KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

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SOLID MEDICAL WASTE MANAGEMENT PRACTICES AT THE UNIVERSITY HOSPITAL, KNUST, KUMASI

BY

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KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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Solid Medical Waste Management Practices at the University Hospital, KNUST, Kumasi

By

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DECLARATION

I hereby declare that this submission is my own work towards the MPhil and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Effective management of solid medical waste (SMW) is an important issue confronting many developing countries including Ghana. Ghana has many health facilities of which the University Hospital, KNUST, Kumasi (UH-KNUST) forms part. This research took place between November 2015 and February 2016 at the UHKNUST, a Level C District Hospital, with an average daily out-patient attendance of 325 patients. Data for the study were gathered from both primary and secondary sources. Primary data was collected through segregation, quantification and weighing of solid medical waste (SMW) generated. Questionnaires were also employed in obtaining primary data. The Hospital generates non-hazardous (general) and hazardous (infectious, pharmaceutical, pathological, heavy metal and sharp) wastes which are currently co-disposed into skip containers on-site. UH-KNUST treats only their sharp waste using incineration, without air pollution control device. Quantities of waste generated were measured twice daily using plastic bags, cardboard boxes and buckets of known weights and a weighing scale. A total of 5422.0 kg and 4262.2 kg of nonhazardous and hazardous wastes respectively were generated within the 16-week study period. Quantities of specific SMW generated in all wards/units were statistically different. The existing management practices, which serves as basis for providing sustainable management measures to issues of waste handling and disposal at the Hospital were identified. This was done by personal observations and administering of questionnaires to waste handlers and healthcare staff. Limitations identified include: inadequate education/sensitization of healthcare personnel and waste handlers, lack of hospital waste management department and policy, non-adherence to segregation of waste, and no documentation of waste generated and waste handling procedures. Sustainable management measures such as effective and regular sensitization of all healthcare workers and patients on the importance of segregation and the risks involved in poor handling of SMW among others were recommended to reduce the negative impacts of improper management of SMW on human health and environmental resources. A waste management plan was developed for the UHKNUST to serve as a guideline in managing its SMW. Putting these measures in place will address the various health and environmental issues identified at the UH-KNUST.

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ACRONYMS AND ABBREVIATIONS

ANOVA	analysis of variance
EA/EI	environmental aspect/environmental impact
EO	Environmental Officer
EPA	Environmental Protection Agency
KNUST	Kwame Nkrumah University of Science and Technology, Kumasi
MLGRD	Ministry of Local Government and Rural Development

OPD	out-patients department
PHU	public health unit
PPE	personal protective equipment
SMW	solid medical waste
SWM	solid waste management
UH-KNUST	University Hospital, KNUST, Kumasi
VIP	very important people
WHO	World Health Organization
WMD	waste management department

DEDICATION

This work is dedicated to my family for their prayers and unrelenting support.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Rapid industrialisation, coupled with population growth, high standard of living and economic development has hastened the rate of solid waste generation worldwide (Minghua *et al*., 2009). Management of solid waste is one of the most difficult issues that the world faces. Huge quantities of solid wastes are generated each day by human activities (Mohee and Bundhoo, 2015). Management of these solid wastes especially its disposal is a very essential problem confronting most developing countries (Van Beukering *et al*., 1999) including Ghana. As discussed by Hosetti (2006) solid wastes can be grouped as: agricultural waste from fields and farms; institutional waste from offices, schools and colleges; municipal waste; commercial waste from markets, hotels and medical facilities and residential waste from households. It also includes waste from sources such as construction and demolition, industrial and treatment plant sites (Tchobanoglous *et al*., 1993).

Osei-Mensah *et al*. (2014) alludes to solid waste management (SWM) as the source separation, proper collection, sorting, transportation, storage, treatment, recycling and disposal of solid waste. The management must be done in an environmentally sustainable manner by considering most appropriate practices of nature conservation, public health delivery, aesthetics beautification, and engineering (Puopiel, 2010; Nyankson, 2013). Recently, poor management of solid waste, mainly domestic, industrial and commercial wastes (Puopiel, 2010) has raised lots of concerns regarding their significant health and environmental related issues (Da Silva *et al.*, 2005; Mensah, 2012). In Ghana, less consideration has been given to various solid wastes including solid medical waste (SMW). As observed by Mensah (2012), the consequences of poor management of SMW is environmentally damaging and threatens human life. Some of the waste-related diseases include dysentery, typhoid and malaria (Akter, 2000; Puopiel, 2010). Environmentally, water, air and soil are polluted if SMW is not properly managed (Hosetti, 2006). The aesthetic value of the immediate environment is also decreased.

Due to their potentially hazardous or unusual features, special waste like SMW (Uriarte, 2008) which comprises of hazardous and infectious materials, sharp objects and other forms of waste generated from hospitals, clinics, laboratories, pharmacies, maternity homes and dental/veterinary clinics need to be treated and disposed separately and should not be mixed with municipal solid waste (Blackman, 2001). A more thorough but economical approach is required to effectively manage the challenges posed by SMW, by managing the different portions of the SMW stream based on their physical, chemical and biological characteristics. Hence, the need for effective segregation of the waste stream.

1.2 Problem Statement

The UH-KNUST forms part of the major hospitals in the Kumasi Metropolis. In the last few years, the UH-KNUST has developed both in infrastructure and administration receiving patients from the University community and over 30 nearby communities. There is a growing perception that, standard practices by the WHO, EPA Ghana and the MLGRD are not observed. This suggests that the existing SMW management practices present occupational hazard to waste management workers and healthcare staff, health risk to patients, hospital staff and the surrounding communities and a potential source of pollution to environmental resources such as air, soil and water. For instance, there have been cases of needle-stick injuries, a situation that can lead to the transmission of infectious diseases. Unfortunately, information on the quantities, characteristics and handling of SMW generated during the provision of healthcare services at the UH-KNUST have not been reported. The situation calls for investigation into the SMW management practices at the UH-KNUST. Hence, the research seeks to examine the practices in place for the management of SMW at the UH-KNUST and provide sustainable measures for lapses if any by answering the following questions:

1. What are the quantities and composition of SMW generated in the wards/units of the Hospital?
2. What are the existing management practices for SMW?
3. Are there any limitations in the current management practices?

1.3 Justification

Taking into consideration the risks, both on human health (patients, hospital staff and nearby communities) and the environment, the rapid increase in the generation of SMW is alarming (Airlina, 2015). Ghana's EPA and the MLGRD acknowledge the urgent need for proper waste management wherever it is economically viable as well as provides a positive influence on the environment (Osei-Mensah *et al*., 2014). Knowledge in the existing management practices at the UH-KNUST, as aimed by the study, will help ascertain the degree of adherence to standard practices and the necessary steps taken to address any shortfalls associated with the effective management of SMW. This will serve as a baseline data for effective decision-making and provision of sustainable strategies for the management of SMW.

1.4 Aim and Objectives

The aim of the study is to examine the SMW management practices at the UH-KNUST and the related health, occupational and environmental risks.

Specific objectives are to:

1. determine the quantity and composition of SMW generated in the UH-KNUST within the period of study;
2. identify existing management measures in place for SMW and
3. propose sustainable management strategies in solving issues related to the management of SMW.

1.5 Scope of Study

The study was carried out at the UH-KNUST in the Ashanti Region of Ghana. Samples of SMW from all the wards and units of the Hospital were collected for analysis within the study period. These included all the Theatre, Dental and Eye clinics, the General OPD with the emergency and casualty unit, Administration, Pharmacy, Laboratory, XRay and Scan unit, the Public Health Unit (PHU) and all five wards namely Children's,

Maternity, Otumfuo Osei Tutu Medical Centre (VIP ward), Male and Female wards. The study covered the sources of SMW generation, its composition, management practices through to the final disposal on-site (at the hospital premises). Waste such as human excreta was exempted from the study. The activities of the waste management firms from when the waste is collected on-site to its final disposal site (off-site) was also excluded from this study.

1.6 Structure of the Thesis

The study was organized in five (5) chapters. The first chapter gives a general introduction about the research work. It provides an overview of the problem of SMW management at the UH-KNUST and gives reasons for the study. In chapter two, relevant literature regarding SMW management is reviewed, thus, the sources, categories and processes of SMW management. Chapter three focuses on the materials and methods employed in the collection and interpretation of data for the research work including personal observations, questionnaire administration and weighing of SMW. The chapter gives a very brief description of the study area. In chapter four, the findings are presented using tables, pictures and figures. Analysis of the work is also given in chapter four. Chapter five concludes the study with a summary of the entire research findings and recommendations.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Healthcare facilities aim at safe guarding health, healing people and ultimately to save lives but generate waste in the course of providing health care (Patil and Pokhrel, 2005; Saad, 2013). Hospitals form part of the major generators of SMW (Pickford, 1977; Bassey *et al*., 2006) which comprises of non-hazardous and hazardous materials (Mato and Kassenga, 1997; Al-Khatib *et al*., 2011). Waste materials from healthcare facilities have detrimental health and environmental effects if not treated with care (Pickford, 1977; Sawalem *et al.*, 2009; WHO, 2011; Joshi *et al.*, 2015). Regardless of the issues related to the SMW management, societies will not survive without health facilities as it is a primary necessity (Nemathaga *et al.*, 2008).

2.2 Definitions of Solid Medical Waste (SMW)

Medical waste according to WHO (2011) are secondary products as a result of the provision of healthcare services and include: pharmaceuticals, human body parts, chemicals and sharps among others. It is the entity of the waste stream produced during the diagnosis, treatment or immunization of patients and can be infectious or noninfectious (WHO Immunizaton, 2005; Mensah, 2012). Medical waste includes any solid waste generated in hospitals during diagnosis and treatment of humans or animals, in research or biological testing and includes such waste as disposed surgical gloves, needles, cultures and culture dishes, blood stained bandages and syringes (ElSalam, 2010). MLGRD and EPA (2002) refers to the untreated wastes such as infectious, pathological and pharmaceutical wastes produced in the provision of healthcare or in conducting research which involves both humans and animals.

2.3 Sources of Solid Medical Waste

Based on the quantity of waste produced during the provision of healthcare services, medical facilities can be categorized as either major or minor sources of medical waste (MLGRD and EPA, 2002; Saad, 2013). The quantity and characteristics of waste produced from all the sources vary. Hospitals (e.g., teaching, specialist) and other medical establishments (including maternity clinics, dialysis centres), medical laboratories and research facilities, autopsy centres, animal testing laboratories, mortuaries, blood banks, nursing homes, research laboratory for animals are major contributors to medical waste (WHO, 2011; WHO, 2014; Asante *et al*., 2014). Minor SMW generators include: ambulance services, first-aid posts, pharmacies, dental and veterinary clinics and other specialized healthcare facilities and institutions with low waste generation (Prüss *et al*., 1999; WHO, 2014).

2.4 Categories of Solid Medical Waste

Medical waste from hospitals have similar characteristics except for the quantity produced which varies widely from one medical centre to another (Cairncross and Feachem, 1993; Al-Khatib *et al*., 2011). Knowing the types of waste generated is important in designing appropriate disposal facilities (Airlina, 2015). Waste generated from hospitals and other healthcare establishments can be categorized broadly into hazardous waste and non-hazardous waste (MLGRD and EPA, 2002; Saad, 2013).

2.4.1 Hazardous Waste

Figures from Prüss *et al*. (1999) and WHO (2014) show that about 15-25 % of waste generated from health facilities are hazardous. These are a potential risk to human health and the environment. Included in this category are infectious, sharps, pathological, pharmaceuticals, radioactive, chemical and pressurised containers and waste with high content of heavy metals Pathological and infectious wastes form the majority part of hazardous waste from medical activities (Asante *et al*., 2014).

2.4.1.1 Sharp Waste

All waste materials such as broken glasses, needles, knives, infusion sets, blades, scalpels and pipettes that can cause wounds or cuts are regarded as sharp waste. Such wastes are hazardous, whether infected or not and must be treated with caution (WHO, 2014). Sharp waste are a small fraction of total quantity of SMW nevertheless are a major risk to human health if mismanaged (Asante *et al*., 2014).

2.4.1.2 Infectious Waste

Waste materials containing significant amounts of pathogenic life (viruses, bacteria, fungi or parasites) (Nkhuwa *et al*., 2008; WHO, 2014) and have the potential to transmit diseases are classified as infectious waste (Prüss *et al*., 1999; Al-Habash and Al-Zu'bi, 2012). Included in this category are: waste contaminated with blood and other body fluids, gloves, dressings, bandages, swabs, towels, laboratory coats and waste items contaminated with blood, waste generated from autopsy and other laboratory cultures (Asante *et al*., 2014; WHO, 2014). Instruments and waste materials that have had direct contact with infected animals or human beings and waste from isolation units should be tagged as highly infectious medical waste (Hossain *et al*., 2011; WHO, 2014).

2.4.1.3 Pathological Waste

Though pathological wastes have different management (collection, handling, treatment, and disposal) processes, they are treated as infectious waste nevertheless.

Within this category are body parts, tissues, organs, waste from surgery and autopsy, animal carcasses that are infected and human body parts that are healthy but removed during surgical procedures or research (Prüss *et al*., 1999; WHO, 2014).

2.4.1.4 Chemical Waste

Disposed chemical waste from medical centres include waste such as mercury and disinfectants (Asante *et al*., 2014). The discarded materials are either solid, liquid or gas (Hossain *et al*., 2011) and considered highly hazardous if it has one of such properties as being toxic, corrosive, flammable, reactive and/or oxidizing (Pichtel, 2005).

2.4.1.5 Pharmaceutical Waste

It has been suggested (WHO, 2011; Asante *et al*., 2014) that medical waste grouped under pharmaceutical waste ranges from contaminated, expired, spilt and unused pharmaceutical products, vaccines, prescribed drugs and sera that are not useful and must be carefully discarded due to their hazardous chemical and biological features. Vials, bottles, gloves, masks and boxes that contain remnants of contaminated pharmaceutical products including genotoxic waste fall within this category (AlHabash and Al-Zu'bi, 2012; WHO, 2014). Genotoxic waste is one of the most hazardous pharmaceutical wastes which has the ability to cause genetic mutation (mutagenic), defects in foetus (teratogenic) or cancer (carcinogenic). These properties makes the disposal and handling of genotoxic waste an important safety issue (WHO, 2014).

2.4.1.6 Radioactive, Pressurized Containers and Heavy Metal Wastes These type of medical waste are waste materials contaminated with radionuclides generated from therapeutic processes, research studies and the analysis of body organs, tissues and fluids. Such wastes come from both sealed sources (usually radioactive substances embedded in medical equipment such as needles) and unsealed sources (mainly liquids) (WHO, 2014). Pressurized Containers are made up of waste such as gas cylinders and cartridges, powdered materials, full containers, empty containers or aerosol cans with pressurized liquids (Prüss *et al*., 1999).

Heavy metal wastes are mostly clinical equipment containing high toxic wastes such as mercury waste found in mercury thermometers. Waste from dental clinics also have high mercury content, disposed batteries contain cadmium with some x-ray equipment containing lead. There are drugs that contain arsenic as well (Prüss *et al*., 1999; WHO, 2011; Asante *et al*., 2014).

2.4.2 Non-hazardous Waste

Non-hazardous waste are general waste materials generated in the administrative offices, wards, Out Patients Department (OPD) and kitchen (Mensah, 2012). Constituting about 85 % of SMW, general wastes are comparable in their characteristics to domestic or municipal solid waste (WHO, 2014). Included in this category are food waste, plastics, paper, glass, fabrics, metal, cardboards, general sweepings from lawns and corridors, unused needles and syringes and empty bottles which have not had any contact with infected patients or equipment, radioactive or hazardous materials. Non-hazardous SMW does not pose any risk or hazard to human health and environmental quality but requires a unique handling process (MLGRD and EPA, 2002; Saad, 2013).

2.5 Solid Medical Waste Generation

The amount of SMW generated worldwide varies due to different healthcare procedures. The quantities of waste generated depends on factors such as type of healthcare facility, the facility's instrumentation, location of the healthcare centre (AlKhatib *et al*., 2011; Hossain *et al*., 2011) population of in and out patients, number of support departments (e.g., radiology) and specialized activities performed (MLGRD and EPA, 2002).

It is estimated that medical establishments in Africa generate an approximate amount of 282,447 tons of SMW yearly (Udofia *et al*., 2015). Generally, quantities generated in Regional, Metropolitan, District and Teaching hospitals are very high unlike private hospitals and health posts whose quantities are usually low (MLGRD and EPA, 2002). Hospitals in developed and developing countries generate 0.5 kg and 0.2 kg of hazardous waste/bed/day respectively on an average scale (WHO, 2011).

2.6 Classification of Solid Medical Waste in Ghana

The basis of categorization of SMW is on the source of production and the available storage, treatment and disposal systems [Table 2.1]. The classification is not stringent on all wastes from medical facilities such that specific health facilities can decide whether certain waste materials are hazardous or not (MLGRD and EPA, 2002).

Table 2.1: Classification of Healthcare Waste in Ghana.

Type	Classification and Description	Examples
A	**Non-Hazardous waste** Similar to municipal waste. Poses less risk to human health and environment.	Pens, papers, plastics, food residue, general sweepings etc.

B	**Infectious waste** Usually contaminated with pathogens and a health risk to patients, health care workers, visitors, and waste handlers. Special treatment, storage, and disposal required.	Infected body organs/tissues Lab cultures Contaminated sharps.
B.1	**Sharps** Includes all sharp surgical and ward equipment stained with blood or body fluid	Scalpels, blades, broken glasses, knives, needles, syringes,
B.2	**Patient or Animal waste** Wastes from surgery, isolation unit, OPD and wards contaminated blood/body fluids	Blood-soiled gloves beddings, wool, swabs, dressings,
B.3	**Culture/Specimen** Lab cultures, body tissues, specimen from clinics	Lab specimen, tissue culture, animal specimen
C	**Pathological waste** Human and animal body parts, organs or tissues from surgery, autopsy, and maternity wards. Serious health and environmental hazard; need to be given special treatment and disposal.	placenta, internal organs, removed limbs, blood and body fluids
D	**Hazardous waste** Similar in characteristics (both physical and chemical) to hazardous industrial waste. Special handling and treatment required.	pharmaceutical, heavy metals, infectious waste and chemical contaminants
D.1	**Pharmaceutical waste** Waste from pharmacies and dispensaries likely to be carcinogenic, genotoxic, or mutagenic.	Contaminated and expired medicines
D.2	**Photographic Chemical waste** Waste material (including liquid and solid waste) generated from radiology unit.	Fixer solution X-ray photographic film and developer
D.3	**Radioactive waste** Any solid or liquid waste contaminated with radioactive isotopes of any kind.	papers, gloves, swabs contaminated sharps, Radiotherapy liquid, g Radium needles
D.4	**Laboratory waste**	Acid, heavy metals Solvents, Alkali
D.4.1	**Acids**	Hydrochloric acid
D4.2	**Alkalis**	Potassium hydroxide
D4.3	**Solvents**	Ethanol, Methanol
D4.4	**Organic substances**	Phenol, Hexamine
D4.5	**Heavy metals**	Mercury
E	**Incinerator waste** Combustion residue	Incinerator ash and sludge

Source: MLGRD and EPA (2002)

2.7 Management of Solid Medical Waste

The efficient management of waste generated in healthcare establishments is an essential part of environmental management (Tsakona *et al*., 2007) and the minimization of risks of infection and injury due to exposure to infectious and hazardous wastes (Alagöz and Kocasoy, 2007). As stated by Patil and Pokhrel (2005) waste management is an emerging issue of concern due to the fatal health and environmental effects associated with it. Poor management, including unsuitable treatment and disposal methods of SMW has increased concerns about environmental and health quality in developing countries (Diaz *et al*., 2005; Hossain *et al*., 2011).

Management of SMW involves taking tough decisions on the proper sorting of waste, on-time collection and safe waste disposal, occupational, health and environmental safety (Joshi *et al*., 2015). To achieve sustainable management of SMW, there should be a management plan outlining the necessary staff training and procedures for safe handling of medical waste (Mensah, 2012). Good management practices such as source reduction, waste segregation, storage, transportation, treatment and disposal must be encouraged to ensure safety to health and environment (Akter, 2000; Al-Habash and Al-Zu'bi, 2012).

2.7.1 Waste Minimization

Mensah (2012) states that waste minimization involves processes to reduce the quantity of waste generated or waste to be treated and disposed. The focus of waste minimization is to significantly or drastically decrease the production of SMW (WHO Immunizaton, 2005) through the implementation of waste reduction or recycling strategies (MLGRD and EPA, 2002). This can be encouraged through behavioural change, improvement or changes in management, record keeping, monitoring of inventory (MLGRD and EPA, 2002; WHO Immunizaton, 2005) waste segregation and better management practices (Prüss *et al*., 1999). Two strategies are employed:

1. Source Reduction
2. Recycling

2.7.1.1 Source Reduction

It has been suggested (MLGRD and EPA, 2002; WHO Immunizaton, 2005) that reducing waste generation at source can be achieved through equipment modification, inventory control, material substitution and putting in place good operational practices. Strategies put in place to minimize waste production should not in any way hinder access to healthcare or have any negative influence on the quality of healthcare provided (WHO Immunizaton, 2005). Minimization can be effectively achieved through:

- Education and training of workers on management of all types of waste;
- Segregation of specific wastes generated e.g. separating hazardous waste from non-hazardous waste;
- Making various departments to bare their waste management costs;
- Enhance inventory control by using old stock first before putting in orders for new stock;
- Purchasing and dispensation of drugs and other materials should be centralized and
- Enforce a waste reduction program throughout the establishment (MLGRD and EPA, 2002; WHO, 2014).

2.7.1.2 Recycling

Recycling is a practice adopted by many institutions including hospitals (WHO, 2014) to salvage parts of disposed materials for reuse (in its original state) or convert it into another product (Mensah, 2012). In health centres such as hospitals, recycling of nonhazardous waste such as paper, metal and plastics is mostly done to reduce waste bulk. It has been suggested (Prüss *et al.*, 1999; WHO, 2014) that recycling of waste materials reduces expenditure for the healthcare establishment through the reduction of cost for disposal or the amount the recycling firm pays for the recovery of materials.

2.7.2 Segregation and Packaging

Segregation of waste at source is an important part of effective waste management (WHO, 2011), waste minimization and identification (Prüss *et al*., 1999). Specific types of waste material have their special handling processes therefore the essential need to separate the waste stream into hazardous and non-hazardous wastes (MLGRD and EPA, 2002). Waste materials are separated by size using screens or by manual separation or by shredding to reduce the size (Tchobanoglous *et al*., 1993). The use of appropriate handling, storage, packaging and disposal of segregated waste reduces the risk to environment and health. Segregation must be done at source by the one generating the waste to ensure effectiveness of the process (WHO, 2014). Personnel involved in the separation process must be well trained on the importance of segregation and use of colour codes as well as have technical expertise in the proper management of medical waste.

Efficiency can be achieved through colour coding of containers and plastic bags used for the segregation (Prüss *et al.*, 1999; MLGRD and EPA, 2002; WHO, 2014). The colour coding scheme for segregation recommended by Ghana and the WHO are given in [Table 2.2] and [Table 2.3] respectively. Biohazard symbols are used in the labelling of containers for the collection of waste that has the potential to cause hazards. It serves as a warning to those exposed to such biohazards so that precautions can be taken when handling hazardous wastes (Mensah, 2012). The use of internationally recommended hazard symbol is essential [Figure 2.1] (WHO, 2014).

Table 2.2: Recommended colour coding scheme for segregation in Ghana.

Colour Code	Waste Type
Black	General/non-hazardous waste (e.g. food residue, stationery waste, general sweepings etc.)
Yellow	Infectious waste (e.g. sharps, pathological waste, etc.)
Brown	Hazardous waste (e.g. contaminated drugs, radioactive waste etc.)

Source: MLGRD and EPA (2002)

Table 2.3: WHO recommended segregation and colour coding scheme.

Waste Type	Container Colour	Container Type
Highly infectious waste	Yellow (with a biohazard symbol & labelled HIGHLY INFECTIOUS)	Durable leak-proof container which can be autoclaved
Other infectious waste	Yellow (with biohazard sign)	Leak-proof container
Sharps	Yellow	Puncture-proof container
Pharmaceutical	Brown	Plastic bag or container
Radioactive	-	Lead box with radioactive sign
General/Nonhazardous	Black	Plastic bags

Source: (Prüss *et al*., 1999; WHO, 2014).

(a) (b)

Figure 2.1: Recommended symbols for (a) biohazard and (b) radiation (WHO, 2014).

2.7.3 Storage

From the sources of generation, SMW is stored up until it is collected for final disposal (MLGRD and EPA, 2002). Poorly stored SMW are a source of hazard to waste managers and other staff of the healthcare facility. Specially designed containers such as safety boxes, plastic containers or bags with lids or cardboard boxes are used for the storage of SMW of all kinds (WHO Immunizaton, 2005). The type of storage facility appropriate for a specific waste type is dependent on the waste type and the risk of infection of such waste to waste handling and disposal workers (MLGRD and EPA, 2002). Biohazard symbols should be attached to the storage containers as a means of precaution to waste collection staff (MLGRD and EPA, 2002; WHO, 2014). It has been shown (MLGRD and EPA, 2002) that storage facilities can be internal or external.

2.7.3.1 Internal Storage

Wastes are temporarily stored at the source of generation until it is transferred to an external storage facility. Measures should be put in place to reduce the risk to healthcare workers and waste managers which include:

- Waste should be removed multiple times in a day
- Puncture-proof and leakage-proof container's must be placed at vantage points
- Every waste generation point must be proved with adequate number of appropriate waste containers
- Storage containers, bins and plastic bags must be placed in areas protected from water, wind, pests (e.g. rats and cockroaches) and other scavenging animals
- Segregation of hazardous waste from non-hazardous waste must be carried out at point of generation
- Sharps must be stored in puncture-proof containers (MLGRD and EPA, 2002).

2.7.3.2 External Storage

The time period within which waste from internal storage points are collected and then transported for various treatment processes and finally disposed is the external storage. External storage facilities are found on the premises of the medical establishment. The type and quantity of waste produced determines how often it is removed. Safe disposal must be ensured by:

- External storage facilities must be easily accessible to transportation vehicles

- The facility must be spacious and very well ventilated
- Must be an enclosed facility which is impervious
- Such facilities should not be located in the wards, kitchen or laundry but must be at an appropriate accessible distance
- Waste bins of volume 240 litres and over must be used for the external storage of waste generated
- Waste bins must be frequently washed and disinfected
- Appropriate PPE's such as gloves, nose masks, safety boots and adequate spill kits must be provided to waste management staff at the storage site. (Prüss *et al*., 1999; WHO, 2014).

2.7.4 Collection and Transportation

Wastes are transferred from collection and storage containers into large transport vehicles for processing or disposal (Tchobanoglous *et al*., 1993). Containers specially designated for the collection of SMW should have the following qualities: must be impervious; not transparent; must be durable to avoid easily breaking during its usage; leak-proof; must have covers that are tightly fitted to it and must have handles for easy usage. Transportation of waste must be done diligently both on-site and off-site.

Equipment like carts used to transport waste on-site must not be used for any other purposes (Mensah, 2012). Healthcare establishments without facilities to treat and dispose waste on-site must appoint a waste management firm to collect waste for treatment and disposal (MLGRD and EPA, 2002). Waste generated must be segregated prior to collection, storage and transportation. This is enhanced by colour-coding containers for storage and transportation [Table 2.4]. Waste transportation vehicles must be labelled with a biohazard symbol if it carries infectious or hazardous waste. Vehicles and containers that are used in transporting waste must be cleaned and disinfected every day (Mensah, 2012; WHO, 2014).

Table 2.4: Colour coding for storage and transportation of SMW in Ghana.

Waste category	**Colour Code**
General Waste	Black plastic bag/bins
Infectious Waste	Yellow plastic bags and containers
Pathological Waste	Yellow containers & plastic bags
Sharps	Yellow puncture-proof container
Hazardous Waste	Brown plastic bags & containers
Pharmaceutical waste	Brown plastic bags & containers
Photographic Chemical Waste	Brown plastic containers
Radioactive Waste	Brown containers with radio-active symbol
Laboratory Waste	Brown containers with appropriate labels • Heavy metal label • Acid label • Alkali label • Organic substances
Incinerator Ash Sludge	Yellow metal containers labelled ash or sludge

Source: MLGRD and EPA (2002)

2.7.5 Treatment of Solid Medical Waste

An essential part of SMW management is the proper treatment of waste generated. Untreated or poorly treated wastes poses risks to both human health and the environment. Treatment methods employed in the management of SMW serves to reduce risks to human and environment, disinfect infectious wastes, restore recyclable waste materials and destroy used syringes and other disposable equipment (WHO Immunizaton, 2005). Measures should be employed to first reduce the quantity of waste and the safe reuse of usable part of the waste, if not, waste must be well treated and disposed (WHO, 2014). According to Airlina (2015) five methods can be employed in the treatment of SMW which can be grouped under incineration and nonincineration systems. Various waste management equipment ranging from those used in handling the waste (e.g., compactors, containers), shredding, conveying, reduction in size, sterilizers (e.g., autoclave) and recycling systems are used in the treatment process (Airlina, 2015). According to Hossain *et al*. (2011) treatment method used must be environmentally sound, economical and implemented without difficulty.

2.7.5.1 Incineration

Incineration is one of the three most important methods of medical waste treatment and disposal (Cairncross and Feachem, 1993). As stated by Williams (1994) during incineration, reduction of the entire waste volume takes place while energy restoration in the form of electricity or steam occur. It is a thermal process achieved at very high temperatures (Airlina, 2015). This technology used in waste treatment converts waste materials into ash, gas and heat through combustion (Denison *et al*., 1994)**.** Incineration is most commonly used for the combustion of pharmaceutical and pathological waste. Not appropriate for plastics. Incineration results in air pollution if the equipment is not designed and equipped with air pollution control devices as well as operated and maintained properly (Pickford, 1977).

Incinerators employed in SWM include the single-chamber, open burning, teepee burners, open-pit, multiple chamber/hearth, controlled air, central station and rotary kiln (Brunner, 1994). All methods employed in combustion of SMW generates byproducts which are either solid, liquid or gas (Diaz *et al*., 2005). Three main types of incinerators are mostly used in the treatment of biomedical waste namely:

- Rotary Kiln: a drum-like incinerator used in the treatment of hazardous and medical waste;
- Multiple Hearth: comprises of a steel furnace circular in nature and has solid refractory hearths embedded with a central rotating shaft which converts the waste materials into ash and
- Controlled Air: mostly used for organic waste. Two process chambers burn and oxidize the waste releasing a mixture of water vapour and carbon dioxide

(Airlina, 2015).

2.7.5.2 Non-Incineration Systems

Other technologies are employed in the treatment of medical waste without combustion. This involves processes such as thermal, irradiation, chemical and biological (Airlina, 2015). These processes sterilizes SMW generated to make them less harmful.

2.7.5.2.1 Autoclaving System (Thermal)

Steam sterilization or autoclaving involves the sterilization of SMW before finally disposing of into landfill sites (Airlina, 2015). Commonly for the treatment of waste such as sharps, microbiological laboratory waste and infectious non-sharps such as gauze, soiled beddings, bandages (Diaz *et al*., 2005; Hossain *et al*., 2011). In its operation, biomedical waste is decontaminated with steam which is produced at high temperatures (thermal). This system is not suitable for pathological waste (Airlina, 2015). Autoclaves are operated at an optimal temperature so as to destroy all disease causing bacteria (Prüss *et al*., 1999; Hossain *et al*., 2011).

2.7.5.2.2 Microwave System (Irradiation)

This technology is another thermal process which requires microwave energy of very high frequency. Heat generated by the wave is applied to the medical waste usually sharp waste and infectious waste. Any bacteria or other form of contamination is killed by the heat produced. This method is not applicable for the treatment of pathological waste (Hossain *et al*., 2011; Airlina, 2015).

2.7.5.2.3 Chemical Decontamination

Treatment of medical waste can be achieved using the chemical disinfection process. It is appropriate for the treatment of waste such as body fluids, sharps, human blood and laboratory liquid waste but cannot be used in the treatment of anatomical waste (Airlina, 2015). The effectiveness of chemical decontamination is dependent on the ability of the specific chemical (which includes alcohol, phenols, detergents) being used to inactivate pathogens in contaminated equipment and infectious wastes (Diaz *et al*., 2005).

2.7.5.2.4 Biological Process (Enzymes)

Enzymes are required for this process. The organic matter in the waste is destroyed by the enzymes introduced into the waste. This process is most seldom employed because the technology is undeveloped for the treatment and disposal of medical waste (Airlina, 2015).

2.7.6 Disposal

SMW waste disposal is an issue of concern in many parts of the world and can be addressed by developing waste management plan (Nkhuwa *et al*., 2008; Saad, 2013).

Disposal of both treated and untreated waste is done by landfilling or land spreading. Engineered landfill sites are the most appropriate methods of disposal for treated waste and does not present any health and environmental effects (Tchobanoglous *et al.*, 1993). The article (Blenkharn, 2006) proposes that disposing of SMW safely and the destruction of same that follows is a very essential step in reducing the risk of injury, spread of diseases and the detrimental environmental effects of such hazardous wastes. To dispose of SMW safely, four important steps such as segregation, collection and storage, treatment and safe disposal must be followed in line with national regulations (Asante *et al*., 2014). The disposal method used is dependent on available space and appropriate facilities which reduces hazards to health and environment (MLGRD and EPA, 2002).

2.8 Hazards of SMW Mismanagement

Mismanagement of SMW produced in healthcare facilities can lead to wide range of direct environmental impacts (Cairncross and Feachem, 1993) and health effects on healthcare workers, waste handlers, patients, visitors and the surrounding community (Al-Khatib *et al*., 2011; Udofia *et al.*, 2015). Such effects include: air and water contamination, risk of infection and injuries (WHO Immunizaton, 2005) and the ability to pollute soil and spread diseases with pathogens and toxic substances present in them (Udofia *et al*., 2015). Proper management of waste is an important part of environmental health because their collection, storage, handling, treatment and disposal may result in environmental risks (Pickford, 1977). Disregarding standards of waste disposal reduces health quality, societal well-being and adds on to workload of healthcare providers (Blackman, 2001; Al-Khatib *et al.*, 2011).

2.8.1 Risk to Environment

2.8.1.1 Atmospheric Pollution

Waste management processes such as open-air burning, autoclaving and incineration causes air pollution. Burning in an open area releases dense smoke, particulate matter as well as gases (sulphur dioxide, nitrous oxide, carbon monoxide) from incomplete combustion processes (Akter, 2000; Hosetti, 2006) into the environment. Incinerators without air pollution control devices or air cleaning devices which is mostly the case in developing countries are also a source of air pollution (WHO Immunizaton, 2005). Plastics in waste materials contain polyvinyl chloride (PVC) referred to as dioxins and furans which discharge hydrogen chloride when burnt and are of great environmental concern due to their toxicity as mutagens and carcinogens (Pickford, 1977; Hosetti, 2006). Pathogens can hardly survive in the environment but the hepatitis B virus can survive in dry air and a serious threat to human health (Prüss *et al.*, 1999). All of the above causes diseases in people who inhale such contaminated air (WHO

Immunizaton, 2005).

2.8.1.2 Aesthetic Nuisance

As observed by Nemathaga *et al.* (2008) overflowing skips, foul smell, flies, cockroaches, rats and other rodents, uncovered skips or bins, uncollected refuse and waste piles are environmentally harmful. These result in visual pollution and reduces the aesthetic value of the immediate environment (Pickford, 1977). This is worsened by the presence of scavenging animals who tend to spread the waste pile in search of food (Hosetti, 2006).

2.8.1.3 Water Pollution

SMW are potential sources of pollution to water bodies (WHO Immunizaton, 2005); the quality of both ground and surface water resources can be affected by the improper disposal of SMW (Diaz *et al.*, 1994; Hosetti, 2006). Runoff from waste piles or landfill sites into surface waters results in accumulation and pollution by suspended solid matter. Organic matter raises the biological oxygen demand of water bodies which can lead to the death of aquatic life such as fishes. Pathogenic load poses health risks to users downstream (Hosetti, 2006). Pharmaceutical and pathological waste disposed in unlined pits can contaminate both surface and ground water resources (WHO Immunizaton, 2005; Asante *et al.*, 2014).

2.8.1.4 Soil Contamination

Soil may be contaminated through incomplete burning or destruction of plastics and this can minimize the rate of infiltration of water into the soil during down pours. Pathogenic organisms in hazardous waste materials can contaminate soil through the introduction of toxic substances. Decomposition of organic matter and consequently soil fertility can be affected as a result of careless and continuous use of chemicals over a period as it adversely affects the microbial load of the soil. The accumulation of toxic substances in soil can have adverse effects on agricultural yield and man as well as wildlife (Akter, 2000).

2.8.2 Health Impacts of Solid Medical Waste

Hospital waste directly or indirectly has damaging health effects on humans. Exposure to hazardous SMW can cause damages to human respiratory, reproductive and nervous systems (Nemathaga *et al.*, 2008) as well as cause diseases and injury (Prüss *et al.*, 1999; Mohee, 2005). The mismanagement of such SMW results also in the spread of diseases like cholera, typhoid, diarrhoea, throat infection and tetanus (Mato and Kassenga, 1997; Akter, 2000; Nemathaga *et al.*, 2008). Exposure to hazardous medical waste can result in infections such as viral hepatitis A, B and C, haemorrhagic fevers, meningitis, skin, respiratory and gastro enteric infections, acquired immunodeficiency syndrome (AIDS) (Prüss *et al.*, 1999; WHO Immunizaton, 2005; Asante *et al.*, 2014; Udofia *et al*., 2015). Health workers, patients, visitors, waste handlers, including all exposed to hazardous medical wastes are at risk (Mensah, 2012; Saad, 2013). Poor sterilization of equipment used in surgery, maternity and other wards transmit infectious diseases from one person to another (Akter, 2000). Sharp and infectious wastes contain pathogens which can enter the human system through inhalation, ingestion, cuts, skin abrasions and through mucous membranes.

Sorting of hazardous medical waste manually and the activity of scavenging waste disposal sites presents a great deal of risk exposure to infection and diseases in developing countries (WHO, 2011). Also present in healthcare facilities are antibacterial and disinfectant resistant bacteria which increases the risk of infection from improper management of medical waste (Prüss *et al.*, 1999). Leachate infiltrating groundwater and entering surface drinking waters affects the health of communities that depend on it for domestic use (Akter, 2000). Particulate matter and smoke released during incineration are bio-accumulative and persistent in the atmosphere which causes cancer and respiratory diseases in humans (Akter, 2000; Bassey *et al.*, 2006; WHO Immunizaton, 2005; WHO, 2011).

Pharmaceuticals employed in medical establishments are very harmful and likely to cause intoxication through ingestion or inhalation, burns and other forms of injury to the eye and skin with minimal exposure. Humans and animals can be poisoned through waste water contaminated with pharmaceuticals such as cytotoxic and antibiotic drugs. Exposure to radioactive waste causes headaches, dizziness, vomiting and causes defects in genetic materials (Prüss *et al.*, 1999; WHO, 2011).

2.8.3 Occupational Risks

Healthcare professionals and waste handlers are at risk of injury and diseases caused by infectious medical waste. Injuries are most likely to occur at the point of waste handling when needles, knives and other sharp waste materials are being collected (WHO Immunizaton, 2005). Risks are greater when sharps are collected into improperly designed and overflowing containers which are not puncture proof. Pits that are not engineered for the disposal of waste such as pathological waste are also a health risk to health workers (WHO Immunizaton, 2005).

2.9 Environmental Management Plan (EMP)

The growing interest in the protection and sustainable management of the environment has raised the need for an EMP to ensure that an organizations activities do not pose any threat to environmental quality. An EMP is a site-specific plan which is developed to ensure that measures necessary for protecting the environment and complying with environmental regulations are identified and implemented (Koomson, 2015). The plan is developed taking into consideration the environmental issues identified at source, the hazards posed by such issues and strategies to manage its effects on the environment (Massoud *et al.*, 2010).

EMP serves to protect the environment by providing information on how existing activities of an organization affects the environment and how those impacts can be managed in an environmentally friendly manner. It ensures the compliance to environmental regulations and improves the organization's environmental performance (Massoud *et al.*, 2010, EPA, 2013). It prevents pollution and conserve resources. It provides a structured system to prove an organization's commitment to protecting environmental quality. Employees' awareness on environmental issues are improved from the development of the EMP (Koomson, 2015). The development of an EMP according to Hersey (1998) involves the stages of commitment and policy, planning, implementation, monitoring and reporting and review and improvement.

- Commitment: This stage of the process involves setting objectives to achieve environmental protection goals. The management of the organization sets objectives indicating its readiness to comply with environmental protection regulations and laws. The objectives are set to show commitment to prevent environmental pollution (Hersey 1998).
- Planning: All environmental issues resulting from activities of the organization are listed and their impacts on the environment identified. All ecologically sensitive areas around the organization that can be affected by the activities must be known. Legal requirements (e.g. EPA requirements) concerning the various issues identified must be made available to all. Working instructions are to be set out for all staff to manage environmental issues identified and to ensure strict compliance to legal requirements. An emergency plan is then

prepared to determine actions necessary to manage the environmental issues/impacts identified (Hersey 1998).

- Implementation: Responsibility is assigned to ensure the implementation of the work. Personnel responsible for carrying out the EMP processes are to be well trained and fully aware of work instructions pertaining to their specific tasks (Hersey 1998).
- Monitoring and Reporting: Regular monitoring is required to ensure tasks are being performed accordingly. A monitoring sheet is to be prepared for such purposes. Specific issues that must be measured for compliance purposes must be identified (for example, smoke emissions, water quality discharges) (Hersey 1998; Koomson, 2015).
- Review and Improvement: A scheduled review of the program must be done and appropriate steps taken to sustain improvements achieved (Hersey, 1998).

2.9.1 Waste Management Plan

Developing an efficient, environmentally safe and economical strategy for the management of medical waste must address certain fundamental elements (Curtis and Mak, 1991). Procedures adopted are healthcare facilities dependent based on the quantity and composition of medical waste generated, availability of equipment for the treatment of waste on-site, regulatory requirements and the costs involved in the appropriate handling and storage of waste (Canadian Standard Association, 1988). To be effective, a solid medical waste management plan must have as its first significant concern the organizations compliance with the laws and regulations governing solid medical waste management. Furthermore, its focus should be on the attaining such benefits as:

- reducing the impact on the environment through waste minimization, proper segregation of waste and reducing the risks of contamination;

- cost-effective solid waste management and minimization processes and implementation of outlined plan in a technically practical way (Battini *et al.*, 2013).

2.10 Classification of Healthcare Institutions in Ghana

Categorizing health facilities helps in planning and putting in place appropriate management measures for the collection, storage, treatment and disposal of SMW at all levels. Classification of healthcare facilities is done on the basis of number of admissions per day, OPD attendance, average bed capacity of the facility and the level of diagnosis done at the medical facility. In a broader view, medical facilities in Ghana can be categorized into public sector medical establishments, private healthcare facilities, quasi-governmental and the traditional healthcare facilities (MLGRD and EPA, 2002).

Public sector establishments are built and managed by the government in various regions, metropolis, municipalities and district assemblies to ensure easy accessibility to healthcare in the country. These healthcare facilities are classified into: Teaching/Specialist Hospitals; Regional Hospitals; District Hospitals; Healthcare centres/clinics and Community clinics/ Maternity homes/Child healthcare centres (MLGRD and EPA, 2002).Teaching/Specialist Hospitals are made up of various departments which provide specialized healthcare services such as ear, nose and throat specialists, heart surgery and radiotherapy. Based on the bed capacity, OPD attendance and daily admissions, district hospital can be classified subsequently into levels of three namely A, B and C [Table 2.5].

Table 2.5 Categories of District Hospitals in Ghana.

Hospital indicators (Averages)	**Levels**		
	A	**B**	**C**
Bed capacity	30	50	70+
OPD attendance per day	1-30	31-90	91+

Admissions per day	1-6	7-12	13+

Source: MLGRD and EPA (2002)

Every regional capital in Ghana has a health facility mostly referred to as the Regional Hospital. They usually have a bed capacity of about 300. Psychiatric hospitals fall under this class (MLGRD and EPA, 2002). Community Clinics and Health Centres are purposely for the provision of primary and preventive healthcare.

2.11 Training and Education on Solid Medical Waste Management

Training of both healthcare and waste management staff in standard waste management practices is essential (Indies, 2004) for capacity building of all staff in the proper management of waste generated in the health facility as well as to the reduction of health and occupational risks (WHO, 2014). According to WHO (2014) training programmes for healthcare personal and waste handling staff aims at: nurturing the responsibility of SMW management among staff; ensuring staff are well informed on the best waste management practices and technologies; ensuring staff can apply knowledge gained in daily activities; providing knowledge on environmental, health and safety with regards to SMW management and preventing hazards relating to exposure to SMW.

Sensitization, when properly done, makes healthcare personnel and waste management staff better proponents in ensuring best practices are enforced. Training must be held separately for all these categories of healthcare staff (WHO, 2014). Others have shown (Indies, 2004; Mensah, 2012; WHO, 2014) that educational programmes for the training should state clearly the responsibilities of each personnel. Training content should be reviewed regularly and must include information or knowledge in: basic procedures in waste handling; update on knowledge through in-service training; SMW management policy; roles and responsibilities of healthcare workers and waste handlers and risks associated with SMW management.

WHO (2014) states that the responsibility for training all personnel lies on the Environmental Officer (EO) or waste management officer in association with the officer in charge of infection control. Records on every training held should be kept. Training information for handlers of medical waste should entail the hazards of handling waste, processes for cleaning spills and accidents and guidelines on the proper or appropriate use of PPE (WHO, 2014).

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The UH-KNUST is situated in the Ashanti Regional capital Kumasi. Established in 1952, the facility served as a dressing station but now a fully recognized hospital due to developments in infrastructure and administration. It is classified as a Level C District Hospital with an average out-patients attendance of 325 patients daily and inpatient admission of 12 daily. The number of patients attended to monthly varies from one ward/unit to another [Table 3.1].

Table 3.1: Monthly patients' attendance to the UH-KNUST.

Ward/Unit	**Month of attendance**			
	November	December	January	February
General OPD	5984	5142	6886	4983
Female	92	98	102	64
Children's	94	83	97	57
Male	70	77	99	42
Theatre	51	59	62	48
Maternity	72	80	71	46
VIP	21	17	20	16
Eye	476	355	406	477
Dental	378	356	373	313
PHU	1270	1259	1464	1831
Laboratory	111	108	126	99

The location of the Hospital makes it easily accessible to people in and outside Kumasi providing healthcare services to students and staff of the university as well as over thirty (30) communities which includes; Boadi, Ejisu, Ayeduase, Kotei, Ayigya, Emena, Fumesua, Oduom, Ejisu, Kwaamo, Anwomaso, and Bomso. The hospital has five wards, a Theatre, Dental and Eye clinics, the General OPD and the Public Health Unit (PHU).

3.2 Data Collection

Data was obtained from both primary (questionnaires, personal observations, and interviews) and secondary (review of literature) sources. Samples of SMW from the wards/units were collected for characterisation and quantification. Field observations were used in collecting the qualitative data.

3.2.1. Questionnaire Administration

Questionnaires (Appendix D) were administered to waste handlers and healthcare personnel such as laboratory technicians, administrators, doctors and nurses. The questionnaires were structured based on the objectives of the study. This was done to ascertain respondents' knowledge on appropriate waste management practices and the associated limitations. Two sets of structured questionnaires containing both open and closed ended questions were designed for the research. In all, a total of sixty (60) questionnaires were administered; the first set was administered to all twenty seven waste handlers and the second set administered to thirty-three (33) healthcare personnel.

3.2.2 Interviews

Personal interviews with healthcare personnel and all waste handlers were conducted. Respondents' knowledge on SMW management and its related health, environmental and occupational risks were ascertained. This aided in the identification of the existing management practices for SMW generated in the Hospital and any limitations associated with its effective management.

3.2.3 Personal Observation

Personal observations were used to gather information on existing SMW management practices at the Hospital. Potential ground problems were identified first hand through these personal observations. Composition of each waste type was determined by personal observation and identification. Photographs of some existing practices were taken and documented.

3.3 Solid Medical Waste Segregation

Segregation of waste was done throughout the study period to determine the composition of waste generated and quantify waste in their appropriate categories. SMW from the all wards/units which were not righty sorted were separated by the researcher into sharps, infectious, pharmaceutical, heavy metal and non-hazardous wastes. Properly segregated waste from the wards/units were also analysed to determine their composition. PPE such as gloves, nose masks, laboratory coat and boots were worn by the investigator during the collection and sorting of wastes. Hand fork was used in sorting the wastes. Cardboard boxes, plastic bins and plastic bags with known empty weights were used for the weighing of wastes. A digital weighing scale of capacity 120 kg was used.

3.4. Quantification of Waste Generated

SMW generated in all the wards/units of the Hospital during the period of the study were quantified. The waste collection was done during the Hospital's waste collection time between the hours of 5 am to 7 am for the morning shift and 4 pm to 6 pm for the evening shift, every day of the weeks within the study period that span from November 2015 to February 2016. SMW were weighed in safety boxes, cardboard boxes, plastic buckets and bowls and polythene bags. The weights of the polythene bags (W_p), safety boxes (W_s), plastic buckets (W_b) and cardboard boxes (W_c) were checked and recorded prior to the introduction of waste after which the total weight (W_t) was determined.

The weight of the SMW was obtained from the formula:

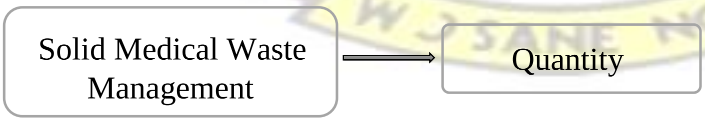
$$\text{Weight of SMW} = W_t - (W_p + W_s + W_b + W_c)$$

3.5 Data Analysis

Data obtained from the administered questionnaires and quantification of SMW were statistically evaluated to obtain useful information. The quantitative data was analysed based on the sources of waste generation, categories generated and the weekly and monthly generation rates. The total value of daily weights (morning and evening recordings) were used. Microsoft excel software was used to organize and analyse the data. Analysis of Variance (ANOVA) was used to determine the overall variations between means of waste generated in all wards/units. The variations between total wastes generated weekly (16 weeks in all) by the entire hospital regardless of source of generation were also determined. Single factor analysis was done with a probability level of 99 % giving an error of 1 % which is represented as alpha = 0.01 in ANOVA. Probability values (p value) $<$ the alpha (0.01) shows variations in quantities of waste generated, therefore significantly different. P value $\geq$ 0.01 shows random differences in quantities of waste generated, therefore no significant differences.

3.6 Conceptual Framework

The conceptual framework of the study focused on three important issues, namely: quantification of the waste generated, composition of wastes and the proper management of SMW [Figure 3.1].



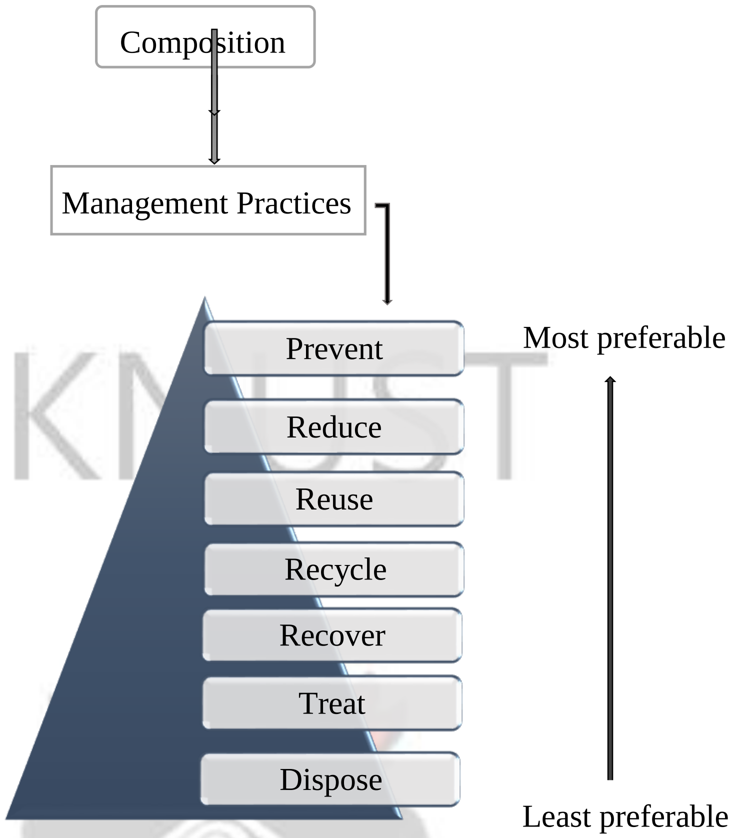


Figure 3.1: The Conceptual Framework (Battini *et al.*, 2013; WHO, 2014).

This concept gives a complete idea of the entire waste stream of the Hospital, the management and handling of waste by personnel and helps to identify any shortfalls in the management (Battini *et al.*, 2013). The waste management hierarchy serves as a guide in choosing the most desirable or appropriate methods that are environmentally sound, economically viable and socially acceptable in managing SMW (WHO, 2014).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Classification and Composition of Solid Medical Waste

Different categories of SMW generated during the study was grouped according to MLGRD and EPA (2002) classification of SMW. The classes were infectious, sharp, pathological, pharmaceutical, heavy metal and general wastes. The infectious, sharp, pathological, pharmaceutical and heavy metal wastes are further categorised as hazardous and the general waste as non-hazardous [Table 4.1].

Table 4.1: Classification and composition of SMW generated at UH-KNUST.

Waste Category		Composition
Nonhazardous	General	Waste generated from landscaping, general sweepings, food waste, plastic bags, plastic bottles, papers, cans, textiles, wood and cardboard boxes.
Hazardous	Sharps	Blades, hypodermic needles with syringes, intravenous needles and broken glass bottles.
	Infectious	Tubing, blood-soaked gauzes, bandages and beddings, cotton wool stained with blood and body fluids, sanitary pads, disposal cups, diapers, swabs, surgical gloves, nose masks, aprons, gowns and towels soiled with blood and other body fluids and blood stained dressings.
	Pathological	Placentas and fibroids.
	Pharmaceutical	Expired and unused drugs.
	Heavy metal	Mercury contained in thermometer and fluorescent light tubes.

Several researchers (Alhumoud and Alhumoud, 2007; Sawalem *et al.*, 2009; El-Salam, 2010; Mensah, 2012; Abor, 2013; Yawson, 2014) have also grouped SMW according to the WHO's classification and composition. In a study by Bdour *et al*. (2007), Nemathaga *et al.* (2008) and Mensah (2012) pathological waste was composed also of foetuses, amputated human body parts and waste from autopsy. No surgical cases involving the removal of foetuses was done within the period of study. Waste from autopsy was also generated offsite as corpses were sent to the School of Medical

Sciences, KNUST where the mortuary is situated for academic purposes. Infectious, pharmaceutical, sharp, heavy metal and general wastes were found in all wards/units with the exception of the Administration. In the Administration only general and heavy metal wastes were generated while pathological waste was generated in the Maternity Ward and Theatre only.

4.2 Measurement of Solid Medical Waste Generated

4.2.1 Total SMW Generated

Total quantity of SMW generated in the 14 wards\units of the UH-KNUST from November 2015 to February 2016 ranged between 43.7 kg to 1329.6 kg [Appendix B (i)]. The highest quantity of 1329.6 kg was generated at the General OPD with the Eye clinic generating the least quantity of 43.4 kg. A monthly average of 2421.05 kg of SMW was generated in all 14 wards/units of the UH-KNUST during the study. Mensah (2012) reported an average monthly SMW generation of 127.27 kg at the SWGH. This value is significantly low compared to the SMW generation at UH-KNUST. The high SMW generation at the UH-KNUST can be attributed to the comparatively high average daily attendance (both in-patients and out-patients) of 337 patients as to 250 patients for the SWGH. Also, SWGH reported on 7 wards/units with this study reporting on 14 wards/units. The extra wards/units made up of Dental, Eye, PHU, Xray, Pharmacy, Administration, and The VIP ward may be responsible for generating the extra high SMW. UH-KNUST has five wards with higher bed capacity compared to the four wards at the SWGH. The General OPD generated the highest percentage of total waste of 13.7 % with the Children's ward following with 13.0 %, PHU 12.6 %, X-ray 0.7 % and the Eye clinic generating the least of 0.5 % [Appendix B (ii)]. Studies conducted by Nemathaga *et al.* (2008) in two hospitals in South Africa and that in

Ghana by Mensah (2012) showed that the Maternity wards generated the highest percentage of waste due to high patients attendance to the maternity.

Contrarily, results obtained from the UH-KNUST indicated that the OPD generated the highest quantity of total waste due to relatively high patient's attendance. The General OPD is made up of four different units: the resuscitation room, Injection and dressing room, voluntary counselling and testing unit (VCT) and the Accident and Emergency unit. SMW from the four units are collected together to represent the General OPD which cumulatively generate high quantities of waste. Services rendered, working hours/days and the number of patients attended to [Appendix C (i)] varied from one ward/unit to the other. This was evident in the quantities of waste generated from all sources [Figure 4.1].

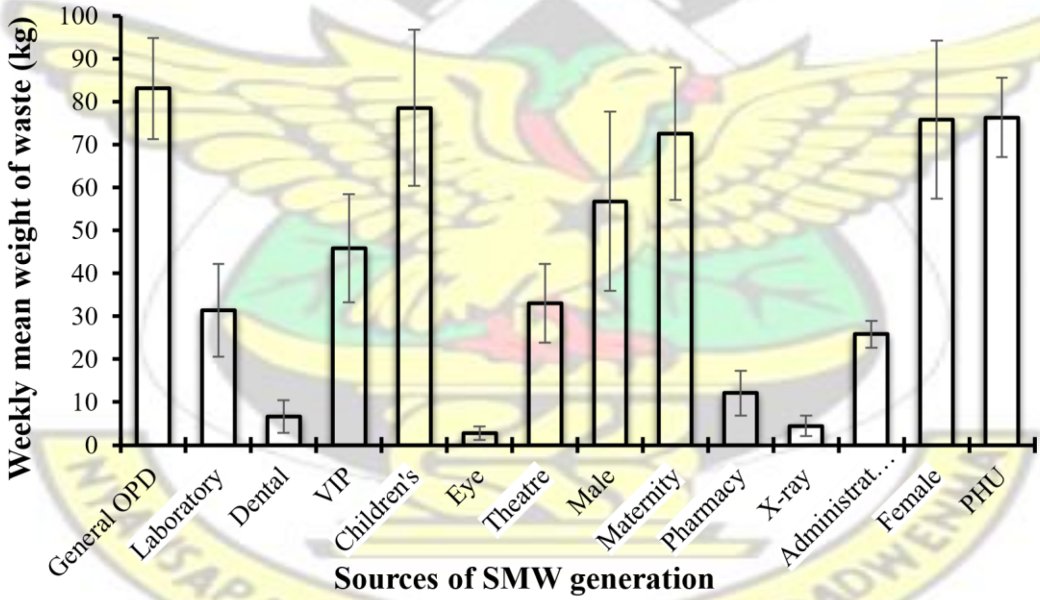


Figure 4.1: Weekly mean weight of total SMW generated in all wards/units.

This finding is consistent with Nemathaga *et al.* (2008) and Mensah (2012) who observed that the amount of waste generated in each ward is dependent on factors such as services rendered, size and number of patients. The weekly mean quantities of SMW generated in the wards/units were significantly different ($p < 0.01$) [Appendix A (i)].

Mean total SMW generated weekly by the entire UH-KNUST were not significantly different (p> 0.01) [Appendix A (ii)]. It may be deduced that the weekly weight of waste generated by the entire UH-KNUST does not vary because the services rendered weekly and number of patients attended to weekly does not vary significantly.

Of the total quantity, 9684.2 kg, of SMW generated, hazardous waste formed 44 % with non-hazardous waste forming 56 % [Appendix B (ii)], similar to reports by Birpınar *et al.* (2009) from a study in Turkey. However, the result is contrary to Battini *et al.* (2013) and WHO (2014) guidelines which states that hazardous waste forms between 15 % to 25 % and general waste between 75 % to 85 % of total SMW generated. The high quantity of hazardous waste generated can be attributed to the poor segregation, collection and transportation of SMW and that 12 out of 14 wards/units studied generates infectious waste which formed the highest quantity of hazardous waste generated. The collection of hazardous and non-hazardous wastes together in the same waste bin renders the entire waste as hazardous (Prüss *et al.*, 1999; WHO, 2014; Yawson, 2014). Overall percentage of non-hazardous waste generated was higher than hazardous waste which is consistent with reports by (Nemathaga *et al.*, 2008; Birpınar *et al.*, 2009; Sawalem *et al.*, 2009) because UH-KNUST offers high out-patient services.

Total waste generated in the month of January was relatively higher than that generated in the months of November, December and February [Figure 4.2] due to the relatively high number of patient's attendance to the various wards/units of the Hospital in January.

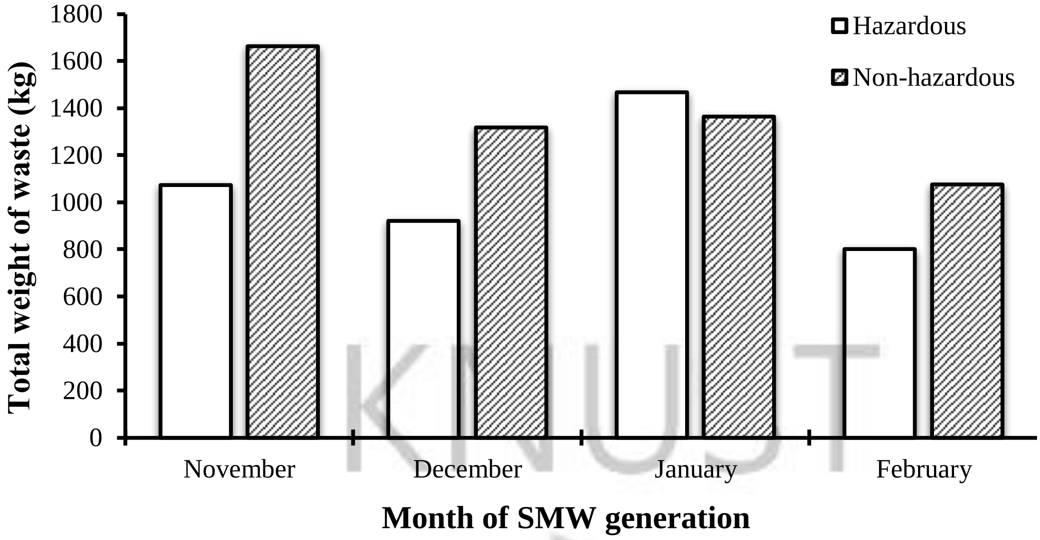


Figure 4.2: Weight of total SMW generated monthly.

The result is contrary to studies by Mensah (2012) in Ghana indicating that highest quantity of waste was generated in November due to high patients' attendance in that month. Non-hazardous waste generated in November, 1661.9 kg, was highest due to relatively high in-patient activities within the month. The highest quantity, 1467.2 kg, of hazardous waste was generated in January as a result of relatively high cases of infectious diseases, surgeries, accident and emergency cases and births handled within that month [Appendix B (iv)].

4.2.2 Non-hazardous Waste

Non-hazardous waste was generated in all 14 wards/units of the UH-KNUST. The General OPD generated the highest quantity of 935.4 kg with the Eye clinic generating the least quantity of 10.8 kg [Appendix B (i)]. The average quantities of non-hazardous waste generated were analysed to determine statistical differences in quantities of waste generated in the wards/units [Figure 4.3].

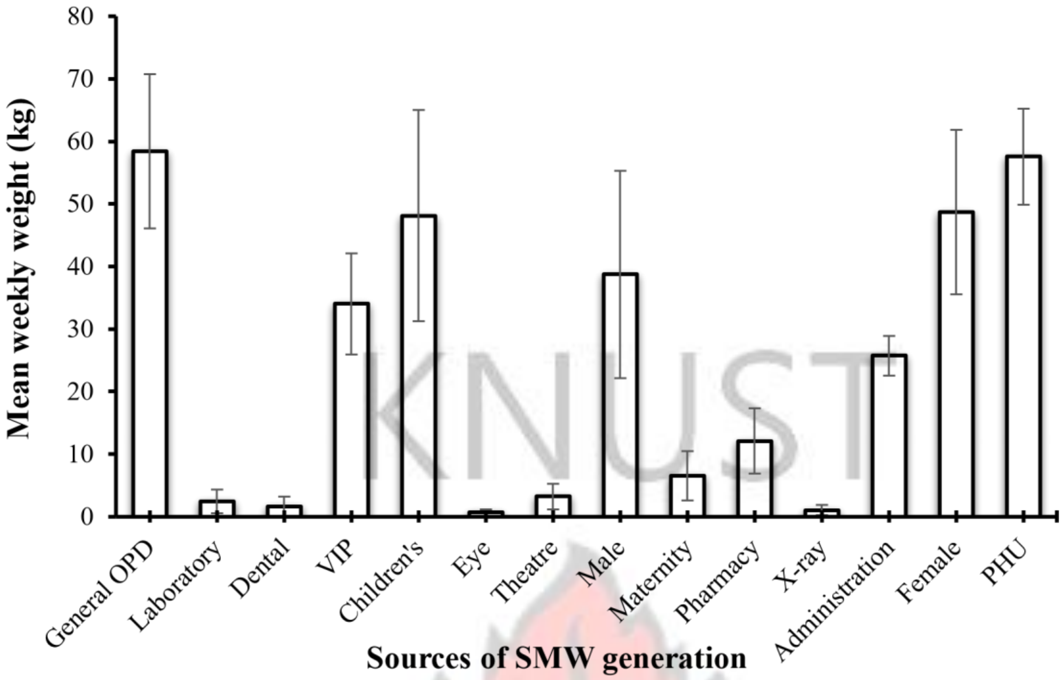


Figure 4.3: Weekly mean weight of non-hazardous waste generated in the wards/units.

ANOVA showed that the mean quantities of non-hazardous waste generated were significant ($p < 0.01$) [Appendix A (iii)]. Results also revealed that, the number of patients attended to, services rendered and the time patients spend in each ward/unit receiving medical attention differed. Services rendered at the General OPD and PHU, for instance, are on out-patients basis, receiving a lot of patients each day. The patients usually generate large quantities of non-hazardous waste mostly food remains, papers and plastics. The long hours spent receiving medical attention at these two units account for the high quantities of non-hazardous waste as some patients end up eating breakfast and lunch there. However, healthcare services rendered weekly by the UHKNUST rarely changed. This was confirmed by the statistical analysis of means of non-hazardous waste generated weekly which did not show any significant difference ($p > 0.01$) [Appendix (iv)]. Non-hazardous waste generation did not generally follow any regular trend [Figure 4.4].

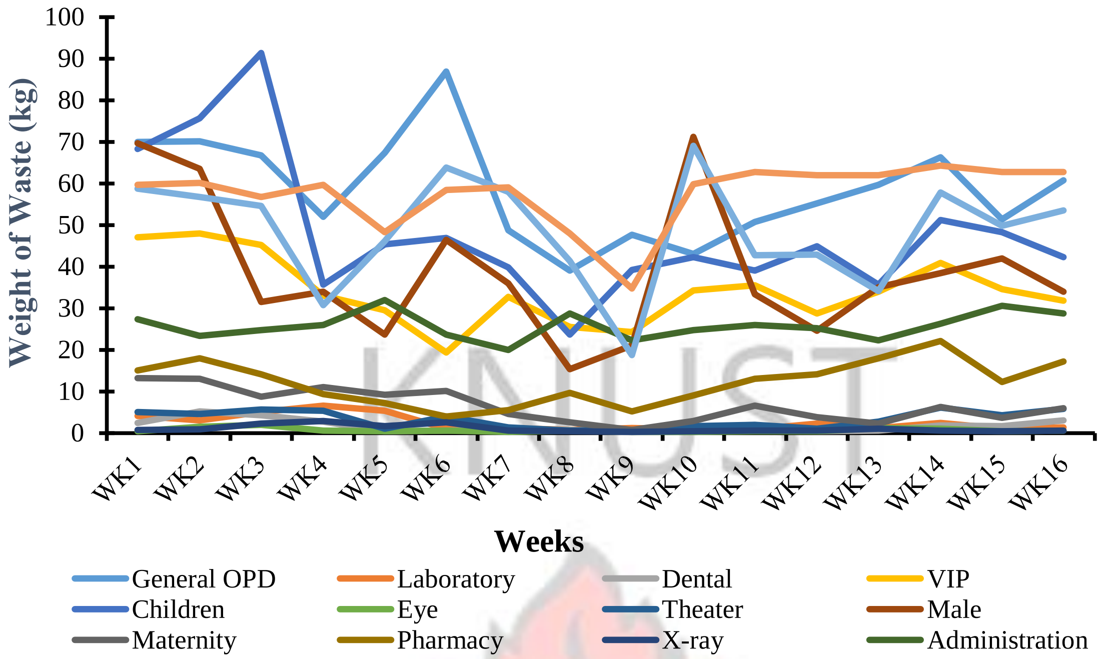


Figure 4.4: Trend in weekly non-hazardous waste generated in the wards/units.

The trend of non-hazardous waste generated rarely changed in the Administration, Maternity, Pharmacy, Laboratory, X-ray, Theatre, Dental and Eye Clinics. The General OPD, Children's and female wards experienced relatively high and low peaks in the amount of waste generated. The Children's Ward experienced a sharp decline from week 3 to week 4 because the number of patients dropped significantly (from 29 to 21 patients) [Appendix C (i)]. The Female Ward also experienced a reduction in waste generated from weeks 7 to 9 due to a decline in the number of inpatients (27 to 9) [Appendix C (i)]. Waste generated in the General OPD, Children's and Female wards declined in week 15 due to a decline in the number of patients. The Maternity, Laboratory, X-ray, Theatre and Dental Clinic had similar trends because activities in all these wards/units were observed to generate relatively low quantities of general waste as the services rendered were more related to the generation of infectious waste. The Male and female wards showed a sharp rise in non-hazardous waste generated in week 10 due to the relative increase in the number of patients within that week.

4.2.3 Hazardous Waste

4.2.3.1 Infectious Waste Generated

Generated infectious waste at the wards/units ranged from 32.9 kg to 861.9 kg. The Maternity Ward generated the highest quantity of 861.9 kg of infectious waste as a result of daily delivery of babies of which each generates large quantities of beddings, clothing, gauzes and tubing stained with blood and other body fluids. The Eye Clinic generated the least quantity of 32.9 kg [Appendix B (i)] and may be attributed to limited working hours, ranging from 8 am to 2 pm daily except weekends and public holidays. Activities that generate infectious waste, patient attendance, services rendered and the working hours of each ward/unit influenced the quantity of waste generated. These factors determined the differences in quantities of infectious waste generated [Figure 4.5].

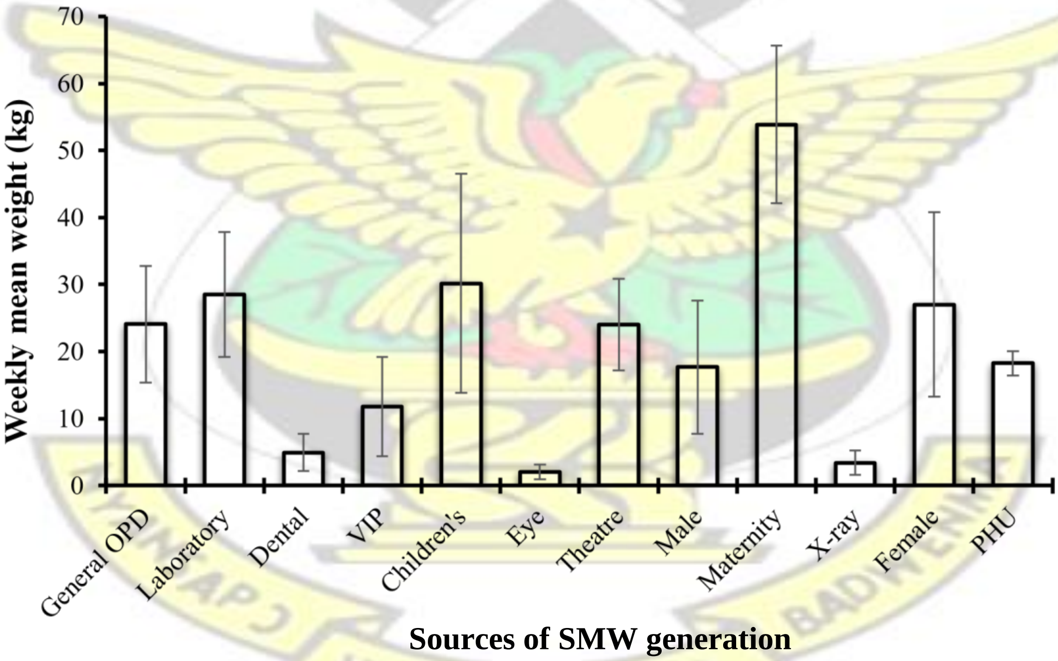


Figure 4.5: Weekly mean weight of infectious waste generated in the wards/units.

ANOVA showed that mean quantities of infectious waste generated in the wards/units were significantly different ($p < 0.01$) [Appendix A (v)]. Differences in means of infectious waste generated weekly by entire Hospital were not significantly different

($p > 0.01$) [Appendix A (vi)]. Weekly generation rates of infectious waste did not follow any general trend [Figure 4.6].

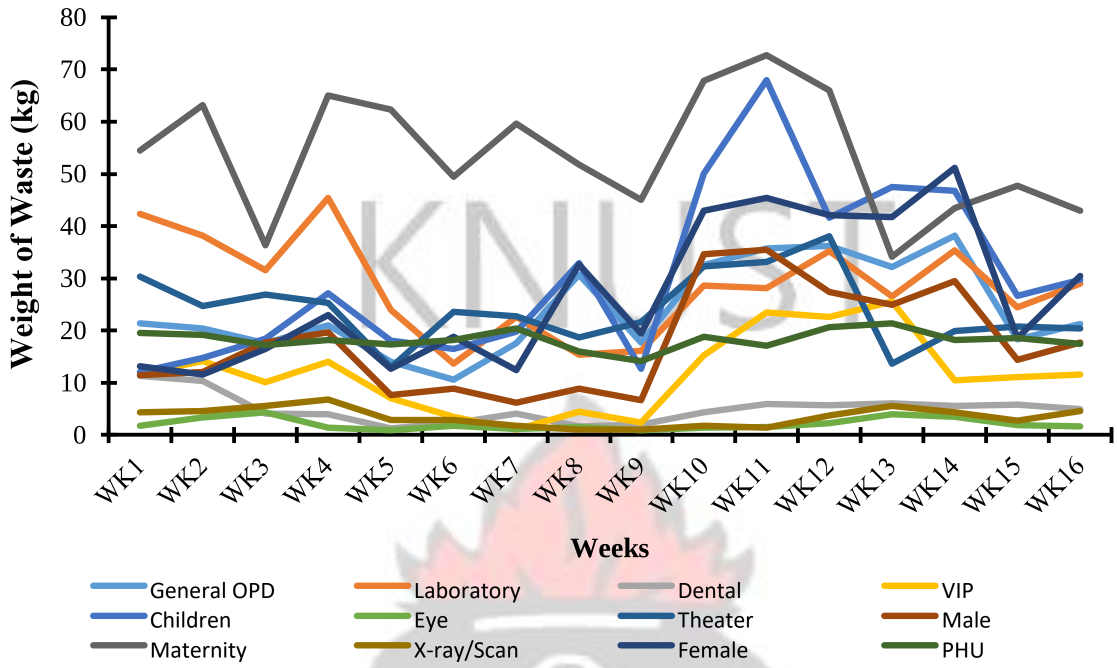


Figure 4.6: Trend in weekly infectious waste generated in the wards/units.

The X-ray, Dental and Eye clinics showed similar trends in their infectious waste generation. This may be due to similarities in working days and hours and the type of services rendered. The mean quantities of infectious waste generated weekly at the PHU rarely changed because the number of patients attended to weekly rarely changed. The General OPD, Female and children's wards showed similarities for the first 9 weeks until the 10th week where Children's Ward had a sharp rise in the quantity of waste generated. The number of in-patients in the Children's Ward between weeks 9 and 13 were relatively higher than the other weeks (January attendance), therefore the sharp rise in waste generated. The trend in generation rate for the Maternity Ward was mostly different from the other wards. Waste generated in the Maternity Ward showed a sharp decline in weeks 3 and 13 because the number of deliveries were relatively low within these weeks of their respective months [Appendix C (i)]. All the wards/units showed a rise in week 4 and a decline in week 9 [Appendix C (i)]. The result revealed that the Hospital, generally, attended to relatively high number of patients in the fourth week than in the ninth week.

4.2.3.2 Pathological Waste Generated

A total of 274.4 kg pathological waste was generated with the Theatre generating the least of 84.8 kg and the Maternity Ward generating the highest of 189.6 kg [Appendix

B (i)]. The quantities of pathological waste generated in both units varied weekly [Figure 4.7].

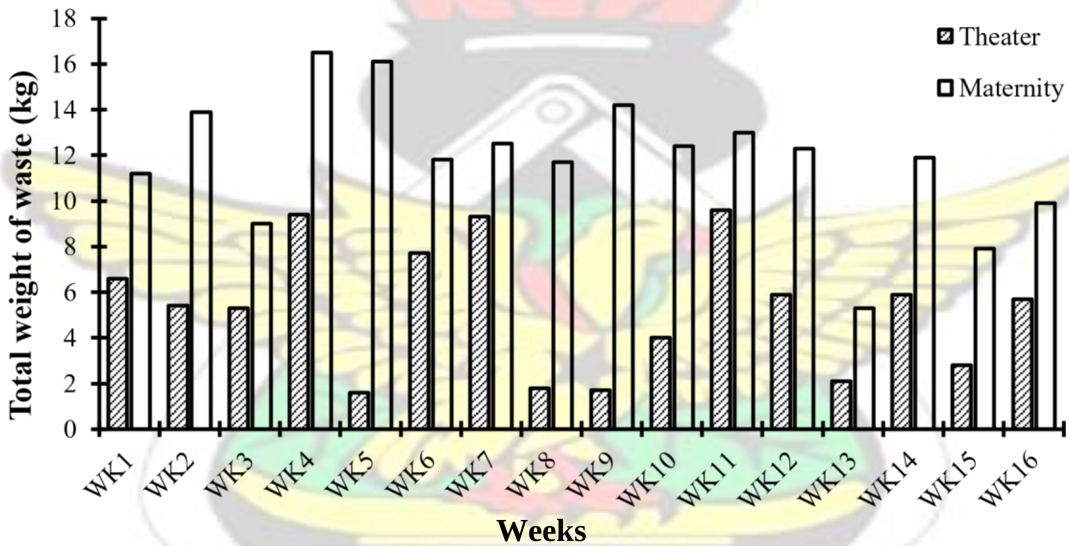


Figure 4.7: Pathological waste generated weekly in the Theatre and Maternity Ward.

Results show that attendance in the Maternity was relatively higher than in the Theatre. Also, an average weight of 0.8 kg of pathological waste was generated daily in the Maternity Ward due to the daily delivery of babies. However, the Theatre had scheduled days for surgery as Wednesdays and Fridays unless there was an emergency. Not all cases attended to in the Theatre generated pathological waste. This finding is consistent with studies conducted in Ghana by Mensah (2012) who noted an average delivery of 6 babies a day of which each generates between 0.5 kg and 1 kg of placenta.

Statistical analysis showed significant differences in mean quantities of pathological waste generated ($p < 0.01$) [Appendix A (vii)]. From the results, the daily pathological waste generated, type of cases, the number of working days and patients attended to in the Theatre and Maternity Ward were different. This influenced the differences in mean quantities of waste generated in the two units. However, differences in means of pathological waste generated weekly by entire Hospital were not significantly different ($p > 0.01$) [Appendix A (viii)]. This may be due to reasons that the weekly activities that generated pathological waste in the Hospital randomly changed.

4.2.3.3 Sharp Waste Generated

Total weight of sharp waste generated was 53.1 kg. Differences in services rendered at the wards/ units and the number of patients attended to resulted in the differences in the quantity of sharp waste generated in each ward/unit. ANOVA showed that mean quantities of sharp waste generated by the wards/units and that generated weekly by the entire Hospital were not significant ($p > 0.01$) [Appendix A (ix)] and ($p > 0.01$) [Appendix (x)] respectively. The General OPD generated the highest quantity of sharp waste and the VIP ward generated the least quantity [Figure 4.8].

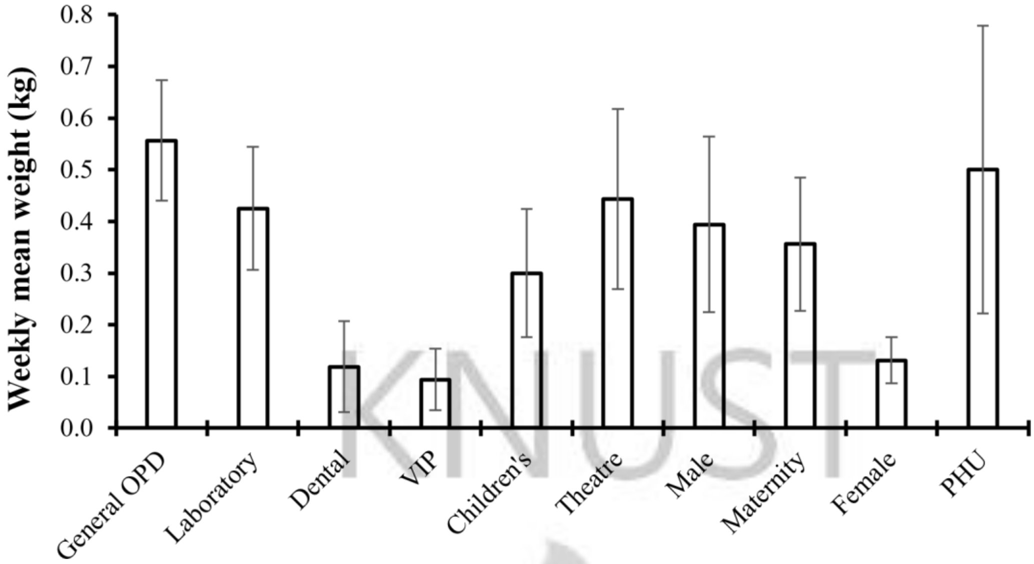


Figure 4.8: Mean sharp waste generated in the wards/units.

The activities at the OPD and PHU such as immunization, administering injections and dressing of wounds generate high quantities of sharp waste. Services rendered in the Laboratory generate high quantities of needles daily. The Dental, Female, Children's and VIP Wards only use needles when patients require injections and infusion. However, the average quantities generated did not differ significantly ($p > 0.01$).

4.2.3.4 Other Hazardous Wastes Generated

A tenth of a kilogram of pharmaceutical waste and 1.5 kg of heavy metal waste was generated [Appendix B (i)]. Pharmaceutical waste was the least (0.1 kg) hazardous waste generated and was consistent with studies by Mensah (2012). This may be explained by the practice that, in-patients are strictly monitored by nurses to take their medication and out-patients also take their medications home. Good inventory strategy consistent with WHO guidelines was also practiced. The quantity of infectious waste generated was higher than pathological waste [Appendix B (iii)] consistent with research by Patil and Shekdar (2001). This is because infectious waste is generated in all units of the Hospital except the Administration while pathological waste is generated in the Theatre and Maternity Ward only. The result is, however, different from studies by Nemathaga *et al.* (2008) where the quantity of pathological waste generated during the research was higher than infectious waste due to high maternity cases received. Nevertheless, infectious and pathological wastes formed the majority of hazardous waste generated [Appendix B (iii)] consistent with studies in Ghana by Asante *et al.* (2014).

4.3 Assessment of Hospital Solid Waste Management Practices

4.3.1 Segregation, Colour Coding and Labelling of SMW

Segregation of SMW was practiced at source specifically in the Dental Clinic, Laboratory and Theatre. However, it was not appropriately done in most wards/units according to guidelines recommended by MLGRD and EPA (2002) and WHO (2014) which states that appropriate segregation of waste must be done at source and it is the primary responsibility of the one generating the waste. Figure 4.9 shows infectious and general wastes from the Dental Clinic which have been properly sorted into appropriate coloured plastic bags at source.

Figure 4.9: Properly sorted waste from the Dental Clinic.

The UH-KNUST had adopted containers, plastic bags and colours for segregation of waste [Table 4.2].

Table 4.2: Containers and colours used in sorting SMW at the UH-KNUST

Waste type	Container and colour adopted by Hospital	Container and colour used by Hospital	Recommended colour/container (WHO, 2014)
General	Plastic/metal bin lined with black plastic bag	Plastic/metal bin lined with black, yellow or brown plastic bag	Black plastic bag or container
Sharps	Safety boxes	White and brown cardboard safety boxes	Yellow punctureproof container
Infectious	Plastic/metal bin lined with yellow plastic bag	Plastic/metal bin lined with yellow, black or brown plastic bag	Yellow leak-proof container
Pathological	Plastic buckets/bowls	Blue plastic bucket/bowl	Yellow leak-proof container
Pharmaceutical	Plastic/metal bin lined with plastic bag	Plastic/metal bin lined with yellow or black plastic bag	Brown plastic bag or container
Heavy metal	No colour assigned	Plastic/metal bin lined with plastic bag	Brown container

UH-KNUST did not strictly comply with its own adoptions made. Hazardous and nonhazardous wastes were mixed in the same plastic bag at waste generating points [Figure 4.10].

Figure 4.10: Non-hazardous and hazardous wastes disposed of together at source.
Proper labelling and colour-coding to waste bins aids effective segregation. The

Hospital's system of segregation has not been effective since waste bins themselves were not colour coded and labelled with the specific waste types. Waste bins for the collection of hazardous wastes did not bear the biohazard symbol contrary to WHO (2014) guidelines and reports in Prüss *et al*. (1999) and Mensah (2012) which states that such bins should be labelled with the biohazard sign. Instead, waste bins were only lined with coloured plastic bags, an observation consistent with studies by Nemathaga *et al.* (2008). Efficiency in segregation at source can be achieved through colour coding of both containers (bins) and plastic bags (Prüss *et al.*, 1999; WHO, 2014).

Studies in Ghana (Mensah, 2012; Asante *et al.*, 2014; Yawson, 2014) reported poor segregation and colour coding and no labelling of medical waste. Poor segregation of specific waste types into coloured plastic bags was an issue of medical waste management in hospitals studied (Abdulla *et al.*, 2008; Yong *et al.*, 2009; El-Salam, 2010). Secondly, coloured plastic bags were used inappropriately [Figure 4.11] as was reported by (Udofia *et al.*, 2015) that segregation of SMW in several countries in Africa have not been effective since colour-coded bags were used inappropriately.

Figure.4.11: Infectious waste from Theatre collected in black plastic bag.

Waste bins meant for the collection of hazardous and non-hazardous waste in the OPD, waiting areas, corridors, nurses' station, patients rooms and PHU had the same colour lining (yellow or brown). Waste bins in the injection room, VCT and accident and emergency room had black plastic bags lined in them for the collection of infectious waste. Results of this study revealed the lack of a WMD and policy to ensure appropriate segregation by all workers. There is also the lack of training and sensitization of healthcare personnel, waste handlers as well as patients on proper waste segregation and the use of colour coding in the management of SMW. However, to a larger extent, sharps were sorted into the safety boxes as was also reported by Mensah (2012) and Udofia *et al*. (2015) with cases of needles and broken glasses mixed with general or infectious waste. Safety boxes for sharp waste, on the other hand, were very distinct and well-labelled with biohazard symbol according to (WHO, 2014) guidelines but not puncture-proof [Figure 4.12].

Figure 4.12: Safety boxes labelled with biohazard symbol

4.3.2 Waste Collection

SMW from all wards/units of the Hospital were collected in plastic or metal bins lined with plastic bags. These bins were with covering, leak-proof and puncture resistant. This is consistent with regulations by WHO Immunizaton (2005) which lists plastic or metal waste bins lined with plastic bags, leak-proof and with covering as appropriate for collection of non-sharp wastes. Figure 4.13 gives an illustration of samples of waste bins used for the collection of SMW at the UH-KNUST.

(a) (b) (c)

Figure 4.13: Sample of waste bins for the collection of SMW at the (a), (b) UH-KNUST entrance and (c) at the General OPD corridor and wards.

Sharp waste was collected in safety boxes. Each waste bag was collected and replaced twice in a day during the waste collection time of the Hospital between 5 am – 7 am in the morning and 4 pm to 6 pm in the evening. The waste collection times were strictly adhered to by waste handlers. Different sets of waste handlers worked on shift basis. Studies by Mensah (2012) and Udofia *et al*. (2015) show that collection of hospital waste was done daily and on time as was the practise at the UH-KNUST. Waste bins were emptied whether they were full or not to prevent bins from overflowing with waste, producing foul smell and the breed of insects which can spread infections. Recommendations by WHO (2014) that safety boxes should be puncture-resistant and collected when two-thirds full were not strictly adhered to by the UH-KNUST. This often resulted in needle stick injuries and infections. Safety boxes were collected whenever it was full with observed cases of some boxes overflowing their volume and needles sticking out of the boxes [Figure 4.14 (a) and (b)].

(a) (b)

Figure 4.14: (a) Safety boxes overly full with sharp waste and (b) needles sticking out of safety boxes.

Non-hazardous and hazardous wastes were sometimes mixed in the same plastic bags during collection or collected at the same time by waste handlers for reasons that bins might not be full so emptying one into the other was convenient. This result is consistent with reports by Coker *et al.* (2009), Sawalem *et al*. (2009) and Udofia *et al.* (2015) indicating that wastes were mixed during collection in facilities where segregation was even done at source. The findings are contrary to guidelines by WHO (2014) which states that non-hazardous and hazardous wastes should not be collected into the same container or bag or within the same period to avoid contamination.

The result may be attributed to lack of training on appropriate waste handling and collection procedures. An observation was made that, the waste bins were not cleaned and disinfected regularly thereby increasing the risk of waste handlers as well as patients to infections and diseases. This situation may be due to poor monitoring and that no waste handler had been assigned to clean so no one felt responsible.

4.3.3 Transportation of Waste

On-site, waste from all sections of the Hospital were transported in the plastic bags in which they were collected. In most cases, SMW from the wards/units were transported to the disposal area by hand [Figure 4.15].

Figure 4.15: On-site transportation of SMW by hand.

Reports by Coker *et al*. (2009) and Udofia *et al*. (2015) indicated that SMW were manually lifted of waste bins by waste handlers as observed during the study. This result is contrary to regulations by WHO stating that SMW should be transported in wheeled trolleys, bins or carts. SMW transported by hand were sometimes quiet voluminous causing the plastic bags to tear and make contact with hospital floors thereby contaminating surfaces. Only wastes from the General OPD and PHU were transported in plastic covered waste bins with wheels consistent with studies conducted in Ghana by (Abor and Bouwer, 2008). This was done in adherence to regulations by (MLGRD and EPA, 2002).

An observation was made that both hazardous and non-hazardous wastes were put together, one plastic bag in the other, when transporting waste as was also observed by (El-Salam, 2010) during a study in Egypt, contrary to guidelines by MLGRD and EPA (2002). This increases the probability of waste mixing up during transportation increasing the risk of contamination of non-hazardous waste thereby rendering the entire waste hazardous (WHO, 2011). Issues identified with the present means of transportation were that the plastic bags used for the transportation of SMW have low resistance to tear, not puncture proof and do not provide any protection against leakage [Figure 4.16].

Figure 4.16: Fragile nature of plastic bags used in transporting SMW.

Waste handlers were at a risk of needle-stick injuries as these bags were not puncture resistant causing needles added to infectious and general wastes to stick out. Waste handlers wore surgical gloves or none at all during the transportation of SMW. This exposes the waste handlers to infections as they tear off easily. Studies in Ghana by Mensah (2012) and Yawson (2014) revealed that waste handlers did not comply with regulations by (MLGRD and EPA, 2002) on the use of appropriate PPE during waste transportation as was the practise of waste handlers at the UH-KNUST.

4.3.4 Treatment of SMW

Incineration was the only treatment method available for sharp waste, specifically needles and blades. A maximum of nine and minimum of seven boxes of sharp waste with unknown quantity were burnt at a time. As observed by Abdulla *et al.* (2008) and WHO (2014) many hospitals employed the use of incinerators in treating sharp waste. LPG was used to produce energy for the combustion process. The incinerator was without an air pollution control device [Figure 4.17] contrary to guidelines by MLGRD and EPA (2002) and WHO (2014) stating that incinerators should be fitted with air pollution control equipment.

Figure 4.17: Incinerator for the treatment of sharp waste.

Smoke from the incineration process escapes through the vent into the atmosphere. Pollutants generated, therefore, cannot be measured and controlled to reduce its effects. There was no set day or time for incineration; it was done when necessary. Infectious, pathological, pharmaceutical and heavy metal wastes were not treated onsite before final disposal. The appropriate treatment according to (MLGRD and EPA, 2002) regulations were not met. Untreated hazardous wastes reduces health and environmental quality through the spread of infectious diseases and pollution of environmental resources. Before final disposal, decontamination of hazardous medical waste should be done (Alhumoud and Alhumoud, 2007). This reduces the volume and weight of waste and any risks of causing infection (Prüss *et al*., 1999, Abor and Bouwer, 2008) and an essential step in SMW management to ensure environmental and health quality which should not be disregarded (WHO, 2014). Practise identified at the UH-KNUST was contrary. Results are contrary to reports by Akter (2000), Alhumoud and Alhumoud (2007) and Abor (2013) which states that several countries worldwide use technologies such as incineration, autoclaving and microwave disinfection to treat hazardous waste of which only incineration was done for sharps at the UH-KNUST.

4.3.5 Storage and Disposal of SMW

The UH-KNUST lacked appropriate facilities for the storage and on-site disposal of SMW. Two available skips were used for the storage and disposal of hazardous and non-hazardous SMW which were sometimes observed overflowing with SMW [Figure 4.18].

Figure 4.18: (a) Skip containers for SMW storage and disposal and (b) skip containers overflowing with SMW at the UH-KNUST.

Specific waste types are to be stored and disposed of separately according to guidelines by WHO but practices identified for hazardous and non-hazardous wastes were contrary. These skips were open, without any covering, exposing the wastes to all weather conditions. Scavenging animals also had unrestricted access to the waste and could transmit pathogens and spread hazardous waste materials. Studies by Bdour *et al*. (2007), Hassan *et al.* (2008) and El-Salam (2010) have shown that hospitals in other countries did not follow WHO regulations on the proper storage and on-site disposal of SMW. Offensive smells were scented on several occasions. Poor storage of waste generates odour, breeds insects and rodents which spread diseases thereby affecting health (Pickford, 1977). Regulations by Ghana's MLGRD and EPA (2002) and WHO

(2014) indicates that containers or bins for storage of SMW must be in roofed areas where waste is protected from water, rainfall, wind and scavenging animals, contrary to practices identified. Ideally, waste may be stored at 200 ^{o}C for 24 h or between -70 ^{o}C to -130 ^{o}C for 72 h (El-Salam, 2010). Only sharp waste were stored in covered plastic waste bins temporarily at the incineration area before the set time for combustion. It was, however, inappropriately done as the bins were in the open, exposed to all climatic conditions and at most times too full to even close [Figure 4.19].

Figure 4.19: Sharp waste stored in plastic waste bins in the incineration area.

Incineration ash or soot [Figure 4.20], residue from the combustion process containing burnt needles and blades were collected into a cardboard box, tied in a plastic bag and co-disposed with SMW in the skip containers.

Figure 4.20: Residue (ash) from incineration containing burnt needles and blades.

This practise is consistent with guidelines by Ghana's (MLGRD and EPA, 2002) which states that ash produced from the incineration process should be landfilled. Heavy metal waste, by (WHO, 2014) guidelines, must be sent back to the original suppliers for disposal or disposed in specially designed disposal site for hazardous industrial waste. However, these wastes were co-disposed with other SMW at a municipal landfill. A dug-out pit, unlined or not engineered, was available for the disposal of pathological waste behind the maternity ward. Open air burning was employed for the disposal of non-hazardous waste such as fallen leaves and branches, cardboard boxes, papers and plastic bags [Figure 4.21].

Figure 4.21: (a) Un-engineered pit for the disposal of pathological waste and (b) open air burning for the disposal of some non-hazardous waste.

Detergents were added to the pathological waste to remove the stench emanating from the pit. Research has shown that, pathological waste was disposed in unlined pits and acid digesters added for easy decomposition (Nkhuwa *et al.*, 2008; WHO, 2014; Udofia *et al.*, 2015). The results suggest that on-site storage and disposal methods for hazardous and non-hazardous wastes at the UH-KNUST do not meet guidelines set by WHO. The absence of a waste management department and policy and unavailability of resources to ensure specific waste types are disposed appropriately might have resulted in the lapses identified.

4.4 Training of Waste Handlers

Monthly meetings were organized by the Environmental Officer for waste handlers where they were advised on the appropriate use of PPE. Their roles as waste managers and appropriate measures to take in order to avoid risks of injury and contamination were also pointed out. Waste handlers were provided with sanitizers and disinfectants for the month. Findings revealed that some form of training was done but not according to guidelines by Prüss *et al.* (1999) and WHO (2014). Mensah (2012) and Yawson (2014) reported that waste handlers were not given any training in hospitals studied in Ghana.

4.5 Usage of Personal Protective Equipment (PPE)

Waste handlers were observed wearing the following PPE: gloves, boots, nose masks and protective clothing during the period of study. The number and percentage of waste handlers observed wearing each type of PPE is shown in Table 4.3.

Table 4.3: The use of PPE by waste handlers.

	Yes		No	
Type of PPE	**Number**	**%**	**Number**	**%**
Gloves	26	96	1	4
Nose mask	5	19	22	81
Boots	9	33	18	67
Protective clothing	27	100	0	0

However, only 15 % were observed wearing complete set of appropriate PPE. Majority (85 %) of waste handlers wore incomplete and inappropriate set of PPE due to reasons that it was uncomfortable to wear. This practice is contrary to regulations by (MLGRD and EPA, 2002) and (WHO, 2014) on the strict use of all PPE to ensure protection against infections and diseases. They were observed wearing surgical gloves and inappropriate footwear instead of the appropriate hard gloves and boots given them by the Hospital [Figure 4.22 (a) and (b)].

Figure 4.22: Waste handlers wearing (a) unsuitable gloves and footwear and (b) appropriate gloves and boots.

Birpınar *et al.*, (2009) and Sawalem *et al.*, (2009) observed that at least 30 % of waste handlers wore complete set of appropriate PPE. Studies by Bangladesh (2005), Yong *et al.* (2009) and that conducted in Ghana (Mensah, 2012; Yawson, 2014) showed that waste handlers wore gloves only or no PPE. This gives an indication that, the Ghanaian setting is weak in implementing standards on the proper usage of PPE in hospitals. The lack of knowledge in the proper usage of PPE is a health risk. The usage of nose masks was very low (5 %) because waste handlers were not supplied with them. Those who were concerned with their health had to borrow nose masks from nurses.

4.6 Educational Background of Waste Handlers

Fifty-six (56) percent of waste handlers interviewed have had formal education with 44 % having no formal education [Table 4.4].

Table 4.4: Educational background of waste handlers.

Educational Background	Frequency	Percentage
Basic	13	48
Senior Secondary	2	8
No formal education	12	44
Total	27	100

Formal education refers to those who have had some level of basic education. To ensure proper waste management, waste handlers should have formal education and also undergo regular trainings on proper management practices (Mensah, 2012). It is needed to ensure workers can read and understand all instructions given them especially with the identification of labels and radioactive or biohazard symbols on waste bins. This helps in the proper handling of waste to avoid the risks associated with its mismanagement.

4.7 Health, Occupational and Environmental Risks of SMW Management. SMW management methods employed by the UH-KNUST may pose threats to human health and environmental quality. It may also pose occupational risks to healthcare personnel and waste handlers. The incinerator available at the UH-KNUST is without an air pollution control device and as such, the emissions from the process is not monitored. Incineration and open-air burning of SMW releases smoke, particulate matter and noxious gases like carbon monoxide, nitrogen oxide, hydrogen chloride, sulphur oxide into the atmosphere (Akter, 2000; Hosetti, 2006). Most of these pollutants released during combustion are of much concern due to their toxicity as mutagens and carcinogens (WHO, 2014). This may cause air pollution and result in diverse respiratory diseases when inhaled. Some of the discharge persist in the environment and can accumulate in soil affecting its fertility (Hosetti, 2006; Mensah,

2012) and reduces the percolation of water into soil (Akter, 2000).

Incineration ash, residue generated from the combustion process is added to municipal waste which is disposed of in landfill site. Leachate from landfill site results in soil and water (both surface and groundwater) contamination (Akter, 2000; Hosetti, 2006).

Pathological waste is disposed of into an unlined pit. Waste disposed is in direct contact with soil and its decomposition leads to soil contamination and the pollution of groundwater as chemicals (bleach and Dettol) were added. Disposal of pathological waste in unlined pits too close to water sources can lead to contamination of potable groundwater resources (WHO Immunizaton, 2005; Nkhuwa *et al.*, 2008; Udofia *et al.*, 2015). Pharmaceutical waste was disposed with other solid waste at landfill site. When recovered, these pharmaceuticals can be ingested which is toxic to scavenging humans and animals. Expired drugs could be sent back to the market for re-sale notwithstanding the abuse of such drugs (Akter, 2000). Improperly disposed pharmaceutical waste can contaminate water bodies which may lead to poisoning of humans and animals.

Skip containers at the UH-KNUST for the disposal of SMW were without covering giving chance to scavenging animals to disperse hazardous waste materials. The uncovered nature also allows for rain to mix with the waste which produces stench and a health risk when inhaled. Uncovered skips and uncollected refuse reduces the aesthetic value of the immediate environment, favours the breeding of flies and attracts scavengers. Fermentation of such waste produces odour which contaminates the air and results in diverse health effects when inhaled (Pickford, 1977; Akter, 2000).

Infectious waste from the UH-KNUST were disposed of with general and other hazardous wastes which were disposed at landfill site without any treatment. This increases the volume of untreated infectious waste disposed and has a high potential to cause infections and transmit diseases among humans who scavenge on such landfills. Scavenging animals may cause diseases through the spread of such waste. Infectious waste carry varying pathogens or disease causing organisms which can cause the outbreak and transmission of diseases if not properly treated and disposed.

Such diseases include candidiasis, hepatitis, HIV, diarrhoea, respiratory and skin infections (Akter, 2000; WHO, 2011; WHO, 2014).

Waste handlers raised much concern about negligence on the part of some healthcare personnel who dropped needles on the floor or disposed them with non-hazardous or hazardous wastes. Waste handlers, healthcare personnel and patients are at risk of injury from needles dropped on Hospital floor. Also, safety boxes were not punctureproof so needles stick out sometimes when collecting and transporting waste which causes injury to waste handlers and transmit diseases. Inappropriate disposal of sharp waste poses risk of infection and disease transmission (e.g. Hepatitis B, Hepatitis C or

HIV) amongst waste handlers, healthcare staff and the public (Yawson, 2014; WHO, 2014). Inappropriate use of PPE during waste handling can cause diseases to waste handlers. Infectious diseases can be transmitted upon direct contact of infectious waste with human body part. Healthcare staff and workers in waste management company are also at risk from exposure to hazardous SMW (Prüss *et al*., 1999; WHO, 2014).

4.8 Proposed Sustainable Solid Medical Waste Management Measures The current SMW management systems employed by the UH-KNUST poses various health, occupational and environmental risks. There is, therefore, the need for the implementation of SMW management measures that are environmentally friendly and does not cause any harm to the health of healthcare professionals, waste handlers and patients. Based on limitations identified in existing SMW management practices, sustainable measures have been proposed to help solve issues being faced by the Hospital. Efficiency in segregation at source can be achieved through colour coding of both bins and plastic bags (Prüss *et al*., 1999; MLGRD and EPA, 2002; WHO, 2014). Coloured waste bins with labels should be used in addition to the colour-coded plastic bags for the collection of specific waste types. This will aid in effective segregation of SMW. Puncture-proof safety containers can be used in the collection of sharp waste to avoid needle-stick injury.

Wheelbarrows or plastic bins with wheels should be used for the transportation of SMW. These are puncture resistant and leak-proof to prevent leakages and contamination of hospital floors as stated in regulation by (WHO, 2014). Skip containers for the storage and on-site disposal of SMW should be designed to have a covering or kept in secured locations to prevent access by scavenging animals that spread hazardous waste. Autoclaving, incineration (with pollution control technology) and microwave disinfection can be employed in the treatment of sharp, pathological and infectious wastes.

Pharmaceutical waste may also be incinerated. The treated waste can then be buried in sanitary landfills. Syringes which form the plastic portion can be shredded or recycled. Sharp waste may be disposed of by non-combustion methods such as recycling as proposed by (Prüss *et al*., 1999; WHO, 2014). Untreated sharp and pharmaceutical wastes can be disposed of by encapsulation. This is achieved by filling encapsulation containers with waste, adding an immobilizing material and sealing the container (Prüss *et al*., 1999).

4.8.1 Waste Management Plan for the University Hospital, KNUST, Kumasi In view of the lapses identified in the management of SMW at the UH-KNUST, a waste management plan has been drafted for the Hospital. The waste management plan should have a compilation and authorization information as shown in Table 4.5.

Table 4.5: Compilation and authorization information

Compilation and Authorization	Signature
Compiled by: Francisca Okyere-Hayford (MPhil. Environmental Resources Management)	
Authorized by: **Dr. Osei Kwaku Owusu-Ansah** (Medical Director)	

When the waste management plan is applied, it will help the UH-KNUST in the proper and sustainable management of their SMW (Mensah, 2012).

1.0 Draft Policy Statement

Procedure Title: Waste Management Policy

The UH-KNUST is situated in the Ashanti Region of Ghana. Established in 1952, the Hospital served as a dressing station but has now become a fully recognized hospital due to developments in infrastructure and administration. It is owned by the Government of Ghana and serves as one of the major hospitals in the Kumasi

Metropolis. The hospital provides healthcare services to students and staff of the University as well as over thirty (30) communities.

The management and staff of the UH-KNUST are committed to quality waste management practices by ensuring that the methods of segregation, collection, transportation, storage, treatment and disposal of SMW are in compliance with environmental laws and regulations to improve the Hospital's waste management procedures through pollution prevention and conservation of resources. The management has therefore set the following objectives to fulfil their commitment to proper management of SMW and environmental protection:

- To ensure that all resources needed to achieve safe SMW management are provided to ensure that healthcare services will be delivered in an environmentally friendly manner;
- To operate in full compliance to Ghana's SMW management laws and policies in order to maintain environmental quality;
- To identify and assess existing and potential SMW management aspects and impacts for setting and reviewing SMW management objectives;
- To educate employees on the need for proper SMW management in the Hospital;
- Regular monitoring to ensure the Hospital's objectives towards SMW management, environmental and health quality maintenance are on course;
- To review the waste management policy statement when necessary and make it available to all employees and the public.

This policy shall be implemented through operational format procedure, work instruction format or periodic briefing. The Medical Director (MD) and the Environmental Officer will be the custodians of the policy document. The document will, however, be posted at public places within the Hospital such as the OPD and all notice boards. Newly employed staff and suppliers shall be briefed on the policy document as part of their orientation. Correspondents can be reached on 0201563147 for further information on the policy document.

2.0 System Procedure

Procedure Title: Waste Management Aspect Identification

Purpose: This process describes the aspects of solid medical waste management and the potential risks to the environment. It can be reviewed at least twice a year or when additional impacts are observed.

Scope: The scope involves the identification of all SMW management aspects arising from the activities and services rendered at the UH-KNUST as well as those arising from services, products and activities of other stakeholders.

Description of Activities

Different aspects of SMW management were identified to determine their potential risks to the environment and human health. This was achieved through personal observations, interviews and administering of questionnaires to waste handlers and healthcare staff to identify various aspects of waste management. Aspects identified include:

- Poor segregation of SMW and improper colour coding of waste bins;
- Inappropriate use of coloured plastic bags for the segregation of SMW;
- Fragile plastic bags used for the collection of SMW. These bags were not resistant to tear nor puncture;
- Infectious SMW were not treated before disposal into landfill;
- Inadequate facilities for the proper storage, disposal and treatment of SMW;
- Co-disposal SMW with municipal waste into two available skip containers;
- Transportation of SMW on-site by hand;
- The spread of hazardous waste materials by scavenging animals;
- Needle-stick injuries resulting from the poor segregation and disposal of waste;
- Dense smoke and harmful gases were released from the combustion of waste in the incinerator and from open-air burning processes;
- The incinerator available was without an air pollution control device to monitor emissions into the atmosphere;
- No record keeping;
- Lack of hospital waste management policy/regulations;

- No training for healthcare staff on SMW management practices and
- Absence of Waste Management Department.

Responsibility: The implementation and preservation of this procedure is the responsibility of the Hospital's Director, Environmental Officer and Administrator.

Performance Indicators

Environmental aspects of all activities related to the management of SMW must be identified with records kept on all current, past and future aspects identified. Records must be 100 % up-dated at least once every year.

Records: This procedure can be successfully implemented by keeping accurate records on identified SMW aspects and impacts. This will be the responsibility of the Environmental Officer. The retention time of the records can be one year after which it must be reviewed.

3.0 Operational Procedure

Purpose

Daily management of SMW generated as a result of the hospital's activities, products and services as well as by other stakeholders.

Scope

This procedure applies to the collection, transportation, storage, treatment and disposal of SMW materials generated at the UH-KNUST.

Procedure

Responsibilities

The management of the UH-KNUST is responsible for all issues related to the management of SMW generated in the Hospital. The waste handlers under the supervision of the Environmental Officer are responsible for the proper collection, transportation to the on-site disposal point, storage, treatment and disposal of SMW materials generated.

Management of specific SMW types in the Hospital

a. Non-hazardous waste should be separated from all hazardous waste which includes expired and unused drugs, sharps, infectious waste etc. and may be disposed in the waste bins for the collection of non-hazardous waste. The nonhazardous waste are to be collected by the waste handlers and disposed of in a sanitary solid waste landfill site.

b. All expired pharmaceuticals should be collected in brown plastic bags or containers, and labelled for safe storage until sufficient quantities are available for proper disposal. Pharmaceutical companies are equipped to manage and use up any drugs that are becoming close to the expiry dates. Pharmaceutical waste generated in the Hospital can, therefore, be sent back to the pharmaceutical companies or major distributors for proper disposal.

c. All infectious and pathological wastes are to be collected in yellow leak-proof containers and bags clearly marked and labelled with BIOHAZARD symbol. The biohazard wastes will be stored in secured and marked containers for safe storage until sufficient quantities are generated for disposal or collected regularly to prevent the development of bad odour.

d. All used sharp waste should be placed immediately after using into specially designed puncture-proof safety boxes or containers. These safety boxes or containers must be well labelled with BIOHAZARD symbol. The safety boxes or containers should be stored in the same secure manner and located as the other "BIOHAZARD WASTE" until ready for disposal.

Management Process

a. The Hospital's waste handlers are responsible for the collection, transportation and disposal of all waste types that are generated.

b. The Environmental Officer is to be contacted, who will coordinate for the appropriate collection, transportation, treatment and final disposal of SMW.

c. SMW will be transported in wheeled plastic bins with covering, directly to the on-site disposal point behind the Maternity ward for proper disposal. Precautions are to be taken to ensure that the transportation process is secured to avoid contamination and spread of diseases and that all of the pharmaceutical, infectious and sharp wastes are properly disposed of.

d. All waste handlers must wear appropriate PPE during the collection, transportation and disposal of both hazardous and non-hazardous wastes.

e. Only authorized personnel are allowed to operate the incinerator. Incineration reduces the weight and volume of the waste as much as 95 %, and is especially appropriate for pathological and sharp wastes.

f. Operations of the incinerator should aim at minimizing the effects associated with air emissions and disposal of the incinerator ash at sanitary landfill sites.

g. Combustion shall take place when a reasonable quantity of sharp waste are collected or at least twice a month.

Monitoring and Records

- The Environmental Officer must undertake regular monitoring to ensure all processes of SMW the collection, transportation, storage, treatment and disposal are done according to requirements.
- The Waste Management Department is responsible for keeping detailed records n all SMW management activities.
- Accurate records should be kept on the quantities and composition of all SMW types generated at the UH-KNUST.
- Records should be kept for the incinerator maintenance, air pollution control equipment and calibration records for the monitoring equipment.

4.9 Factors Responsible for Improper Management of SMW at UH-KNUST

4.9.1 Absence of Waste Management Department (WMD)

A Waste Management Committee (WMC) is essential in developing waste management plans (MLGRD and EPA, 2002) which aids in defining roles and actions to be performed by management, healthcare and waste management personnel to improve SMW management practices (WHO, 2014). The absence of a WMD with a well-established management hierarchy made it difficult for effective planning and implementation of day-to-day activities relating to SWM at UH-KNUST. There was no WMC and in effect no existing waste management policies or regulations to act as a guide for effective management of SMW.

The Environmental Officer was the only one in charge of handling all waste-related issues and also responsible for all the waste handlers. Studies so far in Ghana by Mensah (2012), Asante *et al*, (2014) and Yawson (2014) showed that over 100 hospitals studied in the Greater Accra and Ashanti Regions did not have WMD and policies. Studies in South Africa (Abor and Bouwer, 2008) and Libya (Sawalem *et al.*, 2009) showed that hospitals lack WMD and policies. The University Hospital in Freiburg, Germany had 54 rules at national, regional and hospital levels for managing SMW (Abor and Bouwer, 2008). This suggests that management of SMW in hospitals in Ghana is ineffective as WMD and policy vital in the management processes are absent.

4.9.2 Training for Healthcare Staff on SMW Management Practices

Healthcare personnel such as doctors, laboratory technicians, nurses and pharmacists are not given any training on effective SWM and precautions to be taken when handling any form of SMW. This accounts for the poor segregation of waste being done currently at source. It was also evident through personal interviews where 51 % of personnel had no idea of waste segregation, treatment and disposal. Training of all healthcare personnel is important in capacity building, which helps in improving waste management, the minimization of infection transmission and ensures a well-informed work force (Prüss *et al.*, 1999; WHO, 2014).

Mensah, (2012) and Yawson, (2014) observed lack of training of healthcare staff on appropriate waste management practices in hospitals studied in Ghana. In Northern Jordan (Abdulla *et al.*, 2008), Nigeria (Coker *et al.*, 2009), Libya (Sawalem *et al.*, 2009) and China (Yong *et al.*, 2009), Khartoum State (Saad, 2013) and studies conducted in Africa by (Udofia *et al.*, 2015) showed lack of training for healthcare personnel. This reveals that several countries including Ghana do not adhere to regulations by WHO to train healthcare personnel on waste management practices.

Though all the respondents interviewed had knowledge of the fact that sharp waste had to be separated from non-hazardous and hazardous wastes, they did not strictly comply. Seventy-two (72) percent of respondents had no knowledge that nonhazardous and hazardous wastes had to be separated [Appendix C (ii) (a)]. Also, 51 % of healthcare personnel and waste handlers had no knowledge on the treatment and disposal of specific waste types as some had no idea the sharps collected in the safety boxes for example were treated and disposed [Appendix C (ii) (b)]. The situation identified may be attributed to the lack of a WMD to coordinate these activities and ensure all workers were well trained. There is therefore the urgent need for training of workers, according to WHO guidelines, on appropriate SMW management practices.

4.9.3 Record Keeping

Due to the absence of a WMD, no documentations were made on waste quantities and types generated and the existing management practices. This finding is contrary to guidelines by MLGRD and EPA (2002) which states that proper assessment of waste types and quantities generated must be done by the waste management team in order to develop a good waste management plan. Hospitals studied in Ghana by Mensah (2012) and Yawson (2014) did not keep records on practices related to SMW management. Studies conducted by Abor and Bouwer (2008) and Sawalem *et al*. (2009) in South Africa and Libya respectively also showed that hospitals did not keep records on waste management practices. Records on hospital's waste management practices done accurately serves as a reference for making informed management decisions and for ensuring adherence to environmental and public health principles relating to medical waste management as stated in the report (Mensah, 2012; WHO, 2014).

4.10 Observations from Study

Observations were made about the practices of SMW management performed by the UH-KNUST. These include:

- Unavailability of national waste management policy or guidelines;
- Lack of a Hospital Waste Management Department and policy;
- Non-adherence to segregation resulting in the mixing up of all kinds of waste;
- Ineffective means of waste transportation on-site;
- Storage facilities on-site were open, accessible to scavenging animals and a breeding ground for flies and other insects;
- No training for healthcare personnel on proper segregation of SMW;
- No treatment of SMW except sharp waste and
- Waste handlers had no knowledge about proper waste segregation and treatment.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A total quantity of 9684.2 kg of SMW was generated from November 2015 to February 2016 and was composed of 56.0 % general, 40.6 % infectious, 0.1 % pharmaceutical and heavy metal, 0.5 % sharp and 2.8 % pathological wastes. Segregation, collection, transportation, storage, treatment and disposal were the practices identified for the management of SMW. The existing management practices were not done according to guidelines by WHO and Ghana's MLGRD and EPA since very important practices including recycling, microwave and autoclave disinfection were not observed. A Waste Management Department and policy are urgently needed to properly manage all issues related to SMW management. A waste management plan for the UH-KNUST has therefore been developed which when implemented will minimize the environmental and health risks posed by the poor management system identified. These suggest that, the SMW management practices undertaken by the UH-KNUST do not address the waste management challenges calling for the development of a waste management policy by the hospital.

5.2 Recommendations

Based on the findings of the study, the following recommendations were made:

- A Waste Management Department should be established by the Hospital to coordinate activities of SWM;
- The adoptions made for color-coding should be strictly enforced for effective segregation;

- Accurate and detailed records should be kept by the Waste Management Department on quantities and composition of SMW generated for effective planning and management and
- Regular training of all healthcare personnel and waste handlers and effective sensitization using posters to educate Hospital staff and patients should be organized regularly by the Waste Management Department.

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APPENDICES

Appendix A

Analytical Results

(i) Weekly Mean of Total Waste Generated from the Various Wards/Units

Anova: Single Factor

SUMMARY (For 16 weeks)

Groups	*Sum*	*Average*	*Variance*
OPD	1329.6	83.100	138.949
LAB	501.6	31.350	116.401
DENTAL	106.7	6.669	14.774
VIP	734.2	45.888	158.688
CHILDREN	1256.9	78.556	329.968
EYE	43.7	2.731	2.412
THEATRE	528.5	33.031	84.964
MALE	909.0	56.813	434.205
MATERNITY	1161.6	72.600	238.317
PHARM	193.7	12.106	27.646
X-RAY	71.2	4.450	5.617
ADMIN	413.1	25.819	10.031
FEMALE	1213.3	75.831	341.705
PHU	1221.1	76.319	85.931

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	192754.60	13	14827.28	104.33	5.75×10^{-84}	2.22
Within Groups	29844.13	210	142.11			
Total	**222598.70**	**223**				

(ii) Mean Total Waste Generated weekly by entire Hospital

Anova: Single Factor

SUMMARY (For 14 wards/units)

Groups	*Sum*	*Average*	*Variance*
WK 1	698.6	49.9	1040.863
WK 2	704.6	50.32857	1098.419
WK 3	637.2	45.51429	1027.28
WK 4	611.2	43.65714	844.9211
WK 5	518.0	37	892.1031
WK 6	558.7	39.90714	1138.647
WK 7	520.2	37.15714	839.3596
WK 8	467.0	33.35714	745.5411

WK 9	392.9	28.06429	488.7317
WK 10	708.5	50.60714	1606.051
WK 11	713.2	50.94286	1416.393
WK 12	670.4	47.88571	1133.346
WK 13	605.3	43.23571	1018.262
WK 14	712.6	50.9	1397.711
WK 15	567.2	40.51429	794.8382
WK 16	598.6	42.75714	868.8965

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10030.98	15	668.73	0.65	0.83	2.13
Within Groups	212567.70	208	1021.96			
Total	**222598.70**	**223**				

(iii) Weekly Mean of Non-hazardous Waste from the Wards/Units

Anova: Single Factor

SUMMARY (For 16 weeks)

Groups	*Sum*	*Average*	*Variance*
OPD	935.4	58.463	152.297
LAB	38.4	2.400	3.511
DENTAL	25.9	1.619	2.367
VIP	544.6	34.038	65.336
CHILDREN	769.6	48.100	285.035
EYE	10.8	0.675	0.250
THEATRE	51.8	3.238	4.209
MALE	619.6	38.725	275.327
MATERNITY	104.4	6.525	15.574
PHARM	193.6	12.100	27.711
X-RAY	16.5	1.031	0.698
ADMIN	411.6	25.725	10.293
FEMALE	778.8	48.675	172.801
PHU	921.0	57.563	58.879

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	107854.40	13	8296.49	108.12	2.29×10^{-85}	2.22
Within Groups	16114.30	210	76.73			

Total	**123968.70**	**223**

(iv) Mean Non-hazardous Waste produced weekly by the entire Hospital
Anova: Single Factor
SUMMARY (For 14 wards/units)

Groups	*Sum*	*Average*	*Variance*
WK 1	441.9	31.564	839.121
WK 2	443.6	31.686	834.677
WK 3	413.0	29.500	833.420
WK 4	309.4	22.100	373.060
WK 5	317.6	22.686	498.654
WK 6	368.3	26.307	829.230
WK 7	308.4	22.029	526.467
WK 8	236.8	16.914	300.126
WK 9	216.5	15.464	275.156
WK 10	360.0	25.7143	743.674
WK 11	314.1	22.436	467.861
WK 12	306.2	21.871	487.715
WK 13	309.8	22.129	478.133
WK 14	385.4	27.529	636.867
WK 15	342.8	24.486	541.274
WK 16	348.2	24.871	536.407

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4344.78	15	289.65	0.50	0.94	2.13
Within Groups	119623.90	208	575.12			
Total	**123968.70**	**223**				

(v) Weekly Mean of Infectious Waste Generated in the Wards/Units
Anova: Single factor
SUMMARY (For 16 weeks)

Groups	*Sum*	*Average*	*Variance*
OPD	385.3	24.081	76.124
LAB	456.4	28.525	86.155

DENTAL	78.9	4.931	7.790
VIP	188.1	11.756	54.649
CHILDREN	482.5	30.156	267.605
EYE	32.9	2.056	1.1786
THEATRE	384.8	24.050	46.907
MALE	283.1	17.694	98.887
MATERNITY	861.9	53.869	138.482
X-RAY	54.7	3.419	3.200
FEMALE	432.4	27.025	189.363
PHU	292.1	18.256	3.283

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	36844.92	11	3349.54	41.28	1.86×10^{-43}	2.35
Within Groups	14604.38	180	81.14			
Total	**51449.31**	**191**				

(vi) Mean Infectious Waste Generated Weekly by entire Hospital

Anova Single Factor

SUMMARY (For 12 wards/units)

Groups	*Sum*	*Average*	*Variance*
WK 1	233.7	19.475	245.348
WK 2	236.3	19.692	275.175
WK 3	206.2	17.183	108.065
WK 4	270.8	22.567	317.746
WK 5	180.8	15.067	272.790
WK 6	169.8	14.150	177.761
WK 7	189.3	15.775	265.857
WK 8	215.6	17.967	259.186
WK 9	159.6	13.300	157.664
WK 10	330.2	27.517	416.703
WK 11	367.9	30.658	544.990
WK 12	341.3	28.442	352.928

WK 13	283.1	23.592	201.592
WK 14	306.3	25.525	305.157
WK 15	210.7	17.558	155.181
WK 16	231.5	19.292	154.359

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5133.80	15	342.25	1.30	0.21	2.14
Within Groups	46315.51	176	263.16			
Total	**51449.31**	**191**				

(vii) Weekly Mean of Pathological Waste Generated from the Maternity ward and Theater

Anova: Single factor

SUMMARY (For 16 weeks)

Groups	*Sum*	*Average*	*Variance*
THEATRE	84.8	5.300	7.781
MATERNITY	189.6	11.850	8.169

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	343.22	1	343.22	43.04	2.95×10^{-7}	7.56
Within Groups	239.26	30	7.98			
Total	**582.48**	**31**				

(viii) Mean Pathological Waste Generated Weekly by entire Hospital

Anova Single Factor

SUMMARY (For 2 wards/units)

Groups	*Sum*	*Average*	*Variance*
WK 1	17.8	8.900	10.580
WK 2	19.3	9.650	36.125
WK 3	14.3	7.150	6.845
WK 4	25.9	12.950	25.205
WK 5	17.7	8.850	105.125
WK 6	19.5	9.750	8.405
WK 7	21.8	10.900	5.120
WK 8	13.5	6.750	49.005

WK 9	15.9	7.950	78.125
WK 10	16.4	8.200	35.280
WK 11	22.6	11.300	5.780
WK 12	18.2	9.100	20.480
WK 13	7.4	3.700	5.120
WK 14	17.8	8.900	18.00
WK 15	10.7	5.350	13.005
WK 16	15.6	7.800	8.820

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	151.46	15	10.10	0.37	0.97	3.41
Within Groups	431.02	16	26.94			
Total	**582.48**	**31**				

(ix) Weekly Mean of Sharp Waste Generated in the Wards/Units
Anova: Single factor
SUMMARY (For 16 weeks)

Groups	*Sum*	*Average*	*Variance*
OPD	8.9	0.556	0.217
LAB	6.8	0.425	0.226
DENTAL	1.9	0.119	0.124
VIP	1.5	0.094	0.057
CHILDREN	4.8	0.300	0.244
THEATRE	7.1	0.448	0.485
MALE	6.3	0.394	0.462
MATERNITY	5.7	0.356	0.267
FEMALE	2.1	0.131	0.032
PHU	8.0	0.500	1.240

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.96	9	0.44	1.31	0.24	2.53
Within Groups	50.31	150	0.34			
Total	**54.27**	**159**				

(x) Mean Sharp Waste Generated Weekly by entire Hospital

Anova Single Factor

SUMMARY (For 10 wards/units)

Groups	*Sum*	*Average*	*Variance*
WK 1	5.2	0.520	0.364
WK 2	5.4	0.540	0.474
WK 3	3.7	0.370	0.296
WK 4	4.7	0.470	0.491
WK 5	1.8	0.180	0.164
WK 6	1.1	0.110	0.023
WK 7	0.7	0.070	0.013
WK 8	1.1	0.110	0.054
WK 9	0.9	0.090	0.025
WK 10	1.9	0.190	0.023
WK 11	8.6	0.860	1.463
WK 12	4.7	0.470	0.469
WK 13	4.1	0.410	0.428
WK 14	3.1	0.310	0.377
WK 15	3.0	0.300	0.347
WK 16	3.1	0.310	0.270

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.74	15	0.45	1.36	0.17	2.17
Within Groups	47.53	144	0.33			
Total	**54.27**	**159**				

Appendix B

(i) Total Waste Generated by various Wards/Units

Ward/Unit	Weight of Waste (kg)						
	Hazardous Waste					Non-Hazardous	Total Waste Generated
	Infect*	Path*	Sharps	Heavy metal	Pharm*		
OPD	385.3	0.0	8.9	0.0	0.0	935.4	1329.6
Lab	456.4	0.0	6.8	0.0	0.0	38.4	501.6
Dental	78.9	0.0	1.9	0.0	0.0	25.9	106.7
VIP	188.1	0.0	1.5	0.0	0.0	544.6	734.2

Children's	482.5	0.0	4.8	0.0	0.0	769.6	1256.9
Eye	32.9	0.0	0.0	0.0	0.0	10.8	43.7
Theater	384.8	84.8	7.1	0.0	0.0	51.8	528.5
Male	283.1	0.0	6.3	0.0	0.0	619.6	909
Maternity	861.9	189.6	5.7	0.0	0.0	104.4	1161.6
Pharmacy	0.0	0.0	0.0	0.0	0.1	193.6	193.7
X-Ray	54.7	0.0	0.0	0.0	0.0	16.5	71.2
Admin	0.0	0.0	0.0	1.5	0.0	411.6	413.1
Female	432.4	0.0	2.1	0.0	0.0	778.8	1213.3
PHU	292.1	0.0	8.0	0.0	0.0	921	1221.1
Overall Total	**3933.1**	**274.4**	**53.1**	**1.5**	**0.1**	**5422.0**	**9684.2**
Percentage	**40.6**	**2.8**	**0.5**	**0.0**	**0.0**	**56.0**	**100.0**

* where pharm represents Pharmaceutical waste, infect represents Infectiousaste and path r pathological waste

(ii) Percent Composition of Waste Generated in each Ward/Unit

	Waste category Ward/Unit		Total	Percentage (%)
	Hazardous	Non-hazardous		
OPD	394.2	935.4	1329.6	**13.7**
Lab	463.2	38.4	501.6	**5.2**
Dental	80.8	25.9	106.7	**1.1**
VIP	189.6	544.6	734.2	**7.6**
Children's	487.3	769.6	1256.9	**13.0**
Eye	32.9	10.8	43.7	**0.5**
Theater	476.7	51.8	528.5	**5.5**
Male	289.4	619.6	909.0	**9.4**
Maternity	1057.2	104.4	1161.6	**12.0**
Pharmacy	0.1	193.6	193.7	**2.0**
X-Ray	54.7	16.5	71.2	**0.7**
Admin	1.5	411.6	413.1	**4.3**
Female	434.5	778.8	1213.3	**12.5**
PHU	300.1	921.0	1221.1	**12.6**
Overall Total	**4262.2**	**5422.0**	**9684.2**	**100.0**
Overall Percentage	**44.0**	**56.0**		

(iii) Percent Composition of Hazardous Waste Generated

Specific Waste Type	Total Quantity Generated	Percentage
Infectious	3933.1	92.3
Pathological	274.4	6.4
Sharps	53.1	1.2
Heavy metal	1.5	0.0
Pharmaceutical	0.1	0.0
Total	**4262.2**	**100.0**

(iv) Monthly Waste Generated

Month	Weight (kg)		Total
	Hazardous	Non-hazardous	
November	1072.8	1661.9	2734.7
December	920.2	1319.0	2239.2
January	1467.2	1364.7	2831.9
February	802.0	1076.4	1878.4

Appendix C

(i) Weekly Patient's Attendance

	Wards/Units					
Week	**Maternity**	**Female**	**Children's**	**Male**	**VIP**	**Theatre**
1	15	25	21	18	5	13
2	20	19	22	13	5	15
3	14	23	29	20	5	10
4	23	25	21	19	6	13
5	21	20	15	20	1	11
6	16	18	19	16	1	12
7	15	27	22	12	7	13
8	17	24	15	10	7	11
9	18	19	26	19	2	12
10	15	25	27	29	6	13
11	17	24	23	24	4	18
12	17	21	22	21	6	15
13	7	22	11	25	3	16
14	17	25	22	14	6	18
15	11	16	18	10	5	14
16	14	23	17	18	5	16

(ii) esponses from stration

(a) Questionn

f Segregation oire Admini

Waste Type	**Yes**	**%**	**No**	**%**
Sharps	60	100.0	0	0.0
Hazardous from non-hazardous	17	28.0	43	72.0

(b) Knowledge of Treatment and Disposal Method for Solid Medical Waste

Method	**Yes**	**%**	**No**	**%**
Incineration	38	63.3	22	36.7
Pit disposal	33	55.0	27	45.0
Landfill	47	78.3	13	21.7
Open air burning	23	38.3	37	61.7
Microwave disinfection	7	11.7	53	88.3

Appendix D

Sample Research Questionnaire

Kwame Nkrumah University of Science and Technology

Solid Medical Waste Management Practices: A Case Study of the University Hospital, KNUST

SAMPLE A

Personnel involved in the management of hospital solid medical waste

This study is mainly for academic purposes. Answers given will be treated as highly confidential.

Please tick ONLY THE BOX of the appropriate response. State briefly for an unprovided answer.

(a) Respondent's Personal Data

1. Gender ☐ Male ☐ Female
2. Age ☐ 20 – 34 ☐ 35 – 44 ☐ 45 – 60
3. Level of Education ☐ Basic ☐ Secondary ☐ Tertiary ☐ No formal education ☐ Other (specify)
4. Religion ☐ Christian ☐ Traditional ☐ Islamic ☐ None
5. Which department in the hospital do you work? …………………………
6. For how long have you worked here? ……………………………………

(b) Composition of waste generated

1. What types of wastes are generated in your ward?

☐ Infectious ☐ General ☐ Pharmaceutical ☐ Sharps ☐ Pathological

(c) Quantities of wastes generated

1. Is the waste generated quantified? ☐ Yes ☐ No

2. If yes, how much waste is generated?

……………………………………………………………………………………

3. Do you keep records of the quantity of waste generated? ☐ Yes ☐ No

(d) Waste Management Practices

1. How many waste workers are in your department? ………………………
2. Do you have any job descriptions detailing your specific tasks?
   ☐ Yes ☐ No
3. Have you had any technical training on hospital solid medical waste management?
   ☐ Yes ☐ No
4. If yes, what kind of training? ....
5. How regular is the training?
   ....
6. How often do you collect the solid medical waste from your department?
   ……………………………………………………………………………
7. At what time(s) of the day do you collect the waste?
   Please specify
   ……………………………………………………………………
8. What type of collection equipment do you use?

☐ Plastic bins ☐ Trolleys ☐ Wheelbarrows
☐ Plastic bags ☐ Cardboard boxes ☐ Other, specify ………

9. What personal protective equipment do you wear when working?
☐ Gloves ☐ Nose mask ☐ Protective clothing
☐ None ☐ Boots Other, ☐ specify ……………..

10. Is the waste segregated (separated) at the point of collection? ☐ Yes ☐ No

11. If yes, how is the segregation done?
....

12. Are the waste bins in your ward/department covered? ☐ Yes No ☐ Are waste bins in your department colour-coded for the specific wastes?
☐ Yes ☐ No

14. Has there been any incidence of sharps-inflicted injury?
☐ Yes ☐ No

15. Are there any challenges in handling the waste?
☐ Yes ☐ No
If yes, please specify...

16. How can these challenges be solved?
……………………………………………………………………………………

17. Are there any treatment methods available for the type of waste you collect?
☐ Yes ☐ No
If yes, please specify …………………………………………………………

18. What is the existing final disposal method for the waste type you collect?

SAMPLE B

Questionnaire for Healthcare and Administrative Staff at University Hospital

This study is mainly for academic purposes. Answers given will be treated as highly confidential.

Please tick ONLY THE BOX of the appropriate response/state briefly for an unprovided answer.

(a) Respondent's Personal Data

1. Gender ☐ Male ☐ Female
2. Age 20 – ☐ 34 35 – ☐ 44 ☐ 45 – 60
3. Level of Education ☐ Basic ☐ Secondary ☐ Tertiary ☐ Other (please specify)
4. Religion ☐ Christian ☐ Traditional ☐ Islamic ☐ None
5. Which ward/unit do you work in?

☐ Children's ward ☐ Eye clinic ☐ Male ward ☐ Female ward ☐ Pharmacy ☐ Laboratory ☐ Theatre ☐ Dental clinic ☐ X-Ray department ☐ Out-patient department ☐ Administration ☐ VIP

(b) Waste Management Practices

1) What are the major types of waste generated in the ward/unit?
☐ Sharp ☐ Pharmaceutical ☐ Pathological
☐ General waste (office waste, sweepings, kitchen waste) ☐ Infectious

2) What facilities exist for the management of solid medical waste?
☐ Incineration ☐ Autoclaving ☐ Disposal site ☐ Burying in pit ☐ Microwave irradiation ☐ Open air burning
☐ Other, specify……………………………………………………………………

3) What are the procedures for the collection, storage, and handling of solid medical waste from the various wards/units?
………………………………………………………………………………………

4) Are solid medical waste segregated at source? ☐ Yes ☐ No

5) If yes who does the segregation?
………………………………………………………………………………………

6) Do you colour code the disposal bins for solid medical waste? ☐ Yes ☐ No

7) How is non- infectious waste treated and disposed?
………………………………………………………………………………………

8) How is the sharp waste treated and disposed?
………………………………………………………………………………………

9) How is pathological waste treated and disposed?
………………………………………………………………………………………

10) How is pharmaceutical waste treated and disposed?
………………………………………………………………………………………

11) Have there been any reported cases of infection caused by poorly managed solid medical waste? ☐ Yes ☐ No

12) Have there been any reported cases of disease out-break caused by poorly managed solid medical waste? ☐ Yes ☐ No

13) Who is responsible for hospital solid medical waste management?
………………………………………………………………………………

14) Do you monitor disposal of solid medical waste? ☐ Yes ☐ No

15) If yes, how is monitoring done?
………………………………………………………………………………………

16) Does the hospital train waste management staff? ☐ Yes ☐ No

17) How often do the waste management staff undergo training?

…………………………………………………………………………………

18) What are some of the limitations in managing solid medical waste?

…………………………………………………………………………………

…………………………………………………………………………………

………………

(c) Hospital waste management policy

19) Does University Hospital follow any documented guideline on management of solid medical waste? ☐ Yes
☐ No

20) Is there a manual on management of hospital waste available:
(a) At the Ministry of Health? ☐ Yes ☐ No
If yes, give the document title
……………………………………………………………….
(b) In your hospital? ☐ Yes No ☐

21) Does your hospital have its own SMW management plan? ☐ Yes ☐ No

Appendix E

Researcher's Observational Checklist

1. Workers use of personal protective equipment (PPE's) ☐ Yes ☐ No
2. Appropriate time for waste collection ☐ Yes ☐ No
3. Adherence to segregation at source ☐ Yes ☐ No
4. Covered waste bins ☐ Yes ☐ No
5. Wastes workers punctuality to work ☐ Yes ☐ No
6. Solid medical waste treatment method
   ☐ Incineration ☐ Microwave disinfection ☐ Autoclave ☐ None
   ☐ Burying in pit ☐ Open air burning
7. Records on solid medical wastes generated ☐ Yes ☐ No
8. What happens to incineration ash?
9. Does incinerator have a pollution control device? ☐ Yes ☐ No