the biggest health risks due to potentials for direct exposure to pathogens in blood and other fluid from patients through per-cutaneous injuries (PI), abrasion and a puncture in the skin. Rapiti *et al* (2005) estimated that more than three million HCWs encounter the stressful situation of a PI with a contaminated sharp object each year. WHO has estimated that, in 2000, injections with contaminated syringes resulted in: 21 million hepatitis B virus (HBV) illnesses (32% of all new illnesses); 2 million hepatitis C virus (HCV) illnesses (40% of all new illnesses); 260,000 HIV infections (5% of all new infections) Epidemiological studies indicate that a person who exposed to one needle stick wound from a syringe administered on an infected origin patient has a chances of 0.3%, 1.8% and 30% respectively to be infected with HIV, HCV and HBV (Rapiti *et al.*, 2005).

Gaseous emissions from incineration of clinical waste released directly in to the atmosphere have received the most attention from the public, environmental campaigners and legislators due to purported treats to public health. Emissions of most concern include total PM, acidic gases such as hydrogen chloride, hydrogen fluoride, and sulfur dioxide, various organics and metals, CO, NO_x and other materials such as cyto-toxins, pathogens and radioactive diagnostic materials (Ikome and Mochungong, 2011).

Incinerators, in particular, cement kilns; emit considerable quantities of Sulfur dioxide and Nitrogen dioxide. Being exposure to these substances for a long-term is known to have negative impacts on respiratory health. It was concluded that the high air pollution levels in the areas near incinerators were associated with a harmful effect on lung function in children. Similar studies in Germany, Japan and Spain and have shown that persons working with the incinerator or other residents living near the incinerators have significantly higher blood or urine levels of dioxins, furans, polychlorinated biphenyls (PCBs). Similarly, incinerators emit fine PM, and many studies have reported that exposed for a long time to PM is associated with adverse effects on respiratory function (Sharma *et al.*, 2013).

A study carried in Botswana showed that the higher air pollution levels in the area near the incinerator were linked with a deleterious effect on the condition of the lungs in school children living around a wire-reclamation incinerator and also the purchase of respiratory medication is decreased as the distance of residences from incinerators is increased(Emmanuel, 2007a).

Study conducted in United Kingdom pointed out a small increased risk of liver cancer associated with living within 1 kilometer of an incinerator also after adjustment for deprivation. As potential mistreatment of Primary liver cancer could have altered results of this study, the same author undertook a subsequent investigation to analyze the fraction of actual Primary liver cancer after histo-pathological review. This second study found a proportion of 55 - 82% of true Primary liver cancer and gave revised estimates of between 0.53 and 0.78 excess cases per 105 per year within 1 kilometer (Elliott *et al.*, 2007).

2.7 Conceptual Framework

According on the reviewed literatures, healthcare waste generation rates can be affected directly by the number of patients (the numbers of patients determine by the type of service). In addition, healthcare waste generation rate can be affected by the waste management performs of the healthcare institution for example the presence of waste recycles practices and the proportion of disposable substance used in the healthcare activities directly affect the quantity or amount of waste generated. These are briefly expressed in the following conceptual framework.

CONCEPTUAL FRAMEWORK

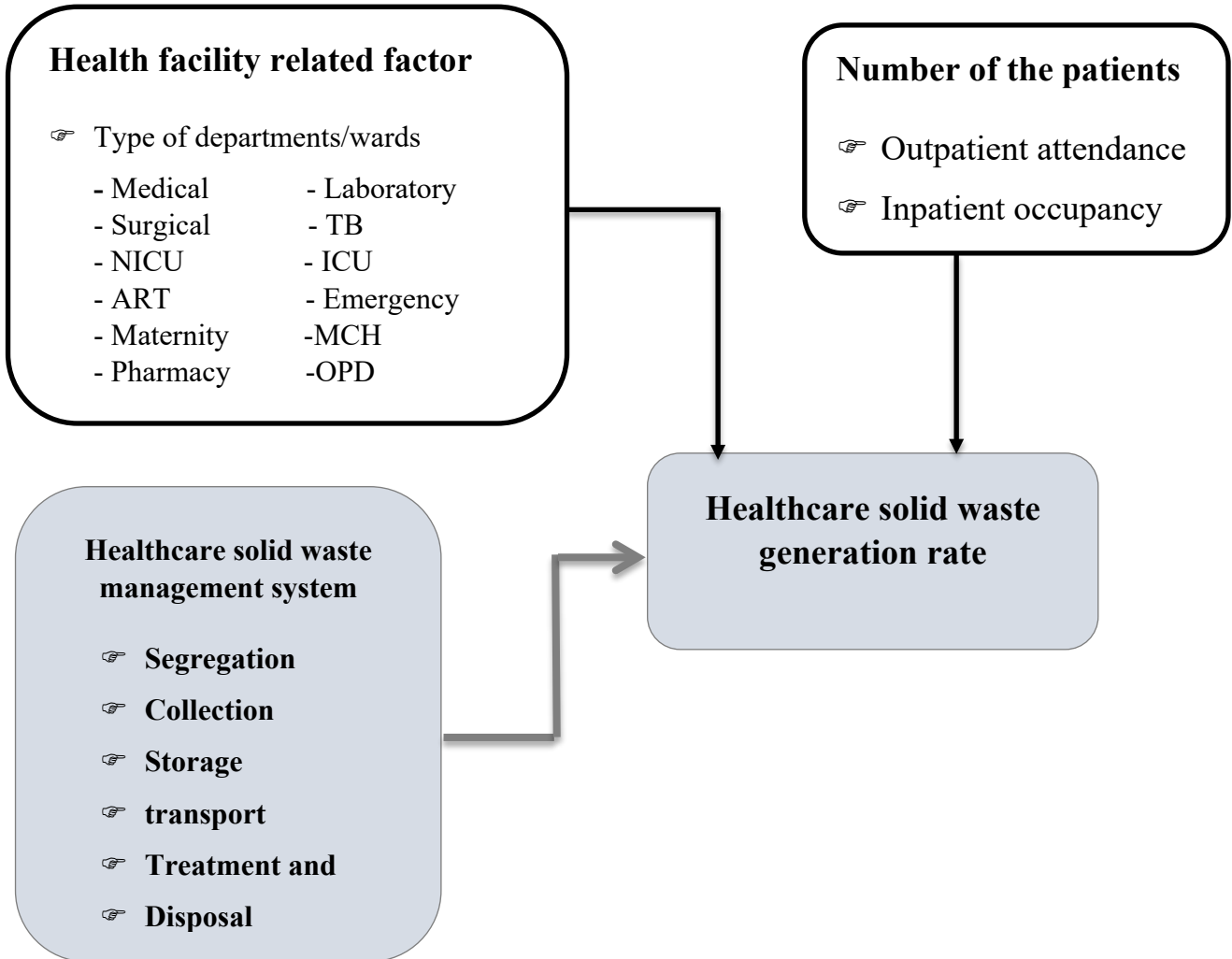


Figure 4: Conceptual framework of factors affecting healthcare solid waste generation rate; and current waste managing system

3. MATERIALS AND METHODS

3.1 Study Area and Period

This study was conducted in departments of Kelle Primary Hospital, Kelle town, Koore Zone, South Ethiopia Region, Ethiopia from February 15 – April 29/2024. It is located in the southern part of the country approximately 468KM of Addis Ababa, the capital of Ethiopia. It has an average altitude range between 1000-3600m above sea level and its temperature range from maximum 25-30 °C and minimum 7-20°C and annual rainfall range from 1200-2000mm.

In Koore Zone, there is 1 Primary Hospital, 9 health centers, 46 health posts, and 11 private health facilities provide health care service. Kelle Primary Hospital is the only Hospital that is found in Koore zone. It is giving service for about more than half millions of the people. It was founded and started giving service in 2017 G.C. The Hospital was built to serve as providing medical services for the community. It was engaged in providing medical services to in-patients in different specialty wards. According to Kelle Primary Hospital resource department, during 2023/2024 the Hospital have 129 functional beds, 148 health professionals, 28 waste handlers.

Currently, the Hospital is providing different services for approximately 1,000 inpatients and 7,000 outpatient attendants from the catchment population of about 500,000 people in the zone (Kelle Primary Hospital documentation, 2023).

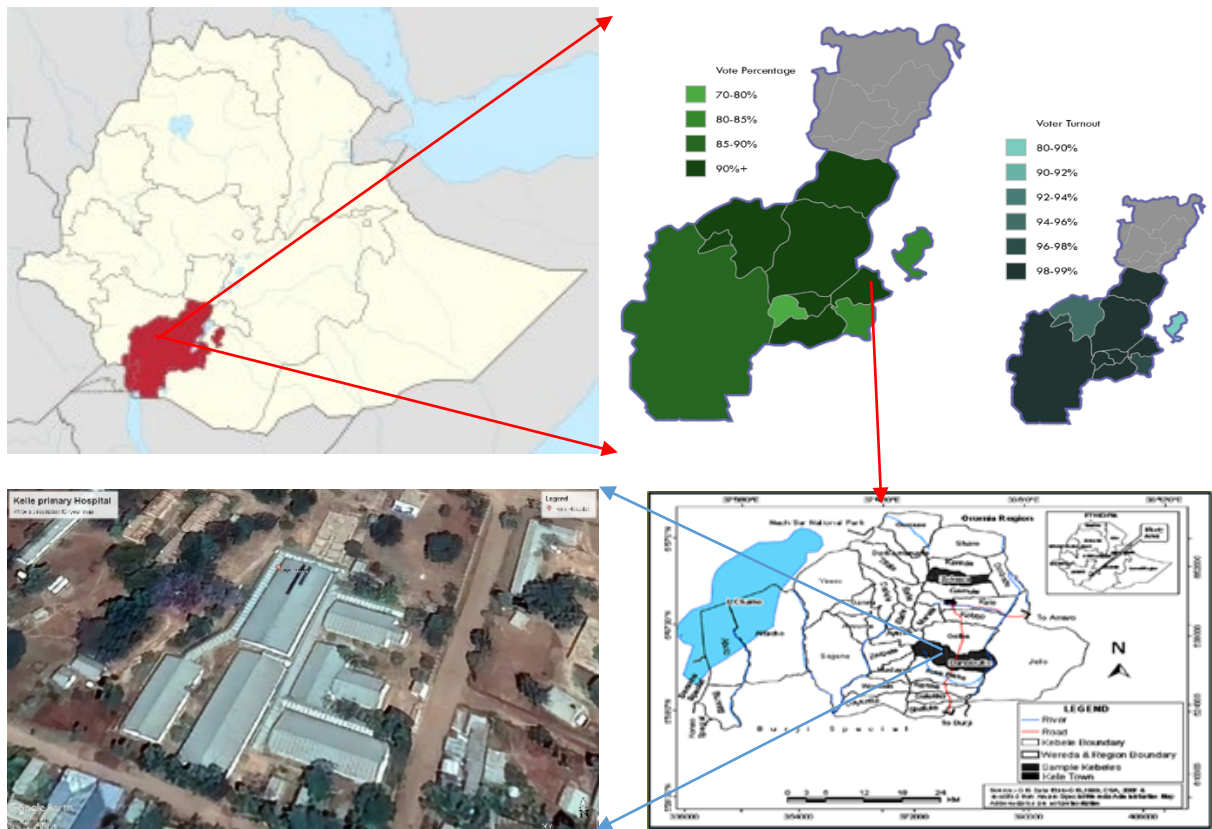


Figure 5: Map of Kelle Primary Hospital (Google Earth Pro)

3.2 Study Design

Institution-based cross-sectional study design was used to assess the healthcare solid waste management system in Kelle Primary Hospital.

3.3 Sample Size and Sampling Technique

All wards/Departments in the Hospital (Medical, Emergency, Operating Room, Laboratory, Pharmacy, ICU, MCH, NICU, Delivery, ART, OPD, TB and Radiology) were considered as a source of Healthcare waste generation. A purposively selected 17 workers (Medical Director, Waste management officer, Infection control officer, Environmental Health Officer and 13 Focal persons from each wards) of the Hospital have participated in key-informant interviews.

3.4 Inclusion and Exclusion Criteria

3.4.1 Inclusion Criteria

All specialty wards and medical related departments including intensive care units were included in the study.

3.4.2 Exclusion Criteria

The study was excluded all administrative offices, laundry room and kitchen.

3.5 Data Collection Tools and Procedure

3.5.1 Measurement of healthcare solid waste generation rate

First, an on-site inspection of all units and/or wards of the Hospital was undertaken by the investigators in order to know the kind of waste generated in relation to the different units/departments of the Hospital: To determine healthcare solid waste generation rate, plastic bags of various colors (black color for general waste, red color for sharps, yellow for infectious waste, brown for pharmaceutical waste and blue for pathological waste) that match national requirements, was supplied to thirteen(13) different wards/departments (Medical, Emergency, Operating Room, Laboratory, Pharmacy Delivery, Radiology, Intensive care unit (ICU), Neonatal intensive care unit (NICU), Tuberculosis (TB), Mother and Child health (MCH), Antiretroviral treatment (ART) and Outpatient Department (OPD) of the Hospital, corresponding to the type of waste produced. The buckets and bags of plastic was labeled to reflect the various groups of healthcare waste, the place of generation, date and time of collection. The waste classification was done according to the National Healthcare Waste Management Guideline in 2008 (FMoH, 2008).

The quantity of healthcare solid waste generated was monitored by collecting and measuring waste collected from all units using a standardized weight balance for seven days in a row (WHO, 2019). The estimation of waste generation in this study was also performed based on the number of beds in use. The first step was to calculate the waste generated per bed, taking into account the total waste generated. In addition, rates was calculated according to the number of patients attended. Finally, data was recorded on the prepared data entry sheet for the daily measurement of the amount of healthcare waste generated. For data collection, 8 data collectors and 2 supervisors was assigned after one day of training. During waste collection, data collectors was used masks, gloves, gown and antiseptics to prevent infection. In addition, during the data collection days, the inpatient bed occupancy and outpatient flow in the Hospital was recorded.

Waste generation rates: waste generation per day, is defined as the total weight of wastes (in kg) generated per day, that is,

$$\text{waste generation rates}(WGR) = \frac{\text{Total waste generated (in kg)}}{\text{days}}$$

Wastes generation per bed per day was calculated by the formula:

$$\text{Waste generated in } \left(\frac{\text{kg}}{\text{bed}} \right) = \frac{WGR}{\text{Number of inpatients (occupied beds)}}$$

The waste generation rate per patient per day was calculated by the formula:

$$\text{Waste generated in } \left(\frac{\text{kg}}{\text{patient}} \right) = \frac{WGR}{\text{Total number of patients (inpatient + outpatient)}}$$


Source: (Kagonji and Manyele, 2011)

3.5.2 Evaluation of Healthcare Solid Waste Management System

The existing healthcare solid waste management system practiced in Kelle Primary Hospital was investigated by developed semi-structured key informant interview guide and observational checklist that are adapted from Ethiopian FMHACA inspection checklist for HCWM practices in healthcare facilities (EFMHACA, 2005). The developed observational checklist was used to assess and capture data on healthcare waste management practice that includes waste generation rate, waste segregation, waste collection, waste storage, waste treatment and waste disposal system at different department or wards of the Hospital. The semi-structured key informant interview guide was held to the purposively selected seventeen (17) persons in the Hospital (Medical director, Waste management officer, Infection control officer, Environmental Health Officer and the Focal persons of each wards (13 in number)). The interview guide was held to Hospital medical director on general information about the institution and its institutional setup. The interview was also held for the waste management officer and Infection control officer to assess information on waste minimization technologies, waste policy, and training program for the staff on waste management and staff protection measures in the Hospital. Furthermore, the interview was also held for the focal persons of each wards on waste management practices in the hospital. Principal investigators was conducted both observation and semi-structured key informant interviews in the departments or wards of the Hospital and for the selected specified department officers and stalkholders in the Hospital.

3.6 Study Variables

3.6.1 Dependent Variables

 Healthcare solid waste generation rate

- ✚ Existing healthcare solid waste management system
- ✚ Healthcare waste types

3.6.2 Independent Variables

- ✚ Type of departments/wards
- ✚ The Number of Patients
 - ☞ Outpatient attendance
 - ☞ Inpatient occupancy

3.7 Data Processing and Analysis

The unprocessed numerical data gathered in the Hospital was entered and coded into Epi-Data version 3.1. After the correction and screening of the entered data faults, the data was transferred to SPSS version 27 for analysis. The analysis of healthcare solid waste production rate among departments/wards was computed using Post-Hoc test by one-way ANOVA and its relation with patient flow was compared by scatter plot. For testing the bivariate association between the Hazardous waste generated, Total waste generated and Patients flow in the Hospital, Spearman's Rank Correlation (r_s) was computed.

The Qualitative data from observation and key informant interviews was analyzed thematically. Thematic evaluation of the data will be conducted manually, by organizing and sorting information according to their thematic comparisons. After that, the information was grouped and evaluated to understand their relationships in the general perspective of the study.

3.8 Data Quality Assurance

For data quality assurance, training to data collectors was given before data collection and the weighing scale was calibrated prior to the real measurements started. The supervisor was made daily on-site supervision when the measurements took place. Key informant interview questionnaires and observation checklists were pretested with pilot survey of comparable study population at Soyama Primary Hospital, which is found in Burji Zone, South Ethiopia region prior to the real data collection time to assure the trustworthiness of data collection tool.

3.9 Ethical Consideration

Cooperation letter and approval was obtained from Hawassa University, College of Natural and Computational Sciences and was given to Kelle Primary Hospital management office. Letter of authorization for the collection data was obtained from Kelle Primary Hospital management office. The objective and aim of the research was described to respondents. During data gathering, each respondent was knowledgeable about the scope, purpose and intended result of the study and appropriate written and verbal consent was obtained.

3.10 Dissemination Plan of the Study Findings

Following the evaluation and clarification of the data, needed information or data was disseminated to Kelle Primary Hospital, Hawassa University, publication and research office and concerned bodies. Furthermore, it will be disseminated through publication in journals and presented on relevant scientific conferences.

4. RESULT

4.1 Patient flow in Kelle Primary Hospital

During data collection, 1103 patients visited all Hospital wards and outpatient departments within a week, of which 855 (77.5%) patients were admitted to inpatient departments and the remaining 248 (22.5%) were seen in outpatient department. The total average daily patient flow in the Hospital, inpatient and outpatient only were 157.57 ± 30.41 , 122.14 ± 23 , and 35.42 ± 7.54 respectively.

4.2 Healthcare waste generation rate

The total Healthcare waste generated in Kelle Primary Hospital within seven successive days was 720.13 kg/week. The average healthcare waste generation rate determined in kg/day, kg/patient/day (sum of outpatient attendants and occupied bed) and kg/bed/day (occupied bed) was 102.9 ± 6.4 kg/day, 0.65kg/patient/day and 0.84 kg/bed/day respectively. The average hazardous waste generation rate determined was 49.2 ± 3.76 kg/day, 0.396 kg/bed/day and 0.31 kg/patient/day. From types of waste, the highest rate was for General waste (0.444 kg/bed/day, 0.34 kg/patient/day) and the lowest average waste generation rate was for Radiological waste, which was 0.006 kg/bed/day and 0.005 kg/patient/day) (Table 3).

Table 3: Average daily healthcare solid waste generation by types of waste in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024

Types of waste	Healthcare solid waste generation rate		
	Kg/Day	Kg/Bed/Day	Kg/Patient/Day
General waste	53.7	0.444	0.34
Infectious waste	36.3	0.28	0.23
Sharps	1.74	0.015	0.011
Pathological waste	7.56	0.07	0.048
Pharmaceutical waste	2.9	0.025	0.018
Radiological waste	0.7	0.006	0.005
Total Hazardous Waste	49.2	0.396	0.31
Total Healthcare waste	102.9	0.84	0.65

The daily distribution of total Healthcare waste generation was higher in weekdays and less at weekends. The highest waste generation rate was recorded on Tuesday (143.33 kg) and Friday (120.1 kg) and the lowest waste generation rate was recorded on Sunday (72.05 kg) and Saturday (77.5 kg) (Figure 6). This was directly related to the variation in the number of patients treated in the medical center on a daily basis (Figure 8).

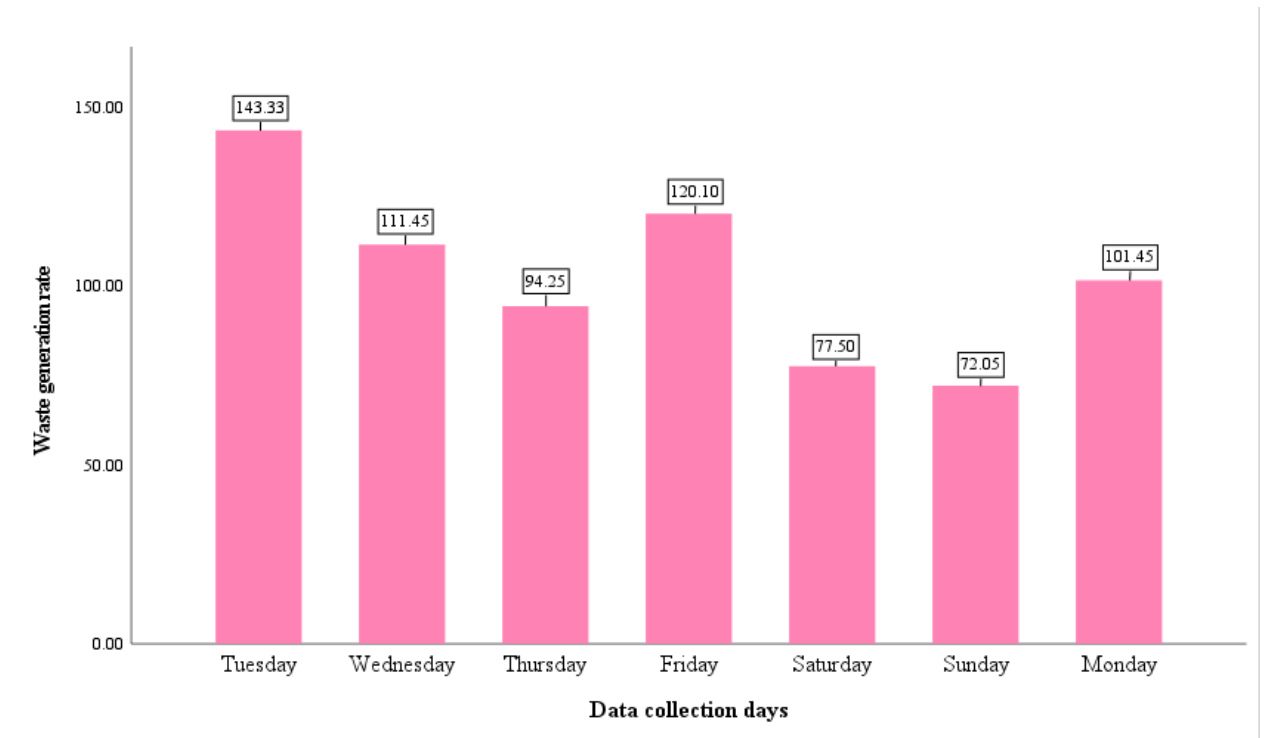


Figure 6: The daily distribution of total amount of healthcare waste generation in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, February 2024

4.3 Healthcare waste generation rate in different wards

The daily average Healthcare waste generated in all departments/wards of Kelle Primary Hospital was 102.9 ± 6.4 kg/day. Large amount of healthcare waste was generated from OPD ($14.1 \text{ kg/day} \pm 4.1$ (13.64%)); whereas fewer amount of healthcare waste was generated from Pharmacy ward ($0.7 \text{ kg/day} \pm 0.16$ (0.7%)) (Table 4).

Table 4: Total Healthcare waste generated in different wards by types of waste in the given seven days of data collection time in Kelle Primary Hospital, Koore Zone, South Ethiopia region, 2024

Types of Wards/ Departments	Healthcare waste generation rate(Kg/week)										
	General waste	Infectious waste	Sharps	Pathological waste	Pharmaceutical waste	Radiological waste	Total	Mean	SD	% by weight	
Medical	48.1	28.5	1.4	0	1.8	0	79.8	11.3	2.2	11	
Emergency	38.9	21.7	1.4	0	1.55	0	63.55	9.1	3.73	8.8	
Operating Room	39.8	19	1.1	23.4	1.9	0	85.2	12.2	4.3	11.83	
Laboratory	33	21.8	1.05		0	0	55.85	7.9	3.2	7.8	
Pharmacy	1.4	0	0	0	3.5	0	4.9	0.7	0.16	0.7	
ICU	31.7	23.2	1.03	0	1.75	0	57.68	8.2	3.9	8	
MCH	24.7	18.7	0.95	0	1.4	0	45.75	6.5	2.47	6.4	
NICU	30.1	19	1.35	0	1.5	0	51.95	7.5	3.82	7.28	
Delivery	33.5	24.1	1.1	29.5	2.1	0	90.3	12.9	3.82	12.5	
ART	19.3	16	0.3	0	1.6	0	37.2	5.3	1.85	5.1	
OPD	53.1	42.2	1.25	0	1.65	0	98.2	14.1	4.1	13.64	
TB	21	19.9	1.25	0	1.5	0	43.65	6.3	2.9	6.08	
Radiology	1.1	0	0	0	0	5	6.1	0.9	0.46	0.87	
Total(kg/week)	375.7	254.1	12.18	52.9	20.25	5	720.13	102.9	6.4	100	
Total HW	0	344.43						344.43	49.2	3.76	47.8

There were significant variation in average General waste generation rate between different wards. The highest significant variation in terms of average general waste was between OPD

and radiological ward (MD=7.43, P=0.000) and between OPD and Pharmacy (MD=7.4, P=0.000). While, the lowest significant variation was recorded between OPD and MCH (MD=4.06, P=0.000) in different wards (Table 5).

Table 5: Comparison of General waste generation rates in different wards using Post- Hoc test in One-Way ANOVA in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024

Types of waste	Types of wards/departments(i)	Types of wards/departments(j)	Mean Difference(i-j)	Sig.
General Waste	Medical	Pharmacy	6.67	.000
		ART	4.11	.000
		Radiology	6.71	.000
	Emergency	Pharmacy	5.36	.000
		Radiology	5.4	.000
	Operating Room	Pharmacy	5.46	.000
		Radiology	5.5	.000
	Laboratory	Pharmacy	4.51	.000
		Radiology	4.56	.000
	ICU	Pharmacy	4.32	.000
		Radiology	4.37	.000
	MCH	OPD	-4.06	.000
	NICU	Pharmacy	4.32	.000
		Radiology	4.37	.000
	Delivery	Pharmacy	4.56	.000
		Radiology	4.62	.000
	ART	OPD	-4.83	.000
	OPD	Pharmacy	7.4	.000
		Radiology	7.43	.000
		TB	4.56	.000

There were significant variation in average Hazardous waste generation rate between different wards. The highest significant variation in terms of Hazardous waste was between Delivery ward and Pharmacy (MD=7.61, P=0.000). While the lowest significant variation was between Operating room and MCH ward (MD=3.48, P=0.000) (Table 6).

Table 6: Comparison of Hazardous waste generation rates in different wards using Post-Hoc test in One-Way ANOVA in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024

Types of waste	Types of wards/departments(i)	Types of wards/departments(j)	Mean Difference(i-j)	Sig.
Hazardous Waste	Medical	Pharmacy	4.02	.000
		Delivery	-3.59	.000
		Radiology	3.81	.000
	Emergency	Delivery	-4.6	.000
	Operating Room	Pharmacy	5.6	.000
		MCH	3.48	.000
		ART	3.93	.000
		Radiology	5.8	.000
	Laboratory	Delivery	-4.85	.000
	Pharmacy	Medical	4.02	.000
		Delivery	-7.61	.000
		OPD	-5.94	.000
	ICU	Delivery	-4.4	.000
	MCH	Delivery	-5.1	.000
	Delivery	Pharmacy	4.56	.000
		Radiology	4.62	.000
	ART	OPD	-3.88	.000
	OPD	Radiology	5.73	.000
	TB	Delivery	-4.88	.000

According to Table 7 Spearman's correlation coefficient (r) showed that there was a positive linear relationship between the number of patients and the amount of Total Healthcare waste (r=0.436, P=0.000) and Hazardous waste (r=0.389, P=0.000). There is also a positive relationship between Hazardous waste and Total Healthcare waste (r=0.951, P=0.000).

Table 7: Spearman's Correlation Matrix (r_s) Hazardous waste, Total Healthcare waste and Patients Flow in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024

		Hazardous Waste	Total Healthcare Waste	Patients Flow
Hazardous Waste	Spearman's rho	1	.951**	.389**
	Sig. (2-tailed)		.000	.000
Total Healthcare Waste	Spearman's rho	.951**	1	.436**
	Sig. (2-tailed)	.000		.000
Patients Flow	Spearman's rho	.389**	.436**	1
	Sig. (2-tailed)	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).				

4.4 Healthcare solid waste generation rate by types of waste

The composition of healthcare waste generated in Kelle Primary Hospital were consists of Non-hazardous (General waste) and Hazardous (infectious waste, pathological waste, sharps, pharmaceutical and radiological wastes) (Table 3). From the waste generated General waste constitutes 52.16% (53.7±2.64kg/day) of the waste and the other 47.84% (49.2±2.48) was Hazardous waste. Following general waste the majority was infectious waste (36.3± 1.9kg/day

(35.3%) then pathological waste (7.56 ± 1.42 kg/day (7.35%)), and the rest were pharmaceutical (2.9 ± 0.14 kg/day (2.81%)), sharps (1.74 ± 0.09 kg/day (1.69%)) and radiological waste (0.71 ± 0.21 kg/day (0.69%)) (Figure 7).

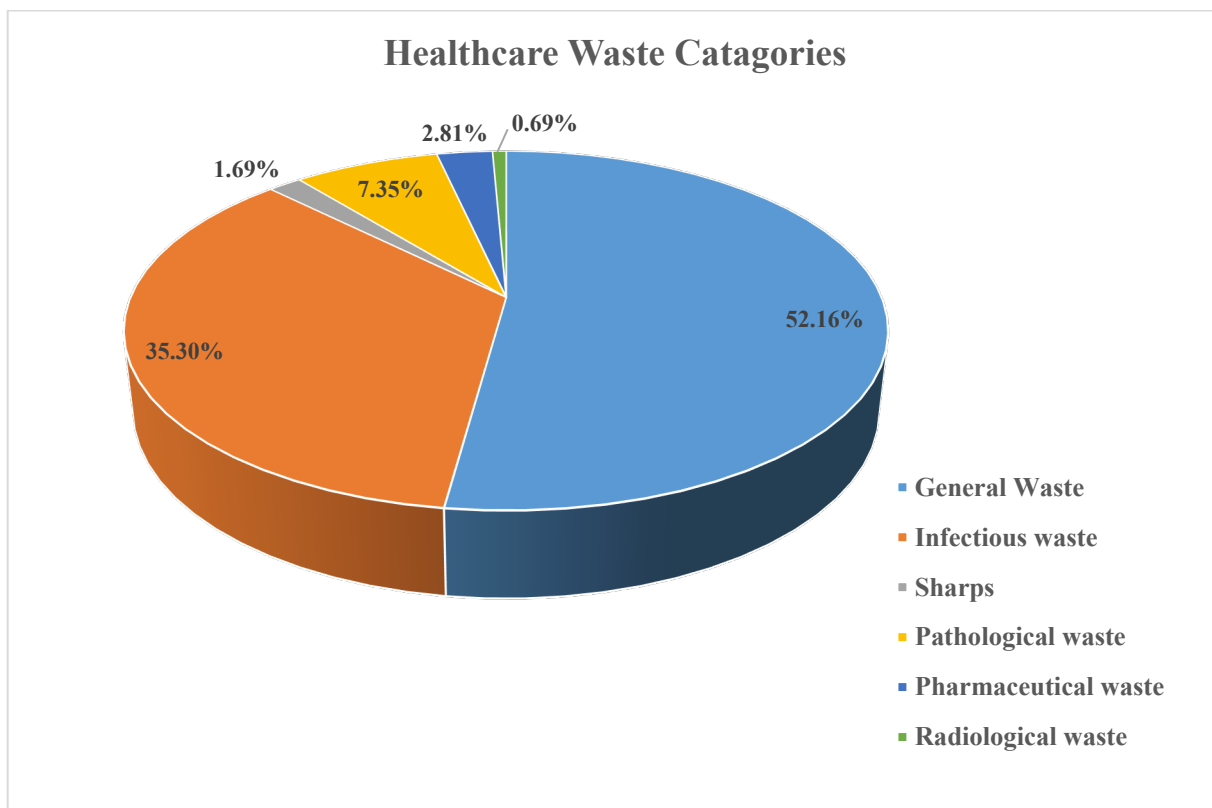


Figure 7: The percentage of healthcare waste generation rate by types of waste in Kelle Primary Hospital, Koore Zone, South Ethiopia region, February 2024.

4.5 Comparison of Daily Healthcare Solid Waste Generation Rate and Patient Flow

The scatter plot between the daily amounts of healthcare waste generated and the total number of patients who visited the medical center for healthcare services. The daily variation of total healthcare waste generated in seven consecutive days had a linear correlation with the variation of the total number of patients treated in the Hospital on a daily basis ($R^2 = 0.927$) (Figure 8).

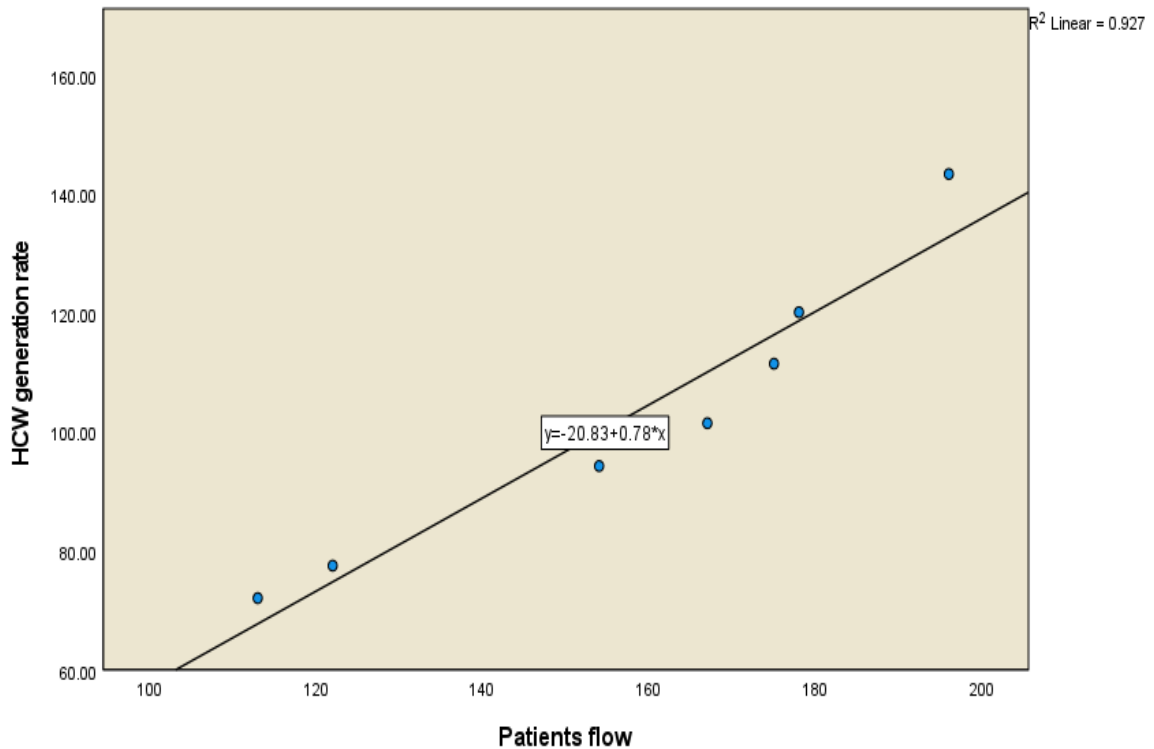


Figure 8: Scatter plot of daily variation in total healthcare waste generation versus total number of patients visited Kelle Primary Hospital, February 2024.

4.6 Healthcare solid waste management system

4.6.1 Segregation of Healthcare Waste Management System

In Kelle Primary Hospital, there was limited segregation of healthcare waste into infectious, pharmaceutical and radiological waste by the use of waste containers with a labeling and standard color-coding at the point or place of generation. It was observed that different categories of healthcare waste were deposited together in perforated plastic baskets that are intended for the use of administrative areas (figure A). The placentas and sharps were kept

separately in red color plastic bucket, but the bucket used for sharps were misplaced at the door on the entrance and exit gate of patient and visitors (figure B). Additionally, from the purposely-selected respondents the majority (61.5%) did not segregate waste at the point of generation. The other 23.1% segregate waste at the point of generation and 15.4% of the respondent did not know about whether they segregate at the point of generation or not. As well the majority (69.2%) of the respondent did not treat hazardous healthcare waste differently from general waste, 23.1% were not sure about whether they treat the wastes differently. Only 7.7% of the respondent treat the wastes differently (Table 8). Furthermore, the medical director of the hospital gave information that there is no SOPs and recording and reporting system in Hospital.

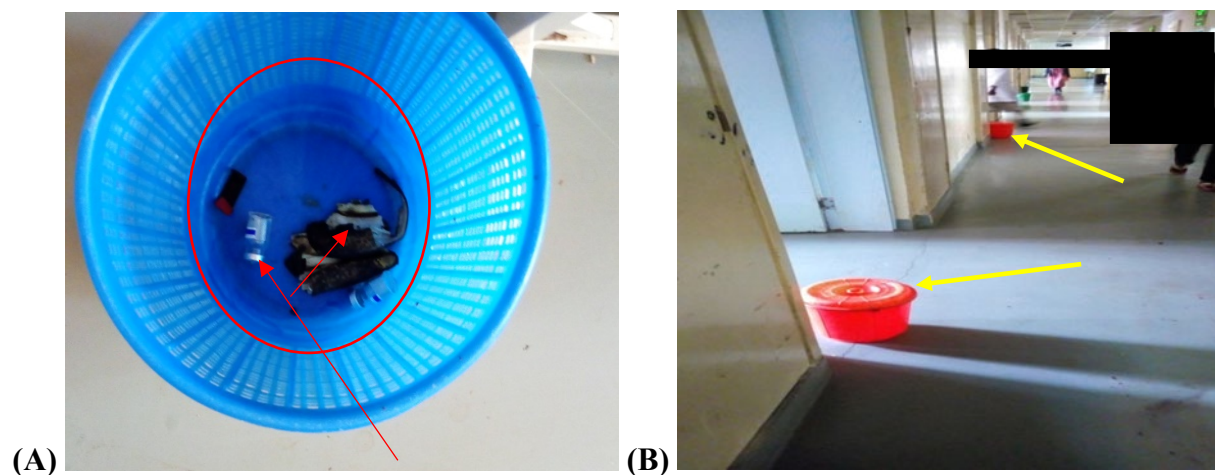


Figure 9: Photo shows, healthcare waste segregation practice at point of generation (figure A), placement of bucket at which sharp waste deposited (figure B), in Kelle Primary Hospital, February 2024

4.6.2 Collection, storage and transportation of healthcare solid waste

Kelle Primary Hospital has no proper and purpose-built waste storage area. It was observed that unsegregated healthcare waste from all departments/wards was collected (figure A) and

transported to dumping and incineration facilities by using uncovered plastic bins once a day (figure B). Moreover, some of the plastic bins were cracked (Appendix III: A) and there was leaking of the waste on the road during transportation (Appendix III: B and figure C and D). Furthermore, from the interviewed respondents the majority (61.5%) did not know whether the bags were filled with more than $\frac{3}{4}$ or not. Other respondents (23.1%) said the bags were filled with more than $\frac{3}{4}$ and 15.4% of the respondents said that the bags were filled less than $\frac{3}{4}$. From the respondents the majority (69.2%) said the filled bags were not replaced with empty one at the same time of discharge and the rest (30.8%) said the filled bags were replaced with empty one at the same time of discharge. From the interviewed respondents the majority (53.8%) said the duration of on-site waste handling which means from patients bed to temporary storage place was Irregular. The other 30.8% and 15.4% of the respondent said the duration was twice a day and once a day respectively. From the interviewed respondents the majority (69.2%) said the duration for the transportation of waste from storage place to final disposal site was once per day and 15.4% of the respondent said the duration was twice a week (Table 8).. Additionally, from the interviewed respondents the majority (76.9%) said the material used to transport of a waste was punctured and leak a waste and the other (23.1%) of the respondents said there is no puncture on the material used for the transport of the waste (Table 7).

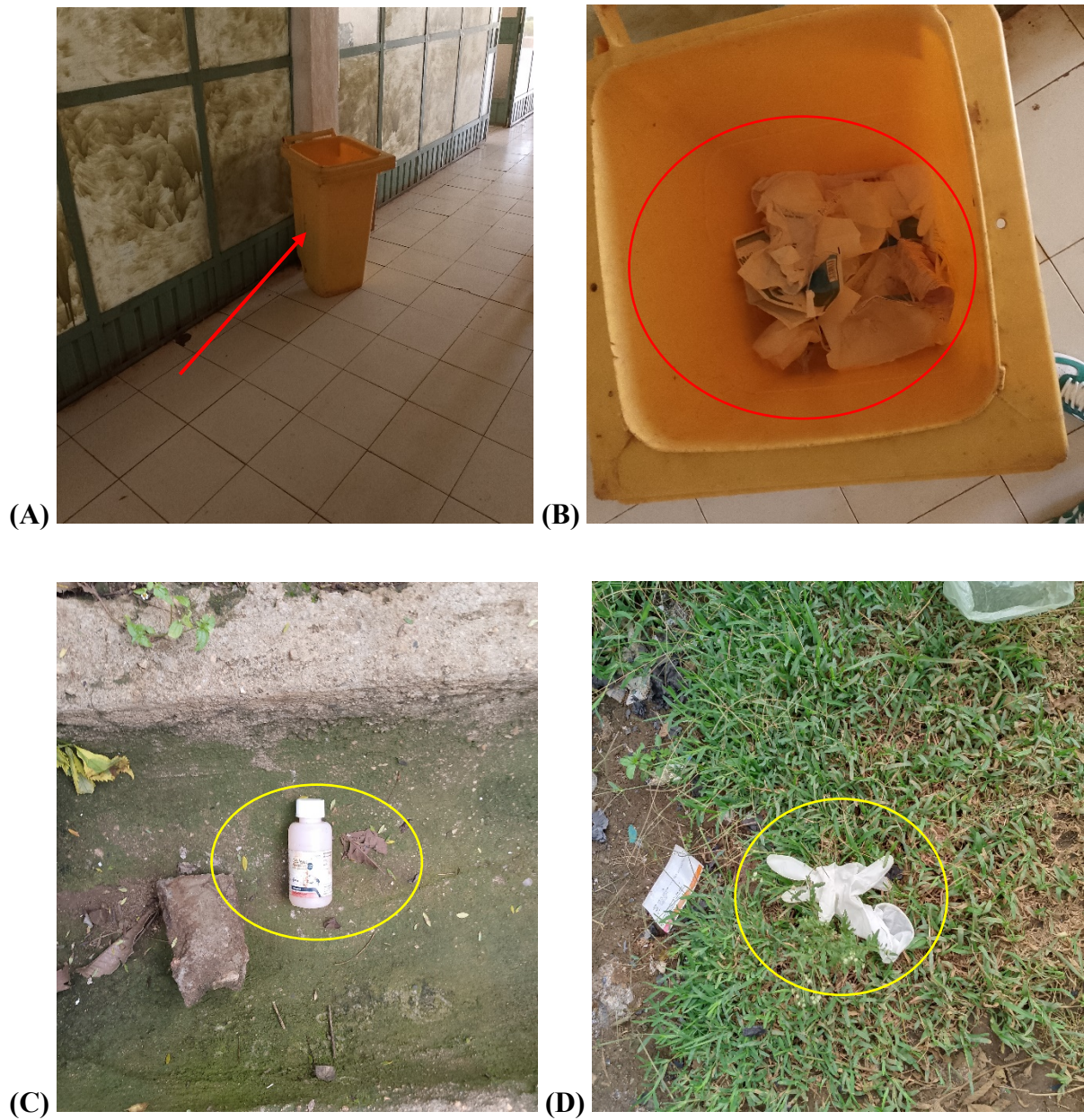


Figure 10: The Photo shows, healthcare waste collection (figure A), transportation by open plastic bin (figure B) and scattered waste on roads and areas (figures C and D) in Kelle Primary Hospital, February 2024

4.6.3 Treatment and Disposal Practice

The Hospital uses a brick incinerator as the common healthcare waste treatment method. As a brick incinerator has operated at low temperature, it has a low performance rate there was incomplete combustion, and heavy blackish smoke was observed (figure 11B). Furthermore, one of the doors of the incinerator was damaged and the other one was missing (figure 11A). The pathological waste was buried in a placenta pit, which had no cover (figure 12B). Furthermore, the Hospital also practices burning in damaged old brick incinerator (figure 12A), burning on open field (Appendix III: C) and practice open dumping (Appendix III: D). As well from the purposively interviewed respondents the majority (61.5%) said incineration was the treatment method in the hospital and the other 23.1% and 15.4% said open dumping and open burning was the treatment method used in the hospital respectively (Table 8).



Figure 11: Photo shows the incinerator site (figure A), firing the waste loaded to the incinerator and smoke emission (figure B), in Kelle Primary Hospital, February 2024



Figure 12: Photo shows, dumping of waste in old brick incinerator (figure A), open and unsecured placenta pit (figure B) in Kelle Primary Hospital, February 2024

4.6.4 Incinerator ash generation and management practice

The generated ash that was produced from the incinerator has been collected and dumped in ash pit. However, the generated ash was not picked and disposed in time. In addition, the ash pit was open and unsecured (figure A). Furthermore, it was observed that there was a vegetable growing near the ash pits (figure B), which was dangerous for the plants and persons consuming it due to contamination.

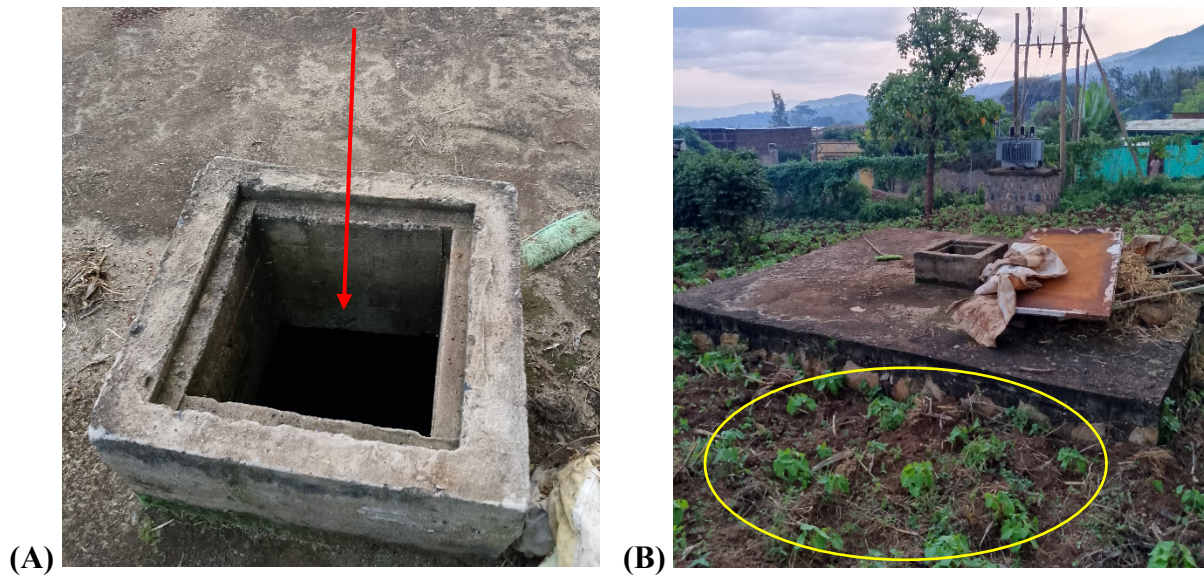


Figure 13: Photo shows uncovered ash pit (figure A), plotted land and growing vegetable near the ash pit (figure B) in Kelle Primary Hospital, February 2024

4.6.5 Waste management guideline, instruction and minimization practices

The National Healthcare Waste Management Guideline was prepared by Ethiopian Federal Ministry of Health in 2008. However, Kelle Primary Hospital does not practice this guideline; also, it had not have its own written instruction to apply waste separation. The waste minimization practices were almost not present in the Hospital. Additionally from the in depth interview collected the medical director informed that the Hospital have a functional committee of infection and prevention and patient safety and healthcare solid waste management committee but there is no healthcare solid waste management plan in the Hospital. The waste management officer of the Hospital informed that, there is no care being taken to implement the waste minimization policy but care was given to avoid re-using needles and syringes. In addition, there is no purchasing policy being implemented to minimize hazardous wastes and chemicals.

4.6.6 Training and safety devices

The Hospital had not organized training related to infection prevention four years ago and did not organized healthcare waste management training to environmental health professional, waste handlers and heads of department since the Hospital was started service. There was no regular training given for waste handlers and all staffs in the Hospital.

Moreover, it was observed that there are instances when waste handlers were using surgical and disposable gloves for handling the healthcare waste because of unavailability of appropriate gloves and lack of awareness on using of personal protective equipment.

In addition, some of the waste handlers were not wearing glove while handling the waste. The Hospital guards works as the incinerator operator due to the Hospital have no incinerator operator. The person who operates the incinerator do not have eye goggle, face mask and safety shoe. It was observed that they fire the waste and remove the ash without wearing the eye goggle, hard glove and safety shoe.

From the interviews gathered, the medical director and the waste management officer informed that there is no national developed training material and external training material available in the Hospital. Additionally, the waste management officer informed that the nation have developed training material on waste management but there is no training given for all staff members and new staff members of the Hospital due to the Hospital management have not allocated budget for waste management. As the information gathered from infection control officer and Environmental Health officer on staff protection measures, there was no regular checks carried out to ensure that protective measures are taken. In addition, there is appropriate personal protective equipment available in the Hospital but it does not worn correctly by the

waste handlers and they does not wear gloves regularly when in contact with the wastes. Furthermore, from the interviewed respondents the majority 61.5% did not use PPE when handling healthcare wastes and the other 38.5% did use PPE when handling healthcare wastes (Table 8).

The medical director of the Hospital gave information that there is fulltime assigned staff of HCW management (Environmental Health Professional) and the professional is responsible for healthcare waste management in the Hospital. The infection control officer gave information that not all staff members of the Hospital were vaccinated against hepatitis A, hepatitis B and tetanus. In addition, there is no system of notices, post-accident care and registration developed in the Hospital for dealing with accidents involving exposure to blood or other body fluids and there is no emergency measures taken in the events of accidents, spilling or splashing occurred in the Hospital.

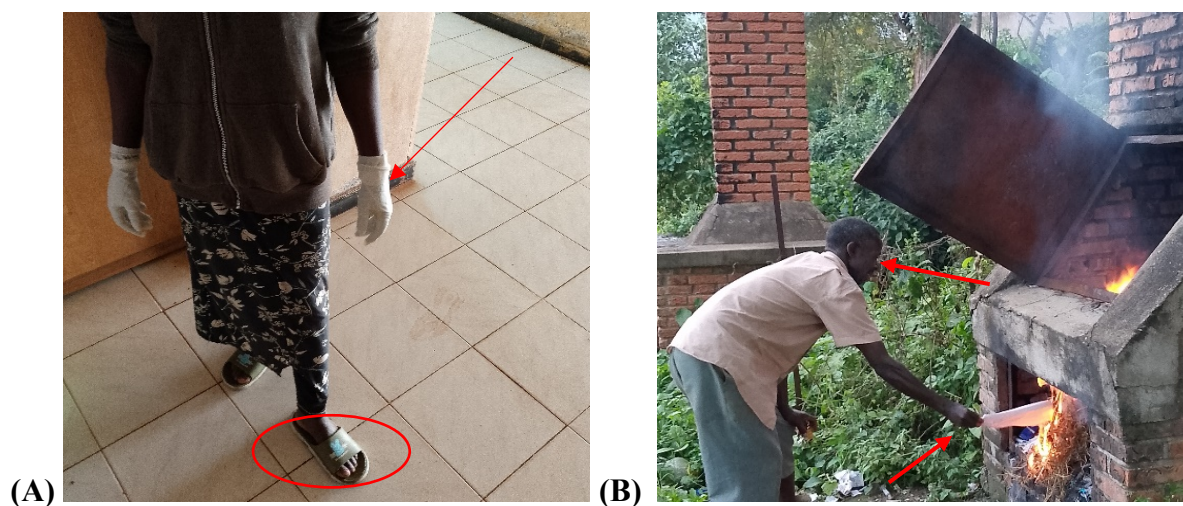


Figure 14: Photo shows the healthcare waste handler using latex glove as protective equipment (figure A) and a person operating the incinerator without using any protective equipment (figure B), in Kelle Primary Hospital, February, 2024

Table 8: Participants' response on the waste collection, treatment and disposal practice in Kelle Primary Hospital, Koore Zone, South Ethiopia Region, 2024

Interview questions	Response	Frequencies	Percentage (%)
Do you segregate waste at the point of generation?	Yes	3	23.1
	No	8	61.5
	I don't know	2	15.4
Do you treat hazardous healthcare waste differently from general waste?	Yes	1	7.7
	No	9	69.2
	I don't know	3	23.1
Do you use PPE (apron, boots, hard gloves and masks) when handling healthcare waste?	Yes	5	38.5
	No	8	61.5
On-site waste handling (patients bed to temporary storage place) duration	Once per day	2	15.4
	Twice per day	4	30.8
	Irregular	7	53.8
On-site waste handling (from temporary storage place to final disposal place) duration	Once per day	9	69.2
	Twice per day	2	15.4
	Irregular	2	15.4
Bags were filled with more than ¾ (75%)?	Yes	3	23.1
	No	2	15.4
	I don't know	8	61.5
The filled bags were closed tightly before transferred	Yes	1	7.7
	No	5	38.5
	I don't know	7	53.8
The filled bags were replaced with empty one at the same time of discharge	Yes	4	30.8
	No	9	69.2
Material used for the transport of the waste was punctured	Yes	10	76.9
	No	3	23.1
What waste treatment method used in the facility	Incineration	8	61.5
	Open Dumping	3	23.1
	Open Burning	2	15.4

5. DISCUSSION

The average healthcare solid waste generation rate in Kelle Primary Hospital was determined to be 0.84 kg/bed/day and 0.65 kg/patient/day. The result of this study is similar with a study conducted in Tepi General Hospital which has a generation rate of 0.65 kg/patient/day (Mekonnen *et al.*, 2021). However, The result of this study was higher when compared with a study conducted in three healthcare facilities in Ghana 0.26 kg/bed/day, 0.39 kg/bed/day and 0.58 kg/bed/day respectively (Wiafe *et al.*, 2015), a study conducted in rural healthcare facilities in South Africa 0.33 kg/bed/day (Olaniyi *et al.*, 2019) and other local study conducted in Mizan Tepi University specialized Hospital 0.073 kg/bed/day (Meleko *et al.*, 2018), a study conducted in two Hospitals of shashemene town showed a generation rate of 0.2 kg/bed/day in government Hospital and 0.19 kg/bed/day in private Hospital(Elie *et al.*, 2023), a study carried out in Addis Ababa, Ethiopia showed that the mean waste production rate was found to be from 0.361 kg/bed/day to 0.669 kg/patient/day (Debere *et al.*, 2011). But the result of this study was lower when compared to a study conducted USA 2.79 kg/bed/day (Emmanuel *et al.*, 2014, in Bahrain 1.177 kg/patient/day (Mohamed *et al.*, 2009), in Mauritius 2 kg/bed/day (Bokhoree *et al.*, 2014), in Nigeria 1.68 kg/bed/day (Abah and Ohimain, 2011). The higher HCW generation rate in developed countries may be due to high economy capacity and high supply and provision of healthcare services (Windfeld & Brooks, 2015). Other local study conducted in Jimma medical center 0.92 kg/bed/day (Lemma *et al.*, 2021), in Hospitals of Addis Ababa 1.6 kg/bed/day (Haile *et al.*, 2008), in Gondar university Teaching Hospital 0.95 kg/bed/day(Tesfahun, 2015) also have higher generation rate result than this study. The difference in average values of waste generation rate could be type of services offered, the number of population who uses the

facilities, difference in level and size of the healthcare facility and it differs from nation to nation based on the level of economy development.

Of the total solid waste generated, over half (52.16%) constitutes general waste and the remaining 47.84% was hazardous waste, which exceeds the WHO limit (10-20%) of hazardous waste (WHO, 2016). The result of hazardous waste percentage for this study was higher than a study conducted in Two Hospital of Shashemene town showed that 46.7% for Governmental Hospital and 42.9% for Private Hospital (Elie *et al.*, 2023), a study carried out in Mizan Tepi Specialized Hospital showed that the constitute of hazardous waste was 44.5% (Meleko *et al.*, 2018), But the result of this study was lower than the study conducted in Addis Ababa city government health centers showed the percentage for hazardous waste was 62% (Tadesse and Kumie, 2014). Furthermore, according to WHO, developed nations generate on average up to 0.5 kg of hazardous healthcare waste per bed per day; whereas low-income (developing) nations produce on average of 0.2 kg of hazardous healthcare waste per Hospital bed per day (WHO, 2016). However, the result from this study identified about 0.396 kg/bed/day of the total hazardous wastes generated from Kelle Primary Hospital, which was not similar with a stated value of WHO. The main reason for the high percentage of hazardous waste generation may be due to less amount of bed service in accordance to high inpatient flow, poor waste segregation practiced in the Hospital, which may have increased the chance high amount of healthcare waste production rate.

The finding of this study showed that there was limited segregation of healthcare waste into different groups: by means of color code containers and labels. This finding is different from the study conducted in different Hospitals of USA, reported that most of the Hospitals are

segregating infectious waste from other healthcare waste (Klangsin and Harding, 2011). Similar noncompliance results had been reported by the study done in eight educational Hospitals of Iran University that neither of the Hospitals routinely segregated general and medical wastes storage system at the Hospital (Ali *et al.*, 2017). different studies conducted on national level (Ethiopia) like in Referral Hospital of Hawassa university (Abebe, 2017), Mizan Tepi university of teaching Hospital (Meleko *et al.*, 2018), Government and private Hospitals in Shashemene town (Elie *et al.*, 2023), Jimma medical center (Lemma *et al.*, 2021) and Hospitals of Addis Ababa (Debere *et al.*, 2011). This clearly indicated that the implementation of healthcare waste segregation is a challenge in different healthcare facilities of Ethiopia.

The Hospital has no temporary and permanent healthcare storage area, it was observed that the mixed wastes were collected and transported in open and standard (cracked) plastic bins to the incineration area. This finding is alike with the study carried out in Healthcare facilities of Amhara region, Ethiopia (Tsefahun, 2015) reported that the sub-standard plastic waste container was used to transport the wastes and the wastes were scattered on the floor, road surrounding treatment areas and another study conducted in Jimma medical center reported that the wastes transported by open and damaged plastic bins and there was a leakage of sharp waste during the transportation (Lemma *et al.*, 2021). There was another study conducted in public healthcare facilities in Adama city, Ethiopia (Fikadu, 2016) that reported unprotective and open plastic bins was used for transportation of health care wastes. This practice may contribute to the risk of infection and injury of waste handlers, medical staffs, patients and visitors.

In Kelle Primary Hospital, brick incinerator was used for treatment of healthcare waste in addition to other types of disposal methods including open dumping and placental pit. However,

the incinerator was operated at low temperature and low performance rate. This was in contradiction of the WHO and national guideline, which recommended the healthcare waste incineration beyond 850 °C, to reduce the formation and emission of chemicals (like dioxin, furans...) or hazardous emissions. These indicates that the current practices of healthcare waste treatment in Kelle Primary Hospital could contribute to the generation of air pollutants and affect nearby community and air quality.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The average healthcare waste generation rate in Kelle Primary Hospital (0.84 kg/bed/day and or 0.65 kg/patient/day). The average hazardous waste generation rate in the hospital was 0.396 kg/bed/day which is above the threshold value of hazardous healthcare waste generation rate in low-income (less developed) countries, as stated by the WHO, and its management was so poor. There was a lack of appropriate waste segregation, storage, transportation, treatment and disposal practices in the Hospital. At the same manner, all healthcare wastes were mixed, collected and transported using sub-standard open and cracked plastic bins that leak waste and hence both the collection and transportation systems were not effective to protect the environment from contamination. Moreover open burning along with the incinerator was performed at low temperatures intended for the treatment of healthcare waste contributing that the emission of large amounts of air pollutants to the environment. Overall, the healthcare waste management system in the Hospital was limited and created a potential health risk for the workers along with the nearby community and local air pollution.

6.2 Recommendation

Based on the finding of this study, the following recommendations were made:

- ✓ The management staffs of the Hospital need to give orders for the proper application of the principle of waste segregation based on international and national guidelines and provide adequate waste collection/gathering and transportation containers for all departments.
- ✓ Continuous training within a regular time interval regarding to healthcare waste management systems needs to be given to for waste handlers and other concerned bodies.
- ✓ In order to avoid the release of toxic chemicals into the environment that may risk pollution, the brick incinerator has to be replaced by a better-performing and standardized type of incinerator.
- ✓ The Hospital should prohibit open dumping and open burning and have to follow applicable regulations.
- ✓ All waste handlers and a person working with the incinerator should be provided with basic personal protective materials and made aware of the use of the equipment.

7. REFERENCES

- Abah, S. O., & Ohimain, E. I. (2011). Healthcare waste management in Nigeria: A case study. *Journal of Public Health and Epidemiology*, 3(3), 99–110.
- Abebe, M. A. (2017). Study of Hazardous Biomedical Waste Management Practices and Development of Hazardous biomedical Waste Management Guidelines in Addis Ababa. *International Journal of Scientific Engineering and Science*, 1(8), 19–32.
- Abebe, S., Raju, R., & Berhanu, G. (2017). Health care solid waste generation and its management in Hawassa Referral Hospital of Hawassa University, Southern, Ethiopia. *Int J Innov Res Dev*, 6(5), 126–132.
- Adu, R., Gyasi, S., Essumang, D., & Otabil, K. (2020). Medical Waste-Sorting and Management Practices in Five Hospitals in Ghana. *J Environ Public Health 2020*, e2934296.
- Alagöz, B. A. Z., & Kocasoy, G. (2007). *Treatment and disposal alternatives for health-care waste in developing countries – a case study in.* 83–89. <https://doi.org/10.1177/0734242X07069497>
- Ali, M., Wang, W., Chaudhry, N., & Geng, Y. (2017). *Hospital waste management in developing countries : A mini review.* June. <https://doi.org/10.1177/0734242X17691344>
- Ansari, M., Ehrampoush, M. H., Farzadkia, M., & Ahmadi, E. (2019). Dynamic assessment of economic and environmental performance index and generation, composition, environmental and human health risks of hospital solid waste in developing countries; A state of the art of review. *Environment International*, 132, 105073.
- Asrat, M., Meleko, A., Tesfaye, T., & Henok, A. (2018). *Asrat Meleko, Abebe Adane.*

Assessment of Health Care Waste Generation Rate and Evaluation of its Management System in Mizan Tepi University Teaching Hospital (MTUTH), Bench Maji Zone, South West Ethiopia. Ann Rev Resear. 2018; 1(4): 555566.

Atnafu, D. D., & Kumie, A. (2017). *Healthcare Waste Composition and Generation Rate in Menellik II Referral Hospital , Addis Ababa , Ethiopia : A Cross Sectional Study Email address : 3(2), 10–19. <https://doi.org/10.11648/j.ijssmit.20170302.11>*

Attrah, M., Elmanadely, A., Akter, D., & Rene, E. R. (2022). A Review on Medical Waste Management: Treatment, Recycling, and Disposal Options. *Environments*, 9(11). <https://doi.org/10.3390/environments9110146>

Azage, M., & Kumie, A. (2002a). *Healthcare waste generation and its management system : the case of health centers in West Gojjam Zone , Amhara Region ,.*

Azage, M., & Kumie, A. (2002b). Healthcare waste generation and its management system : the case of health centers in West Gojjam Zone , Amhara Region ,. *Ethiopian Journal of Health Development*, 119–126.

Banerjee, P., Hazra, A., Ghosh, P., Ganguly, A., Murmu, N. C., & Chatterjee, P. K. (2019). *Solid Waste Management in India : A Brief Review : Proceedings of 6th Solid Waste Management in India : A Brief Review (Issue January). Springer Singapore. <https://doi.org/10.1007/978-981-10-7290-1>*

Belhadi, A., Kamble, S. S., Khan, S. A. R., Touriki, F. E., & Kumar M, D. (2020). Infectious waste management strategy during COVID-19 pandemic in Africa: an integrated decision-making framework for selecting sustainable technologies. *Environmental Management*,

66, 1085–1104.

- Ben, B. (2020). *What is medical waste? Definition, types, examples & more—MEDPRO Disposal, LLC*, <https://www.medprodisposal.com/blog/what-is-medical-waste-medical-waste-definition-types-examples-and-more/> (2020, accessed 21 January 2024).
- Bendjoudi, Z., Taleb, F., Abdelmalek, F., & Addou, A. (2009). Healthcare waste management in Algeria and Mostaganem department. *Waste Management*, 29(4), 1383–1387. <https://doi.org/10.1016/j.wasman.2008.10.008>
- Bokhoree, C., Beeharry, Y., Doobah, T., & Soomary, N. (2014). Assessment of Environmental and Health Risks Associated with the Management of Medical Waste in Mauritius. *Procedia - Social and Behavioral Sciences*, 9, 36–41. <https://doi.org/10.1016/j.apcbee.2014.01.007>
- Capoor, M. R., & Bhowmik, K. T. (2017). Current Perspectives on Biomedical Waste Management: Rules, Conventions and Treatment Technologies. *Indian Journal of Medical Microbiology*, 35(2), 157–164. <https://doi.org/10.4103/ijmm.IJMM>
- Chartier, Y. (2014). *Safe management of wastes from health-care activities*. World Health Organization.
- Chercos, D. H., Dessie, A., & Wami, S. D. (2017). Hospital Waste Handler's Knowledge of Health care Waste Management at Gondar University Hospital: An institutional-based cross-sectional study. *Ethiop. J. Health Dev.*, 7–12.
- Coad, A. (2004). Managing medical wastes in developing countries: Report of a Consultation on Medical Wastes Management in Development Countries. In *Managing medical wastes*

in developing countries: Report of a Consultation on Medical Wastes Management in Development Countries (p. 33).

Col, L., Rao, S. K. M., Cdr, W., Ranyal, R. K., Col, L., Bhatia, S. S., Col, L., & Sharma, V. R. (2003). Biomedical Waste Management : An Infrastructural. *Medical Journal Armed Forces India*, 60(4), 379–382. [https://doi.org/10.1016/S0377-1237\(04\)80016-9](https://doi.org/10.1016/S0377-1237(04)80016-9)

Debere, M. K., Gelaye, K. A., Alamdo, A. G., & Trifa, Z. M. (2013). Assessment of the health care waste generation rates and its management system in hospitals of Addis Ababa, Ethiopia, 2011. *BMC Public Health*, 13(1), 28. <https://doi.org/10.1186/1471-2458-13-28>

Deress, T., Hassen, F., Adane, K., & Tsegaye, A. (2018). *Assessment of Knowledge , Attitude , and Practice about Biomedical Waste Management and Associated Factors among the Healthcare Professionals at Debre Markos Town Healthcare Facilities , Northwest Ethiopia. 2018.*

Derso, S., Taye, G., Getachew, T., Defar, A., Teklie, H., & Amenu, K. (2018). Biomedical waste disposal systems of health facilities in. *Kerman University of Medical Sciences*, 5(1), 29–37. <https://doi.org/10.15171/EHEM.2018.05>

Diaz, L. F., Eggerth, L. L., Enkhtsetseg, S. H., & Savage, G. M. (2008). Characteristics of healthcare wastes. *Waste Management*, 28(7), 1219–1226.

Dieng, C., Mberu, B., Dimbuene, Z. T., Faye, C., Amugsi, D., & Aboderin, I. (2022). Biomedical waste management in Dakar, Senegal: Legal framework, health and environment issues; policy and program options. *Cities & Health*, 6(1), 208–222.

EFMHACA. (2005). *Ethiopian Food, Medicine and Healthcare Administration and Control*

Authority Directive, Healthcare Waste Management. 1, 1–36.

Elie, G., & Fitamo, D. (2023). Assessment of Healthcare Solid Waste Composition, Generation and its Management: the case of Two Hospitals of Shashemene Town, Oromia Regional State, Ethiopia. *East African Journal of Biophysical and Computational Sciences*, 4(xx), 13–30.

Elliott, P., Shaddick, G., Kleinschmidt, I., Jolley, D., Walls, P., Beresford, J., & Grundy, C. (2007). *Cancer incidence*. 702–710.

Emmanuel, J. (2007a). *Best environmental practices and alternative technologies for medical waste management. Eighth International Waste Management Congress and Exhibition, Institute of Waste Management of Southern Africa – Botswana Chapter, Kasane, Botswana, . 25-28, June.*

Emmanuel, J. (2007b). Best Environmental Practices and Alternative Technologies for Medical Waste Management. *EIGHTH INTERNATIONAL WASTE MANAGEMENT CONGRESS AND EXHIBITION Institute of Waste Management of Southern Africa-Botswana Chapter 25, June.*

Emmanuel, J. (2007c). Best environmental practices and alternative technologies for medical waste management. *Eighth International Waste Management Congress and Exhibition. Institute of Waste Management, Botswana, South Africa, 25–28.*

Emmanuel, J., Pieper, U., Rushbrook, P., Stringer, R., Townend, W., Wilburn, S., Zghondi, Raki, 2004, & Chartier, Y. (2014). *Safe management of wastes from health-care activities*. World Health Organization.

- Ferraz, M. C. M. A., Cardoso, J. I. B., Pontes, S. L. R., Ferraz, M. C. M. A., Cardoso, J. I. B., Pontes, S. L. R., Ferraz, M. C. M. A., Cardoso, J. I. B., & Pontes, S. L. R. (2011). *Concentration of Atmospheric Pollutants in the Gaseous Emissions of Medical Waste Incinerators*. 2247. <https://doi.org/10.1080/10473289.2000.10463989>
- FMoH. (2008). *Federal Ministry of Health, Hygiene and Environmental Health Department; Health-Care Waste Management. National Guidelines, Addis Abeba, Ethiopia.*
- Habtetsion, T., Bock, A., Noel, M., Shanadi, Bhat D., Abebe, F., V., & Roekel, K. (2009). *Evaluation of Injection Safety and Health Care Waste Management in Ethiopia: 2009 First Draft Report, September 2009 edition. Addis Ababa, Ethiopia MMIS for the Office of the Global AIDS Coordinator, and the Department of Health and Human Services/USAID.* (Issue September).
- Haile, D., Alemayehu, H., & Abera, K. (2008). Generation and Management practice of HCW in General Hospitals of Addis Ababa. *In Ethiopian Public Health Association Annual Conference.*
- Hassan, A. A., Tudor, T., & Vaccari, M. (2018). Healthcare waste management: A case study from Sudan. *Environments*, 5(8), 89.
- Haylamicheal, I. D., Dalvie, M. A., Yirsaw, B. D., & Zegeye, H. A. (2011). *Waste Management & Research. August 2010.* <https://doi.org/10.1177/0734242X10379496>
- Hayleeyesus, S. F. (2016). *Healthcare Waste Generation and Management in Public Healthcare Facilities in Healthcare Waste Generation and Management in Public Healthcare*

- Facilities in Adama , Ethiopia. May.* <https://doi.org/10.5696/2156-9614-6-10.64>
- Hossain, S., Santhanam, A., Norulaini, N. A. N., & Omar, A. K. M. (2011). Clinical solid waste management practices and its impact on human health and environment – A review. *Waste Management, 31*(4), 754–766. <https://doi.org/10.1016/j.wasman.2010.11.008>
- HSDP IV. (2014). *Federal Democratic Republic of Ethiopia Ministry of Health Health Sector Development Program IV October 2010 Contents. October 2010.*
- ICRC. (2011). *MEDICAL WASTE. International Committee of the Red Cross 19, avenue de la Paix 1202 Geneva, Switzerland.*
- Ikome, P., & Mochungong, K. (2011). *Environmental exposure and public health impacts of poor clinical waste treatment.*
- Jang. (2011). Infectious / Medical / Hospital Waste : General Characteristics. *Elsevier, 227–231.*
- Jang, Y., Lee, C., Yoon, O., & Kim, H. (2006). *Medical waste management in Korea **. 80, 107–115. <https://doi.org/10.1016/j.jenvman.2005.08.018>
- Janik-karpinska, E., Brancaloni, R., Niemcewicz, M., Wojtas, W., Foco, M., Podogrocki, M., & Bijak, M. (2023). Healthcare Waste — A Serious Problem for Global Health. *Healthcare, 11*, 1–14. <https://doi.org/http://doi.org/10.3390/healthcare11020242>
- Jindal, C. A. K., Chatterjee, C. A., Chatterjee, C. K., & Mahen, A. C. A. (2011). *Biomedical waste disposal: the way forward.* 67(4), 309–310. [https://doi.org/10.1016/S0377-1237\(11\)60099-3](https://doi.org/10.1016/S0377-1237(11)60099-3)
- Joy, A. S., Jawa, D., Somani, R., Jaidka, S., Madhu, A., Deepa, Anaswara, & Serene. (2022).

BIOMEDICAL WASTE MANAGEMENT - AN UPDATE ON COVID 19. *International Journal of Advanced Research(IJAR)*, 10(02), 616–629.
<https://doi.org/10.21474/IJAR01/14246>

Kagonji, I. S., & Manyele, S. V. (2011). *Analysis of the measured medical waste generation rate in Tanzanian district hospitals using statistical methods*. 5(October), 815–833.

Kasahun, A. F. A. (2014). *Ethiopia: Needs Assessment for Implementation of a Public–Private Partnership in Health Care Waste Management in Addis Ababa City*. Arlington, VA: AIDSTAR-One. January.

Klangsin, P., & Harding, A. K. (2011). *Medical Waste Treatment and Disposal Methods Used by Hospitals in Oregon , Washington , and Idaho Medical Waste Treatment and Disposal Methods Used by Hospitals in Oregon , Washington , and Idaho*. 2247.
<https://doi.org/10.1080/10473289.1998.10463706>

Korhonen, P., & Kaila, J. (2015). Waste container weighing data processing to create reliable information of household waste generation. *Waste Management*, 39, 15–25.

Lemma, H., Dadi, D., Deti, M., Fekadu, S., & Fekadu, S. (2021). *Biomedical Solid Waste Management System Biomedical Solid Waste Management System in Jimma Medical Center , Jimma Town , South Western Ethiopia*. <https://doi.org/10.2147/RMHP.S315446>

Longe, E. O. (2012). Healthcare waste management status in Lagos State , Nigeria : a case study from selected healthcare facilities in Ikorodu and Lagos metropolis. *Waste Management and Research*. <https://doi.org/10.1177/0734242X11412109>

M. Caniato, T. Tudor, M. V. (2015). International governance structures for health-care waste

- management : A systematic review of scientific literature. *Journal of Environmental Management*, 153, 93–107. <https://doi.org/10.1016/j.jenvman.2015.01.039>
- Mandal, S. K., & Dutta, J. (2009). Integrated bio-medical waste management plan for Patna city. *Institute of Town Planners*.
- Manga, V. E., Forton, O. T., Mofor, L. A., & Woodard, R. (2011). Health care waste management in Cameroon: A case study from the Southwestern Region. *Resources, Conservation and Recycling*, 57, 108–116.
- Manyele, S. (2017). *Management of medical waste in Tanzania hospitals. October 2006*. <https://doi.org/10.4314/thrb.v8i3.45117>
- Mbog, S., Mayi, O., Bitondo, D., & Mbue, I. (2020). State of play on the management of solid biomedical waste in health facilities in Cameroon (North, Adamaoua, East and North-West): Environmental and Social Impacts. *J Cameroon Acad Sci* 2020, 16, 19–28.
- Mekonnen, B., Solomon, N., & Wondimu, W. (2021). *Healthcare Waste Status and Handling Practices during COVID-19 Pandemic in Tepi General Hospital , Ethiopia. 2021*.
- Meleko, A., Tesfaye, T., & Henok, A. (2018). Assessment of Healthcare Waste Generation Rate and Its Management System in Health Centers of Bench Maji Zone. *Ethiopian Journal of Health Sciences*, 28(March), 125–134. <https://doi.org/10.4314/ejhs.v28i2.4>
- Mohamed, L. F., Ebrahim, S. A., & Al-thukair, A. A. (2009). Hazardous healthcare waste management in the Kingdom of Bahrain. *Waste Management*, 29(8), 2404–2409. <https://doi.org/10.1016/j.wasman.2009.02.015>
- Nandy, S., Fortunato, E., & Martins, R. (2022). Green economy and waste management : An

inevitable plan for materials science Progress in Natural Science : Materials International
Green economy and waste management : An inevitable plan for materials science. *Progress
in Natural Science: Materials International, January.*
<https://doi.org/10.1016/j.pnsc.2022.01.001>

Ndiaye, M., Dieng, M., Ndiaye, N., Sambe, F., & Toure, N. (2020). Evaluation of the solid biomedical waste treatment system in the commune of Keur Massar, in the suburbs of Dakar in Senegal. *JAppl Biosci 2020, 148*, 15252–15260.

Ndiaye, M., El Metghari, L., Soumah, M., & Sow, M. (2012). *Management of biomedical waste in five hospital structures in Dakar, Senegal. Bull Company Pathol Exot 2012; 105:*, 296–304.

Niyongabo, E., Chul, Y., Daeseok, J., & Kijune, K. (2019). Generation , management practices and rapid risk assessment of solid medical wastes : a case study in Burundi. *Journal of Material Cycles and Waste Management, 0(0)*, 0. <https://doi.org/10.1007/s10163-019-00854-0>

Nor Faiza, M. T., Noor Artika, H., & Yusof, M. Z. (2019). Health care waste management and sustainable development goals in Malaysia. *Journal of Wastes and Biomass Management, 1(1)*, 18–20.

Nor Faiza MT, Noor Artika H, Y. M. (2019). Health Care Waste Management and Sustainable Development Goals in Malaysia. *Journal of Wastes and Biom Ass Management, 1(1)*, 18–20.

Olaniyi, F. C., Ogola, J. S., & Tshitangano, T. G. (2019). Efficiency of Health Care Risk Waste

Management in Rural Healthcare Facilities of South Africa : An Assessment of Selected Facilities in Vhembe District , Limpopo Province. *International Journal of Environmental Research and Public Health*.

Pasupathi, P., Sindhu, S., Shankar, B., & Ambika, A. (2015). *Biomedical waste management for health care industry : A review International Journal of Biological & Medical Research Review article Biomedical waste management for health care industry. May.*

Patil, G. V, & Pokhrel, K. (2005). *Biomedical solid waste management in an Indian hospital : a case study. 25, 592–599. <https://doi.org/10.1016/j.wasman.2004.07.011>*

Rae, I., & Hirani, D. P. (2014). Biomedical Waste : An Introduction to its Management. *International Journal of Innovative Research in Advanced Engineering (IJIRAE), 1*(September), 82–87.

Rajan, R., Robin, D. T., & Vandananani, M. (2019). Journal of Ayurveda and Integrative Medicine Biomedical waste management in Ayurveda hospitals e current practices and future prospectives. *Journal of Ayurveda and Integrative Medicine, 10*(3), 214–221. <https://doi.org/10.1016/j.jaim.2017.07.011>

Rapiti, E., Prüss-üstün, A., Prüss-üstün, A., Campbell-lendrum, D., Corvalán, C., & Woodward, A. (2005). *Sharps injuries Assessing the burden of disease from sharps injuries to health-care workers at national and local levels. 11.*

S. Wiafe, I.K. Nooni, M. S. Nlasia, S.K. Diaba, S. K. F. (2015). Assessing Clinical Solid Waste Management Strategies in Sunyani Municipality, Ghana– Evidence from Three Healthcare Facilities. *International Journal of Environment and Pollution Research, 3*(3), 32–52.

- Secretary of the Basel Convention/WHO. (2021). Preparation of National Health-Care Waste Management Plans in Sub-Saharan Countries: Guidance Manual. In *United Nations Environment Programme / SBC*.
- Sepetis, A., Zaza, P. N., Rizos, F., & Bagos, P. G. (2022). Identifying and Predicting Healthcare Waste Management Costs for an Optimal Sustainable Management System: Evidence from the Greek Public Sector. *International Journal of Environmental Research and Public Health*, 19(16), 9821.
- Shalini, S., & Harsh, M. (2012). *Evaluation of bio-medical waste management practices in a government medical college and hospital*. 3(1), 80–84.
- Shannon, A. L., & Woolridge, A. (2011). Chapter 23 - Medical Waste. In *Waste*. Elsevier Inc. <https://doi.org/10.1016/B978-0-12-381475-3.10023-3>
- Sharma, R., Sharma, M., Sharma, R., & Sharma, V. (2013). *The impact of incinerators on human health and environment*. 28(1), 67–72. <https://doi.org/10.1515/reveh-2012-0035>
- Singh, N., Ogunseitan, O., & Tang, Y. (2021). Medical waste: Current challenges and future opportunities for sustainable management. *Crit Rev Environ Sci Technol* 2021, 0, 1–23.
- Singh, S., & Prakash, V. (2007). *Toxic Environmental Releases from Medical Waste Incineration : A Review*. 67–81. <https://doi.org/10.1007/s10661-006-9503-3>
- Sisay, A. (2017). *Health Care Solid Waste Generation and Its Management in Hawassa Referral Hospital of Hawassa University , Southern , Ethiopia*. 6(5), 126–132.
- Srivastav, S., & Mahajan, H. (2016). EVALUATION OF BIO-MEDICAL WASTE MANAGEMENT PRACTICES IN A GOVERNMENT MEDICAL COLLEGE. *National*

Journal of Community Medicine, 3(November 2011).

Tadesse Legesse, M., & Kumie, A. (2014). Healthcare waste generation and management practice in government health centers of Addis. *BMC Public Health*, 1–9. <http://www.biomedcentral.com/1471-2458/14/1221>

Tesfahun, E. (2015). *Healthcare waste in Ethiopia a study of waste generation , composition and management in the Amhara national regional state , Ethiopia.*

Tesfahun, E., Kumie, A., Legesse, W., Kloos, H., & Beyene, A. (2014). Assessment of composition and generation rate of healthcare wastes in selected public and private hospitals of Ethiopia. *Waste Management & Research*, 32(3), 215–220. <https://doi.org/10.1177/0734242X14521683>

Teshiwal Deress Yazie*, M. G. T. and K. A. C. (2019). Healthcare waste management current status and potential challenges in Ethiopia : a systematic review. *BMC Research Notes*, 1–7. <https://doi.org/10.1186/s13104-019-4316-y>

UNEP. (2008). best environmental practices. (*Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants Waste Incinerators.*)

UNEP. (2012). *Compendium of Technologies for Treatment or Destruction of Healthcare Waste.*

UNSD. (2020). *United Nations statistics Division -Environment statistics. [Online].; 2020 [cited 28 December 2023. Available from:<http://unstats.un.org/>].*

Vitale, K. (2008). *Management of hazardous medical waste in Croatia.* 28, 1049–1056.

<https://doi.org/10.1016/j.wasman.2007.01.021>

WHO/UNICEF. (2015). Water, sanitation and hygiene in health care facilities: status in low- and middle-income countries. In *World Health Organization, Geneva*. World Health Organization, Geneva. <https://doi.org/https://www.who.int/publications-detail-redirect/9789241508476>

WHO/UNICEF. (2019). *Water, sanitation and hygiene in health care facilities: status in low- and middle-income countries*. World Health Organization, Geneva.

WHO. (2004a). *Healthcare waste management*. Geneva: WHO. Fact sheet No 281.

WHO. (2004b). *Safe health-care waste management*, WHO. Policy paper. 3(August), 3–4.

WHO. (2015a). *Healthcare waste*. [Online].; 2015 [cited 25 December 2023]. Available from: http://www.who.int/topics/medical_waste/en/.

WHO. (2015b). *Status of health-care waste management in selected countries of the Western Pacific Region, 2008–2013*.

WHO. (2016). WHO. *Waste from Health Care Activities*. [Online].; 2016 [cited 8 February 2018]. Available from: <http://www.who.int/mediacentre/factsheets/fs253/en/>. March.

WHO. (2017). *Safe management of wastes from health - care activities A summary*.

WHO. (2019). *Overview of technologies for the treatment of infectious and sharp waste from health care facilities*. ISBN 978-92-4-151622-8.

Windfeld, E. S., & Brooks, M. S. (2015). Medical waste management e A review. *Journal of Environmental Management*, 163, 98–108. <https://doi.org/10.1016/j.jenvman.2015.08.013>

APPENDICES

Appendix I: Verbal Consent sheet, Observational Checklist and Interview Questionnaires

HAWASSA UNIVERSITY

1. Information and Verbal Consent Sheet

Greeting!

Introduction and Objective: I am a postgraduate student from Hawassa University, Ecotoxicology and Environmental Health specialty. I am conducting a study on healthcare solid waste management system in Kelle Primary Hospital. This study is intended to assess healthcare solid waste generation rate and its management system.

Benefits and Harms: This study will contribute in interventions to promote safe healthcare solid waste management system in the Hospital. So participating in this study means you are playing a role for the adoption of changes (interventions to be made) to minimize potential threats to environment and public health. You will receive no payment for your participation.

Confidentiality: The information you will provide will be kept strictly confidential, your name will not be registered and will never be used in connection with any information you tell us. I would like to assure you that your participation would not have any effect at all on your health or other administrative services that you get from the Hospital.

Rights of the participant: Your participation is on your free will. If you feel discomfort with the interview, please feel free to drop it at any time you want. Moreover, you can ask any question, which is not clear for you concerning this interview.

Responsibility: If you want to be sure the reliability, you can contact:

Dr. Mekuria Teshome (Ph.D. Assistant Professor)

Contact Address: Tel.:+251911766972 E-mail: mekuriamergia@gmail.com

Hawassa University, Department of Biology

Consent form: Are you willing to contribute in this study? Yes / No

2. DATA COLLECTION TOOLS

1. Data collection form for measuring the Healthcare solid waste generation rate

- | | |
|---------------------------------|--------------------------------|
| 1. Name of data collector _____ | 4. No. of occupied beds: _____ |
| 2. Signature _____ | 5. Date _____ |
| 3. Type of ward : _____ | 6. Time: _____ |

Waste category (specify)	Quantity of waste generated per day(weight)													
	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	weight	volume	weight	volume	weight	volume	weight	volume	weight	volume	weight	volume	weight	volume
Infectious waste														
Sharps														
Pathological waste														
Pharmaceutical and chemical waste														
Radiological waste														

2. Observational checklist for assessing Healthcare Waste Management practices

I. Waste segregation:

1. Does wastes are segregated into at least three labeled bins at the generation point. a. yes ___ b. no ___
2. If yes, is proper waste segregation/separation system practiced in according to color-coding of bins? yes ___ b. no ___
3. Is the facility used, national standard color coding option? a. yes ___ b. no ___ If no, specify:
4. Is there posted SOP for segregation? a. yes ___ b. no ___
5. Availability of PPE? a. yes ___ b. no ___
6. Are visual aids or instructions present near the waste receptacles to help in proper segregation? a. yes ___ b. no ___
7. Is the hazardous waste containers labeled with the word "Hazardous Waste? a. yes ___ b. no ___
8. Are the containers marked with the accumulation start date? a. yes ___ b. no ___

II. Waste collection

1. Is the waste collection do with timetable of the frequency of collection? yes ___ no ___
 - a. Sharps (collected when 3/4 full) yes ___ no ___
 - b. Infectious waste (collected daily) yes ___ no ___
2. Proper labeling yes ___ no ___
3. Availability of Vehicles (trolley,) yes ___ no ___
4. Availability of Supplies of vehicles? yes ___ no ___
5. Availability of PPE yes ___ no ___

III. Waste storage

1. Availability of room for storage yes____ no____
2. Location of the room
 - ✓ Close to the treatment unit yes____ no____
 - ✓ Easily accessible for transportation yes____ no____
 - ✓ Away from food storage and preparation area yes____ no____
3. The storage room shall have adequate space, easy to clean and disinfect with an impermeable hard-standing base, good water supply, drainage and ventilation and protected from sunlight; yes____ no____
4. Lockable/secured storage room and yes____ no____
5. The universal biohazard symbol shall be posted on the storage area door, yes____ no____
6. waste containers yes____ no____
7. Is a healthcare solid waste storage containers was labeled and covered with lids? yes____ no____
8. Is an infectious wastes may be stored no longer than two days prior to treatment or discarding and safety boxes stored for a maximum of one week? Yes____ No____
9. Is a supply of protective clothing, cleaning equipment and waste bags or containers shall be located nearby to the storage area? Yes____ No____

IV. Waste transportation

1. Availability of appropriate waste transport wheel/trolley/cart yes____ no____
2. Adequate handling of waste during transportation yes____ no____
3. A space for cleaning vehicles and linked with sewerage line (drainage) yes____ no____
4. Availability of cleaning agents and disinfectants yes____ no____

5. The Existence of Personal Protective Equipment (PPE) yes ____ no ____

V. Waste Treatment

1. Is sharp and infectious waste treated before disposal yes ____ no ____

2. If yes, what types of treatment methods used _____

- a. incineration
- b. on-site steam sterilization
- c. gas or vapor sterilization,
- d. Thermal inactivation or chemical disinfection.

3. The Existence of Personal Protective Equipment (PPE) yes ____ no ____

VI. Waste Disposal

a) What kind of healthcare solid waste disposal system does your health-care facility use recently?

a. Presence of Incinerator yes ____ no ____

If yes, type of incinerator

i. Controlled air double chamber incinerator yes ____ no ____

ii. Rotary kiln Yes ____ No ____

iii. Pyrolytic incinerator Yes ____ No ____

iv. Specify if other type _____

b. Condition of incinerator (functional, distance) _____

c. Open burning Yes ____ No ____

d. Availability of placenta pit yes ____ no ____

e. Land disposal Yes ____ No ____

If yes, 1- Open dumps to municipal disposal site Yes___ No_____

b) Proper disposal of healthcare solid waste yes_____ no_____

c) Availability of Personal Protective Equipment (PPE) yes_____ no_____

3. Key informant interview questionnaire

Medical director

General Information of the organization

1. Name of the organization _____

2. Type of the organization _____

3. How many beds? _____

4. How many average patients/days? _____

5. Is there full-time assigned staff for BMW management? yes___ no___

Its organizational setup

6.1. Is there fulltime assigned staff for BMW management. Yes___ no___

a) Environmental health/ public health professional yes___ no___

b) Sanitary engineer yes_____ no___

c) Waste handlers yes_____no_____

Other, specify

6. Is there a functional Committee for Infection prevention and patient safety/healthcare solid waste management? yes_____ no_____

7. Is there any policies and procedures?

a. Availability of Guidelines/directives yes___ no___

b. SOPs yes___ no___

- c. Recording and reporting system yes ____ no ____
- 8. Availability of Healthcare solid waste management plan? yes ____ no ____
- 9. What departments are responsible for BMWM at your health care facility?
 - a. Health and Safety _____
 - b. Maintenance/facility _____
 - c. Environmental Health _____
 - d. Nursing _____
 - e. Other (specify) _____

Waste management officer

Waste minimization

1. Is care being taken to implement the waste minimization policy - i.e. to decrease the quantity of waste produced at source (less packaging, returning containers to the supplier? yes ____ no ____
2. Is care being taken to avoid re-using needles and syringes? yes ____ no ____
3. Is purchasing policy being implemented to minimizing hazardous wastes being applied – i.e. PVC free and mercury-free supplies, choice of less toxic substances, safe injection equipment? yes ____ no ____
4. Is the purchasing of chemicals and drugs centralized? Is stock management satisfactory (has the quantity of outdated or unused drugs been reduced?) yes ____ no ____

Waste policy

1. Are there any national legislative provisions on waste management? If so, what are they? yes ____ no ____
2. Is there any national waste management plan? yes ____ no ____
3. Is there any waste management plan in the health facility itself? yes ____ no ____

4. What is the local practice regarding anatomical waste? _____

5. Is any budget allocated to waste management? yes _____ no _____

Training

1. Has the national developed any training material, or is external training material available?

Yes _____ No _____

2. Have all staff members been trained? Are courses held for new staff members and whenever changes are made in the waste management plan? Yes _____ No _____

3. Is the content of the training adjusted to suit each category of staff? Yes _____ No _____

Infection control officer and Environmental health officer

Staff protection measures

1. Are regular checks carried out to ensure that protective measures are taken? Yes _____
No _____

2. Is the PPE appropriate for the activity concerned, and is it worn correctly? Yes _____
No _____

3. Do employees wear gloves regularly when in contact with waste? Yes _____ No _____

4. Do employees in contact with waste wash their hands properly and regularly? Yes _____
No _____

5. Have all staff members been vaccinated against hepatitis A and B and tetanus? yes _____
no _____

6. Is there a system for dealing with accidents involving exposure to blood or other body fluids (posters/notices concerning the measures to be taken, post-accident care, and registration)?
Yes _____ No _____

7. Is every staff member aware of the emergency measures to be taken in the event of an accident, spilling, or splashing/ spraying? Yes _____ No _____

Wards/Departments Focal Person

Waste Collection, treatment and disposal practices

1. Do you segregate waste at the point of generation? Yes ____ No ____ I don't know ____
2. Do you treat hazardous healthcare waste differently from general waste Yes _____
No _____ I don't know _____
3. Do you use PPE (apron, boots, hard gloves and masks) when handling healthcare waste
Yes ____ No ____
4. On-site waste handling (patients bed to temporary storage place) duration
Once per day _____ Twice per day _____ Irregular _____
5. On-site waste handling (from temporary storage place to final disposal place) duration
Once per day ____ Twice per day _____ Irregular _____
6. Bags were filled with more than $\frac{3}{4}$ (75%) Yes ____ No ____ I don't know _____
7. The filled bags were closed tightly before transferred Yes ____ No ____
I don't know _____
8. The filled bags were replaced with empty one at the same time of discharge Yes ____
No _____
9. Material used for the transport of the waste was punctured Yes ____ No _____
10. What waste treatment method used in the facility
 - a) Incineration
 - b) Open dumping
 - c) Burial
 - d) Open burning

Appendix II: Parts of National Healthcare Waste Management Guideline (2008)

Segregation of HCW

Proper segregation must follow standardized procedures to reduce the risk of infecting workers, and enable use of the most efficient treatment procedures for each waste stream. Segregation must:

1. Be simple to implement for medical and ancillary staff
2. Ensure the absence of infectious and hazardous HCW in the domestic waste flow
3. Be applied in all HCFs
4. Be regularly monitored to ensure compliance

The following guidelines should be included for HCW segregation:

1. Segregation of HCW should separate the different types of waste so that each can be handled safely and economically.
2. Health care facilities should provide colored waste receptacles specifically suited for each category of waste. The color-coding system aims at ensuring immediate and non-equivocal identification and segregation of the hazards associated with the type of HCW that is handled or treated. In this respect, the color-coding system shall remain simple and be applied uniformly throughout the country. In the absence of color-coded bins, however, labeled waste bins with an infectious waste symbol or text can be used as an alternative to ensure safe segregation practices.

3. Segregation shall take place at the source—at the ward bedside, operation theatre, medical diagnostic laboratory, or any other place where the waste is generated.
4. The nine categories of HCW shall be segregated and color-coded as outlined in table 1 and table 2.

Table 1: Three-bin system used in all Hospitals, health centers, health posts, and patient wards

Segregation category	Color	Container
Non-risk waste	Black	Bag or bin
Infectious clinical waste (different type)	Yellow	Bag or bin
Sharp waste	Yellow	Safety box

Table 2: Other categories of waste used in specialty wards and laboratories

Segregation category	Color	Container
Anatomical waste and placenta (infectious)	Yellow	Bag or bin
Hazardous pharmaceutical and cytotoxic waste (hazardous)	Yellow	Bag or bin
Highly infectious waste (infectious)	Yellow	Bag or bin
Radioactive waste (hazardous)	Yellow	Secure container with radioactive symbol
Wastes with high contents of heavy metals	Red	Secure container
Effluents	Red	Flask or container

Color-coding system

The following guidelines should be included for the color-coding system:

Black: All bins or bags containing non-risk HCW.

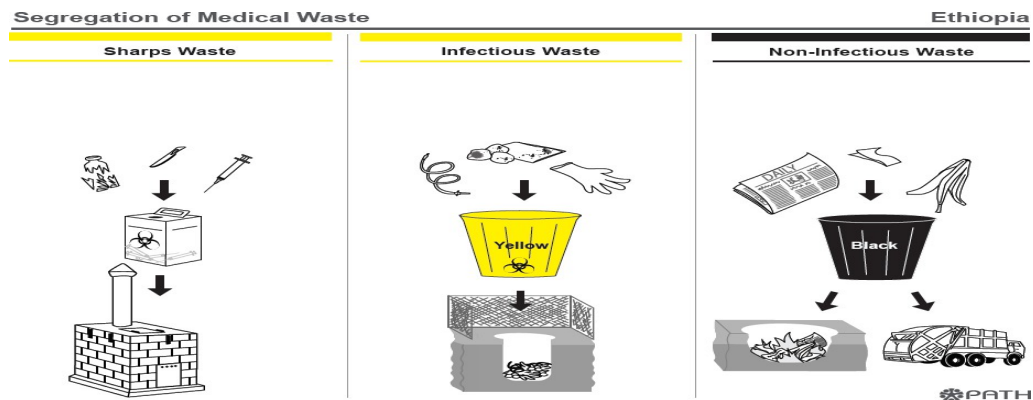
Yellow: Any kind of container filled with infectious HCW, including safety boxes.

Red: Any kind of container filled with heavy metal or effluent.

White: Any container or bin filled with drug vials, ampoules, or glass bottles for glass recycling or reuse. This system is used only where a municipal glass recycling system is available.

In resource limited HCFs, red containers can be omitted and heavy metals and other effluents can be handled as any other infectious waste using yellow receptacles. However, heavy metals and other effluents should not be incinerated. Regarding the disposal of pharmaceutical wastes, please refer to the guideline document developed by Drug Administration and Control Authority of Ethiopia (DACA).

Health workers must properly segregate waste at the point of use and ensure proper segregation bins and safety boxes are available at all injection sites (see the next figure).



APPENDIX III: Photos showing solid healthcare waste management practice in Kelle Primary Hospital, Koore Zone, February 2025

