ENVIRONMENTAL AND HEALTH IMPLICATIONS OF MANAGEMENT OF MEDICAL WASTES IN SELECTED HOSPITALS IN NIGER STATE, NIGERIA

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PhD/SPS/2017/989

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OCTOBER, 2021

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL MANAGEMENT

OCTOBER, 2021

ABSTRACT

Generation of medical wastes is a global issue and if not properly managed, could constitute potential risks to the environment and public health. It concerns everyone. Unfortunately, awareness that it causes environmental pollution is low in many parts of the globe, especially in the developing countries. This study was carried out with the aim of examining the environmental and health implications of management of medical wastes in some parts of Niger State, Nigeria. Accordingly, public and private hospitals were selected using purposive method. Ten hospitals were selected for the study. A cross-sectional study design was used to examine the current practice of medical wastes management systems and morbidity in children (≤ 10 years) using questionnaire, field participant observations, interviews and focus group discussions (FGD). Samples of wastewater were taken from the hospitals during the period for laboratory tests. A longitudinal study design was conducted to determine the hospitals wastes composition and generation rates. Collection and weighing of wastes from all departments of the sampled -hospitals using a calibrated sensitive weight scale for seven consecutive days were done. Data description was made using mean, graph, standard deviation (SD), frequency, and percentage. Majority of the staff of the hospitals were nurses/midwives (49.7%), paramedical (33.8%), medical doctors (9.7%) and waste handlers (6.8%). From the responses, about 72.7% of the respondents said only syringe and needle wastes were segregated, 98.1% said that the hospitals have no waste management manual and plan while 98.6 had no specific training on medical wastes management. Use of wheel barrows was the commonest means of transporting wastes and open surface burning was the common final method of medical wastes treatment and disposal by the hospitals. Hospital wastewater treatment plants were not available in all the selected hospitals thus wastewater was discharged directly into the environment. Wastewater quality parameters (pH, BOD, COD, TSS, DO, TC and FC), all indicated severe pollution of the hospital wastewater. Risk ratios (RR) for respiratory, intestinal and skin infections were 0.25:0.18, 0.44:0.31 and 0.27:0.19 respectively indicating that, the exposed children suffered more from such diseases than the unexposed. Average generation rates of hazardous hospital medical wastes in the selected public hospitals were 0.71kg/bed/day, 0.92kg/patient/day, while those of the private hospitals were 0.10kg/bed/day and 0.13kg/patient/day. Similarly, the average rate of the total hazardous wastes generation for the inpatients and outpatients was 0.25 kg/patient/day. Percentage average hazardous wastes components generated in each of the hospitals based on the number of patient /bed/days were; H1: 58.21%, H2: 65.01%, H3: 61.41%, H4: 52.70%, H5: 64.49%, H6: 60.36%, H7: 61.33%, H8: 53.27%, H9: 67% and H10: 57.26%. From this result therefore, it could be concluded that, improper medical wastes management in the selected hospitals were generally poor due to absence of medical wastes management policies and plans, inadequate financial resources, poor awareness and training of medical personnel. Therefore, there is an urgent need for raising awareness among stakeholders on healthcare waste management issues (segregation, storage, collection, transport, treatment and disposal) and their relevance in addressing public health and environmental issues.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATION

AIDS	Acquired Immune Deficiency Syndrome
Al2O3	Aluminum Oxide
Ba	Barium
BOD	Biochemical Oxygen Demand
BMW	Biomedical Waste
CaO	Calcium Oxide
COD	Chemical Oxygen Demand
DA	Disagreed
D.O	Dissolved Oxygen
EC	European Commission
EEA	European Environment Agency
EMF	Ellen MacArthur Foundation
ERIT	Environmental Review of Incineration Technologies
ESM	Environmental Sound Management
FC	Faecal Coliform
FGD	Focus Group Discussion
GH	General Hospital
HCE	Health Care Establishment
HCF	Health Care Facility
HCW	Health Care Waste
HCGW	Health Care General Waste
HCWM	Health Care Waste Management
HHIC	Hospital Hygiene and Infection Control
HIV	Human Immunodeficiency Virus
HVB	Hepatitis B
HVC	Hepatitis C
ICRC	International Committee of the Red Cross
IEP	Innovative Environmental Product
I-TEQ	International – Toxic Equivalent Quantity
LAWMA	Lagos State Waste Management Authority
MC	Medical Care
MPPCB	Madhya Pradesh Pollution Control Board

MW	Medical Waste
MWD	Medical Waste Disposal
MWM	Medical Waste Management
NESREA	National Environmental Standard Regulation Enforcement Agency
NGO	Non-Governmental Organization
NHCW	Non-Infected Health Care Waste
NISEPA	Niger State Environmental Protection Agency
OTA	Office of Technological Assessment (United States Congress)
PAHs	Polycyclic Aromatic Hydrocarbons
Pb	Lead PeCDF = Pentachlorinated Dibenzofuran
PCBs	Polychlorinated Biphenyls
PCDD/Fs	Polychlorinated Dibenzodioxins/ Furans
PE	Polyethylene
POPs	Persistent generation of Organic Pollutants
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
SDA	Strongly Disagreed
SD	Standard Deviation
SDG	Sustainable Development Goals
SiO2	Silicon dioxide
SMW	Solid Medical Waste
SO2	Sulphur dioxide
SOGA	State Global Air Database
SPSS	Statistical Package for Social Science
TC	Total Coliform
TCDD/F	Tetrachlorinated Dibenzodioxin/ Furan
TEF	Toxicity Equivalent Factor
Ti	Titanium
TSS	Total Suspended Solids
UN	United Nation
UNCED	United Nations Conference on Environment and Development

UNEP	United Nations Environment Programme
US-EPA	United State Environmental Protection Agency
WG	Waste Generation Rate
WHO	World Health Organization
WMP	Waste Management Plan
Zn	Zinc µg/kg = Microgram per kilogram

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The medical waste (MW) has been considered a global problem that could poses a severe danger to the environment and public health if not properly managed (Yazie *et al*., 2019; Karki *et al.,* 2020; Ghimire, 2020). These issues are associated to the way the society produces and consumes directly. It concerns all and sundry and its management is one of the critical challenges globally in the 21st century, particularly in less developed countries. This is on the grounds that, arrangement of sustainable healthcare services is essential human needs and can likewise be viewed as a 'fundamental human right'. Since it believed that, accessibility of sufficient healthcare facilities in a given nation is a method for ensuring and restoring good health saving patients' lives as well (Annette *et al*., 2013; Ahmed *et al*., 2018). Therefore, sustainable medical care is vital for our lives, health and wellbeing of general public. There has been an increase in public concern about the management of MW generated from medical care services on global basis particularly in less developed countries where knowledge, technology, finance and political will on Medical waste management are still lacking (Babanyara *et al*., 2013). In fact, the submission from researchers declared that out of the complete waste produced from health services organizations/offices, 20 percent of these can be hazardous nature and because of their high potential for diseases transmission and environmental pollution (International Committee of the Red Cross (ICRC), 2011); Babanyara *et al*., 2013; (World Health Organization (WHO), 2018a); (Yazie *et al.,* 2019).

Since the provision of social amenities such as potable water, security, food, shelter, transport, energy, and communications to the society as well as its economy as a whole must go alongside with appropriate wastes management. it is unforeseen that the medical care services centres which are aimed to cure patients, vaccination, protect all and sundry health against sicknesses as well, has now known as the centres of transmission of infection and means of spreading diseases in the process of handling healthcare cases (United Nation Environmental Protection (UNEP), 2015). This is on the grounds that, the high paces of wastes produced from the healthcare facilities compounded by unsustainable MW management have been accounted for to have prompted expanded dangers in ecosystem contamination and infections transmission (Hassan *et al*., 2017; Yazie *et al.*, 2019; Ghimire, 2020). Consequently, the waste produced must be properly discarded for the safety of general public (ICRC, 2011).

Regardless of this, general society and political profiles of MW management in developing nations are regularly less fortunate than other utilities provision. Lamentably, the results of doing close to nothing or in any event, nothing to address improper MW management can posed significant environmental pollution and general public health risks (UNEP, 2015). Along these lines, great dynamic about how we deal with the waste we make is one of the most significant commitments mankind can have to diminishing its effect on the normal world. This is on the grounds that, ecological maintainability is the centre issue that should be tended to for advancement to concentrate on human prosperity. However, about 75 - 90% of wastes generated by healthcare activities are categorised as general or non-hazardous wastes while the remaining 10 - 25% are classified as hazardous or infectious wastes (Healthcare waste Management guideline (HWM), 2018; WHO, 2018a and Ankita *et al*., 2019). In developing nations, wastes are not regularly separated and arranged into risky or dangerous classes making the whole waste generated hazardous (WHO, 2018a).

These wastes are both in solid and fluid structures and by and large, a standard hospital produces 750 litters of wastewater on average for each bed every day with the present of pathogenic microorganisms, pharmaceutical materials, radioactive components and other harmful synthetic substances. It was ascertained that, the individuals as well as the general public can be infected by micro-organisms loaded in wastewater if not appropriately discarded (Babanyara *et al*., 2013). It was affirmed that wastes produced in the healthcare centres entail a profound risk of danger as well as contamination than general or municipal solid waste (Babanyara *et al*., 2013). The UN submission at the convention considers MW as the second most hazardous wastes after atomic emissions. Those waste pose serious threats to public and environmental health because of the potential to transmit diseases, pollute the air, contaminate soil, surface and underground water sources with the pathogenic, heavy metals and toxic substances present in it. In this manner, MW require explicit treatment before final disposal in order to protect public health and environment (Sabiha *et al*., 2008; Karki *et al.,* 2020).

Scholars referred MW as all the wastes generated by all health care activities, research offices and related labs (ICRC, 2011) and (Ahmed *et al.*, 2018). They additionally incorporate wastes formed by home human activities, for instance, dialysis and insulin infusions (WHO, 2018a). Yearly an expected 16 billion injections are given around the world, however not the entirety of the needles and syringes are discarded appropriately (WHO, 2018a). In developing nations, searching families get by reusing untreated waste materials due to free accessed to open unsanitary destinations and these are at incredible dangers particularly from sharp wastes from hospital facilities. The position of World Health Organization (WHO) which evaluated that, exposed to untreated waste syringes alone responsible between 8 to 16 million cases of hepatitis B while, 2.3 to 4.7 million cases of hepatitis C and 80,000 to 160,000 cases of HIV consistently (Emmanuel *et al.*, 2007). Similarly, the reported findings indicated that, exposure to untreated hazardous MW caused the dead of about 5.2 million people and 4 million children in the world each year from MW related transmission diseases (Akter, 2007). Also, in 2010 risky syringes cause 33,800 new contaminations instances of HIV, hepatitis B and hepatitis C (WHO,2018a).

In many developing nations, guidelines administering safe management of MW are either missing or inadequate. In these nations, unsustainable clinical wastes management practices such as poor separation, treatment and final disposal affect the environment and potential for the transmission of diseases. The submission on appraisal done in 22 Africa nations by WHO shows that, ranges from 18 to 64% of healthcare facilities (HCFs) in the region does not utilize legitimate waste removal techniques (WHO, 2004). Notwithstanding the way MW are rarely ineffectively dealt with in these nations making extra environmental fiascos since MWs likewise contain a huge extent of polyvinyl chloride (PVC) plastics. At the point when PVC plastics are burned, they discharge dioxin into the atmosphere. Dioxin is a lipophilic and bio-aggregate poison, which climbs the natural way of life effectively from plants to creatures and afterward to individuals. Dioxin is a notable human cancer-causing agent, endocrine and destruction of immune system through the water and air transportation (Esubalew, 2015).

As indicated by WHO (2019), air contamination in Nigeria is deteriorating, as figures from the 2017 State Global Air database ((SOGA) demonstrated that the nation drove Africa in air contamination related deaths. As indicated by the report of Health Effects Institute and the Institute for Health Metrics and Assessments, more than 114,000 unexpected premature deaths in Nigeria in 2017 were inferable from air contamination. As indicated by the 2019 SOGA report discharged on Wednesday 3 April 2019, Western

Sub-Saharan Africa has the second most noteworthy particulate issue (PM2.5) exposures on the planet, with Niger (94 µg/m^3) positioning the most elevated. Cameroon was second most noticeably awful with (73 µg/m^3) and followed intently by Nigeria (72 µg/m^3). In the West Africa sub state in 2017 around 264,000 losses of lives were credited to air contamination. In Nigeria, contamination levels surpassed the WHO rule for open air PM2.5 as much as multiple times (WHO, 2019).

The WHO also, suggested yearly rule for PM2.5 is 10 µg/m^3. PM2.5 are ultra-fine particles of 2.5 micrometres or less in measurement, which are connected to heart infections, stroke and lung malignant growth. However, in Nigeria, urban areas do not consistently screen and report their air quality. Air contamination in Nigeria is caused essentially by fumes from vehicles, flames from waste material and diesel generators (WHO, 2019). There is a critical connection between the air pollution and MW management practice in the region, since surface open burning of mixed MW is the commonest practice in those countries. In most developing countries, including Nigeria and Niger State in particular, the use of substandard incinerators and pits/open surface burning of medical wastes are common practice which profoundly contributes to the air pollution problems in the region (Plate 1).

Plate I: Treatment and final disposal practices in the study areas (Open surface burning) (Source: Field work, 2018)

Unfortunately, studies in this regard in developing countries are few and limited in scope. Indeed, this gap requires a wider research. Similar submission by Omofunmi *et al.* (2016); Yazie *et al.* (2019) has it that, in developing countries, practical information on hospital wastes management is inadequate and limited in scope especially those for the development of strategic management plans for hospital wastes. Though, information on MW management practice in Niger State is limited in both primary and tertiary care facilities asserting that, MW is poorly handled in respects to segregation, treatment, collection, transportation and training of healthcare personnel. It was also established that, the techniques of wastes treatment/handling before disposal as well as the management agencies required for hospital wastes treatment were lacking (Shaibu, 2014).

To establish effective sustainable MW management system, it is imperative to know the current practice, wastewater treatment practices, healthcare waste composition and generation rates. The significance of the forgoing has been highlighted by their inclusion in Sustainable Development Goals (SDGs). Specifically, SDG 3 emphasizes the **i**nsurance of healthy living and promotion of well-being for all at all ages (United Nation (UN), 2019). Strengthening primary health care on medical wastes generated, their management practices and adequate motivation of professional workforce in terms of funding and other supports. Sadly, however, these are far from the reality in most developing countries. Thus, the realization of SDG 11 goal is a far-fetched issue in most developing countries (UN, 2019). Consequently, these will contribute to the large amounts of healthcare wastes being generated. Therefore, a comprehensive research is required for the development of a sustainable MW management system that can minimize the health and environmental risks in a given country. Thus, Niger State, if it is to be recognized in the committee of states that are ready to realize the SDG goals especially SDGs 3, 6 and 11, needs to consider management of wastes and particularly the healthcare wastes a major issue in its fiscal planning. However, with the promotion of circular economy and its application in MW management thus, will lead to the significant attainment of the SDGs, particularly SDGs 3, 6, 9, 11 and 12 (Adenaike and Omotosho 2020).

1.2 Statement of the Research Problem

The interactions with key ministries, departments and agencies in Niger State, profoundly helped this study in identifying the major issues associated with the current practices of MW management in the selected hospitals. Although some researches have been carried out in Nigeria and Niger State, notably are those by Umar and Mohammed (2014), Joshua *et al*. (2014), Shaibu (2014), Olufunsho *et al.* (2016), Omofunmi *et al.* (2016) and Sawyerr *et al.* (2017), they have been characterised by limited coverage of core issues.

The previous scholarly work did not cover MW composition, generation rates, characteristic of wastewater generated, their treatment as well as current MW management practices of the large public and private hospitals in the state. Furthermore, there paucity of reports on the available management practices, policies and strategic plans for sustainable MW management in Niger State.

1.3 Aims and Objectives

The aim of this study was to identify the environmental and health implications of current medical wastes management practices in selected hospitals in Niger State, Nigeria. This aim was achieved through the following specific objectives:

i. Examination of the current practices of medical waste management in Niger State.
ii. Determination of the characteristics of hospital wastewater

iii. Investigation of morbidity in children (≤ 10 years) within the medical waste disposal and treatment of the study area.

iv. Determination of the compositions of solid medical wastes and generation rate.

1.4 Research Questions

i. What are the current management practices for medical waste operational systems in healthcare establishments in Niger State?

ii. What are the characteristics of hospital wastewater?

iii. What are the impacts of the use of sub-standard medical waste incinerators and other disposal methods on the vulnerable population surrounding such operations?

iv. What are the compositions and generation rates of medical wastes generated?

1.5 Justification of the Study

The justification of this research is based on threats of poor MW management to human life and environment due to low awareness of its pollution among the stakeholders, particularly in less developed nations and Niger State specifically. This study sought to create awareness among the stakeholders. Since improper handling of MW leads to transmission of different kind of diseases and environmental pollution imposing huge costs on the public and the government, investigation of hospital wastes management and treatment is germane. Disposal of unsafe medical wastes such as contaminated syringes and needles (Plate II) has been reported to have caused 21 million hepatitis B virus (HBV) infections making 32% of all new infections, 2 million hepatitis C virus (HCV) infections

(40% of all new infections) and at least 260,000 HIV infections (5% of all new infections) (WHO, 2018). Thus, investigation of this issue in the study area is very important.

Plate II: Open surface mixed medical wastes disposed. Source: Field survey, 2019

Also, this study is germane due to following contributions: Ascertained the issues surrounded the current practices of MW management at the public and private healthcare facilities in the state, the results and recommendations from the study can be utilized to help ensure sustainable MW management the state thus, help to reduce environmental impacts, health risks to patients, healthcare personnel, visitors and the community at large. In addition, findings of the study could provide an opportunity to the Ministry of Health to collaborate with the relevant stakeholders in terms of training on best global practices on proper management of MW and the research may also help the Government in developing policies and planning strategies to address the current practices of MW management in the state.

1.6 Scope and Limitation of the Study

The study covered Ten (10) selected hospitals in the geo-political zones of the state. One referral hospital in the state (IBB Specialized Hospital Minna); Six (6) General hospitals (GH); In addition, three (3) private hospitals (one from each zone) were studied. The hospitals selection profoundly depended on the research topic as the implications of MW are influenced by hospital size, proportion of inpatients and outpatients treated on a daily basis, type of healthcare establishment, hospital specialization, hospital location and established waste management methods (Razali and Ishak, 2010). In this study, MW management practices, hospitals wastewater treatment system, waste composition, their implications on the environment and human health particularly children less than or equal to the age of 10 years were examined. In addition, the wastewater from these hospitals were collected and examined for some microbial and physico- chemical properties. Thus, this study aimed at examining hospital waste composition and generation rate, wastewater quality parameters and morbidity on children exposed to them.

1.6.2 The limitations of this research

The key limitations of this study were difficulties in terms of obtaining information from the doctors who were too busy by attending to the patients and several numbers of visits to some parents in order to obtain the required information on their children concerning the topic of study.

1.7 Study Area

The study which was investigated in Niger State, North-Central Nigeria involved selected towns in three political zones of the state (Minna, Kontangora, Bida, Suleja and Wushishi). The state has a land area of 76,363 square kilometres with population of

4,082,558 (National Population Commission, Census 2006). It is bordered by Kwara and Kogi states in the South West. FCT and Kaduna state in the North East. The state is also bordered by Kebbi and Zanfara states in the North West. Niger State is within the savannah region (Ministry of Land and Survey, 2019). Figure 1.1 shows the location of the study area.

The study covered 10 selected hospitals (Table 1.1). The public hospitals with respective bed capacities; IBB Specialized Hospital Minna (100), General Hospital Minna (296), Minna Public Hospital New Extension (150), Public Hospital Kontagora (250), Public Hospital Bida (100), Public Hospital Suleja (140) and Public Hospital Wushishi with 87 bed capacities were chosen for the research work. Also selected for this study as the private hospitals with their bed capacities were; Standard Hospital Minna with 50, Maraba Hospital Bida with 20 and Al-Azeez Hospital Kontagora with 24 respectively. These are amongst the largest hospitals which generate considerable amounts of hospital solid wastes and wastewater in the state. Since they have the average flow of inpatients and outpatients of between 50 and 200 per day.

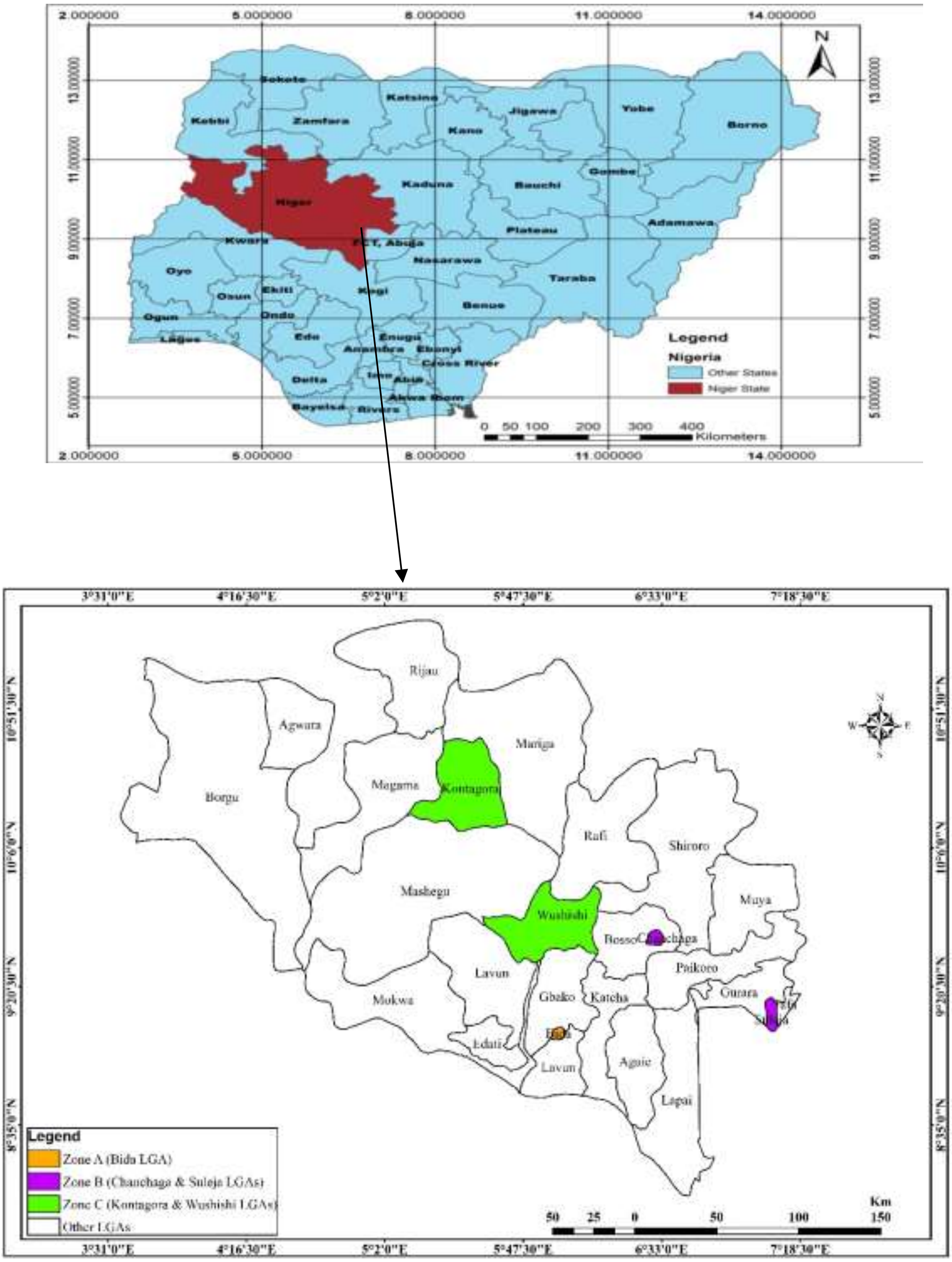


Figure 1.1: Location of the Study Area in Niger State, Nigeria.
Source: Remote Sensing and GIS Lab., FUT Minna, 2018.

Table 1.1 Distribution of the Location of Selected Hospitals in the Study Areas

S/N	Hospitals	Location	Zone
01	General Hospital	Bida	A
02	Maraba (Aisha Usman Hospital	Bida	A
03	IBB Specialist Hospital	Minna	B
04	General Hospital Minna	Minna	B
05	General Hospital New Extension	Minna	B
06	General Hospital	Suleja	B
07	Standard Hospital Minna	Minna	B
08	General Hospital	Kontagora	C
09	General Hospital	Wushishi	C
10	Al-Azeez Hospital	Kontagora	C

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Key Concept

The medical waste management (MWM) issues attracted consideration for the first time and discussed at the United Nations Conference on Environment and Development, UNCED (1992). MWM has from that point forward, become an issue of logical examination and political consultations as a result of its potential health hazards, environmental impacts and policy issues of national interests. The common interchangeably synonyms to MW used in different parts of the world are healthcare wastes, clinical wastes, hospital wastes and bio-medical wastes.

Many researchers, international NGOs and other global institutions defined MW differently. Indian Government in (2016), through the Ministry of Environment used biomedical waste (BMW) as any waste generated as a result of diagnosis, treatment, or immunization of humans being or animal as well as research activities in the production or testing of biological vaccines. According to ICRC (2011) and the precautionary principle, healthcare waste (HCW) is defined as about 75-90% of the total waste generated from a healthcare facility (HCF) is similar to general or domestic wastes such as paper, plastic, packaging and food preparations that have not been in contact with patients. This fraction also, referred to as healthcare general waste (HCGW). If these categories of wastes are not segregated properly, from hazardous wastes 10-25% the entire volume of HCW is considered as being infectious wastes according to the precautionary principle. Therefore, proper safe and integrated wastes management systems in a given country or community is germane. This is because exposure to HCW can result in transmissions of diseases or injuries due to the characteristics of hazardous nature of HCF\W Harhay *et al*. (2009). Mohammed and Sandeep (2019) defined BMW as all types of waste such as liquid and solid waste generated as a result of treatment, diagnosis and operations of human being and animals.

The submission by Al-Mutair *et al.* (2004) referred to clinical waste as any solid or liquid wastes capable of causing infectious diseases, produced during patient diagnosis, treatment and immunization of humans or animals. The definition of clinical waste by Awodele *et al*. (2016) as the waste generated from the investigation, treatment or medical care of patients, while Abor and Bouwer (2008) focused their definition on all types of wastes generated by healthcare facilities. The WHO (2014) based it on healthcare waste products produced at healthcare centres such as sharps, non-sharps, blood, body parts chemicals, pharmaceuticals, medical devices and radioactive materials.

According to the WHO (2004) suggests that around 80% of healthcare wastes are non-hazardous, 15% are hazardous/infectious wastes from infected patients or wastes contaminated with blood. While, sharps (1%), toxic chemicals and pharmaceuticals (3%) and genotoxic and radioactive wastes (1%) (WHO, 2004); (Ahmed *et al*., 2018). By the forgoing therefore, this study defined MW as all types of solid or liquid hazardous and non-hazardous wastes generated as a result of patient diagnosis, treatment, prevention of diseases or in related researches that pose danger to the environment and public health.

2.1.1 Sources of medical wastes

Medical waste can be classified into two sources. Major or minor. The greater part of MW is by and large created by medical clinics or hospitals, for example, College or Teaching university, general and district hospitals. Other major MW include: medical care (MC), maternity clinics and outpatient facilities, dialysis units, transfusion units and military clinical centres. Notwithstanding these are connected laboratory, for example, clinical and biomedical labs, biotechnology labs, clinical examination communities, mortuary, blood donation centres and animal research and testing centers. While the minor MW are: little health-care establishment's such as physicians' offices, dental centres, home treatment, ambulance services and funeral services (WHO, 2011).

2.1.2 **Types of medical wastes**

The MW are classified into two types: general or non-hazardous wastes; in this classification roughly 75-80% of the total waste generated in medical care centres is general waste or non-hazardous (WHO,2018a); (Ahmed *et al*., 2018); (Yazie, 2019). It comes for the most part from managerial and housekeeping exercises and the services of maintenance units. These incorporate wastes involving food leftovers, paper containers, fruit peels while the 10-25 % MW generated are considered unsafe or infectious and may pose dangers into the environment and health risks (Visvanathan, 2006); (Chartier *et al*., 2014); (Ahmed *et al*., 2018); (WHO, 2018a);

Most damage is brought about by infectious and pathological wastes (15%). Other dangerous MW are sharps (1%), synthetic substances and pharmaceuticals which represent about 3% of dangerous MW. Then again, genotoxic, radioactive issue and substantial metals amounted to 1% of all out risky MW. It has gotten critical to take note that if both these categories are combined and disposed of the entire waste becomes hazardous (Babanyara *et al*., 2013) and (WHO,2018a).

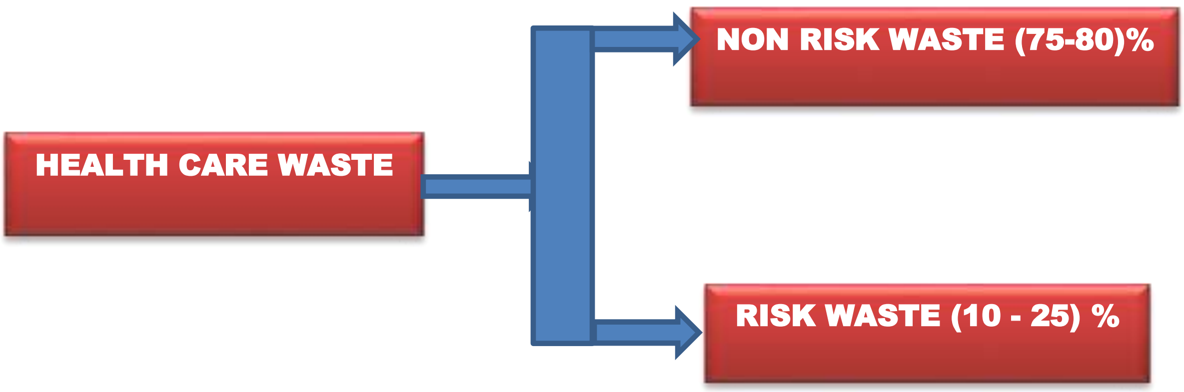


Figure 2.1: Types of Medical Wastes (Ahmed *et al.*, 2018)

2.1.3 Classification of medical wastes

Medical wastes could be classified into the following categories

2.1.3.1 *Infectious wastes*

The present of pathogens (infections or growths) in adequate amounts to pose health risks. They incorporate disposed of materials utilized for the finding, prevention and treatment of infections, for example, swabs and dressings. This gathering likewise incorporates fluid wastes, for example, patient urine, blood and sputum or lung infection discharges (WHO, 2005); (Visvanathan, 2006) and (Alhadlaq, 2014).

2.1.3.2 *Pathological wastes*

This category of wastes includes tissues, blood, body parts, human embryos, carcasses of animal, blood and body liquids and different wastes from medical procedure. These are additionally called anatomical wastes and this classification could be considered as a subcategory of irresistible waste despite the fact that it might likewise incorporate sound body parts (Pichtel, 2005); (Visvanathan, 2006).

2.1.3.3 ***Sharps wastes***

Sharps are any objects or things that could cause cuts or cut injuries including different cutting edges, blades, saws, mixture sets, broken glass and nails. Regardless of whether they are tainted these things are generally considered profoundly risky (WHO, 2005); (Ananth *et al.*, 2010).

2.1.3.4 ***Hazardous Pharmaceutical wastes***

Pharmaceutical wastes incorporate expired, lapsed, vaccines, unuse medications, antibodies and sera that are not, at this point required and should be discarded cautiously. These likewise incorporate disposed of things utilized in treatment of pharmaceuticals, for example, gloves, covers, bottles or boxes with build-ups, associating tubing's and medication vials (WHO, 2005); (Schwartz *et al*., 2010).

2.1.3.5 ***Genotoxic wastes***

The category of this wastes is gotten from drugs that are profoundly perilous and may have properties of mutagenic, teratogenic or cancer-causing which are mainly administered in the oncology or radiotherapy units, whose primary job is treatment of cancer. Those wastes pose serious safety issues, both at temporary storage inside the medical clinics and after final disposal. This class of wastes may likewise incorporate regurgitation, pee, or patients defecation administered with cytostatic medications and radioactive material ought to be considered genotoxic from 48 hours and some of the time as long as a week after serving the medication. Special treatment of these wastes is germane (WHO, 2005); (Prüss *et al.*, 2013).

2.1.3.6 *Chemical wastes*

The category of this wastes comprises of disposed of solid, fluid and vaporous synthetic compounds that are created during indicative and exploratory work. They could likewise be from cleaning, housekeeping, and sterilizing systems. These wastes might be risky (poisonous; destructive; combustible; responsive) or non-hazardous in the event that they comprise of synthetic compounds with nothing from what was just mentioned properties and instances of these are sugars and amino acids (Chartier *et al.*, 2014). These hazardous MW with high contents of heavy metals such as cadmium or mercury from thermometers or manometer also come under this category and required proper treatment (Fu and Wang, 2011). The sort of these dangerous hospital wastes includes; Phenol-based synthetic substance utilized for cleaning floors known as organic chemical wastes, perchlorethylene utilized in workshops and laundries. Others incorporate; bug sprays and rodenticides (Fu and Wang, 2011).

Though, inorganic category of this wastes comprises for the most part of acids, for example, hydrochloric (HCl), nitric (HNO3), chromic (H2CrO4) and sulphuric (H2SO4) and soluble bases, for example, sodium hydroxide (NaOH) and smelling salts arrangement (NH4OH). Different oxidants, for example, potassium dichromate (K2Cr2O7), potassium permanganate (KMnO4) and diminishing operators, for example, sodium bisulphite (NaHSO3) and sodium sulphite (Na2SO3) are likewise found in this class (Fu and Wang, 2011). Similarly, chemical wastes from photographic. These are photographic fixing and developing chemical solutions used in x-ray units/ departments. The fixer as a rule contains 1-5% of potassium hydroxide, hydrounione 5-10%, and under 1% silver. While Acidic corrosive is utilized in both stop showers and fixer arrangements (Fu and Wang, 2011).

2.1.3.7 *Gas pressurized containers*

Normally various kinds of gases utilized in medical clinics are frequently put away in pressurized cylinders and aerosol cans. When unfilled or of no further use, which may even now contain little quantity. While mist concentrate sprayer types must be discarded, regardless of whether latent or possibly hurtful, gases in pressurized holders should consistently be maneuverer carefully since they may detonate if incidentally punctured or burned (WHO, 2005) and (Alhadlaq, 2014).

Table 2.1: Most Common Gases Used in Healthcare Services

Anaesthetic gases	**Ethylene oxide**	**Oxygen**	**Compressed air**
Nitrous oxide, volatile Halogenated hydrocarbonss (such as haloethane, isoflrane, and enflrane). Applications-in hospital operating theaters, during childbirth in maternity hospitals, in ambulances, in general hospital wards during painful procedures. In dentistry for sedation	Applications-for sterilization of surgical equipment and medical devices, in central supply areas, and, at times, in operation rooms.	Stored in bulk tank or cylinders, in gaseous or liquid form, or supplied by central piping. Application is inhalation supply for patients.	Application-in laboratory work, inhalation therapy equipment, maintenance equipment, and environmental control system

Source: Prüss *et al*, 1999

2.1.3.8 *Radioactive wastes*

These are gases, fluid and solid substances tainted with radionuclides whose ionizing radiations have genotoxic impacts (Demirbas, 2011). They are created because of systems, for instance, *in-vitro* analysis of body tissues and liquids, (Demirbas, 2011); (WHO, 2005)

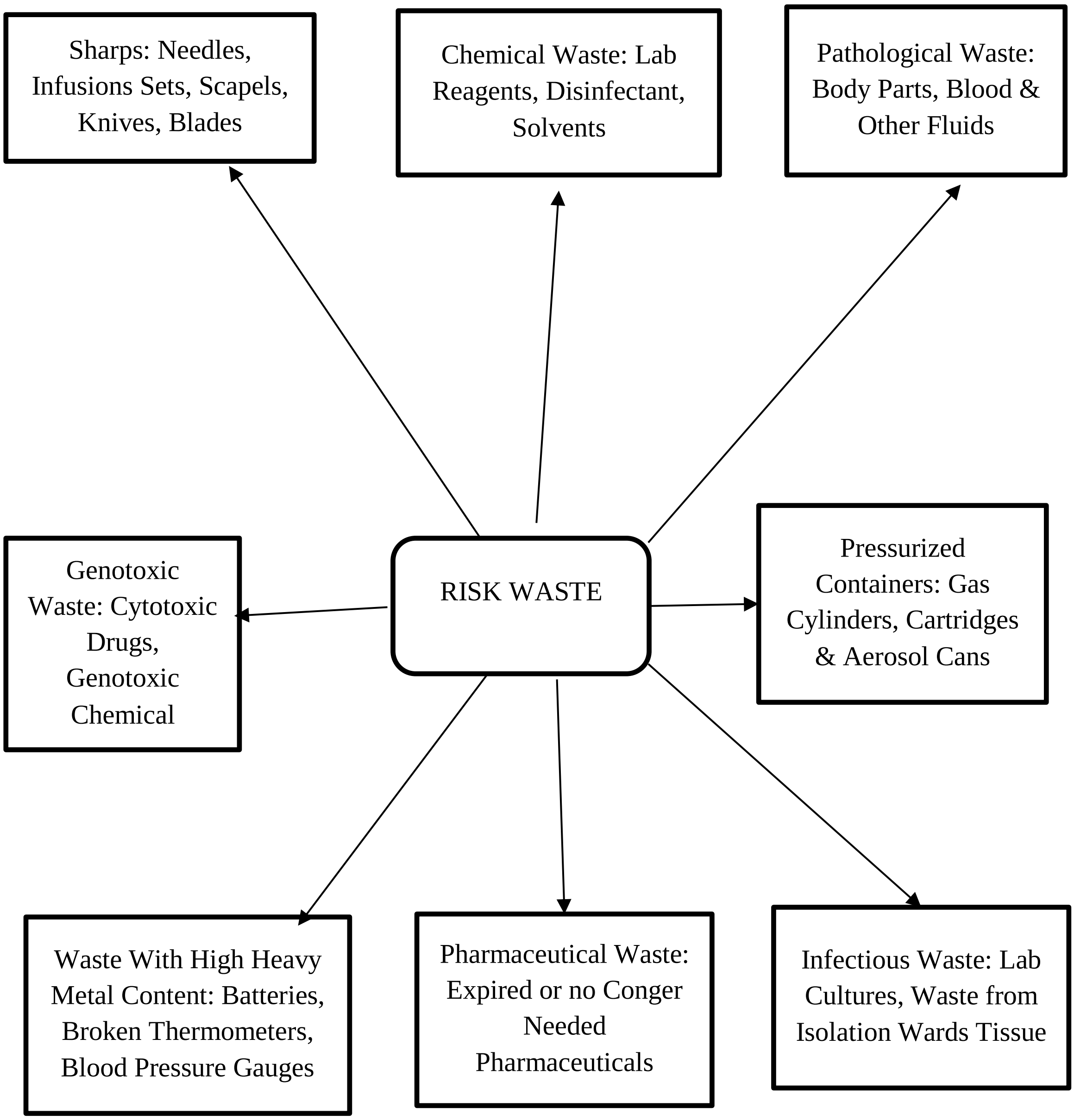


Figure 2.2: Categories of harmful medical waste (Designed by the researcher)

2.1.4 Technical guidelines on medical waste classification

The biomedical or healthcare wastes classifications (Figure 2.3) depend on specialized rules on environmentally sound management (ESM) as agreed by the parties at the Basel Convention on the Control of Trans-boundary Movements of Hazardous Waste and their final Disposal (UNEP/SBC, 2002)

2.1.4.1 *A. Non-risk healthcare wastes (NHCW)*

The NHCW are the kind of wastes generated from hospital that have not been infected, for example, general office and unused food. They are in comparable classes to the ordinary family unit or civil waste and can be overseen by the city waste administrations. They constitute the range of 75 and 90% of the aggregate sum of NHCW produced by clinical centres (UNEP/SBC, 2002). Three categories are classified (A1, A2 and A3). A1. Recyclable wastes: They incorporate paper, cardboards, non-defiled plastics or metals, jars or glass that can be reused for various purpose. A2. Biodegradable NHCW: This classification of waste involves unused food or plants wastes that can be composted and A3. Other NHCW: Additionally, this classification incorporates all the NHCW that don't have a place with classifications A1 and A2.

- **A: Non-risk health care waste**
  - **A1**: Recyclable waste
  - **A2**: Biodegradable waste
  - **A3**: Other non-risk waste
- **B: HCW requiring special attention waste**
  - **B1**: Human anatomical waste
  - **B2**: Sharps
  - B3: Pharmaceutical waste
    - **B31:** Non-hazardous Pharmaceutical waste
    - **B32:** Potentially hazardous Pharmaceutical waste
    - **B33:** Hazardous Pharmaceutical waste
  - **B4**: Cyto-toxic pharmaceutical waste
  - **B5:** Blood and body fluids
- **C: Infectious and highly infectious waste**
  - **C1**: Infectious waste
  - **C2**: Highly infectious waste
- **D: Other hazardous waste**
- **E: Radioactive waste**

Figure 2.3: Classification of health-care wastes (Source: UNEP/SBC, 2002)

2.1.4.2 *B. Hazardous healthcare waste (HCW) requiring special attention*

B1: Anatomical human wastes: This type of waste constitutes non-infectious and infectious parts of human body, organs, tissues and blood bags. The examples are tissue waste, removed organs, amputated body parts, and placentas. B2: sharps waste: are all objects and waste materials with characteristic of puncture or cut property, example of such wastes includes needles, ampoules, scalpel blades, broken glassware, lancets and vials without content which are closely associated with medical care activities and when expose to it pose a potential risk of injury and infection. Thus, these categories of MW are classified as one of the most hazardous wastes generated in the HCF and requiring special attention (UNEP/SBC, 2002). B3. Pharmaceutical wastes: This class of wastes includes expired pharmaceuticals drugs and unusable drugs and these categories are divided into three classes. B31. This category are non-hazardous pharmaceutical wastes that poses no hazard during collection, intermediate storage and treatment. They are not considered hazardous wastes and have similar management to municipal waste. The examples of such waste include camomile tea or cough syrup (UNEP/SBC, 2002).

B32. Potentially hazardous pharmaceutical wastes: This class of wastes required treatment and appropriate waste disposal facility due to potential hazard they pose when used improperly. (UNEP/SBC, 2002). B33. Hazardous pharmaceutical wastes: This class of hazardous wastes are wastes comprising heavy metals and unidentifiable pharmaceuticals as well as disinfectants, which require proper management. B4. Cytotoxic pharmaceutical wastes: This class of wastes have the properties of mutagenic, carcinogenic and teratogenic. These wastes are generated during the administration of drugs to patients as well as manufacturing. The mixtures of this drug are; alkylated substances, antimetabolites, antibiotics, plant alkaloids and hormones. Thus, these wastes pose great hazard and require scientific management (UNEP/SBC, 2002). B5. Blood and body fluids wastes: This category of wastes become infectious or contaminated when mixed with infectious human or animal blood, secretions and excretions waste. Examples of such wastes are syringes without needles, dressing materials, swabs and infusion equipment without spike, bandages (UNEP/SBC, 2002).

2.1.4.3 *C. Infectious and highly infectious wastes*

This category of wastes needs special attention and should be treated with most extreme consideration: C1. Infectious wastes: This category of wastes is usually generated in the isolation wards of hospitals, pathology departments, theatre operating rooms, dialysis wards. In this case, all the wastes from such units could pose great risks to the general public if not handle properly. This class of MW also includes; blood of HIV patients, hepatitis viral, faeces from typhoid fever patients, enteritis, cholera, brucellosis, Q fever, respiratory tract, secretions from TB patients, anthrax, rabies and poliomyelitis (UNEP/SBC, 2002).

C2. Highly infectious wastes: This class of wastes are generated in medical laboratories, virology and microbiology. Examples of these wastes include all types of devices and dishes used to transfer, inoculate and cultures of infected patients and animals from. Usually, it is the healthcare workers particularly nursing staff and wastes handlers who are at risk of infection through contaminated needles as regards viral infections such as AIDS and hepatitis B and C (UNEP/SBC, 2002).

2.1.4.4 *D. Other harmful wastes*

This category of waste is not limited to the healthcare facilities. These include gaseous, liquid/solid chemicals and heavy metals. These hazardous wastes have the properties of toxic, corrosive, flammable, reactive, explosive, shock sensitive and cyto- or genotoxic. The disposal of these wastes must be according to the guidelines provided with each type of chemical substance (UNEP/SBC, 2002).

2.1.4.5 *E. Radioactive health-care wastes*

The category of this wastes includes, solid, liquid and gaseous waste generated from in vitro examination of body tissues and fluids, *in-vivo* body organ imaging, tumour localization, investigative and therapeutic procedures which are contaminated with radionuclides (UNEP/SBC, 2002).

2.2 Hospital Waste Generation Rate

Several evidences from researchers agreed that MW generation varies from country to country and also within different hospitals of a city or state of a country (Farzadkia *et al.*, 2015). MW generation depends on various factors which includes income levels, socio-cultural patterns, climatic factors, established waste management practices system, daily number of inpatients and outpatients treated, hospital location, type of healthcare establishment and hospital specializations. Statistical analysis is always be performed in order to evaluate the relationship between these important factors and the amounts of healthcare wastes generated (Eker and Bilgili, 2011). Table 2.2 indicates that, high-income countries usually generate higher wastes than low and middle-income countries (WHO, 2005).

Table 2.2: Waste Generation Rate per Bed at Hospitals

Countries	Daily waste generations (kg/bed)
England	3.3
Brazil	3- 5
Taiwan	2.41-5.26
Libya	1.3
Canada	1.5- 3.9
Tanzania	2.4

Germany	3.6
Bangladesh	1.2
Nigeria	0.6-1.7
Dhaka	1.2
Turkey	0.63

Source: Farzadkia, *et al*. (2015)

Another submission that, the generation of HCW rate varies from hospital to hospital and at different times (Rahele and Govindan, 2013). The MW generation rate data is germane for the development of sustainable hospital waste management strategies (Kagonji and Manyele, 2011). A wastes examination study conducted in Jordan affirmed that there was high factually critical direct connection between the number of patients and quantity of daily wastes generated similarly, a lower significant statistically relationship between the number of beds and MW generated daily (Awad *et al.*,2007).

2.3 Reasons for Medical Waste Management Failure

The associated factors that lead to waste management failure particularly in developing countries includes; absence of medical wastes policy, guidelines and strategies plans, inadequate training on MW management and disposal systems, low level of awareness on the environmental and health hazards related to MW as well as insufficient financial or zero MW management budget allocation. These are the critical problems associated with medical wastes management. In addition, lack of political well toward MW management makes it difficult to achieve sustainable waste management system. To achieve safe and sustainable management of healthcare wastes therefore, all aforementioned factors require urgent attention at all levels (Babanyara *et al.*, 2013; Yazie *et al.*, 2019; Karki *et al.*, 2020).

2.4 Medical Waste management Methods

Waste classification, waste segregation, waste minimization, waste containers, colour coding, labelling and signage, handling, transport, storage, treatment and final disposal of waste. These are the key independent variables of a healthcare waste management system. Other includes: training, assessments and planning, budgeting, monitoring and evaluation (Prüss *et al.*, 1999).

2.4.1 Medical waste segregation

Medical waste segregation is the fundamental step of sustainable waste management. According to WHO (2018a), MW segregation involve separation and sorting of wastes into different categories. Implementation of proper segregation would greatly reduce the cost of treatment and disposal of MW. Generally, segregating medical hazardous from general or non-hazardous wastes profoundly reduces the risks of infecting healthcare workers, wastes handlers as well as the general public. In developing countries MW are not segregate or improperly done (Zarook and Shareefdeen, 2012). Sorting of MW according to their colour containers is the appropriate way of identifying the categories of MW (Dohare *et al.*, 2013; Alhadlaq, 2014). However, WHO (2005) submission that, storing of MW in colour-coded, well-packed and labelled containers accordingly to categories of MW was recommended. Essentially, at source of wastes generation segregation must always be applied. In this case, colour coded and labelled waste vessels must be provided at each point close to the points of generation as possible. In addition, many scholars confirmed that, the major reason why hospital waste is collected in mixed forms is lack of awareness and training of healthcare workers in proper MW segregation technique (Yazie *et al.*, 2019); (Karki *et al.*, 2020); (Ghimire,2020).

2.4.2 Handling of medical waste

Proper handling of MW is the next step after segregation, it is essential because, it includes all stages of medical wastes management system (Sarangi and Dhirendra, 2018). The system consists of packaging, labelling and marking of the segregated wastes (Madhya Pradesh Pollution Control Board (MPPCB), 2010). The appropriate steps should be followed when handling HCW, because higher risks are mostly associated at this stage. Therefore, the use of protective kits such as overalls or industrial aprons, boots and heavy-duty gloves by healthcare workers, waste handlers, sanitary staff and cleaners when handling HCW should always be monitor and enforced (WHO, 2018a).

2.4.3 Colour coding/labelling

Colour coding is utilized for simple recognizable proof of categories of wastes. Red or yellow bags are usually used to assign infectious waste in most nations, while general waste is assigned with black or clear bags. International biohazard symbol in a clear colour should also be included in infectious waste containers (Prüss *et al.*, 1999). In a similar submission that, “Biohazard Wastes” or international biohazard symbol are words labelled on MW contained in a red biohazard bag (Bala and Narwal, 2013). To sustain safety, therefore, MW are sufficiently marked or coded so as to decrease their dangerous consequences for the handlers or the surrounding environment. Table 2.3 shows the recommended colour coding scheme of HCW. So also, the international symbols of biological medical wastes are presented in Table 2.4.

Table 2.3: The Recommended Colour Coding Scheme of Healthcare Waste

Type of waste	Colour container and making	Type of container
Highly infectious waste	Yellow, marked Highly in factious	Strong, leak-proof plastic bags or container capable of being autoclaved. `
Other infectious waste, Pathological and anatomical waste	Yellow	Leaked-proof plastic bags or container
Sharps	Yellow, marked Sharps	Puncture-proof container
Chemical and pharmaceutical waste	Brown	Plastic bag or container
Radioactive waste	-	Lead box, labeled with the radioactive "symbol
General health-care waste	Black	Plastic bag

Source: WHO, http://www.WHO.com.

Table 2.4: International Symbols of Biological and Medical Wastes

Type of biological and medical waste.	Symbol
Highly infectious biological medical waste	
Burning chemical waste	
Medical waste with environmental hazards	
Radioactive waste	
Toxic chemical waste	
Toxic pharmaceutical waste	
Chemical waste with strong water reaction	
Flammable waste	

Source: WHO, 1998

2.4.4 Storage of medical waste

The storage of MW is very key before final disposal in order to avoid scatter of hazardous wastes on the surrounding. Waste's collection and transportation on regular daily basis to the central storage area is essential (WHO, 2018a). The central storage areas should be well designed in terms of sized and facilities to accommodate the volumes of wastes generated in a particular point and time. Only approved staff should have access and its location should avoid pedestrians, private or public transportation routes and marked clearly with warning signs. Additionally, prevention of rodents, insects or birds from entering it must be put into consideration during the designed stage, the site must be easy to clean, have good lighting system and ventilation as well. Furthermore, wastes store at the central area ought not surpass 24-48 hours before being treated/disposed of especially in warm and humid climates regions (Pichtel, 2005; WHO, 2018a). Separate location from the infectious, hazardous MW and general waste or Non- risk MW is very vital in order to avoid cross- contamination (WHO, 2018a).

2.4.5 Medical waste transportation

Transportation of medical wastes involves moving them from the generation pint or source to temporary site storage facility or to treatment site or disposal facility within the hospital (Hassan *et al*., 2017). The means of transportation includes; wheel bins or trolleys. It is importance to note that the wheel bins or trolley should have no sharp edges that could harm the handlers or damage waste bags, be easy to move, and clearly marked with the right colour coding (Bala and Narwal, 2013). Additionally, transportation of special MW outside the source of generation should be handle by trained staff, attached with a dedicated vehicle with closed covered (UNEP,2015; WHO, 2018a). It is also importance to adequately label the waste to be transported of-site. Thus, the categories of wastes can be quickly identified and appropriate measures applied in case of an accident (Bala and Narwal, 2013).

2.4.6 Medical waste treatment

Medical waste treatment is very vital stage in waste management. Therefore, the application of technology for MW treatment and disposal should always be in line with the objective of profoundly reducing environmental and health implications of MW. Hence, the choice of technologies should be simple to operate, cost effective, available technologies, environmentally safe and sustainable. Additionally, the cultural practices of a particular environment should be put into consideration in choosing technology for the treatment/disposal of MW. Generally, in Muslim and Christen practices, body parts are buried below the ground while other cultures practice cremated (Prüss *et al.*, 1999). The principal aim of treatment of toxic and infectious medical wastes is to render them non-toxic or non-infectious. Therefore, all hazardous or infectious wastes be treated before final disposal (Alhadlaq, 2014). Those treatment technologies include: Incineration, hydroclaving, shredder, autoclaves, retorts, chemical disinfections, microwave disinfection, wet and dry thermal treatments, inertization, and encapsulation (Prüss *et al.*, 1999).

2.4.6.1 *Incineration of medical waste*

Incineration is the commonest method utilized for the treatment of MW particularly in less developed countries including Nigeria and Niger State in particular. Incineration consists of the process of destroying wastes by way of burning at sufficient high temperatures (between 1,000°C and 1,200°C) for a sufficient "time" in a combustion chamber with sufficient "turbulence". These processes as summarized as (TTT) known as key parameters of controlled incineration (Johannessen *et al.*, 2000). Thus, there is a very significant reduction in waste volume, weight and converts it into ashes. Ashes require further treatment, but left in an open space and eventually transported into rivers, well and homes in developing countries and Niger State in particular resulted to environmental pollutions and health risks. Usually wastes such as pathological and infectious waste or sharp wastes that cannot be recycled, reused, or disposed of in a landfill site are suitable for this process (Auta and Morenikeji, 2013). The used of incinerator for the treatment of MW found to release pollutants which have environmental and public health implications (Auta and Morenikeji, 2013; Hassan *et al* 2017; WHO, 2018a; Yazie *et al*., 2019). The advanced countries such as United States, Germany and Netherlands have phased out the use of incineration for MW management due to negative impacts on environment and public health. These countries have moved to treat MW through the use of autoclaves, microwaves and recycling as a way of mitigating environmental and health implications (Prüss *et al.*, 1999); (Innovative Environmental Product (IEP), 2010). In addition, higher operating temperatures is requiring by the incineration process in order to reduce or limit the atmospheric pollution and odours produced. The followings are different types of incineration technology for the treatment of medical wastes:

In another submission that, double chamber or pyrolytic incineration are most reliable and commonly used for the treatment of infectious medical wastes (Prüss *et al.*, 1999). Rotary kilns incineration: This kind of incinerators require higher temperatures and is used to burn chemical MW. The high temperatures caused the decay of genotoxic substances and chemicals with heat-resistant. It accommodates large scale medical wastes such as a regional assemble of MW thus, significantly decreasing the volume of wastes by 50 - 400 times and the cost of disposal reduce which form part of it advantages (Zarook and Shareefdeen, 2012). The disadvantages of this type of incineration are a challenge which includes high costs of operations, higher smoke generation as well as environmental pollution risks. The best incinerator used for the treatment of pathological, pharmaceuticals and infectious wastes in small medical facilities and laboratories is called MediBurn or drug terminator (IEP, 2010). Generally, incinerators used for the treatment of MW produce more furans and dioxins than municipal incinerators due to waste composition categories (United State Environmental Protection Agency (USEPA), 2007).

2.4.6.2 *Disinfection of medical waste*

The infectious liquid MW such as urine, blood, faeces as well as hospital sewage can be best treated by disinfection method This type of treatment is used in treating infectious liquid wastes such as blood, urine, faeces or hospital sewage. It involved the use of (0.5%) of diluted active chlorine solution and other solutions. However, a non-diluted solution of bleach and more than 12 hours contact time are required for liquids wastes with high protein contents such as blood. Similarly, disinfection of solid wastes require waste materials must be shredded to obtain good result. Disinfectants substances have negative impacts and are not use for treating chemicals, pharmaceutical and some types of infectious MW (Zarook and Shareefdeen, 2012).

2.4.6.3 *Disinfection by plasma*

This technology is capable of eliminates and control the formation as well as release of high-toxic metals (dioxins) into the environment (Diaz *et al*., 2005); (Zarook and Shareefdeen, 2012). Generally, very strong disinfectant substances at same time reasonable number are very harmful to skin and mucous membranes. The treatment handlers or officers therefore, require full protective kits (WHO, 2017).

2.4.6.4 *Wet and dry thermal treatment of medical waste*

These processes require that infectious wastes be shredded before treatment while in the case of sharps, milling or crushing is suitable. However, this treatment cannot be used for pathological wastes and incomplete treat pharmaceutical and chemical wastes. The wet thermal treatment has some advantages such as low operating costs and low environmental impact while the disadvantage of this process is the mechanical failure of shredder (Blenkharan, 2006). Similarly**,** dry thermal disinfection process, involve shredded of wastes and heated in rotating augers in continuously operated units.

Consequently, about 25 mm in diameters of shredded waste particles require a temperature of 110-140ºC. Thus, the quantity of wastes is reduced by 80% in volume and 20-35% in weight (Blenkharan, 2006). Effective method for the treatment of infectious and sharps wastes and not good for treatment of pathological, ecytotoxic, or radioactive wastes. (Blenkharan, 2006); (WHO, 2018a).

2.4.6.5 *Autoclaving of medical waste*

Autoclaves is the disinfection process or sterilization of hospitals reusable medical equipment used in different operations. Highly infectious waste such as microbial cultures, sharps, blood contaminated items, surgical residues and laboratory waste. Autoclaves are good for the treatment of these categories of MW (Blenkharan, 2006). Thus, if these processed once complete, the materials become general wastes. Therefore, pre-treating of these highly infectious MW by autoclaving before final disposal is vital (WHO, 2018a). Therefore, it is highly essentially that all general hospitals be equipped with autoclaves. Complete destruction or elimination of pathogens in the waste to occur it require introduction of *Bacillus stearothermophilus*is in to the autoclave with the waste at the beginning of each treatment which requires steam exposure for about 90 minutes and these processes guarantees sufficient pathogen destruction in the MW (Diaz *et al*., 2005); (Blenkharan, 2006). This can be measured at the end of the cycle treatment via spore tests.

The advantages of Autoclaving include: it is simple to operate, facilitates the recycling of plastics and is environmentally friendly while disadvantages are: it requires electricity, higher cost of the machine, contaminated wastewater produced during the process needs to be treated so, additional cost (Johannessen *et al.*, 2000).

2.4.6.6 *Microwave irradiation of medical waste*

Microwave treatment involved shredding of the wastes into small particles and microwaves rapidly heated water contained within the wastes and at this stage heat conduction destroyed the infectious components of wastes at about 2450 MHz and a wavelength of 12.24 cm. Subsequently, the waste is irradiated for about 20 minutes in irradiation chamber which is equipped with a series of microwave generators. After irradiation processes, the waste are no longer infectious materials and sent to the municipal waste stream. The efficiency of these processes can be measured through bacteriological and virological tests (Blenkharan, 2006). The advantage of microwaves; the volume of waste is reducing while disadvantages include; it can only treat solids waste such as sharps and needles, offensive odours around the treatment unit, cannot be used to treat some hazardous wastes such as pharmaceutical and cytotoxic. Other includes; it is highly required skilled operator, very costly. It also, generates contaminated wastewater that require treatment and attract additional cost (Johannessen *et al.*, 2000); (Diaz *et al.*, 2005).

2.4.6.7 *The use of landfills/open surface burning for the treatment of medical waste*

The utilization of landfills or open surface burning remains the most common treatment used for MW developing nations (Yazie *et al.*, 2019). Usually, at such sites mixed MW are deposited and scattered. Scavengers, birds and animals have uncontrolled access to the such sites. Thus, this practice resulted in higher risks of disease transmission as well as environmental acute pollution either directly such as through wounds, inhalation or indirectly through the food chain (Yazie *et al.*, 2019; Karki *et al.*, 2020). Ashes were left open and untreated which transported to rivers, well and homes lead to higher risks of disease transmission. The following are the key factors that must be taken into consideration for the sustainable use of MW for sanitary landfill: Trained staff must be present at the site, landfill most be controlled and restricted access to human being and animals, the bottom of landfill must be waterproofed, spread lime on the waste for health protection or to cleared odour, landfill site should be located far away from residential housing due to odour, the water table must be more than 2 metres below the bottom of the landfill, drinking water sources or wells in the surrounding area site must be avoided and importantly, prevention of rainwater infiltration and collection of leachates and treated at all time (Prüss *et al.*, 1999; Hassan 2017; WHO, 2019;).

The advantages of these method include; Simple to operate, inexpensive, occur within the hospital, hazardous materials remain inside the hospital and scavengers cannot access to the burning point of healthcare waste inside the hospital. The disadvantages are: hazardous MW are not treated before final disposal, pollution of water sources, present of very bad odour, insects and rodents are not controlled and special site is required within the hospital (ICRC, 2011).

2.4.6.8 *Encapsulation/inertization of medical waste*

This process of treatment consists of the mixture of waste and other substances, for example: 65% pharmaceutical waste or other wastes, 15% lime, 15% cement, 5% water. Thereafter, the items are mix and filled up into containers or boxes and allowed to dried, than the dried containers are sealed up and disposed of at approved sanitary landfill or waste burial pit. Advantage of the process is that, migrating of toxic elements contained in the waste into surface or ground water are significantly minimizes or eliminate, simple to operate, inexpensive and safe, no room of scavengers having free access to the hazardous MW while, disadvantage of this treatment allowed small quantities of MW that can be treated and the solution is regarded as a temporary (http://www.who.int/topics/medical_waste/fr/index.html)

2.5 Environmental Releases from Medical Waste Incineration /Open Surface Burning

2.5.1 Bottom ash and fly ash

Process of MW incineration or open surface burning usually not completely burned the waste or incompletely destroy the metallic elements of the waste thus, concentration of heavy metals into the bottom ash (Anamul *et al*., 2012). These are the major concern of environmentalist and researchers because of the persistent risks it poses to the environment and public health as a result of organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), dioxins, polycyclic aromatic hydrocarbons (PAHs) and other organics cancer-causing materials both in bottom and fly ash (Annette *et al.*, 2013). It was ascertained that bottom ash of incinerated or open surface burning of MW contained large heavy metals (cadmium, lead, zinc, chromium, mercury and arsenic). Whereas, organic compounds (dioxins, benzene, PCBs, and other cancer-causing organics). These bottom ashes were left untreated mostly in developing countries. Therefore, the associated health challenges include; acute respiratory syndromes, gastrointestinal abnormalities, and various cancers (Zhao *et al.,* 2010; Auta and Morenikeji, 2013; Mohajer *et al*., 2013).

In addition, the major problem in operating incinerators or open surface burning is the management of its bottom and fly ash (Shen *et al.,* 2010). Bottom ash represents about 75-90% of the total ash content generated by clinical waste incinerators or open surface burning while fly ash, depending on the APCDs, constitute about 2-3% (Auta and Morenikeji, 2013). In addition, bottom ash has attracted scientific interests and researches on its chemical contents and potential impact on environment and public health (Auta and Morenikeji, 2013). On the other hand, fly ash attracts less scientific interests and researches probably, due to its limited amount (Auta and Morenikeji, 2013).

2.5.2 Inorganic releases

The process of incinerators/open surface burning of hospital wastes released heavy or trace metals which are associated with environmental and health implications (Yazie *et al.*, 2019). Other pollutants which might be present include mineral oxides and various organic compounds. In the case of fly ash which contains fine particles that rise with the flue gas and substantial amounts of SiO2 and CaO, including heavy metals and organic substances which may vary from trace amounts to several percent (National Research Council of the National Academies (NRC), 2006); U.S.EPA, 2007). They can travel long distances before falling to earth and can accumulate in the food chain.

2.5.3 Organic releases

The organic compounds such as PCBs, PCDD/Fs and PAHs which are contained in the bottom ash from MW incinerators/ open surface burning, those substances are left untreated some can be transported cover long distances before falling into the environment which gradually accumulate in the food chain. It can produce toxic effects in humans at extremely low doses (International Agency for Research on Cancer (IARC), 1987); U.S.EPA, 2001). The general main concern over the release of organic compounds into the environment is because of its environmental impacts and health hazards. Therefore, MW with the chlorine concentrations and other dangerous substances need to be sorted (NRC, 2006; U.S.EPA, 2007).

2.5.4 Gaseous emissions

Gaseous emissions released directly into the atmosphere such as total PM, acidic gases such as hydrogen chloride, hydrogen fluoride and suphur (III) oxide, dioxide, various organics and metals, CO, NOX and other materials such as cytotoxins, pathogens and radioactive diagnostic materials (Mbongwe, 2008) from the used of incineration/ open surface burning for the treatment of MW have attracted attention from the environmentalist, researchers and general public due to associated risks to public health such as respiratory irritation, eye irritation, acid rain and human lungs infections (Babanyara *et al.,* 2013; Yazie *et al*., 2019).

2.6 Environmental and Health Implications

Improper medical waste management poses negative effects on environment and health risks due to soils contamination, air as well as surface and underground waters due to discharging of raw hazardous chemical residues from medical establishments into the environment. In most developing countries MW are disposed of poorly in open surface dump sites or openly burned, impact of these processes is highly significant particularly to the healthcare workers, patients, residents living close to the such sites as well as environmental pollutions (WHO, 2017; Yazie *et al.,* 2019; Karki *et al.,* 2020).

Based on paediatrician findings that, many children were admitted with symptoms of infectious diseases as a result of contact with MW in Sadr City Hospital in Iraq (Prüss *et al.,* 2005). Another reported impacts of healthcare waste on health and the environmental related issues as a result of medical waste incinerator or openly burned due to variety of pollutants release into the environment. thus, these pollutants are human carcinogen and have been associated with a range of adverse health effects as well as contaminate surface and underground water (Emmanuel *et al.,* 2007).

Furthermore, workers or children and other residents living near incinerators have significantly higher blood or urine levels of dioxins, furans and polychlorinated compared to control groups that no exposed to such sites (Kumagai and Koda, 2005). Similar submission in Finland, Germany and the United States that, higher levels of mercury in the hair, cadmium and lead in the blood, arsenic in urine among incinerator workers or residents living closer to incinerators sites (Kurttio *et al.*, 1998). Other studies indicated that, residents particularly children living near incinerators have increases in laryngeal cancer, lung cancer and specifically of stomach, colorectal and liver in France, Japan, Italy, United Kingdom, and Sweden (Viel *et al.*, 2000). More so, poor incineration of MW in Taiwan led to a severe outbreak of acute respiratory syndrome that prompted the Government to take deliberate actions in managing MW (TEPA, 2003).

2.6.1 Occupational health hazards

The most concerns of researchers are the impacts of MW on health workers such as doctors, nurses, paramedical personnel, maintainers, laundry and waste handlers. Since are directly involved in generating MW and its management. However, improper management of MW particularly in developing countries caused injuries from sharps. Similarly, exposure to hazardous and radioactive waste causes health hazards to employees handling MW such as headache, dizziness and vomiting to much more serious problems (Demirbas, 2011). Similar findings in Italy, U.S, and Sweden Porta *et al*. (2009); in Mexico City by Thompson *et al.* (2010). Table 2.5 gives instances of diseases through hazardous MW.

Table 2.5: Example of Infections caused by Hazardous Medical Wastes

Type of infection	Infective agent	Transmission agent
Gastrointestinal infection	Entero bacteria (salmonella, vibrio cholera, shicella	Faeces, vomit
Respiratory infection	Mycobacterium tuberculosis, streptococcus pneumonia, SARS virus (severe Acute Respiratory Syndrome), measles virus	Inhaled secretions, saliva
Eye infections	Herpes virus	Eye secretipons
Skin infections	Streptococcus	Pus
Anthrax	Bacillus anthracis	Cerebro-spinal fluid
Meningitis	Neisseria meningitides	Cerebro- spinal fluid
Aids	Human Immunodeficiency	Blood, sexual, secretions, other body fluids
Haemorrhagic fever	Lassa, Ebola, Marburg and Junin Viruses	Blood and secretions
Viral hepatitis A	Hepatitis A Virus	Faeces
Viral hepatitis B & C	Hepatitis B & C Viruses	Blood and other biological fluids
Avian influenza	HSNI Virus	Blood, faeces

Source: (Prüss *et al*., 1999)

However, environmental factors such as temperature, solar radiation, humidity and presence of disinfectants substances in the waste determine the survival period of individual pathogenic microorganism present in the waste. Variety of micro-organisms are contained in MW and more in concentration from MW generated in laboratory cultures of pathogens and the excreta of infected patients. The micro-organisms present in medical waste their survival time is short may be due to disinfectants (ICRC, 2011). Table 2.6 gives a summary of the survival period of various pathogens in MW.

Table 2.6: Example of the Survival Time of Certain Pathogens

Pathogenic micro-organism	Observed survival time
Hepatitis B virus	-Several weeks on a surface n dry air -1 week on a surface at 25°C -Several weeks in dried blood -10 hours at 60°C -Survives 70% ethanol
Infectious dose of hepatitis B & C viruses	1 week in a drop of blood in a hypodemic needle
Hepatitis C	7 days in blood at 4°C
HIV	-3-7 days in ambient air -Inactivated at 56°C -15 minutes in 70% ethanol -21 days in 2NI of blood at ambient temperature -Drying the virus reduces its concentration by 90-99% within the next few hours

Source: (ICRC, 2011)

2.7 Waste Minimization

Waste minimization is a key strategy employed in MW management. It involves avoids, allows reuse or recycling of the waste, eliminates or reduces a waste production and its source (http://www. ssmo.gov.sd). The strategies also include changes in management, modification of purchasing procedures and production of less toxic materials. These generally reduce the hazards of these harmful materials to human health and environment, reduce costs and conserve resources (http://www. ssmo.gov.sd)

2.7.1 Avoidance of excessive waste generation

Hospital management should review modification of purchasing procedures and changes in management to avoid excessive waste generation without compromising standards. Simple product modifications to minimize waste streams including requesting the manufacturer and supplier chain centre on less hazardous wastes (http://www. ssmo.gov.sd).

2.7.2 Recycling and reuse of the waste produced/generated

The hospital administrators should ensure that, modification of purchasing procedures should focus on re-useable items than disposable items. Implementation of total waste segregation and sorting at the point of generation is necessary as well as adequate personnel training for effective reused, recycling and minimization of MW to be sustain (WHO, 2018a; Yazie *et al*., 2019). Thus, these practices (reused and recycling), reduced the quantities of waste to landfill by up to 60 % (http://www. ssmo.gov.sd). Generally, treatment and disposal cost of hazardous waste are extremely reduced (WHO, 2018a; Yazie *et al*., 2019).

2.8 Hospital Wastewater

Raw wastewater produced from hospital contained large quantity of radioactive elements, pharmaceutical partially metabolized, pathogenic microorganisms and other toxic chemical substances, which can pollute or contaminate the environment and pose health risks as well. Therefore, it requires appropriate treatment before final discharge in order to safeguard the environment and protect public health (Nazik, 2004); (Ojo and Adeniyi, 2012).

2.8.1 Characteristics of wastewater and their quality parameters

Physical, chemical, biological and radiological are the characteristics of wastewater which determined their quality parameters present in wastewater (Nazik, 2004); (Mohammad *et al*., 2014). The examination of quality parameters of a given wastewater is very essential for any wastewater study. The parameters: Biochemical oxygen demand (BOD). This parameter is essentially test for finding the polluting level of wastewater and measurement of the organic matter present in wastewater. It also determined the amount of oxygen contained in a given sample of the wastewater in the presence of microorganisms for a specific period, usually 5 days at a particular temperature, generally 20ºC (http://www.iwk.com.my/sewerage-fact-o3.htm).

The chemical-oxygen demand (COD): This involved the measurement of the strength of a given wastewaters. It is a measure of oxidation requirements of a sample by using a chemical oxidant under defined conditions. The quantity of oxygen required to consume the organic matter is determined by COD. Relationship may exist between COD and BOD in a given system. When raw wastewater discharge into the sewage system, many chemicals may then enter the system that influences either with treatment, processes or with the quality of the receiving waters (Emmanuel *et al*., 2007). Total suspended solids (TSS) are also called no filterable residue (NFR) or idental measurement. It measures a quality of water and specified pore size of the dry weight particles is trapped by a filter (Nazik, 2004).

The hydrogen ion (pH). This is a value of a given medium measure the acidity or basicity (alkalinity) of the medium. Generally, the pH of a medium is given as the negative logotrithin for base 10 of the hydrogen ions concentration of the medium. The effect of pH test makes it an important in wastewater treatment. For example, wastewater with low pH may mean that the wastewater is polluted or septic. A pH value of 6.5 to 8 is within the right for treatment plant influent (Gautam *et al*., 2007). Similarly, a very high or low value of pH may mean wastewater require urgent attention (Gautam *et al*., 2007).

Dissolved oxygen (D.O.). This consists measurement the amount of gaseous oxygen (O2) dissolved in a given water solution. Usually, oxygen enters into water by of diffusion method from the surrounding air, rapid movement and as a waste product of photosynthesis (Ojo and Adeniyi, 2012). Only grab samples should be used when carrying out dissolved oxygen test and the immediate analysis is required. Therefore, the test should be performed in the field (Ojo and Adeniyi, 2012). Total coliform (TC). This is a good potential indicators of water contamination from the source and determined quality of water by coliform bacteria found, this mean that, coliform organisms are used as indicators of water pollution level. Similarly, faecal coliforms are a good indicator of contamination level from hospital wastewater and have greater risk of exposure to pathogenic organisms than total coliforms (Pauwels and Verstraete, 2006).

2.8.2 Environmental impact of wastewater

The water consumption in the hospitals varies from 400 to 1200 litters/bed/day. This level of consumption generates significant volumes of wastewater that contained pathogenic microorganisms, pharmaceutical, radioactive elements and other toxic substances that, pollute the underground and surface water and lead to general health risks if expose to it. Therefore, proper treatment is required while physical, chemical and biological parameters of wastewater should no excess standard set limit by WHO in order to reduced or eliminate their effects on the environment and public health (Nazik, 2004; (Ojo and Adeniyi, 2012).

2.9 Review of Existing Environmental Legislations in Hospital Waste Management

The existing review of policies and strategic plans governing MW management.

2.9.1 Review of international agreements and underlying legislative and regulatory principles

The consideration of global agreements on hazardous waste management and they principles should be promoted when national legislations or policies governing MW management are formulated. Those agreements and the four principles on MW management, includes: The Basel and Stockholm conventions with mandates (environmentally sound management of waste) and the four principles include duty of care, polluter pays, precautionary and proximity principles. It is important that the forgoing should be incorporated in national policy and programmes at all levels. According to the principle of "polluter pays" that said, wastes producer are financially and legally responsible for the sustainable management of the waste they produce for the safety of environment as well as liability in case of damage while the "precautionary" principle take care the protection of the stakeholders. It also, designed protection measures for the anticipated risk (Secretariat of the Basel Convention (SBC and WHO, 2005).

In the case of “duty of care" principle specifies that, any individual or association that produces wastes has an obligation to discard the waste properly. In this way, it is the HCF that has extreme obligation regarding how waste is appropriately managed (SBC and WHO, 2005) and lastly, the principle of "Proximity" suggests that, performing treatment and discarded of infectious or hazardous waste should be closer to the generation area to its source so as to limit the dangers associated with its movement to the treatment site. (SBC and WHO, 2005).

2.9.2 Basel convention

The challenges and way forward of hazardous wastes were amongst the issues discussed at Basel Convention. Nigeria and some 178 member countries consented to this agreement which mean that, each country would design implementation strategies for the all levels. The Secretariat based in Geneva (Switzerland). The Secretariat provides important services such as; training, legal and technical guidelines on issues of best global practices of management of hazardous waste as well as provide facilitation services for the implementation of the agreements reached at convention (HCWC, 2007). The convention specifically covered healthcare related wastes (HCRW) as a category of hazardous wastes and it was first adopted in 1989, the convention's principally focus on the controls of movement of hazardous wastes a crossed the geographical boundary called "transboundary." The strategy strictly regulates the transboundary movements of hazardous wastes and obligates all the member countries to environmentally friendly manner disposed of these wastes by ensure properly treatment before final disposal (Johannessen *et al*., 2000). Categories of HCW that required special attention as specific by convention includes: sharps, pathological infectious, hazardous chemical, and pharmaceutical wastes.

2.9.3 The Stockholm convention on persistent organic pollutants

Environmental and human health protection from releases of persistent organic pollutants (POPs) into the environment also received a boost from this convention. POPs are released into the environment due to MW incineration or open surface burning and those chemicals are generally toxic to humans and wildlife because they remain in the environment for long periods. They covered profound areas and can cause damage to both environment and public health ae well wherever they landed. The convention was adopted in 2001. Nigeria is a party to this Convention in (2002) (HCWC, 2007). Implementing the convention agreements, at the national and state levels requires strategies and guidelines for waste incineration in order to eliminate or reduce the release of those POPs pollutants such as dioxins and furans into the environment. On the other hand, the Global Alliance for Vaccines and Immunization (GAVI) has been given financial support in a similar project of healthcare wastes related issues in 72 countries in collaboration with the WHO since 2006, to guide those countries to develop a policy, strategy and plan for sustainable MW management, also Nigeria is a party to the GAVI in 2006.

2.9.4 Review of the existing environmental and health legislations in Nigeria

There is no particular current enactment, guideline or bye-law for the administration of MW management in Nigeria, in spite of the fact that there are pertinent laws and guidelines in relating to protecting the environment and human health. However, the first environmental laws in Nigeria were introduction of sanitary inspectors by the colonial administrators in 1975 (FMenv, 2012; Rain Forest, 2012). Consequently, the incident of Italian six ship loaded with toxic waste found in Koko, Delta State in 1988, promote and facilitate environmental laws and their effective enforcement in Nigeria (FMenv, 2012).

In 1988, Federal Government established Federal Environmental Protection Agency (FEPA) by Decree Number 58 with the responsibilities to monitor and enforcement of environmental protection measures, with the collaborations of related Ministries at all levels of Government. Similarly, Decree Number 42 of 1988 was promulgated tagged 'Harmful Waste Special Criminal Provisions'. Which prohibits the carrying, depositing and dumping of harmful wastes into the environment in Nigeria territory (FMenv, 2012). More so, National Standard Effluent Permissible Limits set in 1991 that directed installation of anti-pollution equipment, provision for the treatment of effluent parameters and ensure that permissible effluent limits are not exceeded in all the industrial facilities. In the same vein, the 1991 Regulation of Waste Management and Hazardous Wastes with the provisions of planning for the collection, treatment and disposal of solid hazardous wastes from facilities. The regulations also demand yearly environmental audit report within 90 days of demand by the Agency (FMenv, 2012). The Act of 1992 No 86; Environmental Impact Assessment (EIA) requires EIA study of a proposed project at all levels of public or private (FMenv, 2012). Furthermore, in 1999 Federal Ministry of Environment was established, charged with the overall responsibility of protecting the environment including biodiversity, conservation as well as sustainable development of natural resources (FMenv, 2012). Finally, National Environmental Standards and Regulation Enforcement Agency (NESREA) was established by Act 2007, with the responsibilities to enforce compliance with environmental regulations, create public awareness, provide environmental education on sustainable environmental management and data publications. (NESREA, 2011). Accordingly, no specific policy was made on management of MW. Therefore, MW management need urgent attention for the development of a specific MW management policy in Nigeria.

2.10 Cost Related to Medical Waste Management

The cost of waste management as indicated by the "polluter pays" guideline suggests that, all makers of waste are lawfully and monetarily liable for the safe and environmentally friendly management of the waste they produce. This guideline additionally provides that, individual or parties take the liability damage causes. The costs of appropriate MW management as well as treatment are vested on the hospital administrators (ICRC, 2011).

2.10.1 Training and education of healthcare personnel

The cost of proper training of healthcare personnel and waste handlers is very germane (Kumari *et al*., 2013). It is necessary that all the categories of staff members who are involved from the source of MW generation to final disposal should be provided with the specific training (Hassan *et al*., 2017; Yazie *et al.*, 2019; Karki *et al.*, 2020; Ghimire, 2020). The purpose of educating and training of healthcare workers and waste handlers is to reducing treatment and disposal costs, minimize the risk of injury, protect the environment and public health. Therefore, education and training programmes are expected to cover areas of waste collection, quantification, segregation, treatment, minimization and disposal (ICRC, 2011).

2.10.2 Cost estimation for handling healthcare wastes

All healthcare centres require standard accurate record-keeping and cost analysis procedures for effective MW management with a separate budget head. This practice would provide review and helps to project as well as reduce management costs (ICRC, 2011).

2.10.3 Staff protection measures in healthcare environments

The protection of staff involve in MW management is very vital in healthcare services system. The objectives provide protective measures to reduce the risks and cost of treatment on accident/exposure to hazardous MW. Two categories of preventive measures: primary and secondary. Firstly, the primary preventive measure consists of four levels of action: the elimination of hazards by using fewer toxic substances, such as mercury, while other includes collective and technical preventive measures. Secondary prevention measures deal with the individual roles handling MW management. Lastly, enforcement of personal protective equipment, vaccination and hands washing reduce the cost of handling healthcare waste in a given healthcare centre (ICRC, 2011).

2.10.4 Personal protection and hygiene

The cost of purchasing safety protective tools for MW handlers is associated with the size and types of services provided by a given hospital (Nazik 2004). The strategies for MW management in reducing risks of infections and eliminate transmission of infection cycle are very key and cost effective. However, hot water and soap should be installed close to MW storage and treatment sites for washing one’s hands constantly. It was well established that, the practice would eliminate over 90 % of the micro-organisms present in the hand (Nazik 2004).

2.10.5 Vaccination of healthcare waste management staff

Vaccination of MW management staff in a given healthcare centre is very germane in order to reduce the cost exposure and treatment. MW handlers requires appropriate protection by vaccination against infection diseases present in the wastes such as hepatitis A and B and tetanus. vaccination can prevent transmission of hepatitis B virus disease which has been happening for long period, 1980 (ICRC, 2011). Table 2.7 given the risk of transmission of major infection after a needle prick injury.

Table 2.7: Risk of Transmission

Virus	Risk of transmission of infection %
HIV	0.3
Hepatitis B Virus	5-30
Hepatitis C Virus	1-3

Source: http://www.healthcarewaste.org

2.10.6 Methods of financing healthcare waste disposal

Healthcare wastes management require appropriate funding methods, separate budget for a complete sound healthcare delivery system. Funds may come from the private or public sector as well as individual, national and international organizations. In some cases, the private sectors are allowed to use the public facilities (in the case of USA) (ICRC, 2011). These regulations may have specific treatment technology or disposal system and standards of operation methods. Many countries have been utilizing public private partnership policy of financing some public projects including MW management. (WHO, 1999); (ICRC, 2011).

2.11 Global Perspectives of Solid Medical Waste Management

Environmentally sound waste management is one of the key elements for the sustainable development. It consists taking appropriate strategies for the sustainable MW management by implications generation of hazardous MW would be reduce to zero level. It also implements total wastes segregation, reuse, recycling, storage, transport, treatment and final disposal (United Nations Environment Program (UNEP), 2000). Segregation of wastes usually reduce quantity of hazardous MW generated in a given healthcare centre to about 10-15% (WHO, 1999). Whereas, 85% of wastes generated from such centres are referred as non- hazardous or general MW and can be treated as normal municipal solid waste but these 10-15% such as sharps, pathological, pharmaceutical and hazardous chemical wastes require special attention (World Bank, 2000).

Illegal dumping and improper management of MW such as used of open surface burning and sub-standard incinerators, these are the commonest practices treatment methods in most of the less developed nations due to poverty, absence of MW policies, guidelines, strategic plans as well as weak enforcement. Those are basic factors that, lead to failure of sustainable sound environmentally management of hazardous waste in most part of the regions. Subsequently, the emissions such as toxic gases like HCl, CO, co organics, furans and dioxins poses serious health risk to the patients, healthcare workers, visitors, environmental pollution as well as community (Puspalata, 2018; Karki *et al*., 2020).

The investigation by Ahmed (2017) on management practices of MW in El Shifa and Al Aqsa hospitals in Gaza Strip centre on key parameters management practices such as collection, segregation, treatment and disposal. Questionnaire and interviews were utilized for data collection. Results revealed that, the hospital implement MW segregation into hazardous and non-hazardous wastes according to (WHO) standard. 51(66.2%) of respondents said that temporarily stored exist in the hospital while 100% of respondents agreed that, the storage site located inside the hospital is not suitable due to poor ventilation, lighting and easy access. Incineration of hazardous MW was only method utilized for the treatment. Also, not provision for specific training on MW management for doctors and others paramedical personnel. The study recommended synergy between relevant stakeholders such as the Ministry of Health (MOH) to develop a strategic plans and policies for sustainable MW management.

Desta and Abera (2017) directed an examination in Menellik II Referral Hospital, Addis Ababa, Ethiopia. MW composition and generation rates were determined by utilized a cross-sectional method in Menellik II medical centre in which a weight scale was utilized to measured MW generated for seven consecutive days. The quantity of MW generated and other variables were examined by employed correlation and regression analyses techniques. The outcomes demonstrated that, the MW generation rate mean was given 1.94±0.335 kg/bed/day include 40.9% (130.20±38.22 kg/day) general and 59.1% (187.89±38.85 kg/day) hazardous wastes. In this manner, the study proposed that, giving safe waste administration advancements, adherence to national arrangement and mindfulness be embraced in the medical centres.

Investigation of MW management practices in Kumbo hospitals in Cameroon by (Lanyuy *et al*., 2017). A qualitative cross-sectional technique was utilized to examined 30 health facilities. Questionnaires, interviews and direct field observations were the instruments utilized for data collection. SPSS V 17.0. P-values < 0.05 was employed to analysed the results obtained. The outcomes demonstrated that, the majority of the waste handlers (55.6%) utilized assessment gloves which were wrong. Wastes segregation was poorly implemented. Waste containers were not colour-coded and safety boxes for sharps were properly utilized in all facilities study. Treatment of mixed MW was done by open burning pits 400 m located away from the facilities and the pits were not protected before and after burning. Similarly, four hospitals used sub- standard incinerators in treating mixed MW. It was concluded by researchers that MW management system in the study hospitals far bellowed best global standard.

In another detailed investigation by Derso *et al.* (2018) on biomedical waste management methods in selected healthcare facilities covered 11 regions in Ethiopia through stratified random sampling. Absolutely, 1327 of healthcare facilities centres were evaluated utilizing the WHO guideline. The outcomes showed that, clinical waste in 62.6% of the examined points were stored in the containers with covered about 40% of study centres kept their MW in an open location. Similarly, 2.8% and 39.3% healthcare facilities used 2-chamber modern incinerators and 1-chamber drum incinerators, respectively. About 58% of the healthcare facilities utilized dangerous treatment techniques for MW. The study inferred that dumping of MW outside the hospitals was a typical practice in the investigation zone.

Qadir *et al.* (2016) led their examination in Karachi tertiary hospitals to investigate the knowledge and practices of MW management. A cross sectional techniques was utilized, fifteen tertiary clinics were chosen. Questionnaire was employed for data collection. The outcomes indicated that only 20% of the study hospitals were using proper methods for the separation of the sharps. 93.3% of the respondents were not vaccinated against hepatitis ‘B’ and other infectious diseases. 53.3% clinics had their own incinerators. The study concluded that, the practices of MW management was rated poor and there was urgent need to actualize the suggested by WHO MW disposal standard.

Adekunle *et al.* (2018) directed their examination in district area clinics of KwaZulu-Natal region. The study centre on examination of the practical knowledge, attitudes and practices concerning HCW management. Questionnaires and observations were used for data collection and the Statistical Package for the Social Sciences (SPSS) was utilized. Results demonstrated that, information on HCW management system was commonly lacking, with 42.7% of the members scoring 'poor' by and large. While, 53.9% exhibiting great understanding of HCW management practices. The connections among the variable's knowledge, attitudes and practice are significant ($p < 0.05$). In forgoing, it was noted that different hospitals studied in South Africa handled MW poorly. They at that point suggested that, strategic plans and specific training in HCW handling must be presented or enhanced at all levels of learning in the tertiary/higher establishments.

Udofia *et al.* (2017) led their examination in Assembly South Municipal Accra, Ghana which focused on implications of household's solid medical wastes (SMW) produced in the community at large. Questionnaire were administered for 600 family units. Drug application related practices, ailments related with SMW, SMW removal or disposal system practices at home were researched. The outcomes indicated that 80 and 89% of the respondents disposed of MW in family unit decline receptacles while, 23 and 35% of respondents disposed of these wastes on an open surface. Similarly, 5 and 3% of the respondents revealed harm from SMW in the family unit and in the network separately. Also, 95% of respondents accepted that, they were in danger of sicknesses related with SMW. The findings indicates that, the practice have negative health implications to the community.

Peter (2011) directed his investigation in the Northwest region of Cameroon which centre on MW management in the region. Three medical centres were chosen for the investigation. The incinerators at each of the previously mentioned medical centres were assessed for structure and operational proficiency. Sampled from bottom ashes were collected from every one of the incinerators for substance examination; respiratory, intestinal and skin diseases among kids living close and with access to those disposal points were investigated. Results demonstrated that, huge imperfections identifying with respect to MW separation, collection, transportation, treatment and final disposal techniques were the same in the three medical centres. Additionally, wastes segregation was improperly done as well as transportation was done by waste handlers with complete disregard for safety. Ashes collected from the three incinerators contained high amounts of selected heavy metals, especially Pb, which was 230 mg/kg in one of the incinerators. Similarly, samples from OFP and an EI in Mozambique hospitals contained significant levels of 15PAHs, dioxin-like PCBs and PCDD/F. the study recommended urgent strengthen political and economic will towards the development and implementation of a sound policy on efficient MW management.

2.11.1 Nigeria perspectives of solid medical waste management

Sound specific strategy for MW management is lacking in Nigeria and most other developing countries (Longe and Williams 2006). Moreover, in Nigeria and other similar countries, management of MW has gotten less consideration. Specific practical information and studies on environmental and health implications of MW management are very inadequate and limited in scope (Abahand and Ohimain 2011). Likewise, absence of dependable records of the amount and nature of MW and the administration procedures to satisfactorily and logically discard these wastes has pose a serious impact in most less developed nations. Similarly, several hundreds of tons of mixed hazardous and general MW deposed and burned openly (Alagoz and Kocasoy 2007); (Abahand and Ohimain 2011).

Jibrin *et al.* (2018) completed their examination in Hadejia Metropolis, Jigawa state, Nigeria to evaluate the effect of environmental and public health on poor MW disposal (MWD). The targeted inhabitants living close to the healthcare centres as well as healthcare workers that worked either inside or outside the clinical centres. Around 150 participants were involved. The outcomes indicated that, clinical waste created at clinic centres were unsafe in nature. Around 80 percent of the respondents showed that, open surface burning was the main method of MW treatment practiced. Likewise, 96.7% of the respondents accepted that, poor handling of these wastes would pollute the nature and influenced their wellbeing. The specialists suggested required appropriate strategy for MW treatment methods at all levels.

Sawyerr *et al.* (2017) led their exploration planned for assessing biomedical wastes in Kogi State University Teaching Hospital, Ayingba. The study assessed the biomedical wastes produced in which case; seven wards were chosen to decide the amounts of wastes produced. The outcome uncovered that the complete waste produced in seven successive days was 19.89 kg/week. The average waste measured in seven wards was 2.8 kg/week and per day was 0.4 kg/day. The amount of waste expanded as the quantity of patients and guests expanded. There were not colour coded containers used and segregation of wastes was not done in all the seven units. The analysts showed that, the MW gathered from such units were exposed to open surface burning which may influence the health risks of the laborers, patients, guests, inhabitants and nature. Subsequently, they suggested sustainable MW management practices.

Olufunsho *et al*. (2016) directed an examination in Lagos with the intend to survey the clinical waste administration in chosen healthcare centres and furthermore decided the effect of LAWMA in Lagos intercession programmes. The scientists utilized a clear cross-sectional study strategy. Information was gathered utilizing three instruments (survey, site appearance and top to bottom meeting). Two Government healthcare centres and five private's healthcare centres were selected. SPSS form 20, Chi-squared test was utilized to decide the degree of centrality at $p < 0.05$. The outcomes demonstrated that 56 (53.3 %) were females' respondents. The clinics studied, with the exception of one, all arranged both general and hazardous wastes independently. They likewise revealed that the staff handled wastes collection utilized medical hand gloves as defensive material. Since all the medical clinics utilized the services of LAWMA for final waste disposal and treatment. It was likewise revealed that just a single medical clinic offered only sharp wastes treatment with an incinerator while hydroclave was utilizes by LAWMA to treat the wastes gathered. Also, detailed that, there are no plans or rules in all the examined clinics for overseeing MW. The scientists suggested uniform and standard MW handled in the whole state in this manner calling for the development of policy/guidelines and strategy on MW management at all levels.

Umar and Mohammed (2014) did his examination in Fagge neighbourhood government region, Kano State with the point of looking at the current practices of MW management. The specialist utilized a cross sectional expressive investigation to assess wastes separation, treatment, transportation, storage and final disposal at Primary Healthcare Centres of Fagge. A sum of 132 healthcare workers participated. A self-controlled administered questionnaire was utilized as an instrument for information assortment of MW management practices. The outcomes demonstrated that, 98.4% of respondent concurred that, sharp were only separated from wastes generated, while 62.2% utilized uncovered hands for the collections. it was accounted for that 32.5% utilized wheel pushcart for MW transportation inside the medical clinic while 44.0% utilized trucks for off-site transportation by Yaro Boys. For the treatment and storage that, 76.6% kept wastes for 12 hours, while hazardous MW treatment was 0.0%, and open surface waste disposal 74.2%. The study concluded that, MW was poorly handled in Fagge Primary Health Centres and suggested appropriate MW management in the areas.

Stephen and Elijah (2011) directed their investigation in Nigeria at Teaching Hospitals. The study utilized a cross sectional patterned to investigate the tertiary healthcare centres with the point of surveying the current practices of MW management in these centres. The study evaluated the amounts of HCW produced, level of segregation and the healthcare workers level of understanding MW management concept. Results demonstrated that, the average amount of HCW for out -patient and in-patient were 0.62 kg/person/day and 0.81 kg/bed/day respectively. Whereas, participants who had received specific training in the management of HCW was 11.5% (6/52) while 46% (24/52) of respondents said there understand implications of MW to the public health. The study recommended appropriate training and funding in order to improve on the current management practices.

Omofunmi *et al.* (2016) led their investigation on clinical waste administration in private healthcare centres in Lagos State. The study utilized questionnaires surveys, top to bottom meeting and field observations to create information on the levels of MW administration such as MW generation rate, amount, sorting/separation, collection, temporary stockpiling, as well as training in nine healthcare centres. The outcomes demonstrated that, the quantity of MW was 207.16 kg/day, with 119.07 kg comprising of dangerous MW, 85.91 kg general wastes and 2.18 kg sharp. On the other hand, the average MW were 1.14 ± 0.2, 0.72 ± 0.01, 0.47 ± 0.01 and 0.01 ± 0.002 kg/bed/day for hazardous, infectious, general and sharp wastes respectively. Similarly, the (%) of hazardous, general and sharp wastes were 60.00, 39.10 and 0.83% respectively. The MW management practices were assessed to be poor.

Joshua *et al*. (2014) carried out their study which assessed hospital wastes management practices among selected hospitals in Zaria, Nigeria. A cross sectional descriptive pattern and questionnaire surveyed and field participant observations were utilized. Results showed that, sampled healthcare workers that had training on MW management were 73% while injury by sharps were 31%. About 66% were reported to have used hand gloves. The wheel barrows were reported to be the commonest means of transporting final waste by the PHC facilities visited. The study recommended adequate funding of all facilities needed for proper MW management as well as training and re-training of healthcare workers.

Shaibu (2014) conducted his study which investigate small healthcare centres MW management practices within Minna town, Niger State Nigeria. Questionnaires and oral interviews were utilized to examine the current disposal and treatment methods of MW. The outcomes demonstrated that, the participants recognized the implication of hazardous nature of MW but, there was no wastes segregation/sorting as well as treatment. Similarly, it was also observed that, the agency responsible with wastes management has low capabilities of MW management due to the poor equipment. The study recommended that, committee of MW management should be set up to managed the generated wastes.

2.11.2 Global perspectives of medical wastewater (WW) management practices

Reports of Emmanuel *et al*. (2007) and Sim *et al*. (2011) revealed that, the values of BOD were 242 to 632 mg/L and COD were from 616 to 1388.75 mg/L. Also, hospital WW samples in various parts of the world found to contained heavy metals such as mercury, chromium, copper, lead, zinc, nickel and cadmium. Similar submission by Muhammad *et al*. (2014) reported a case study of three general hospitals in Lahore revealed that WW characterizations were investigated. Samples were taking from each hospital for laboratory analysis. The results indicated that, BOD, COD and cadmium values were more than the permissible limits prescribed by National Environmental Quality Standards (NEQS).

2.11.3 Nigeria perspectives of the hospital wastewater (WW) management practice

Reports of Eze *et al.* (2016) on examination the discharge of WW from wards at Park Lane General Hospital Enugu, Nigeria. In all three (3) samples were collected from the hospital. The outcomes demonstrated that, aerobic bacteria mean total counts were 14. 40 ± 0. 86 x 10^{10} cfu/mL, 13.70 ± 0. 65 × 10^{7}cfu/mL and 22. 8 ± 1. 14 ×10^{10} cfu/mL, the respective WW samples. While, the mean total anaerobic bacteria were 6.00 ± 1.60 × 10^{3} cfu/mL, 4.00 ± 2.50 ×10^{3} cfu/mL and 1.70 ± 0.41 ×10^{4} cfu/mL for the sample wastewater respectively. Similarly, the presence of *Candida albican-a* pathogenic fungus in two of the three samples studied with respective populations of 1. 70 ± 0. 41 x 10^{3} and 2. 3 ± 0. 16 × 10^{5} cfu/mL respectively. However, the concentrations of most of the heavy metals were found to be within the level of the WHO permissible limits such as, cadmium, chromium, lead, mercury and arsenic. The study therefore, recommended that, treatment of WW before discharging into the environment is very germane.

Reports of Ojo and Adeniyi (2012) on examination of the impacts of wastewater discharges from the Hospital on the receiving water bodies in Ile–Ife, Obafemi Awolowo University Teaching Hospital (OAUTHC) by determined the physico-chemical qualities of the two wastewater point sources and Elekete receiving stream were investigated. In all eight sampling points were selected. Samples were collected from each sampling points for nine months and analysed using standardised laboratory methods. The physical and physio-chemical parameters determined were temperature, turbidity, solids, pH and electrical conductivity and for physio-chemical parameters were: oxygen parameters, major cations, major anions, nutrient compounds. The results indicated significant difference ($P < 0.05$) for all parameters between the impacted and unimpacted samples of wastewater of receiving stream. $SO4^{2}$-, total organic carbon, NH4+, $PO4^{3}$-, and BOD5 were found to be about three times higher in the impacted section than in the unimpacted section while sample colour, turbidity, total suspended solids, total dissolved solids, total solids, conductivity, alkalinity, acidity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO 3-, NO 3-, and $NO2^{-}$ also reported to be about two times higher in the impacted section of the receiving stream than in the unimpacted section. The overall mean concentrations of 293 mgl^{-1} and 270 mgl^{-1} BOD5 in the two effluent streams indicated were said to have the medium/ strong strength wastewater discharges from OAUTHC. This study showed that the wastewater discharge from the (OAUTHC) Ile-Ife had significant impact on the water quality of the receiving streams, therefore, recommended treatment before final discharge.

2.12 Circular Economy Approach in Medical Waste Management

According to Ellen MacArthur Foundation (EMF) (2017), circular economy is a transition from a linear system (take, make, use, dispose model) to a circular (restorative and regenerative model) in general term. The concept is classified into two main categories:

The resource based which focuses on the need to reshape the inflow of materials and reduce consumption of virgin resources and those that go beyond the resources management by developing additional measures of changing the patterns of consumption (WHO, 2018b). To achieve this transition, the implementation strategies required include: efficient use of resources, recycling, equipment refurbishment and reuse, remanufacturing, waste treatment and minimization. In line with these strategies, the options of phasing out the use of incineration and landfills for MW management is seen as a good direction. It is therefore, the strong belief of this study that the transition to a circular economy as presented in Figure 2.4 could provide a significant opportunity for addressing the challenges of current MW management practices in the state and yield substantial environmental and health benefits that will contribute to the achievement of reasonable number of SDG goals thus corroborating the submission by EMF (2017).

This proposal is made since it is generally accepted that, the circular economy action plans can help in addressing many environmental challenges in the world given the fact that in 2012, outdoor air pollution alone caused about 3 million premature deaths worldwide, with 87% being in low- and middle-income countries (European Commission (EC), 2017; (European Environment Agency (EEA), 2016).

CIRCULAR ECONOMY

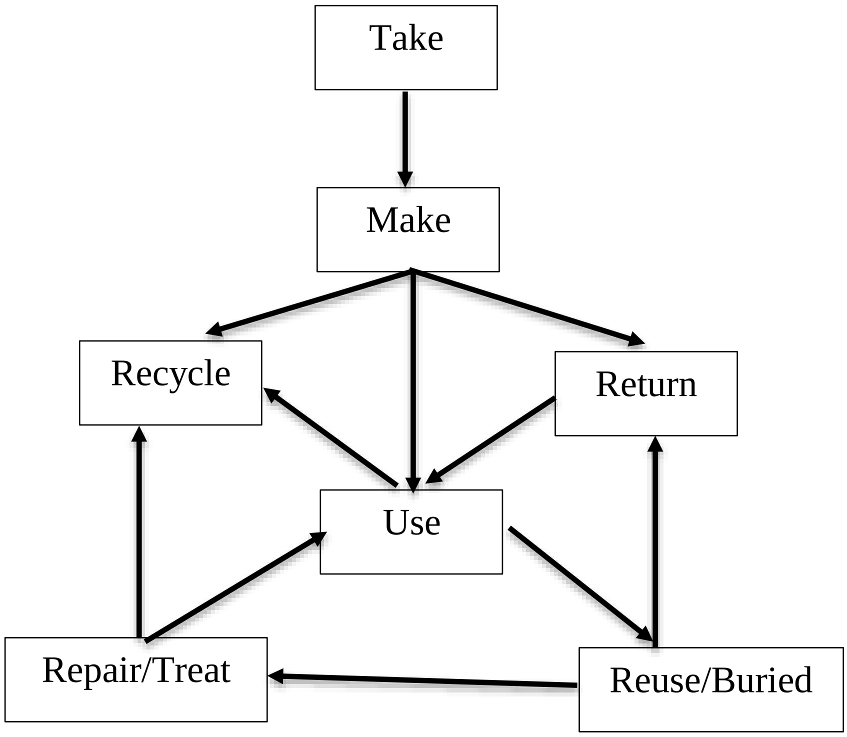


Figure 2.4**:** Circular economy waste management (Source: EMF, 2017)

Most importantly, the transition to a circular economy and according to its principles have significantly provided a means achieving several of the (SDGs) goals, particularly SDG 3, 9, 11, 12 (EMF, 2015). Similarly, EMF (2015) submitted that application and utilization of principles of circular economy could significantly reduce MW produced in the health care facilities. However, the transition to circular economy also need to identify and address the health and environmental effects associated with the transition cycle such as treatment, recycling, refurbishment and reuse of products and components (WHO, 2018b).

2.13 Summary of the Literature Review

The management of MW in less developed and developed nations were altogether investigated in this examination however a significant unanswered inquiry is the degree to which poor MW management contributes to the environmental and health implications at the all levels in these countries. Accessibility of information on the measures of MW created by medical services centres was recognized as a significant segment for an effective MW management. It was cleared that only few public and private hospitals have data on amounts of MW generated. Studies underscored appropriate MW handling as significant issues from idea to implementation however neglected to plainly recognize the duties of every one of the accomplices or partners engaged with the procedure; from top government organizations, for example, Ministries of Health and Environment. Moreover, the duties of healthcare workers, for example, medical attendants, specialists/doctors, nurses, waste handlers and others inside the medicinal services still stay indistinct. An all-around organized waste segregation method was recognized in many of the papers as basic in diminishing the quantity of clinical waste created.

Indeed, a portion of the researchers referenced that appropriately actualized and well-working waste segregation/sorting would decrease the quantity of hazardous wastes to be discarded by as much as 80% of what is disposed of without such measures. Zero separation/sorting practice was regular in less developed nations thus, increases the quantity of infectious or hazardous wastes. The inquiry that strikes a chord is the amount of the waste is as of now burned, in surface open/pits or dumped in open landfills or even disposed of along with household or general wastes in these nations. Various sorts of advanced environmentally friendly technologies for treating MW were also covered in the literature reviewed but how these advances technologies which incidentally, are novel and expensive, can be moved, worked and appropriately kept up in less developed nations is still a challenge. More so, little data on how liquid waste or hospital raw wastewater been managed in these countries remains a major problem.

Various researchers distinguished the sorts of pollutants or toxins that were conceivably discharged as a result of poor incineration, open surface /pits burning of MW as well as wastewater discharged. These pollutants are heavy metals and organics such as dioxins and furans, PAHs and PCBs. In any case, the degree of environmental and health implications from improper MW incinerators and open surface /pits burning of MW is still uncertain. The questions of health implications such as skin, respiratory and intestinal infection particularly the vulnerable group such as children in living close to the clinical waste treatment and disposal sites attracted researcher's attention.

Generally, the reviewed demonstrated that, the use of incinerators and open surface burning of medical wastes are the significant methods for discarding these materials in most medical care centres settings and compounded with high releases of toxic congeners of PCDD/Fs (Chen *et al.,* 2008). Accordingly, the majority of these PCDD/Fs from waste incineration or open surface burning are absorbed in fly ash and bout 80% is discharge in to the nature (USEPA, 2007; Zhao *et al.,* 2010). Moreover, from these reviewed different procedures/ methodologies have been utilized by various analysts everywhere throughout the world to evaluate and measure MW such as questionnaire survey, physical waste measurement, interview, physical observation, laboratory samples analysis as well as checklists. This study employed all these methods except checklists.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The methodology utilized for this study were physical waste characterization, measurement, experimental field observations and field-level information assortment through, questionnaire survey, samples collection, Focus Group Discussion (FGD), formal and informal interviews. A semi- structured questionnaire was designed to gather data on current MW management practices field supported were trained on physical waste measurement addressing the categories of MW generated, volume and sources from different health care facilities. Various top to bottom meetings were orchestrated to upgrade the comprehension of past and existing administration practice of MW. Visits were paid to the selected hospitals, the State Ministry of Health, State Hospital Services Management Board and Niger State Environmental Protection Agency for interaction before beginning the principal exercises. Expected to distinguish the procedure of MW administration, related issues and vital designs for the investigation were developed.

3.1 Theoretical Framework

This segment concentrated on the general system for the acquired significant information in the investigation which were utilized answer the several research questions raised. The reason of this study was for the most part an examination concerning the ramifications of MW management practices in ten hospitals in Niger State. It likewise applied the independent and dependent variables so as to respond to the research questions brought up in the scourge of the examination. Independent variables such as quantities and composition, assortment, training services, incinerators, segregation and containers, storage areas, transportation of medical waste, treatment and disposal, policies/strategies and guidelines while the dependent variables are medical waste management practices, place, method and time of training. these were totally utilized in the investigation. This is on the grounds that they played a significant role in management of MW (Ahmed, 2017).

3.1.1 Conceptual framework

Based on the reviewed literature, hospital healthcare wastes generation rate and composition can be directly affected by income, socio-cultural patterns of inpatients and outpatients, type of service, geographical location and hospital sizes. Other factors include practices of the hospitals for example, the presence of wastes segregation, recycling practices and the proportions of disposable substance used in the hospital activities this is because all these activities directly affect the amounts of waste generated and managed. These are vividly illustrated in Figure 3.1.

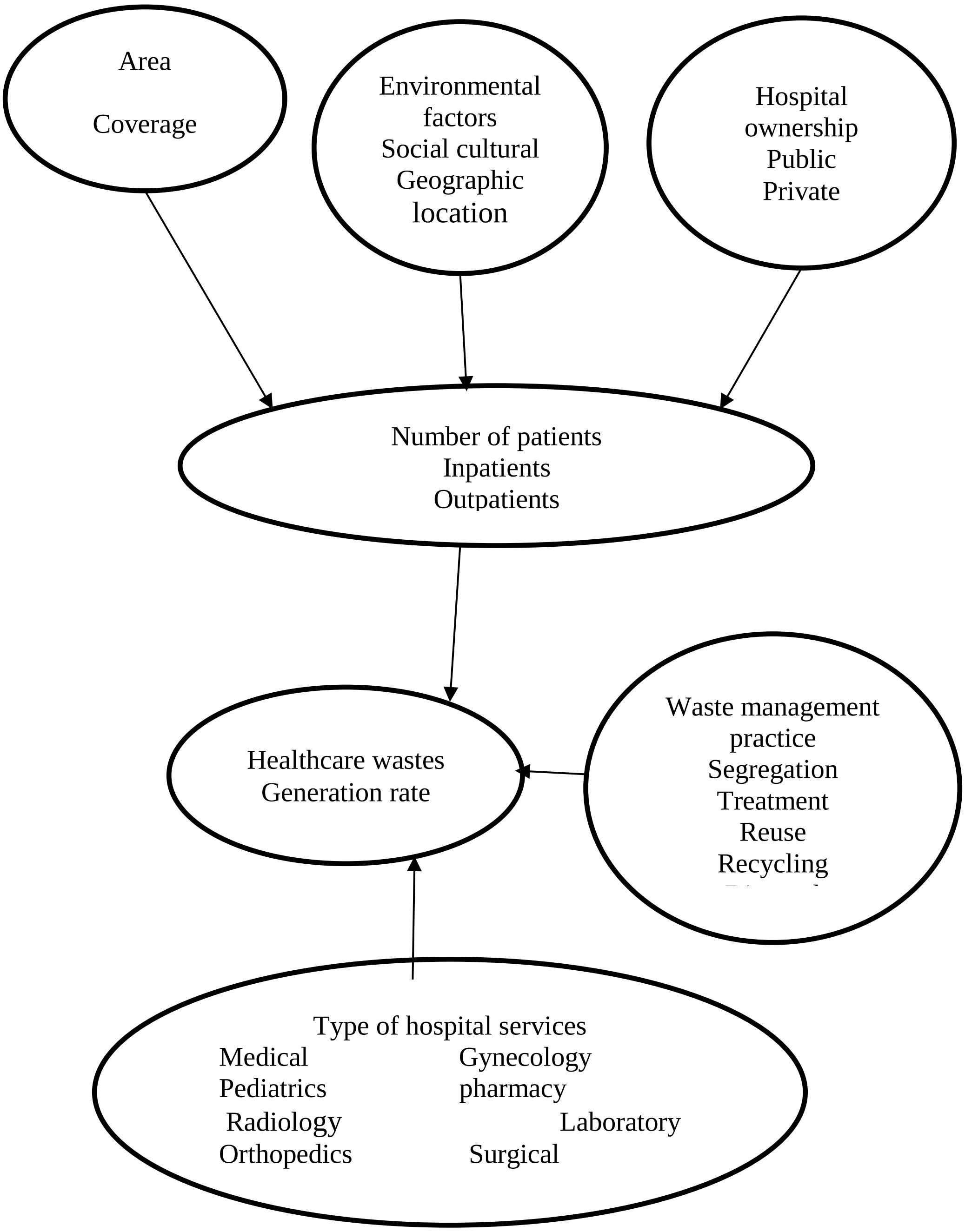


Figure 3.1: Conceptual framework of the relations between factors affecting healthcare waste generation rates (Source: designed by the researcher)

3.2 Study Design

This study utilized both qualitative and quantitative standard methods to generate data. Mixed methods were utilized such as quantitative, semi-structured questionnaire, self-administered, field observations and focus group discussions (FGD) with heads of hospitals, medical doctors, nurses, pharmacists, laboratory technician and cleaner to enhance the understanding of current medical wastes management practices. Laboratory analysis and wastes composition determination were conducted. In addition, close ended interview questionnaires were used face-to-face with the parents/guardians of children that live close to MW treatment and disposal sites as well as unexposed children in distant communities surveyed, triangulation was done by combining the obtained primary data from both quantitative and qualitative approaches with the secondary data. The precise results were obtained on the current MW management practices in the study area.

3.3 Sampling Procedures

The sampling procedure that was utilized for this study is non-probability technique.

3.3.1 Selection of hospitals

Purposive sampling was used in the selection of the hospitals which included seven government hospitals: General Hospital Minna, General Hospital New Extension Minna, IBB Specialist Hospital Minna, General Hospital Bida, General Hospital Suleja, General Hospital Kontagora and General Hospital Wushishi were selected while for the private ones: Maraba (Aisha Usman Hospital Bida, Standard Hospital Minna and Al-Azeez Hospital Kontagora, were considered. The purposive sampling technique, also known as selective, judgment and subjective sampling procedure was employed in order to obtain reliable results in the study. Essentially, this is a type of non-probability sampling that is most effective when one needs to study a certain cultural domain with knowledgeable experts within the field (Gawad *et al.,* 2016). The choice of an informant is deliberate due to the qualities the informant possesses. The technique is a non-random application that does not require basic theories or a set number of informants. This means that, the researcher decides what needs to be known and select sets of people who can and are willing to provide the information by virtue of their knowledge or experience in the research area (Bernard 2002, Lewis and Sheppard 2006).

3.3.2 Sampling frame/size

Non-probability sampling (census survey) technique was utilized. In another submission that, sometimes the sample may be sufficiently small and the researcher has to include the entire population of a target group (Mohajer 2013). The required data are gathered on every member of the target population known as census research study method. This type of sampling procedure was employed in this study because, the target groups (medical doctors, nurses/midwifes, paramedical and wastes handlers) constituted the population of a hospital and they are directly responsible for hospital wastes generation and handling.

3.4 Research Instruments/Materials

Questionnaires were used to generate data in this study. The study utilized close ended questionnaires in which questions have categories of response concerning relevant topics of study and they were administered to all the healthcare workers waste handlers in the 10 selected hospitals. The materials utilized for data collection from the field included, a tape recorder, a camera and verbal interviews as described by (Bryman, 2004). Pictures of different key objects in the field were taken right from the waste generation/collection unit/ward, storage, transportation, open surface burning, incinerator or disposal sites. Upon completion of the field work, all recorded interviews were transcribed and the pictures grouped were analysed.

3.5 Methods of Data Collection

This study used both primary and secondary types of data collection. The Primary data were obtained through questionnaires, laboratory analysis, field observation, interviews and focus group discussion. Whereas secondary data were retrieved through extensive desk review of relevant literatures such as different documents and reports from different departments, journals and previous studies.

3.5.1 Examination of the current practices of medical waste management in Niger State.

To examine the overall practice of MW management in this study, both quantitative and qualitative methods were utilized. A semi- questionnaire, self-administered questionnaire, focus group discussions (FGD) and field observations with heads of hospitals, doctors, nurses, pharmacists, laboratory technicians, waste handlers, NISEPA, Ministry of Health and Hospital Services were engaged in the study. The main questions asked were on wastes collection, segregation methods, transportation means, storage facilities, treatment methods, disposal pattern, re-cycling and re-use of generated wastes, occupational health plans and safety, policies, plans, training and budget for MW management.

3.5.2 Determination of the characteristics of hospital wastewater

Samples of medical wastewater were taken randomly from the ten (10) selected hospitals. Sample collection was done for seven consecutive days once in month for the 3 consecuti ve months (May to July, 2019), three samples were collected at 2-hour intervals per day and pooled together to form the composite samples for the day for seven days in a week. The samples obtained from each of the sampled hospitals were used to determine their BOD, COD, TSS, DO, pH, TC and FC. The samples were taken during the period of maximal hospital activity (8:00 a.m. to 3:00 p.m.) and put into polyethylene bottles. At least triple samples were collected for each parameter (APHA, 1998).

3.5.3 Survey of morbidity in children (≤ 10 years) within the vicinities of the medical waste disposal and treatment sites of the study area

Data on morbidity in children within the MW disposal and treatment sites were generated using questionnaire. Questions on the frequencies of diseases were designed to generate data on how often children in neighbourhood communities suffer from respiratory, intestinal and skin infections. In this study, two cohorts' children less than or equal to the age of 10 years were selected. The first cohort was considered as the exposed group (children living close to the poor medical disposal and treatment sites and having unrestricted access to such sites). The unexposed cohorts were children who live in separate neighbourhoods of about 20 km from the exposed groups. This was in accordance with the descriptions given by Peter (2011). Two-by-two epidemiological table was employed to analyse the data generated by the disease frequency questionnaires. Risk ratios and risk differences were compared among the groups including the total risks and the risks in each of the groups in accordance with the method described by Peter (2011).

3.5.4 Determination of the compositions of solid medical wastes and generation rate

Collection of data was conducted in two seasons (the raining and dry seasons) with the first round; the dry season commencing from November, 2018 to March, 2019 while, the second round was from June, 2019 to October, 2019. The study utilized items such as buckets, safety boxes and plastic bags and labelled to indicate the different categories of the medical wastes, date of collection and sample location in order to achieve proper waste collection. The quantities of categories of MW generated were calculated by samples weighting from all the affected departments or units of the selected hospitals. The standard measurement scale based on WHO standards was utilized. Samples were collected for consecutive seven days in each of the hospitals. This method was adopted because, it gave room to capture all different categories of patients that visited the hospitals within the week. Overall samples were firstly weighed to determine their total overall weights after which they were sorted manually in accordance with the methods described by WHO (1999) and WH (2001). The sorted components were reweighed to determine their percentage weights from the total weights of samples following the methods described by (Awodele *et al.*, 2016), Esubalew (2015) and Umar and Mohammed (2014). Three field supporting staff were engaged.

3. 6 Questionnaires Design

This study designed both semi-structured and self-administered questionnaire survey and were administered to different heads of departments for workers in the different departments of the selected hospitals. Different themes were covered such as evaluation of MW, segregation of categories of waste, collection, transportation, storage, policy and guidelines, strategic planning, staff training, occupational safety and budget.

3.7 Site Visits/ Personal Field Observations

Number of visits were paid to all the hospitals selected in order to examine and understand the details of current MW management practices in them. That is, the pattern of segregation practices daily of MW, collection items, storage facility, transportation means, treatment and disposal methods were enquired upon. This was in accordance with methods described by (Ahmed, 2017).

3.8 Interviews

During these of periods interviews with key stakeholders, decision makers and waste handlers were conducted. In this case, more in-depth answers, clarification and clear understanding of the actual situation of management of MW in the selected hospitals were obtained. This was in accordance with methods described by (Ahmed, 2017).

3.9 Methods of Data Analysis

The data obtained from the field were in four sets: analysis of waste compositional study, surveys of questionnaire, laboratory test, interviews/observations and focus group discussions. These were collected and treated according to the methods described by (Ahmed, 2017; Esubalew (2015) and Peter (2011).

3.9.1 Examination of the current practices of medical waste management in Niger State

The results obtained from the questionnaire, FGD, field observations and face to face interviews were analysed using statistical Excel and SPSS version 22.0 software (Statistical Package for the Social Sciences). The data obtained were entered in a configuration format and each question in the study were represented by rows and variables (the various answers to one question in the study) were also entered into columns. At that point the information's were controlled, manipulated and changed to percentage scale. Descriptive analysis such as tables, frequencies, means and charts/graphs were used to depict different factors experienced in this investigation.

3.9.2 Examination of the characteristics of hospital wastewater

Hospitals wastewater samples collected in this study were analysed at Quality Laboratory Federal Ministry of Water Resources and Rural Development in Nigeria. The results obtained were compared with the standards provided by WHO (1996) and NESREA (2011) for wastewater. The obtained data were analysed by utilized descriptive statistics such as mean, standard deviation (SD), frequency, percentage and graph,

3.9.3 Survey of morbidity in children (≤ 10 years) within the medical waste disposal and treatment

Two-by-two epidemiological table was employed to analyse the data generated by the disease frequency questionnaires. Risk ratios and risk differences were compared among the groups including the total risks and the risks in each of the groups. This method also adopted in accordance with the description given by (Peter, 2011). In addition, descriptive statistics such as mean, table and percentage were utilized to elucidate results obtained.

3.9.4 Statistical analysis of the compositions of solid medical wastes and generation rate

The data obtained from the waste compositional study were analysed using SPSS version 22.0. Data analysed were entered in a format into waste categories. The data were again manipulated and changed to kilogrammes (kg) and percentage scale. Descriptive analysis tables, frequencies, percentages, means, (ANOVA), charts and standard deviation (SD) were utilized to describe the volumes of the medical wastes generated in the study.

ANOVA: Analysis of Variance

The analysis of variance (ANOVA) employed in this study made use of t-tests and the standard errors obtained in the determinations as given in equations.

$$SS = \Sigma(x - x)^2 \qquad 3.1$$

Where SS = sum of squares, x = estimate of individual and *x* = mean or average score

Therefore, variance of *n* measurements is given by: 3.2

$$t = \frac{\bar{x}_1 - \bar{x}_2}{Se(\bar{x}_1 - \bar{x}_2)}$$

$$Se\,(\bar{x}_1 - \bar{x}_2) = s(\frac{1}{n_1} + \frac{1}{n_2})^{½} \qquad 3.2$$

Where $\bar{x}_1 and\ \bar{x}_2$ represent individual scores and group's mean score, respectively. The *sum of squares* of deviations from the mean is called numerator and *degrees of freedom* is the denominator.

The square root of variance is standard deviation, S, a measure of variability.

S = √S2 3.3

The MW generation rates (WG) per inpatient, per occupied bed and available bed per day was determined as follow Omofunmi *et al*. (2016).

$$\text{WG} = \frac{\sum(w_t - w_b)}{\text{inpatient}} \qquad 3.4$$

or

$$\text{WG} = \frac{\sum(w_t - w_b)}{\text{Occupied Bed}} \qquad 3.5$$

where

WG = Waste generated rates (kg/day) or (kg/bed/day)

∑ = Summation

w_t = Weight of the bin filled with sample waste (kg)

w_b= Weight of empty bin (kg).

Inpatient = Number of patients hospitalized.

Occupied bed = Number of hospital patient who occupies a bed.

3.10 Ethical Approval

The ethical approval to conduct this research was obtained from Niger State Ministry of Health and Hospital Services Management Board thereafter, approval was obtained from the Health Research and Ethics Committee (HREC). The key basic procedures were explained to the individual participants in the selected hospitals and accordingly their consent to participate in the study was obtained.

3.11 Data Quality Assurance Management

The study employed different strategies to ensure reliability during data collection which includes: the standard calibrated measuring instruments were used. Secondly, professionals field assistants were recruited as supervisors. In addition, daily on-site supervision by the investigator during the actual measurements was conducted.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Examination of the Current Practices of Medical Waste Management

The clear pictures of these cannot be obtained unless the classes of the people involved are clearly spell out. In this vein, the following stakeholders that were directly involved in MW management from the source of generation to final disposal point were presented in Figure 4.1. A total of 1, 405 questionnaires were returned by all the four (4) target groups. 137 of these numbers were from medical doctors, equivalent to 9.7%, 698 responses (49.7%) were received from the nursing/midwifery staff, 475 (33.8%) from paramedical, while 95 (6.8) were received from waste handlers.

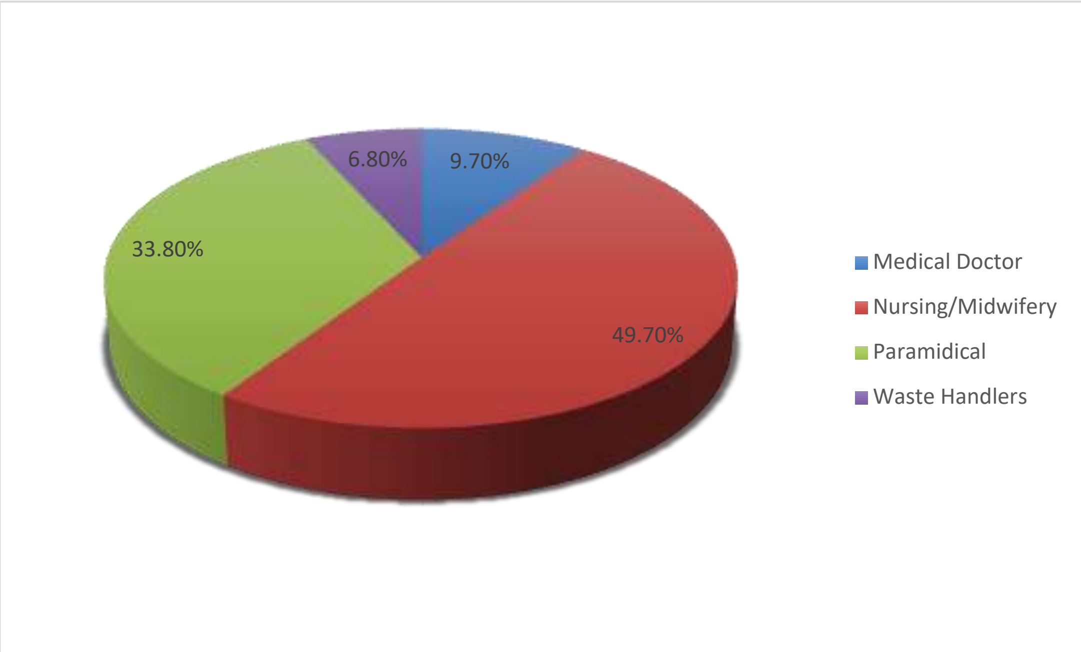


Figure 4.1: Distribution of stakeholders in medical waste management in the Study Area

4.1.1 Segregation

The results of respondents presented in Figure 4.2, reveals that, about 1021(72.7.%) of the respondents agreed that, MW is segregated at each departmental level, while 342 (24.3%) strongly disagreed (SDA) the implementation of segregation methods/processes for MW in the hospitals, whereas 42(3.0%) disagreed of segregation (DA) processes for these wastes.

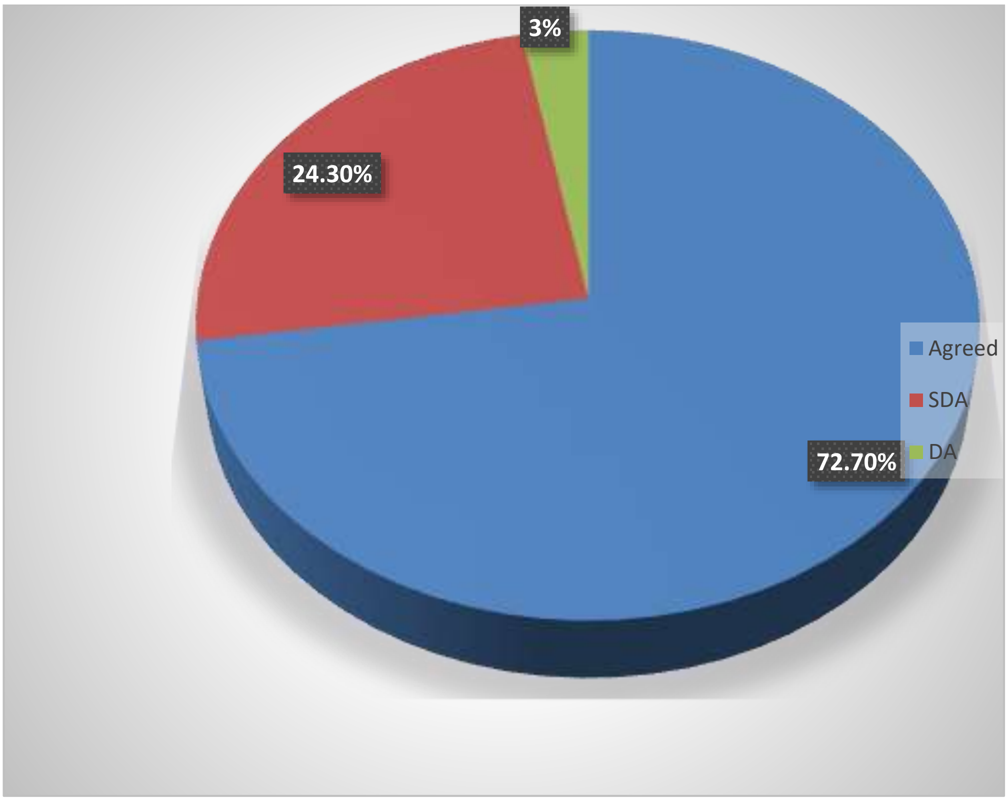


Figure 4.2: Distribution of respondents' awareness on the existence of medical waste segregation practices in the selected hospitals

The types of MW segregated in the surveyed hospitals were show in Figure 4.3. The most common categories of MW segregated by the respondents were; sharp objects like syringes and needles, 1296(92.2%) and pathological wastes, 109(7.8%). Only these two categories of wastes were therefore said to be segregated before final disposal on an open surface. In the case of segregated syringes and needles, it was noticed that they were not destroyed before final disposal with other wastes as shown in Plate III. On the other hand, hazardous wastes were not segregated but disposed of with the general wastes as depicted in Plate IV which is a common practice in all the studied hospitals.

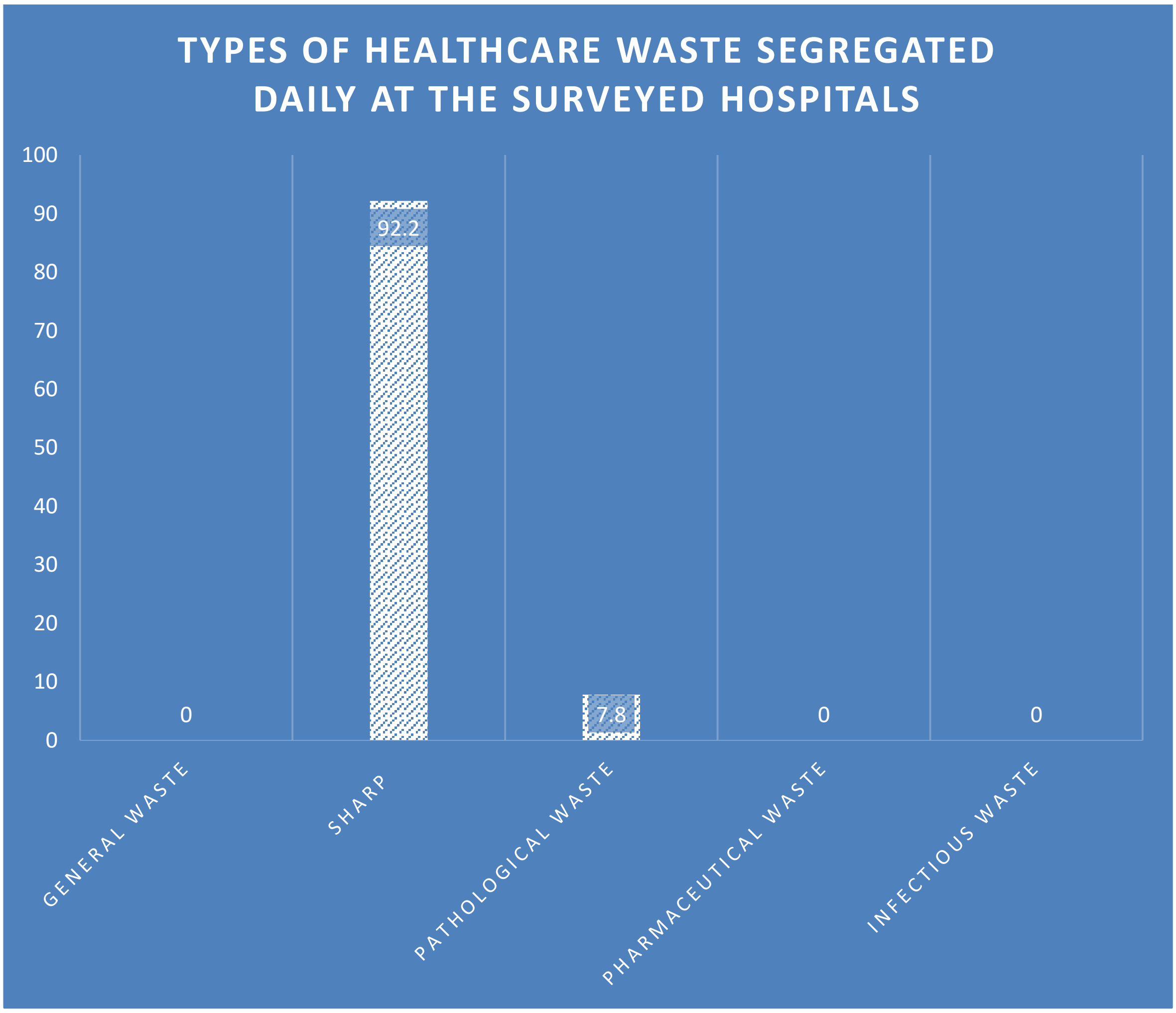


Figure 4.3: Distribution of respondents' knowledge on the type of medical wastes segregation practices in the hospitals

Plate III: Syringes and needles disposed with other wastes on an open surface, a practice in all the selected hospitals (Source: Field work, 2018)

The dumping of hazardous MW with the general wastes in open surface areas as being practised in all the selected areas in this study, can pose negative direct environmental problems due to the contamination of air, soils, surface and underground water that result from such environmentally inimical practice. Plate IV depicts the practice that is commonly carried out in all the selected hospitals in this study.

Plate IV: Mixed Hazardous and non-hazardous wastes disposed on an open surface in one of the hospitals (Source: Field work, 2018)

4.1.2 Labelling and colour coding of the segregated wastes

The absence of standard waste colour- coded containers, waste polyethylene (PE) bags and safety boxes for sharp wastes makes it difficult to apply the regulations of the WHO in many hospitals especially in Niger State. Labelling of hazardous and other waste types was completely absent in all the selected hospitals. As shown in Figure 4.4, about 0.4% of the respondents agreed that there were practices of labelling and colour coding of hospitals wastes in all the hospitals in Niger state while, about 1378 respondents, equivalent to (98.1 %) strongly disagreed (SDA). Also, 1.5% of the respondents equally disagreed (DA) the practices of labelling and colour coding of waste generated.

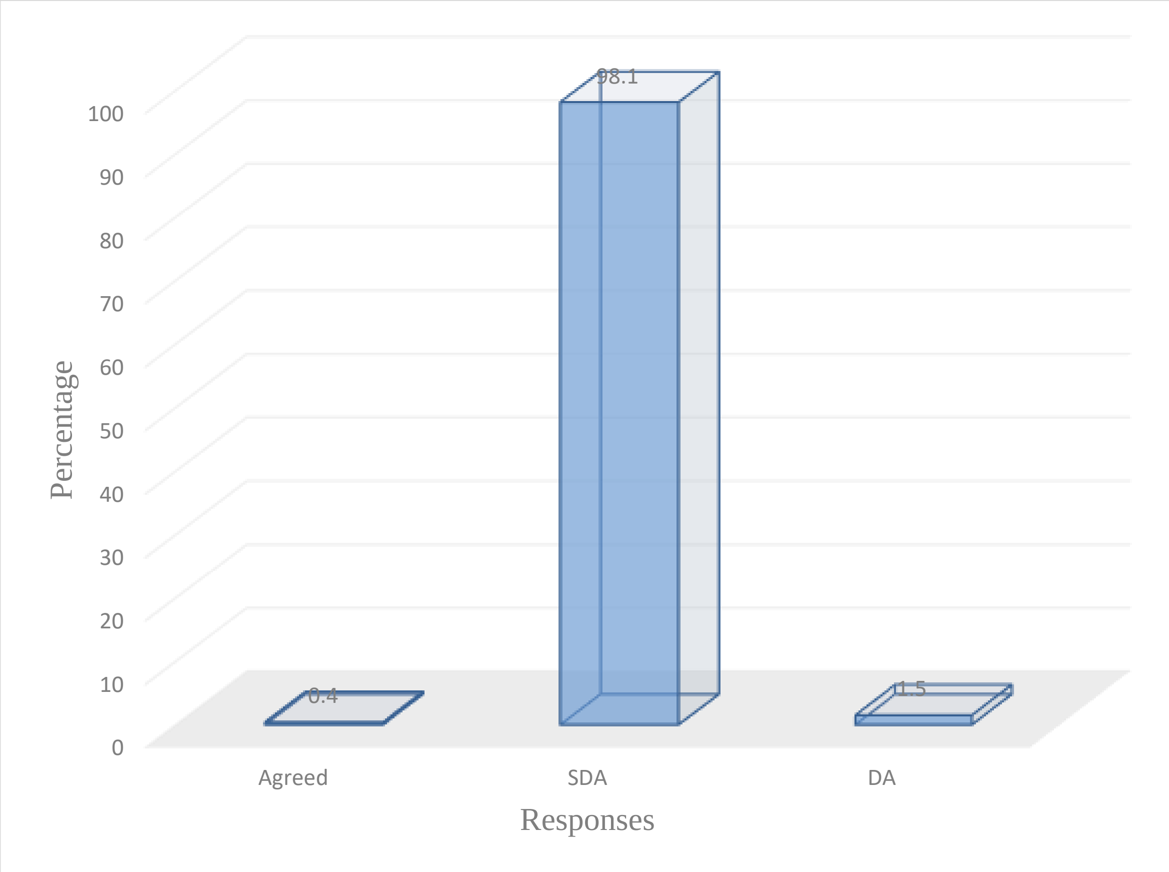


Figure 4.4: Distribution of respondents' knowledge on the practice of labelling and colour coding used for segregated wastes

4.1.3 Temporary storage of healthcare wastes and on-site transportation practices

The results of this study, Figure 4.5, revealed that, about 1137 (80.9%) of respondents agreed that medical wastes are stored temporarily in their healthcare facilities while, 213 (15.2%) strongly disagreed. 55 respondents, equivalent to 3.9%, disagreed and could not distinguish between temporary storage of medical wastes and the use of surface dump sites located in the hospitals, since these storage sites do not bear clear marks for these purposes. However, it was noticed that, the selected study hospitals use big metal containers, plastic bins and bare ground surfaces for the storage of the collected hospital wastes (Plate V).

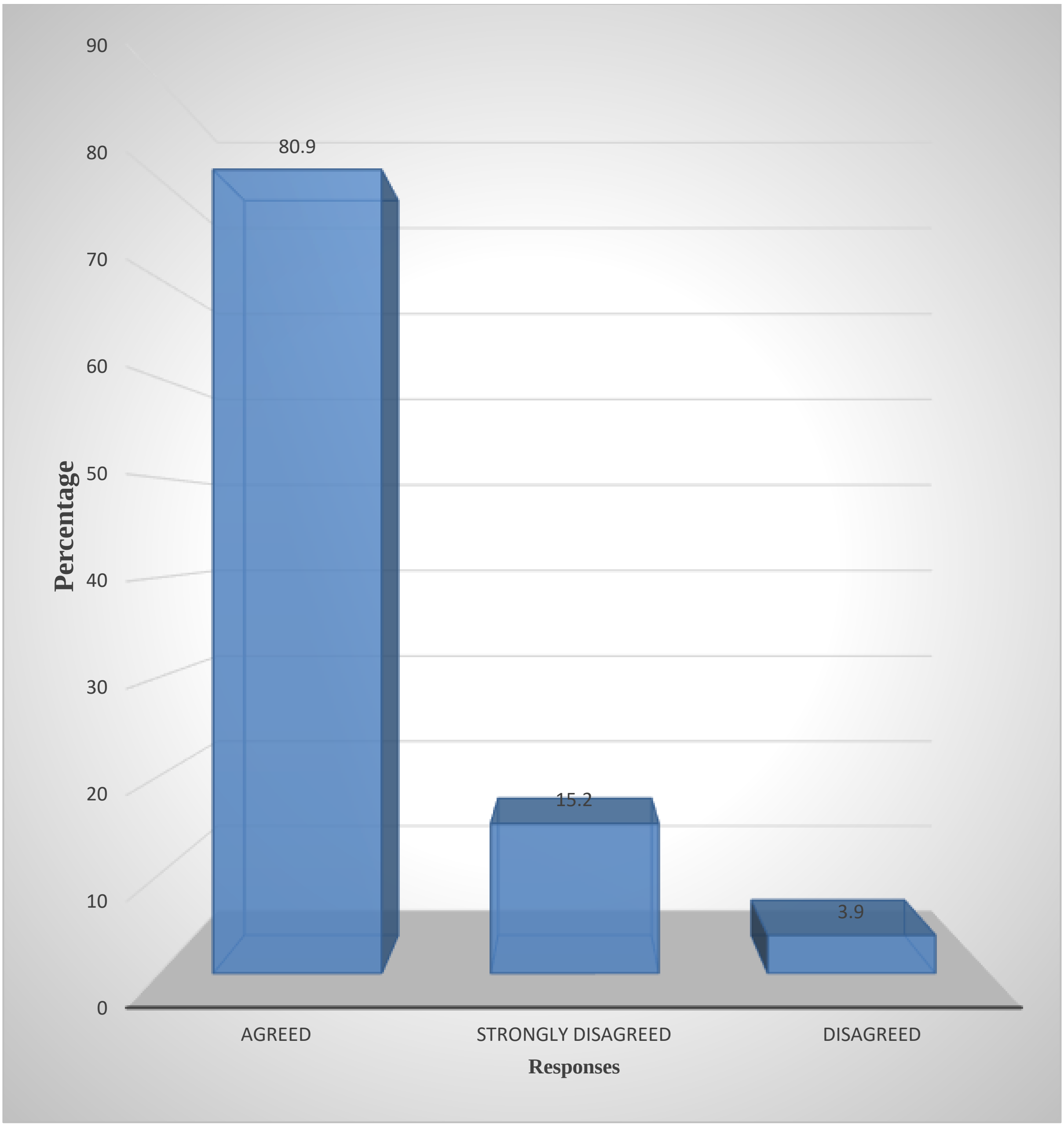


Figure 4.5: Respondents' knowledge of the existence of temporary storage practices for medical waste disposal

Plate V: Temporal Storage Facilities Available in Hospitals (a) Polythene bags and metal drums (b) Open metal container (c) Open metal container and polythene bags under roof (d) Ground surfaces (e) Plastic containers (Source: Field work, 2018)

4.1.4 Hospital healthcare waste collection practices and containers used

At the selected hospitals for this research, there were no defined collection systems for general and hazardous wastes. Wastes were collected at the points of generation (wards, operating rooms, laboratories, and offices) using various containers. Results presented in Figure 4.6 and Plate VI, shows that, the most common types of containers used to collect the medical wastes mentioned by the respondents are black plastic bags; 177(12.6%), open plastic and metal buckets; 683 (48.6%), plastic bin and safety boxes; 188(13.4%), small plastic bins of 3-10 kg; 206 (14.7%), while 151(10.7%) represent the respondents who said 50kg plastic bins are being used in their facilities.

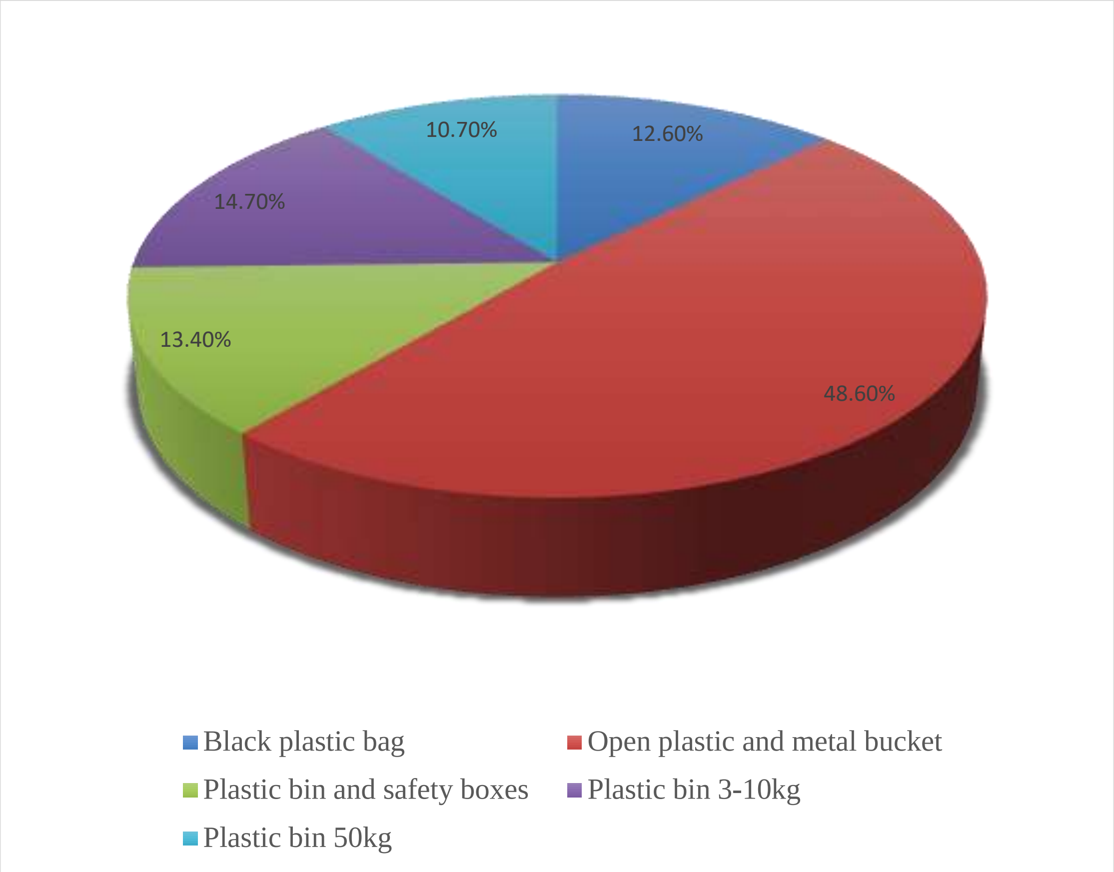


Figure 4.6: Knowledge of respondents of the type of containers used to collect medical wastes

Plate VI: Type of containers used to collect hospital waste (a) Open plastic (b) Plastic and metal buckets (c) Carton safety box (d) Close plastic bin (e) Carton safety box and open plastic bin (f) Open metal bucket (g) Open plastic bin (Source: Field work, 2018)

4.1.5 Off-site transportation of medical waste in the study area

The interviews conducted at the selected hospitals revealed that, the heads of hospitals have a contract with the Niger State Environmental Protection Agency (NISEPA) that collect their wastes once a week but the arrangements were not effective. Hence, more than two third of MW produced in the areas were disposed of inside the hospitals. However, the vehicles used for the transportation of off-site MW are similar vehicles (open Tipper) used for ordinary municipal solid wastes disposal, a practice which falls far below the WHO standard specifications required for medical wastes transportation and in most cases, wastes were transported without proper covers. These practices posed health risks to the public.

4.1.6 On-site treatment and final disposal of healthcare waste generated in the study area

The patterned of treatment and disposal options in the hospitals selected in this study ranges from the use of open surface burning, open fire pits, surface dumps and sub-standard incinerators. Based on the interviews conducted and physical observations, Niger State Ministry of Health and Hospital Services have four MW incinerators; during the period of this research, only one of them is currently working and the others are out of service. The incinerator in General Hospital, Minna currently working is operated by three workers who operates it once in a week with 1-3 cycles per day. The capacity of the incinerator for each is 70-100 kg of MW and a complete cycle takes about five hours per cycle. The operation temperature for this process is from 700 - 800 °C. The New Extension General Hospital which is opposite the Old General Hospital equally utilizes this same incinerator. Direct observations and the results of interviews conducted on the residents within and outside the hospital indicates that, the residents considered this incinerator as the main source of air pollution within and outside the hospital due to the thick smoke released by the process. This is mainly as a result of the fact that, the operators are not properly trained and the operational capacity of the incinerator is not efficient.

The remaining three incinerators located at Bida, Suleja and Kontagora General Hospitals are out of service and needed maintenance. While the rest of the hospitals sampled in this study burn their medical wastes in open fire pits and surfaces at their backyards except IBB Specialized Hospital that burns its medical wastes outside opposite the hospital premises by open surface. Most importantly, segregated syringes and needle wastes from wards/units were burnt together with all other wastes at the hospitals backyards, without prior pre-treatment before burning (Plate IV). Additionally, after the burning, the bottom ash was left untreated Plate VII (e). Thus, leaving the residual waste in the open as Bottom Ash. However, both fly and bottom ash ends up in the environment thereby contaminating the air, surface and underground water and soil as well. Since it was well established that, dioxins and furans are found in hospital wastes burning or incineration ash at levels of the order of micrograms per gram of ash. Furthermore, only hospital H1 provided a pit for bottom ash burial Plate VII (g) but, improperly buried. The ash was buried without any form of treatment which allow migration of toxic substances content in the ash that could contaminate the surface and underground water.

PLATE. VII: Treatment and final disposal practices in in the study area (a) Incinerator (b) Residual of open surface burning of MW(c) Open pit burning (d) Surface burning (e) Untreated ash (f) open surface burning (g) Ash buried pit (Source: Field work, 2018)

4.1.7 Off-site Treatment and final disposal of healthcare waste generated in the study area

According to the interviews, Niger State Environmental Protection Agency (NISEPA), surface burning and open fire pit are the commonest treatment of medical waste treatment practices disposed together with domestic wastes, without prior pre-treatment before burning, a practiced which is totally against the WHO standard for medical waste management and this calls for urgent intervention.

4.1.8 Hospital waste reuse and recycling practices in the study area

The results presented in Figure 4.7 shows that, reuse and recycling of hospital wastes practices in all the selected hospitals were completely absent. During the survey, it was observed that the absence of policy documents and guidelines on medical wastes reuse and recycling were practices absolutely unknown to the health workers. From the figure, the percentage of responses that agreed that such practices were unavailable in the hospitals was 97.1, while 2.9 percent of them disagreed saying that such practices were fairly known though not available in most of the healthcare facilities studied.

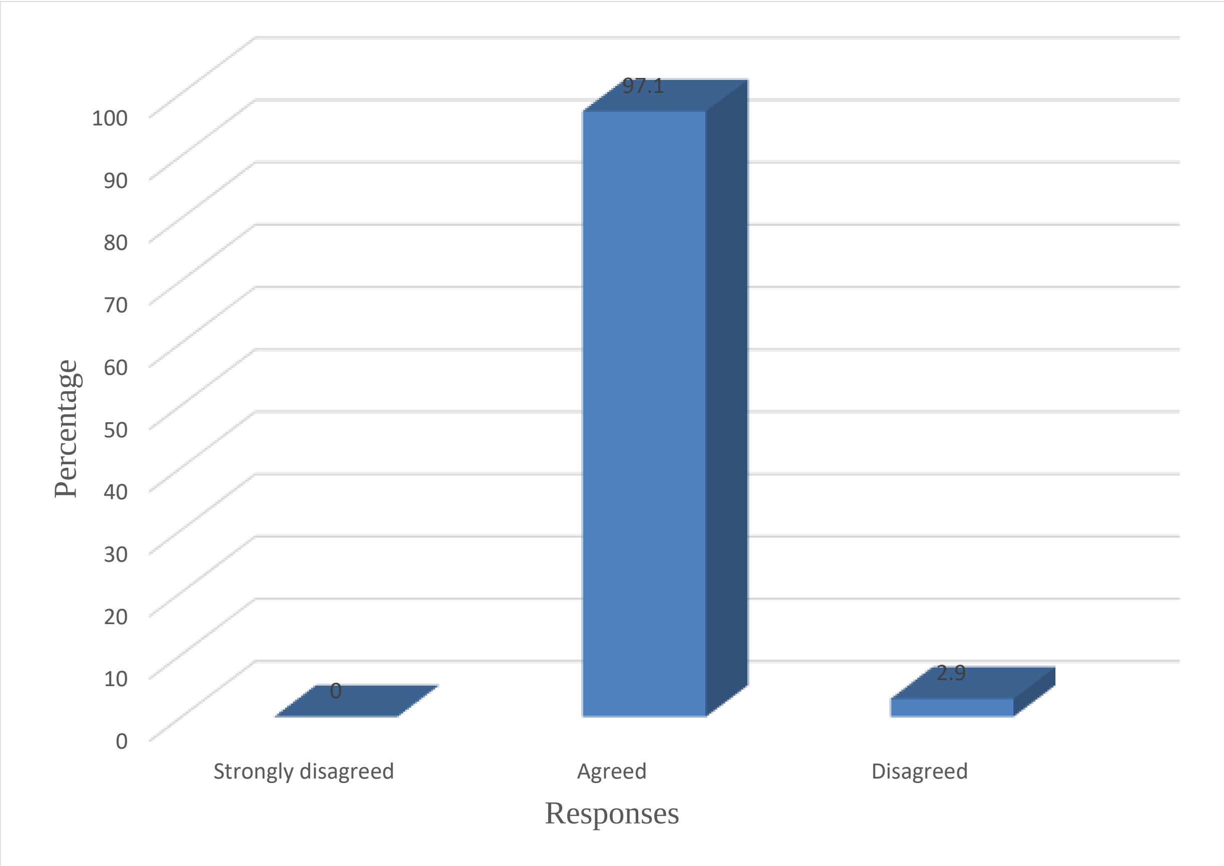


Figure 4.7: Respondents knowledge of presence of reuse and recycling of medical wastes practices in the hospitals

4.1.9 Supervision and budget allocation for medical waste management

In order to establish this, health workers were interviewed and the key officers of the Ministry of Health interviewed 95% of the responses asserted that, there is no monitory and evaluation supervision committee or body saddled with the role of supervising hospital wastes management by the Niger State Ministry of Health for both the public and private hospitals surveyed. Also, it was pointed out that, no separate budget is allocated for healthcare waste management in the Ministry of Health budget. All these are attributed to the absence of specific healthcare waste management policy documents in the state.

4.1.10 Test for the knowledge of the existence of hospital waste management policy and guidelines in the study area

Figure 4.8: Respondents knowledge on presence of hospital waste management policy and guidelines indicates that 97% of the respondents agreed that no hospital waste management policy, manual and plan exist in the hospitals in the study area.

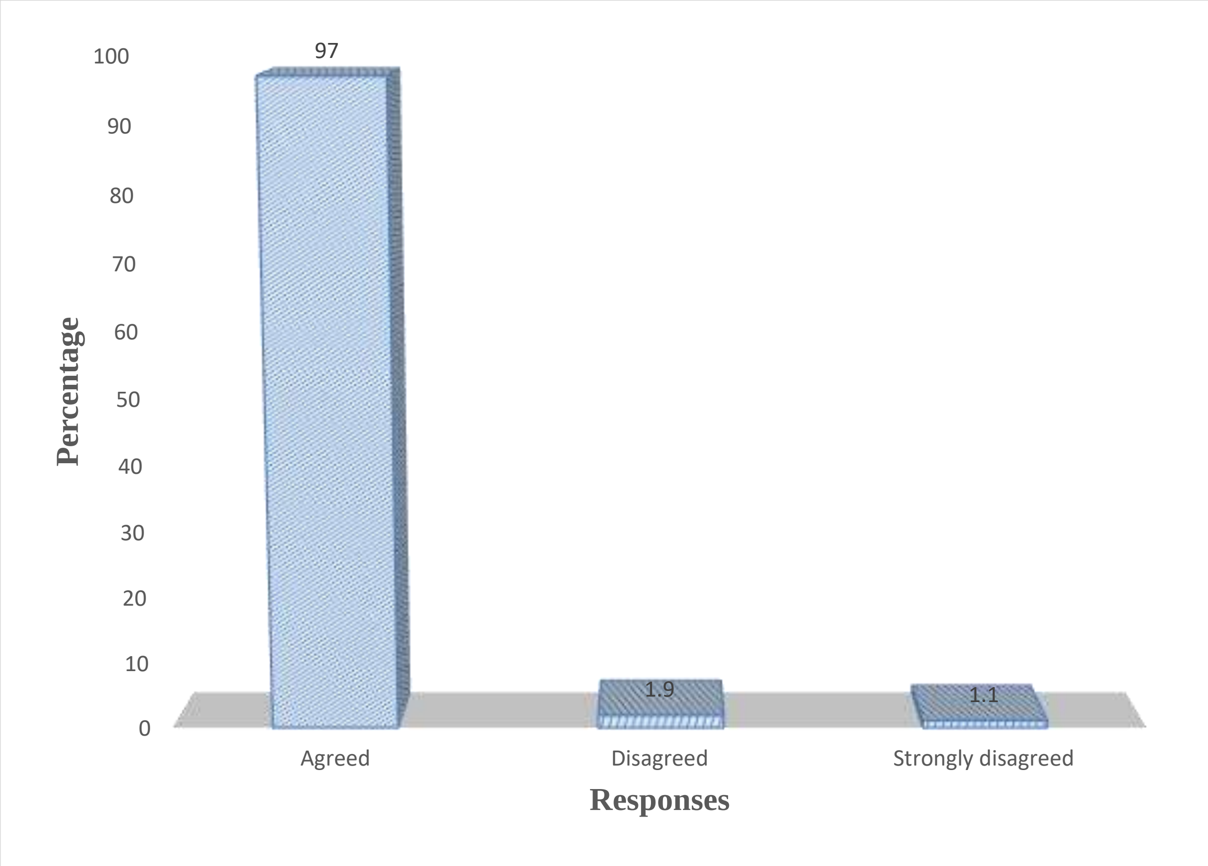


Figure 4.8: Respondents knowledge on presences of hospital waste management manual and plan

4.1.11 Availability of staff training and safety devices in the selected hospitals

The results of this study indicates that, 97% of the respondents strongly disagreed that staff in the study area received training in the field of medical wastes management while, 1.4% agreed that, they receive training on the job while, 1.6% of the respondents said that they were no aware or disagreed of any form of training on management of MW in all the hospitals studied Figure 4.9. Only waste handlers claimed to be given introductory trainings which is not enough for full awareness required on the dangers of such waste to the handlers and the entire society. Similarly, environmental health professionals and heads of departments in the public hospitals said that they are not given any specific training on medical waste management and reasonable numbers of them showed a significant lack of knowledge on how to deal with MW. In addition, all the private hospitals surveyed did not provide any training related to healthcare waste management to its members of staff. The Nursing Heads that clean and collect the wastes from patient wards to the temporary storage containers. It is not considered a necessity as they were not aware of how the infection spreads through the waste. Plate VIII, given example of Waste handler with safety kits in the study area.

PLATE VIII: Waste handler with safety kits (Source: Field work, 2018)

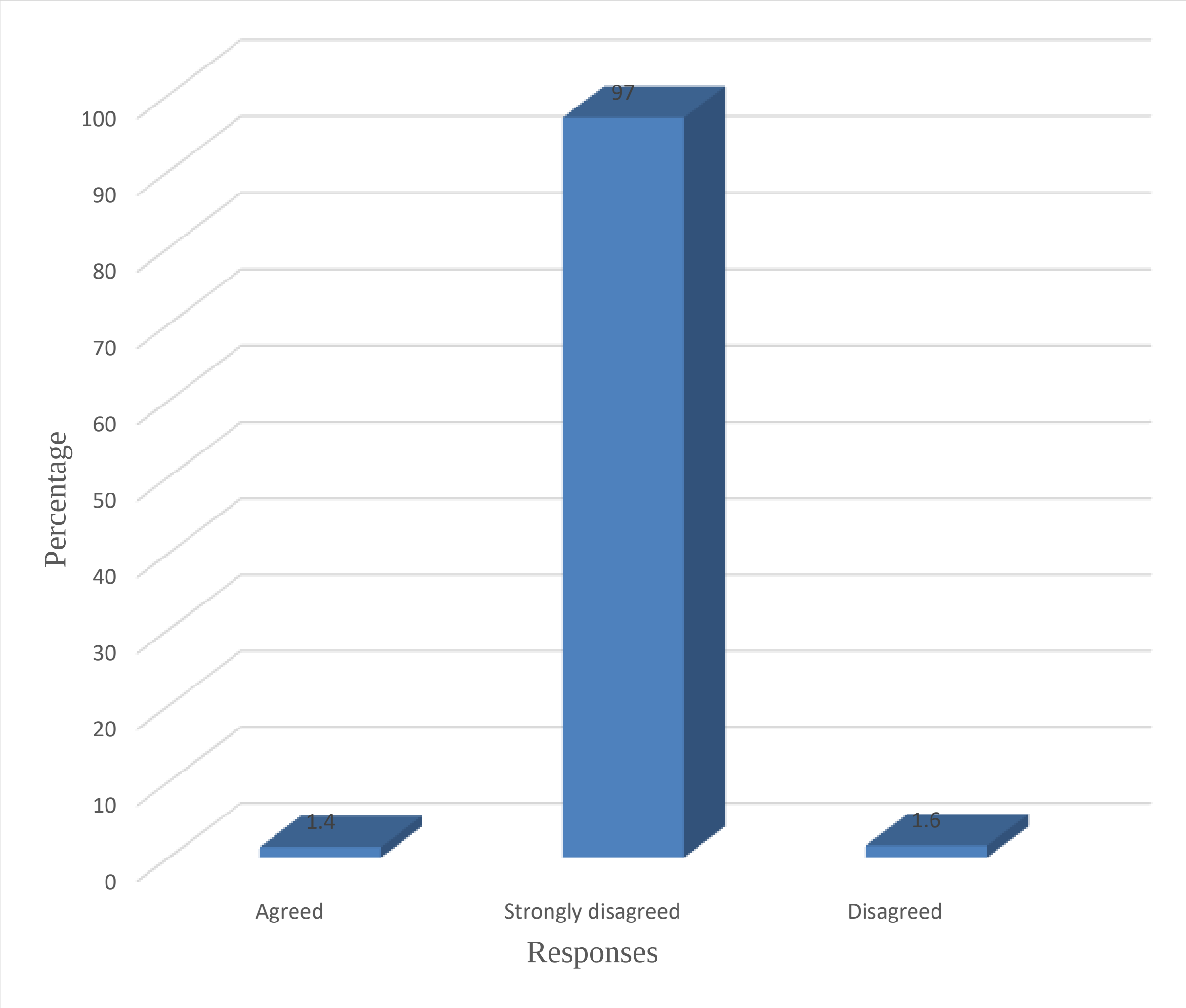


Figure 4.9: Respondents knowledge on presences of staff training on medical waste management practices

4.1.12 Risks Associated with the current medical waste management practices in the study area

The absence of policy, guidelines, plans as well as separate budget directly allocated for the proper MW management in the study area strongly jeopardize the current practices of management in the selected hospitals. No adequate standard incinerators, temporary storage facility, container, plastic bag holders, colour plastic bins for segregation of the categories of waste and no prior MW treatment before final disposal. Therefore, the methods of the current management practices in handling medical wastes in the state and absence of standard control procedures increase the transmissions of diseases, risk of environmental contamination and public health in the state.

4.1.13 Results from Focus Group and Interviews Analysis

The results obtained from Focus Group Discussion and interviews of relevant stakeholders presented.

4.1.13.1 *Parallel Focus Group Sessions*

Thus, the discussion sessions provided relaxed atmosphere that encouraged participants to freely discuss exhaustively, all aspects of management of MW were provided by presenting the aim and objectives of the study to the participants to enhance their degree of understanding of the subject and this, in no small measure, facilitated the discussion.

4.1.13.2 *Position of the FGD on the overall responsibility of the management of hospital wastes in the study area*

The FGD general position was that, management of MW in the state is still at a very low level. This is because, in all of the selected healthcare facilities there was no focal person or professional waste manager responsible for HCW management was found. Consequently, these healthcare facilities have engaged and is still engaging the services of untrained Nursing Heads as cleaners and Waste Collectors which in entirely is an unacceptable practice going by the dictates of the WHO conditions for MW management.

4.1.13.3 *Modes of waste collection, segregation and storage in the study area*

The result obtained from the FGD ascertained that, wastes were collected daily by nursing heads and dumped directly into temporary storage receptacles or bins. From the outcome, it was ascertained that in most healthcare facilities selected no any form of colour coding waste bins available to indicate the categories of waste to be deposited in particular waste bins. In addition, although at wards level segregation of sharp waste was done and emptied in the temporary storage facilities daily, no other form of categories of waste segregation was done at any other level in all the selected healthcare facilities selected in the study area. As a result, both hazardous and non-hazardous hospital wastes were collected and disposed together in storage facilities temporary located in all the hospitals. In most cases, the results also revealed that the temporary storage facilities of the MW in the hospital were kept inappropriately in either front or back yards within the hospitals. This is a practice that is quite contrary to the standards stipulated by the WHO for the treatment of a given generated medical waste.

4.1.13.4 *The result of medical waste management policy, manual and strategic plans in the study area*

The results of FGD revealed that, HCW management policy, manual and strategic plans are not available in the State Ministry of Health and Hospitals Services or even the selected hospitals in the state which led to improper MW management in the state. This, in effect, calls for an urgent provision of effective HCW management policy, manuals and strategic plans by the state Ministry of Health and other bodies responsible for the proper implementation of robust healthcare waste management services acceptable by any world standard.

4.1.13.5 *Focus group discussion position on hospital wastes*

The general position of FGD is that, no prior treatment of medical wastes takes place before final disposal by the selected healthcare institutions in the state. Similarly, NISEPA are responsible for wastes management in the state, equally disposed of both hospital and household wastes without prior treatment. The open surface burning of medical wastes was the commonest treatment practice by the selected public and private hospitals as well as NISEPA in the state. In addition, treatment of hospitals raw wastewater before discharge into the environment was absolutely lacking, because no wastewater treatment plant is available in any of the healthcare facilities selected for the study. These practices are in effect, up to the standards stipulated by the WHO for the treatment of medical wastes.

4.1.13.6 *The state of Waste re-cycling and re-use in the in the study area as found by focus group discussion*

The results FGD revealed that no form of waste re-cycling or re-use practice exists at the healthcare facilities selected for this stud. In addition, no plan to put these processes in place in the nearest future either by the authorities of the selected healthcare facilities management or the state government. This was informed by the fact that no single authority interacted with that has an inkling of any plan for the establishment of these facilities in the nearest future.

4.1.13.7 *Other factors mentioned by FGD that lead to poor medical wastes management*

The other factors stated by FGD that lead to poor medical wastes management in the state are institutional gaps in term of specific training of healthcare workers and wastes handlers on medical wastes management. Also, the issue of zero budget for MW management affected all the hospitals for this study and was a major concerned to the FGD. Furthermore, training opportunities, which are vital in sustainability of MW management practices which are not readily available for all levels of operational staff in the healthcare facilities selected in this study. The effect is that, medical wastes management generally in the state is given a poor attention which could pose negative environmental effects and public health risks, the situation that is highly unacceptable by the WHO standards.

4.1.14 Results of interviews of key stakeholders in the study area

The results from the interviews conducted on the hospital administrators/managers, heads of departments indicate that, deficiency is linked with absence of medical waste management policy, guideline manual, strategic plans which lead to inadequate training, zero budget for MW management and these gave birth to improper management of MW produced from all the selected hospitals for this study. This implies that, hazardous and non-hazardous hospital wastes were mixed and improperly disposed of together. Regarding the patients interviewed across the selected hospitals, the health risks of black smoke released from surface burning of hospital wastes inside the hospitals were adequately perceived. Similarly, in the case of the residents living close to the hospitals and disposal sites of the existing surface burning of the hospitals wastes, the majority of residents said that, they have to temporarily vacate their houses during the burning processes particularly asthmatic patients and that, the case was always reported to the hospital administrators in the study area. It was ascertained that no action was taken in these regards at the period of this research.

4.1.15 Medical wastes stream flow

The stream flow according to data obtained from the hospitals selected could be as presented in Figure 4.10 and 4.11 vividly shows the current MW management practices in Niger State where non-hazardous and hazardous hospital wastes were mixed and improperly disposed of in an open surface as well as unscientifically treatment by open surface burning system. This practice is a linear economy waste management system (Take-Make-Use-Waste) that pose higher risks to environment and public health by ways of disease transmissions. According to the USEPA (2001) these practices are one of the largest sources of dioxin and mercury pollutants.

LINEAR ECONOMY

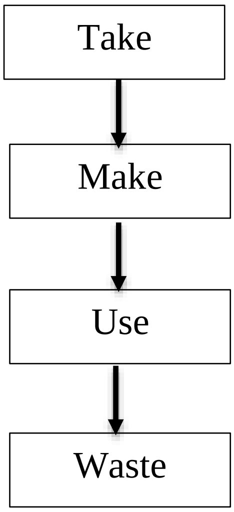


Figure 4.10: Medical wastes stream flow in the study area based on linear economy practices

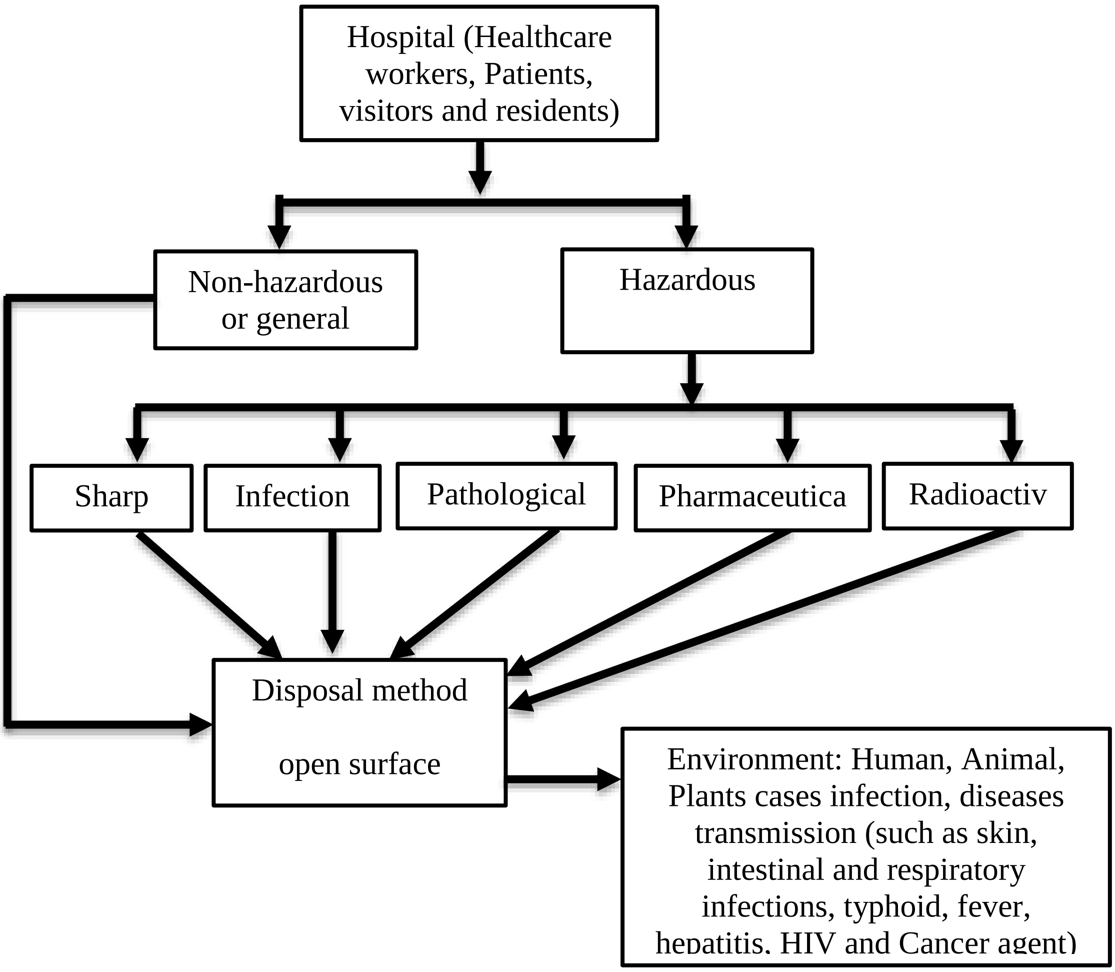


Figure 4.11: Medical wastes stream flow in the study area based on the obtained data

4.2 Characteristics of Hospital Wastewater of the Selected Hospitals in the Study Area

4.2.1 Treatment and disposal systems of raw hospital wastewater in the selected hospital

100% of the hospitals surveyed were not equipped with any form of hospital wastewater treatment plant system at the time of this study. This survey shows that, all the hospitals discharged their wastewater directly into drainages and pits. None of the Hospitals have a septic tank treatment system. Without any doubt, this is a practice that is inimical to the goals of SDGs on the environment and the WHO guidelines for sustainable healthcare delivery in the world.

4.2.2 Results of wastewater parameter in the study area

The results of hospitals raw wastewater parameters analysed in comparison with assessment of pH, BOD, COD, TSS, DO, TC, and FC, values of the hospitals raw effluents with WHO and National Environmental Standards Enforcement Agency (NESREA) standards are presented in Table 4.1. From the result, the biological oxygen demand (BOD) of the samples ranged from 0.3 (Al-Azeez Hospital, Kontagora) to 85.8 (General Hospital Minna) mg/L while the highest value of chemical oxygen demand (mg/L) was obtained for Al-Azeez Hospital, Kontagora (373.1) and the lowest for IBB Specialist Hospital, Minna.

Also, the total coliform values of water samples from the General Hospital, Minna (1099 cfu/100cm$^{3)}$ and General Hospital New Extension, Minna (72334cfu/100cm^3) were so high that they are higher than 1000 cfu/100cm^3 set as the maximum for a given wastewater sample by either NESREA (2011) or WHO (2004). The total faecal coliform contents of General Hospital New Extension, Minna (60338 cfu/100cm^3) and General

Table 4.1: Results of Analysis of the Wastewater Parameters tests (Values are means of triplicate determination)

Parameter	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	WHO	NESREA
pH	7.5	7.3	5.2	7.6	7.3	7.4	7.2	8.1	9.2	7.5	5 - 9	6.5 – 9.8
BOD (mg/L)	85.8	10.2	1.6	1.1	1.8	0.6	97.2	1	0.5	0.3	30	30
COD (mg/L)	214	23.1	ND	0.1	43.1	3.4	242.5	341.4	297	373.1	60	50
TSS (mg/L)	213.1	49.1	99.1	1211.7	252	11.3	154.3	73.3	62.7	258.5	100	100
DO (mg/L)	1.6	1.8	3.6	1.3	3.7	3.6	2.3	1.3	3.6	1.5	ND	4
TC (CFU/100)	1099.3	72334.7	312.2	403	255.9	1.1	0.01	6.2	3.2	514.4	1000	1000
FC (CFU/100)	409	60334	303.3	320.4	520.4	0.003	0.01	ND	0.003	400.4	400	400

H1 = General Hospital Minna, H2 = General Hospital new extension Minna, H7= General Hospital Wushishi, H8= Standard Hospital Minna, H9= Maraba (Aisha Usman Hospital Bida and H10= Al-Azeez Hospital Kontagora. (Source: Field surveyed, 2018)

Hospital, Suleja (520 cfu/100cm^3) also exceeded the respective 400 cfu/100cm^3 maximum permissible limit set by the WHO (2004) and NESREA (2011) respectively.

4.2.3 Statistical test of variance in hospitals raw wastewater parameters

To further explore the relationships of parameters in wastewater and data obtained, a statistical analysis was undertaken using Microsoft Excel Table 4.2. Statistical analysis became necessary because some variations in the parameters and composition of the samples both within the sampling points and across the study area were discovered.

4.2.3.1 *Analysis of variance (ANOVA) results for hospitals raw wastewater parameters*

One-way ANOVA was particularly useful in this comparison because it could compare means irrespective of whether the parameters are within the acceptable limits or not (Chukwunonye, 2010)

Table 4.2: Mean and Standard Deviation of the Selected Physico-chemical and Microbial Properties of the Wastewater Samples from the Study Area

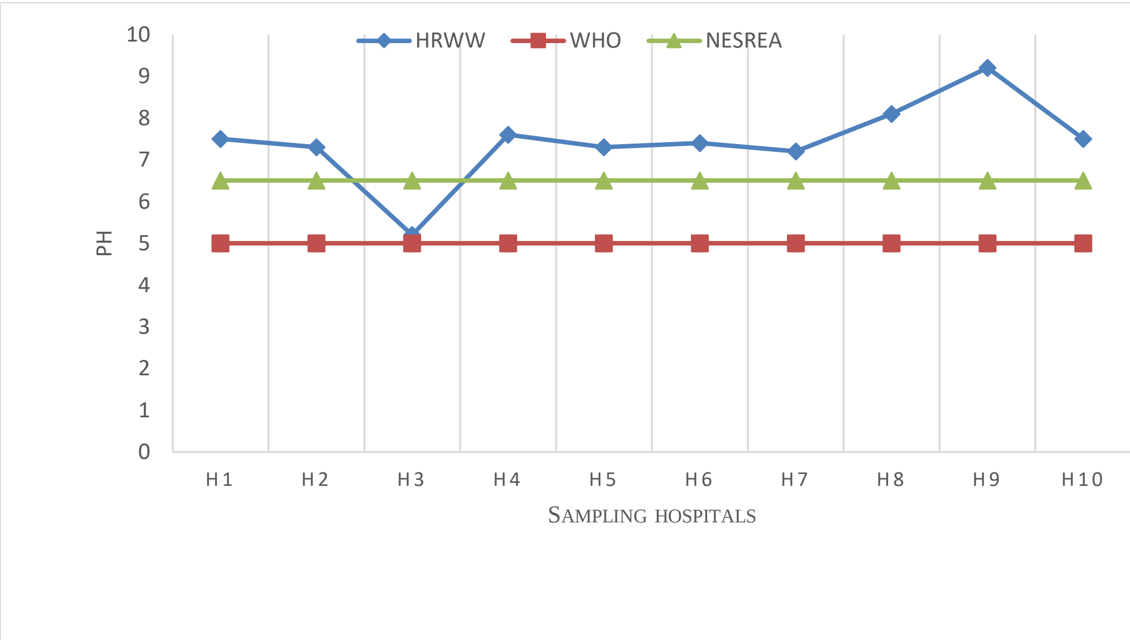
Parameters		H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
P^H	Mean	7.47	7.27	5.18	7.6	7.3	7.41	7.17	8.06	9.15	7.47
	Std.	±0.15	±0.2	±0.1	±0.1	±0.1	±0.1	±0.25	±0.15	±0.22	±0.5
BOD	Mean	85.77	10.2	1.62	1.1	1.83	0.63	97.17	1	0.5	0.3
	Std.	±1.46	±0.2	±0.06	±0.1	±0.06	±0.25	±0.21	±0.26	±0.3	±0.2
COD	Mean	214	23.07	0.003	0.67	43.13	3.43	241.37	341.37	297	373.07
	Std.	±2.65	±0.31	±0.006	±0.12	±1.31	±0.45	±2.06	±0.64	±0.9	±2.2
TSS	Mean	212.6	48.97	99.07	12.17	252	11.27	154.27	73.3	62.67	258.5
	Std.	±1.31	±0.15	±0.31	±0.12	±1	±0.74	±0.64	±0.61	±10.89	±0.5
DO	Mean	1.6	1.77	3.6	1.33	3.67	3.63	2.33	1.27	3.57	1.5
	Std.	±0.1	±0.06	±0.1	±0.06	±0.06	±0.15	±0.35	±0.06	±0.12	±0.1
TC	Mean	11006.7	72000.7	312.2	402.97	255.93	1.07	0.007	6.23	3.2	514.4
	Std.	±7.64	±3.06	±0.72	±1	±0.4	±0.21	±0.01	±0.21	±0.2	±2.52
FC	Mean	409	60334	303.33	320.43	520.38	0.003	0.01	NA	0.003	400.43
	Std.	±9	±576.77	±3.51	±0.67	±0.55	±0.006	±0.02	NA	±0.006	±0.67

H1 = General Hospital Minna, H2 = General Hospital new extension Minna, H7= General Hospital Wushishi, H8= Standard Hospital Minna, H9= Maraba (Aisha Usman Hospital Bida and H10= Al-Azeez Hospital Kontagora. (Source: Field surveyed, 2018)

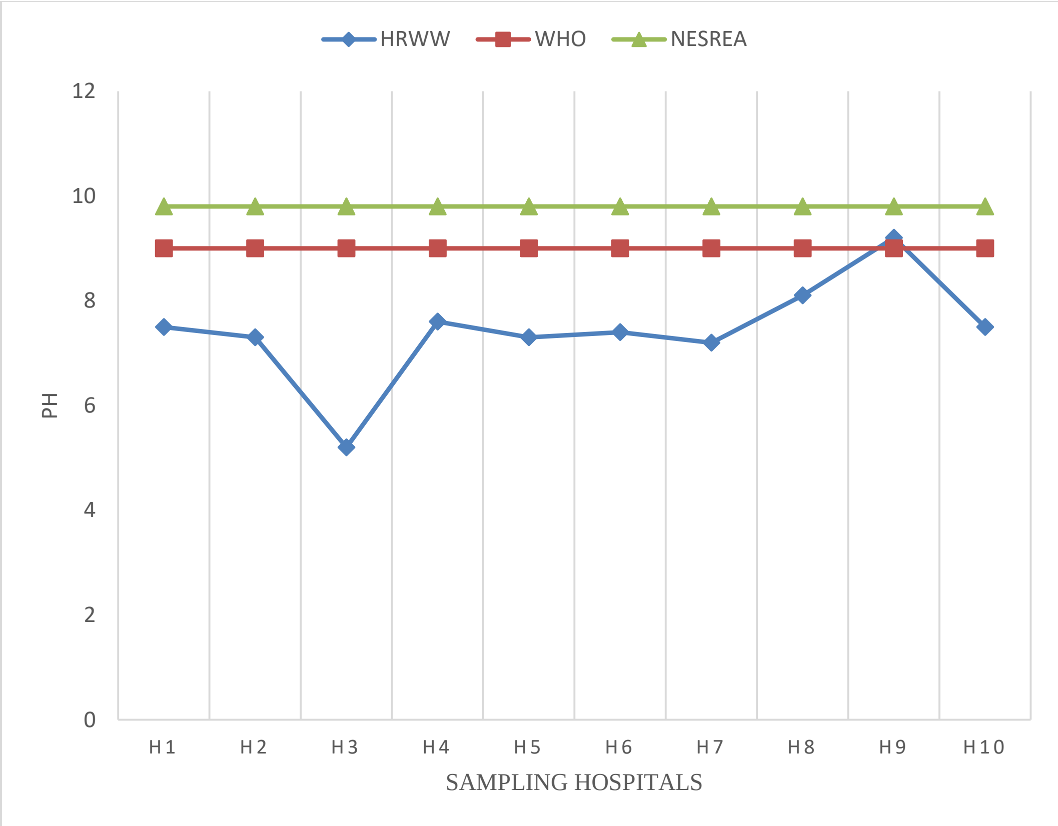
4.2.4 Parameters Standard Limit

4.2.4.1 *pH- Value*

One of the germane parameters in biological wastewater treatment processes is pH. The overall suitable pH for bacterial growth and activity ranges from 6.5 to 8.5 (Emmanuel *et al*., 2001) and Muhammad *et al*. (2014). The activities of most bacteria on wastewater treatment are disrupted or stopped at pH > 9.5 (Emmanuel *et al*., 2001). While acceptable effluent pH for discharge into surface water and rivers ranges between 6.5 to 8.5, while for agricultural purposes and green spaces irrigation ranges between 6 to 8.5 Muhammad *et al*. (2014). The pH values of the samples obtained in this study ranging from lower limit with 5.2 (IBB Specialized Hospital, Minna) to upper limit of 9.2 (Maraba (Aisha Usman) Hospital, Bida) Figure 4.12 and 4.13. These values are within the permissible limits of WHO (5-9) and NESREA (6.5 – 9.8), which are thus acceptable according to these standards.



HRWW= Hospital raw wastewater
Figure 4.12: Plots of effluent pH compared with WHO and NESREA set lower limits



HRWW= Hospital raw wastewater
Figure 4.13: Plots of effluent pH compared with WHO and NESREA set upper limits

4.2.4.2 *Biological oxygen demand (BOD) and chemical-oxygen demand (COD)*

Figure 4.14 indicates that, BOD mean, values in the studied hospitals varied from 0.3 - 10.2 mg/L. These concentrations are within the respective lower permissible limits of 30 mg/L given by WHO, (2004) and NESREA (2011) respectively for BOD of wastewater while the highest concentrations were measured for two hospitals (H1 and H8) with 86 and 97 mg/L respectively. In the case of COD, Figure 4.15 reveals that the mean COD values ranged from 3.4 – 43.1 mg/L and 215 – 373 mg/L respectively.

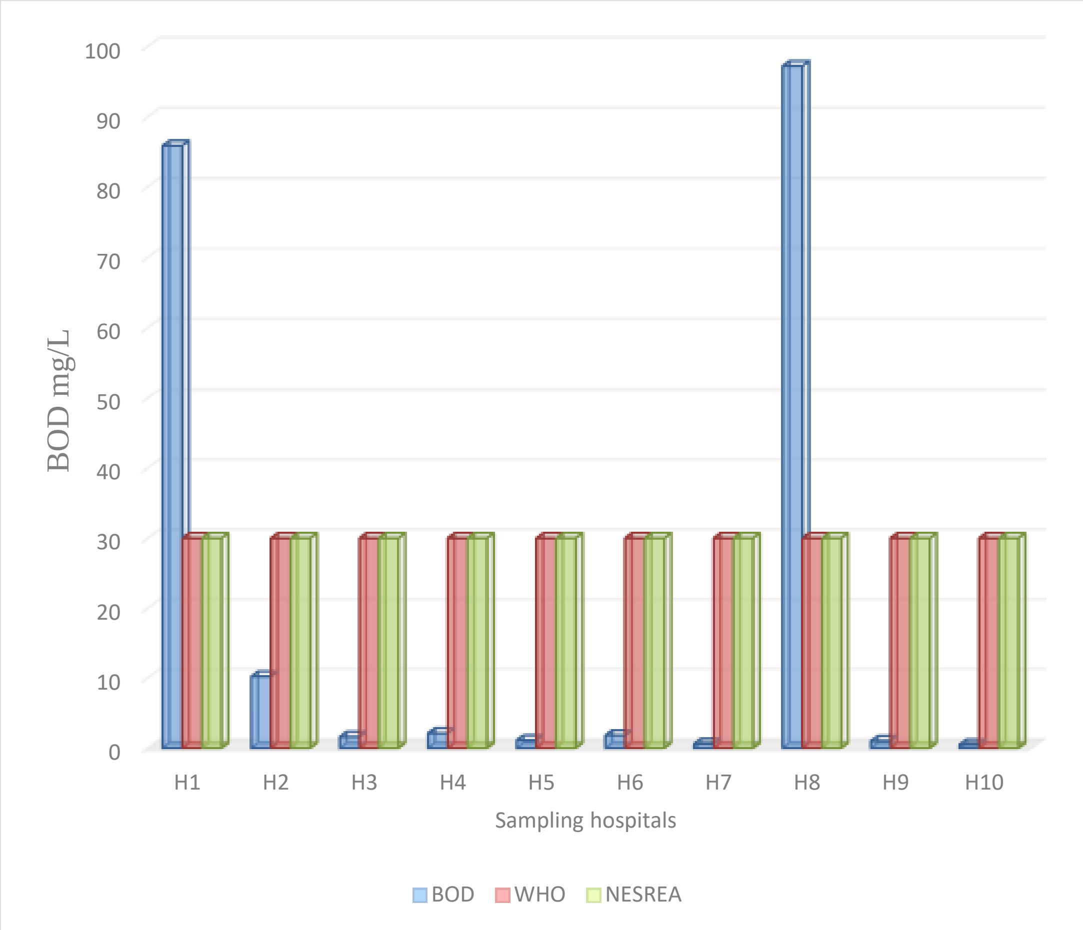


Figure 4.14: Plots of effluent B.O.D compared with WHO and NESREA set limit

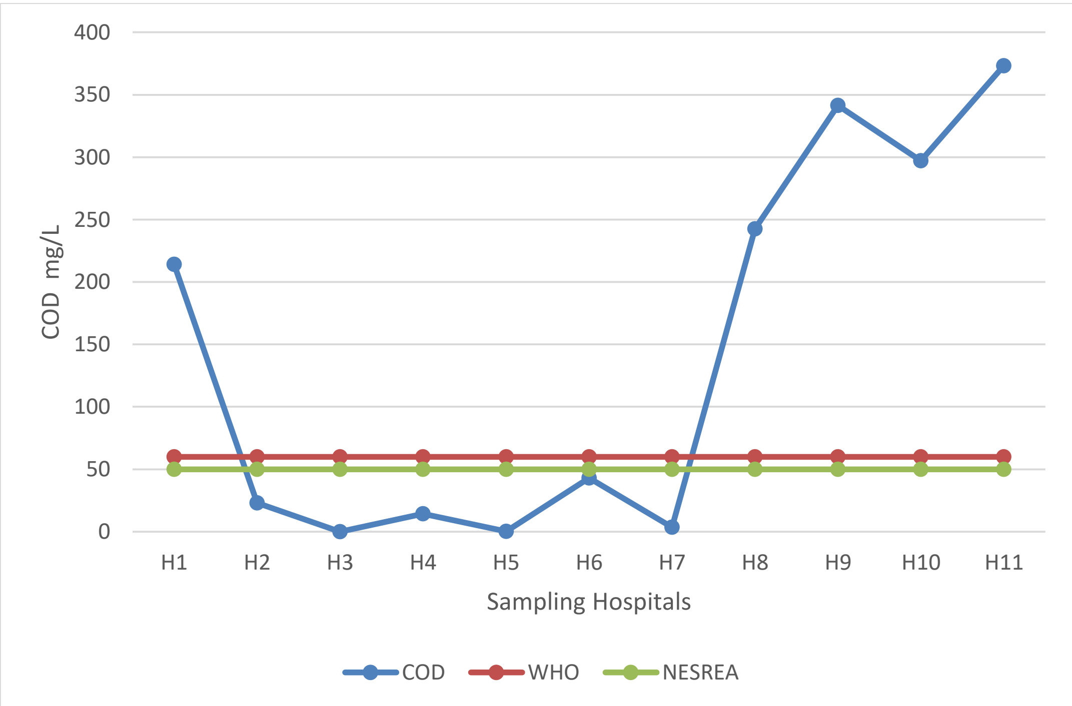


Figure 4.15: Plots of effluent C.O.D compared with WHO and NESREA set limits

4.2.4.3 *Total suspended solids (TSS) in the wastewater of the selected hospitals in the study area*

This is one of the common parameters used in defining a wastewater (Muhammad *et al*., 2014) and (Sim *et al*., 2011). The results presented in Figure 4.16 indicates that, TSS concentration of hospital raw wastewater varied from lower limit with 11.3 (H6) to upper limit 1211.7 mg/L 99.1(H4). These values for lower limits are within the permissible limits of WHO (100) and NESREA (100 mg/L), while the values for upper limits are above the permissible limits of WHO and NESREA (100 mg/L) which are thus unacceptable according to these standards.

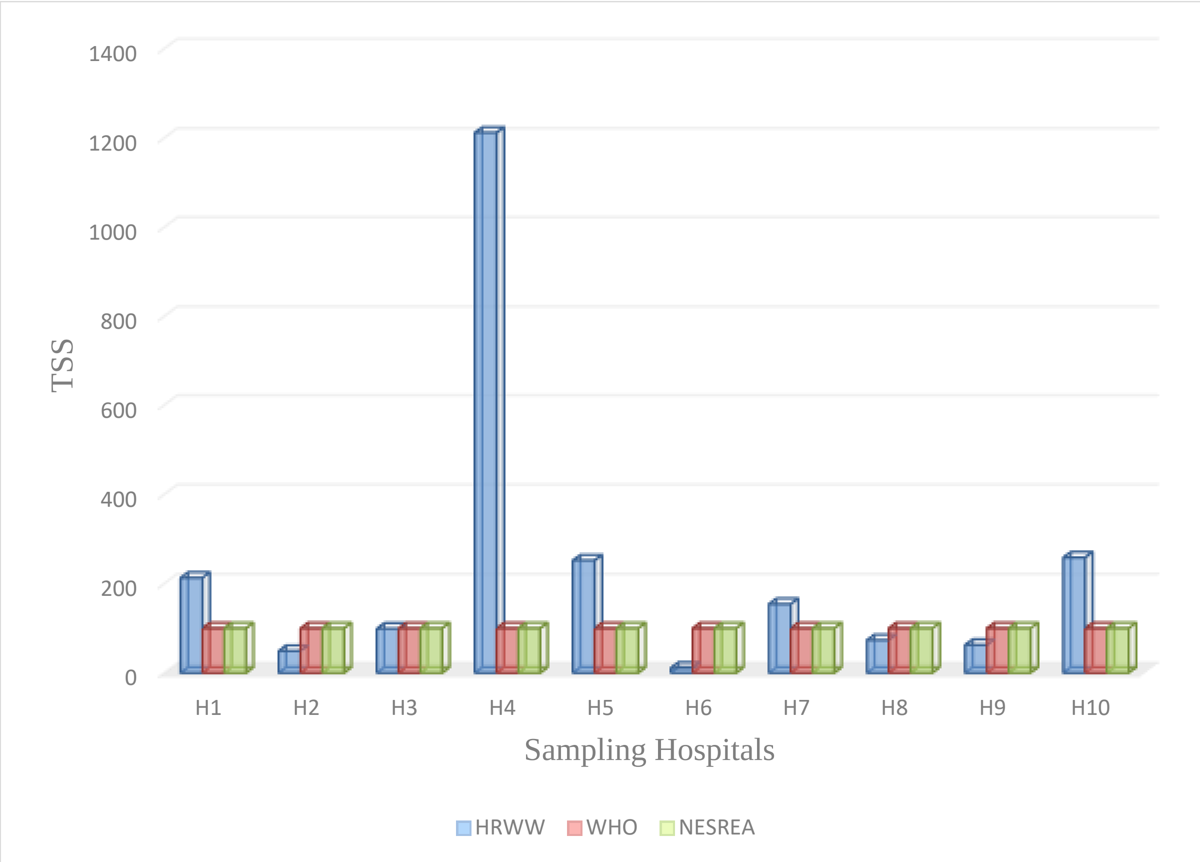


Figure 4.16: Plots of effluent T.S.S compared with WHO and NESREA set limits

4.2.4.4 *Dissolved oxygen (DO)*

One of the most important bio- monitoring parameters of water quality in the aquatic environment is dissolved oxygen (Muhammad *et al*., 2014; Sim *et al*., 2011 and Eze *et al*., 2016)**.** From Figure 4.17, shows that, the values of DO ranged from 1.3-4.1mg/L these values were lower than the NESREA 4.0 mg/L permissible limit. The DO values of the samples obtained in this study ranging from 1.3 lower limit (H4) to 3.7 mg/L upper value (H5) Figure 4.17. These values are too low and have implications in the water qualities of the study area. In this case these values are unacceptable according to the standards since their oxygen levels are too low for microbial activities which means that pollution levels in these samples are very high. These observations are similar to the findings reported by Nazik (2004), Sim *et al*. (2011) and Muhammad *et al*. (2014) who all had DO levels in wastewater samples of their studies that were below the standard 4.0 mg/l.

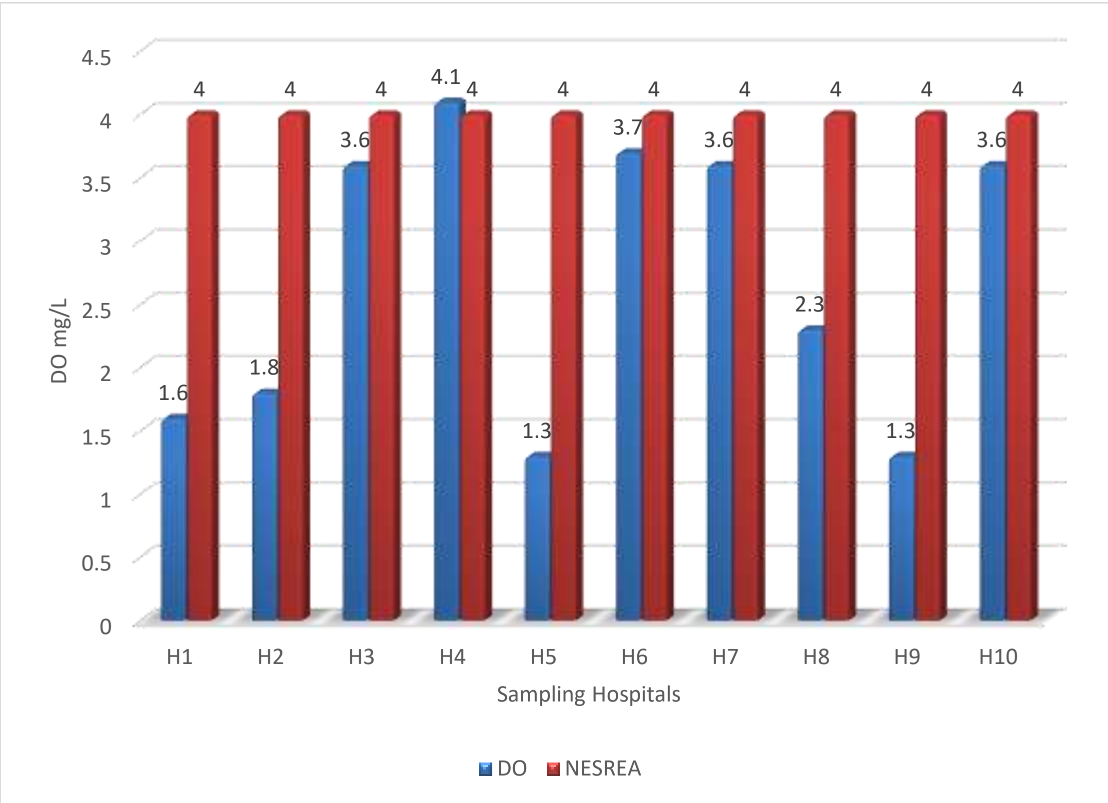


Figure 4.17: Plots of effluent DO compared with WHO and NESREA set limits

4.2.4.5 *Total coliform (TC) and faecal coliform (FC) contents of the wastewater samples in the study area*

Treatment of patients with enteric diseases is a critical issue at the time of outbreaks of diarrhoeal diseases. Therefore, the knowledge of the microbial quality of hospital wastewater is very critical (Pauwels, *et al*., 2006). To achieve this, some bacteriological indicators are used to reflect the presence of pollution pathogens in wastewater. These include the determination of TC and FC that are the most world-wide known parameters used for the establishment of contamination (Pauwels, *et al*., 2006). The microbiological qualities of the water samples varied from hospital to another due to variations in the consumption of water by the hospitals during the study.

The acceptable limit of TC and FC in hospital effluent discharge into surface water, for agricultural purposes and green spaces irrigation are 1000, and 400 MPN/100 ml, respectively (Majlesi and Yazdanbakhsh, 2008). Figure 4.18 indicates that, TC mean, values in the studied hospitals varied from 0.01 (H7) to 514.4 cfu/100ml (H10). These concentrations are within the respective lower and middle permissible limits of 1000 cfu/100ml given by WHO, (2004) and NESREA (2011) respectively for TC of wastewater while the upper concentrations were measured for two hospitals (H1 and H2) with 1099.3 and 72334.7 cfu/100ml respectively. These values for upper limits are above the permissible limits of WHO and NESREA (1000 cfu/100ml) which are unacceptable according to these standards. In the case of FC, Figure 4. 19 reveals that FC lower values obtained varies from 0.003(H6 and H9) to 409 cfu/100ml (H1), these values are within the limit 400 cfu/100ml set by (WHO and NESREA). Whereas, the upper concentrations were obtained for two hospitals (H2 and H5) with 60334 and 520.4 cfu/100ml respectively. These values for upper limits are above the permissible limits of WHO and NESREA (400 cfu/100ml) which are thus unacceptable according to these standards set.

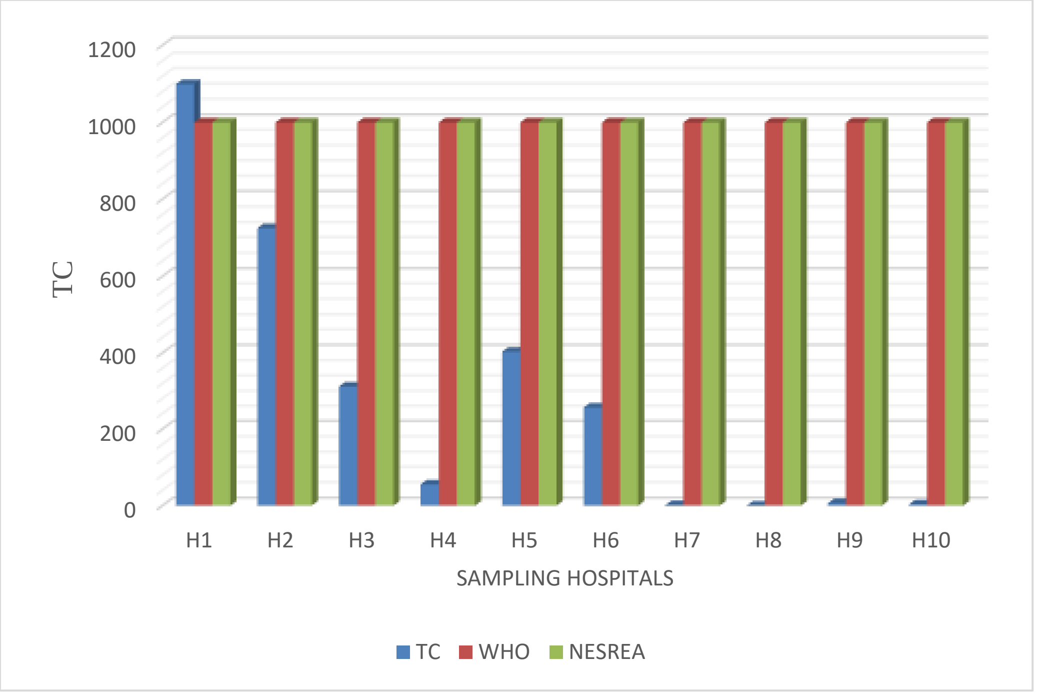


Figure 4.18: Plots of effluent T.C compared with WHO and NESREA set Limits

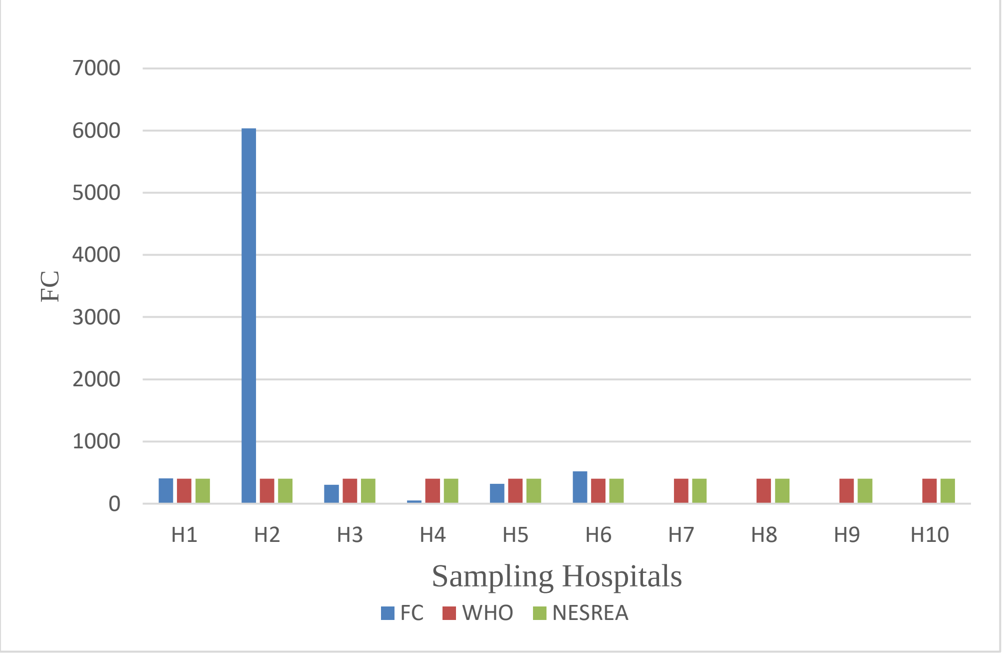


Figure 4.19: Plots of effluent F.C compared with WHO and NESREA set limits

4.3 Morbidity in Children (≤ 10 years) within the Medical Waste Disposal and Treatment of the Study Area

The findings of face-to-face disease frequency questionnaire administered and interviews on morbidity in children within the age of 0 – 10 years were presented in Tables 4.3 – 4.5. The rate of response on the disease frequency questionnaire surveyed was 100%. The diseased covered during the study were the skin, intestinal and respiratory infections. Risk factors associated with improper healthcare waste management are; cross/ auto infection is the most important risk factor when it comes to improper healthcare waste management thus, this could occur through physical injuries or transmission of diseases. Second factor is environmental contamination of soil, water and air and poor healthcare waste disposal sites as breathing ground for vectors (Peter, 2011).

4.3.1 Skin infection frequency or the degree of close vicinities to the hospitals

Table 4. 3 shows that exposed group recorded 51 cases of skin infection while unexposed were 42 cases. Whereas, in exposed group non-cases of skin infection were 69 and 78 unexposed group recorded 78 of non-cases. This given the risk factor of 0.43 in the exposed group of children to skin infections and 0.35 for the unexposed children in the study area.

Table 4.3 The Result of Analysis of the Risks and Risk Ratios for Skin Infections (n = 120)

Characteristic	No. of Children Exposed	No. of Children Unexposed	Total
Male	70	50	120
Female	50	70	120
	Skin Infection		
Cases	51	42	93
Non-Cases	69	78	147
Risk	0.43	0.35	0.78
Risk Different	0.08		
Risk Ratio	0.25:0.18		

4.3.2 Respiratory infections cases in the various groups of populations

The total cases in both groups were 124. The respective risk factors were 0.75 and 0.28 (Table 4.4) for the exposed and unexposed children to the healthcare wastes generated in the area.

Table 4.4: The Result of Analysis of the Risks and Risk ratios for Respiratory in the Study Area (n = 120)

Characteristic	No. of Children Exposed	No. of Children Unexposed	Total
Male	70	50	120
Female	50	70	120
Respiratory Cases			
Cases	90	34	124
Non-Cases	30	86	116
Risk	0.75	0.28	0.52
Risk Different	0.47		
Risk Ratio	0.44:0.31		

4.3.3 Intestinal infections recorded on the children living in the vicinities of medical waste treatment/disposal sites in the study area

Regarding cases of intestinal infections Table 4.5 shows 50 and 21 cases for exposed group and exposed group respectively. The total cases for two groups were 71. The risk factor obtained for the exposed children was 0.46 whereas, 0.20 was obtained for the on exposed group.

Table 4.5: The Result of Analysis of the Risks and Risk Ratios for Intestinal Infections in the Study Area (n = 120)

Characteristic	No. of Children Exposed	No. of Children Unexposed	Total
Male	70	50	120
Female	50	70	120
Intestinal Cases			
Cases	55	24	79
Non-Cases	65	96	161
Risk	0.46	0.20	0.33
Risk Different	0.26		
Risk Ratio	0.27:0.19		

4.4 Determination of the Compositions of Solid Hospital Wastes Generated and the Generation Rate

The results of compositional analysis of medical wastes that was conducted between November 2018 to October, 2019 to categories the MW produced in the hospitals selected in the study area. For the ease of the process, three main categories comprising number of beds, inpatients and number of outpatients by determine categories of medical wastes generated.

4.4.1 Number of healthcare facilities of the study area

The daily distribution of inpatients, outpatients of the selected hospitals in the study for seven consecutive days were higher in both the public hospitals and private hospitals as indicated in Table 4.6 and 4.7 respectively. Also, the total number of beds varied from one hospital to another. Similarly, the number of patients treated in the hospitals on a daily basis varies due to the nature of the hospital, type of services provided, location and sizes as indicated in Tables 4.6-4.7 and Figures 4.20 – 4.22. These all has direct influence on the amounts of MW produced in the selected hospitals. This agreed with the findings reported by Razali and Ishak (2010).

Table 4. 6: The Number of Inpatients

No. of Inpatients/day						
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
18	17	26	23	18	20	27
27	23	20	22	28	19	39
49	40	22	31	56	72	109
17	10	8	24	12	11	11
30	24	29	19	33	26	32
24	10	19	27	25	24	27
12	9	17	30	12	24	17
43	34	23	30	41	34	37
7	3	2	4	9	5	5
14	6	4	8	18	10	10

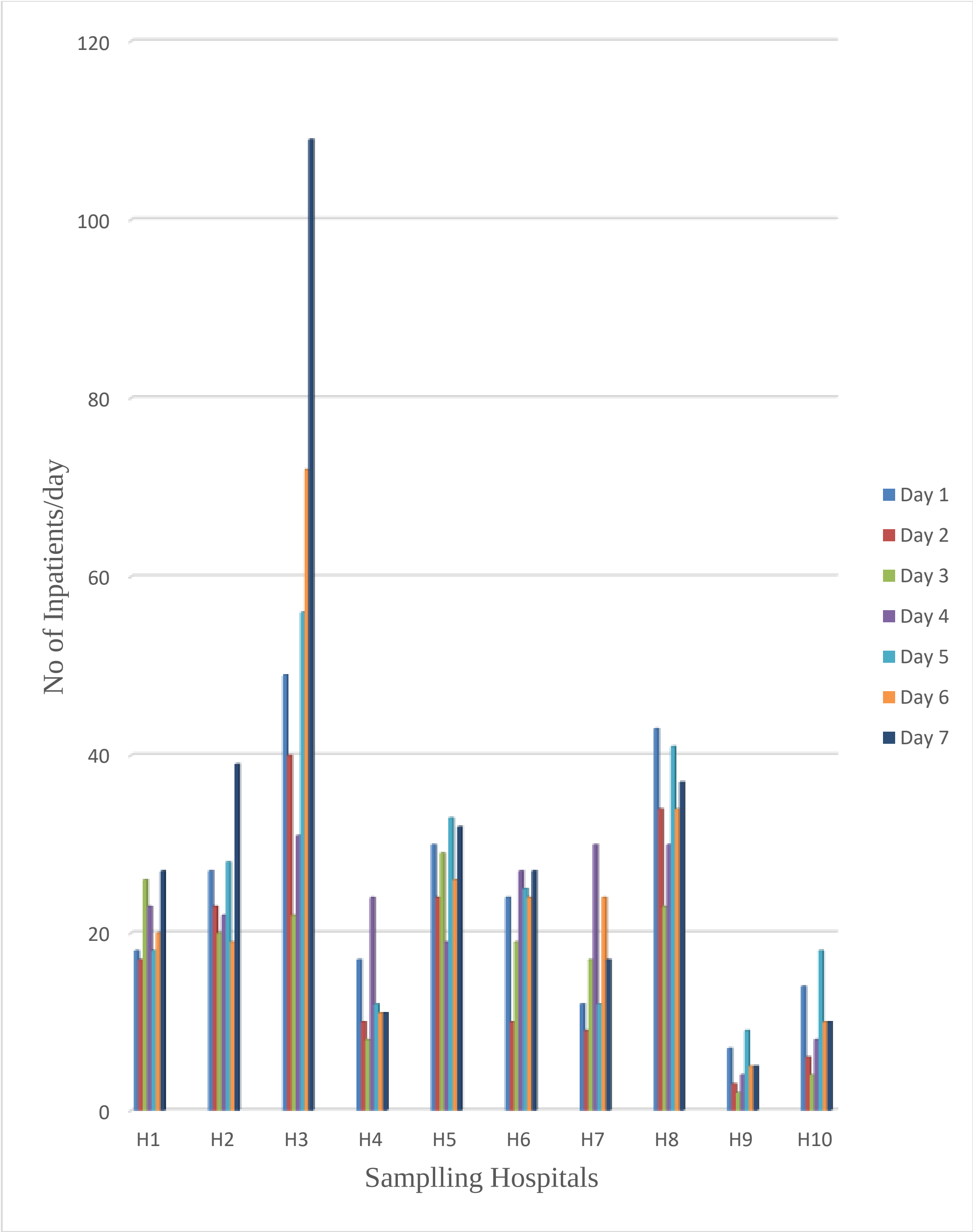


Figure 4.20: The daily distribution of number of inpatients in the selected hospitals

Table 4. 7: The Number of Outpatients

	No. of Outpatients/day						
CODE	1	2	3	4	5	6	7
H1	311	403	507	101	204	303	297
H2	33	28	22	19	43	33	52
H3	112	99	56	47	211	321	345
H4	39	20	10	5	73	35	8
H5	260	155	43	41	403	252	341
H6	112	41	19	21	142	76	103
H7	38	19	11	9	85	46	62
H8	180	129	21	67	229	166	113
H9	14	7	4	2	11	8	13
H10	28	14	8	4	22	16	26

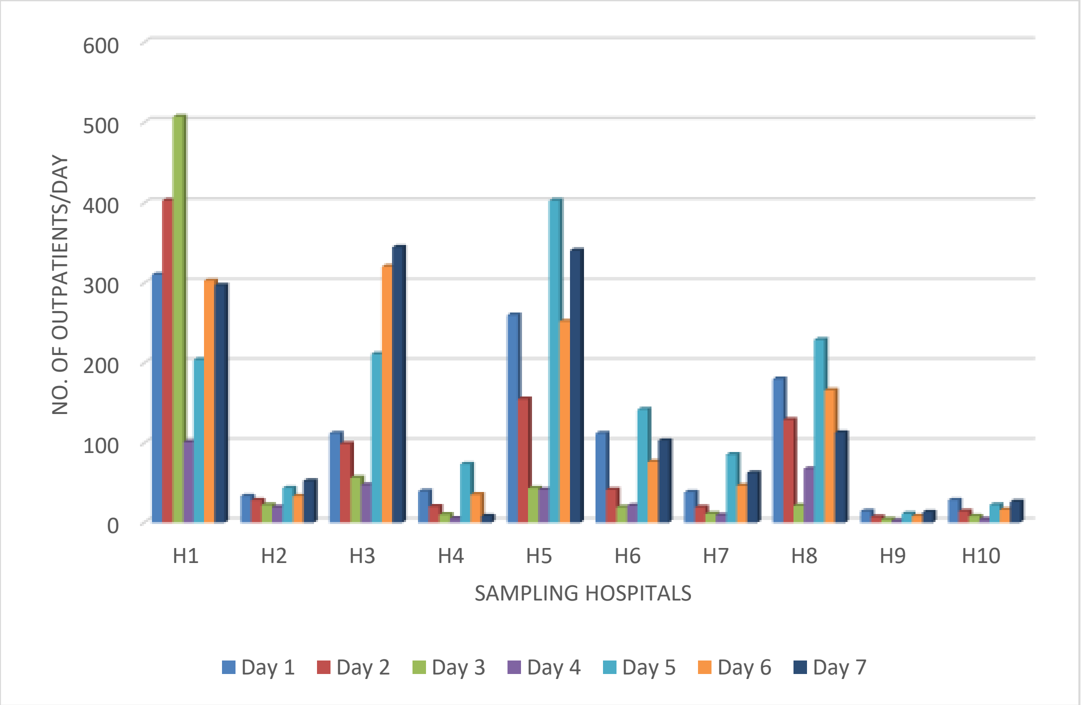


Figure 4.21: The daily distribution of number of outpatients in the selected hospitals

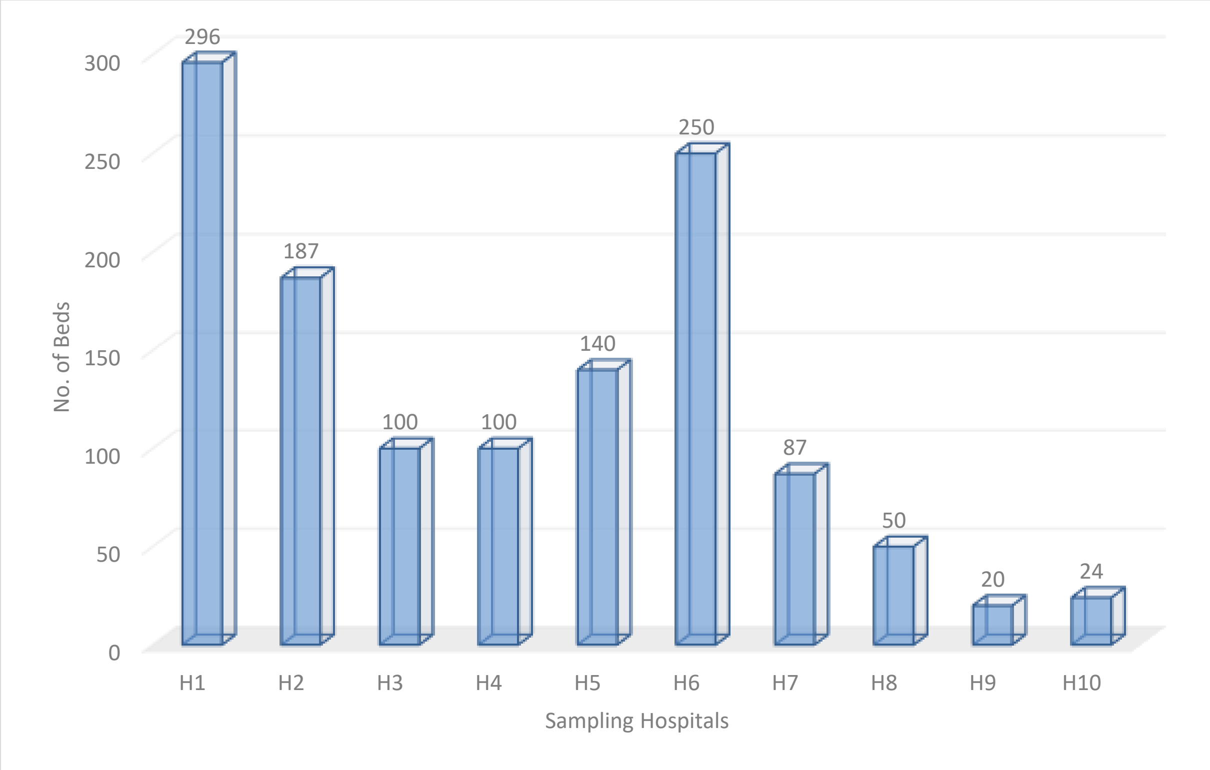


Figure 4.22: Distribution of total number of beds according to hospitals

4.4.2 Medical waste composition analysis based on the selected hospitals in the study area

The categories of MW generated in dry and wet seasons from the ten hospitals selected for this study were presented in Figures 4.23 – 4.32. This section was subdivided into the selected hospitals shown in the figures for easy introductions.

4.4.2.1 *Results of the composition of medical wastes generated in General Hospital Minna (H1)*

The composition of MW analysis generated from H1, were shown in Figure 4.23. From the figure, the main components of the medical wastes in H1 were; general (42.36%), infectious (32.66%), sharps (14.5%), pathological (4.69%), pharmaceutical (5.67 %) and radioactive (0.12 %). The hazardous wastes (57.64%) which were the sum of infectious, sharps, pathological, pharmaceutical and radioactive wastes were higher than the non-hazardous wastes (42.36%).

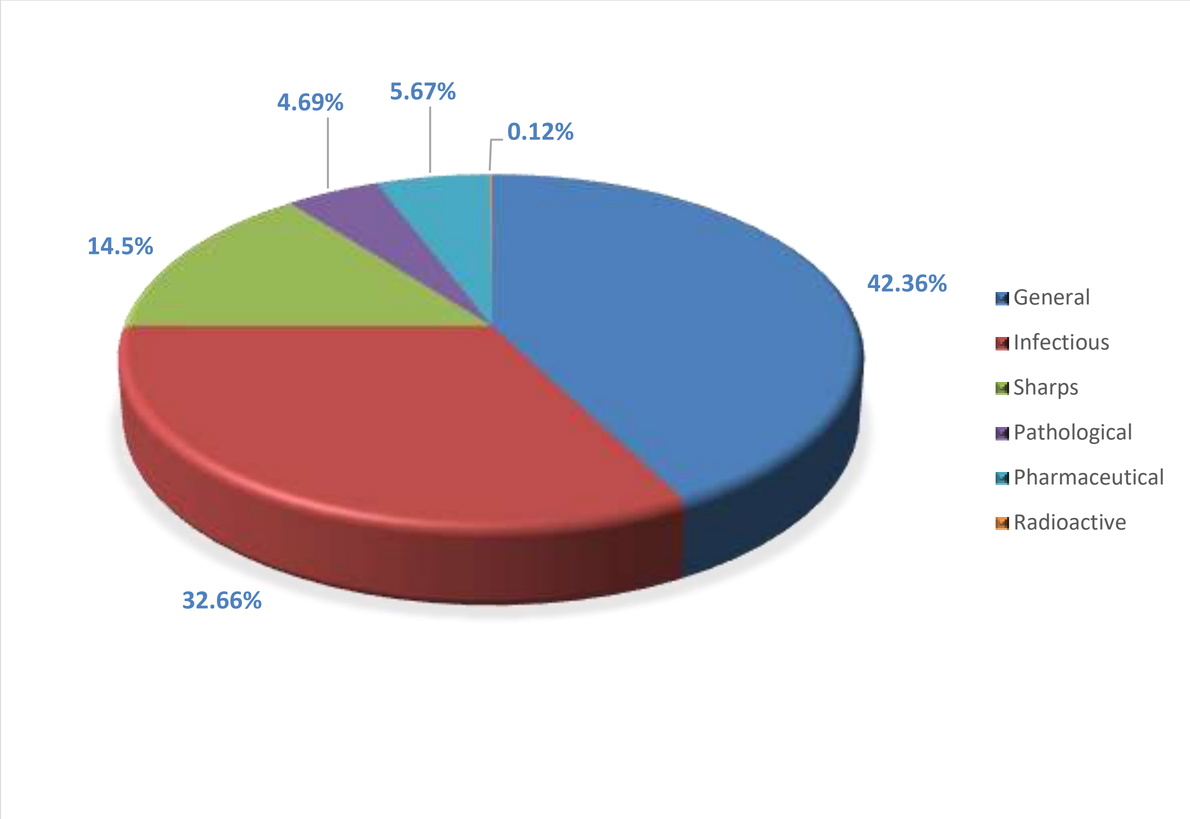


Figure 4.23: Composition of medical wastes generated from General Hospital Minna (H1)

4.4.2.2 *Results of the composition of medical wastes generated from General Hospital New Extension Minna (H2)*

The composition of MW generated from H2, Figure 4.24 shows that, the main components of medical wastes in H2 were; general (69.98%), infectious (23.33%), sharps (5.77%), pathological (0.41%), pharmaceutical (0.5 %) and radioactive (0.01 %). The hazardous wastes consisted (30.02%) which is lower than the non-hazardous wastes (69.98%). This could probably be as a result of the age of the hospital which is fairly newer than the main General Hospital, Minna.

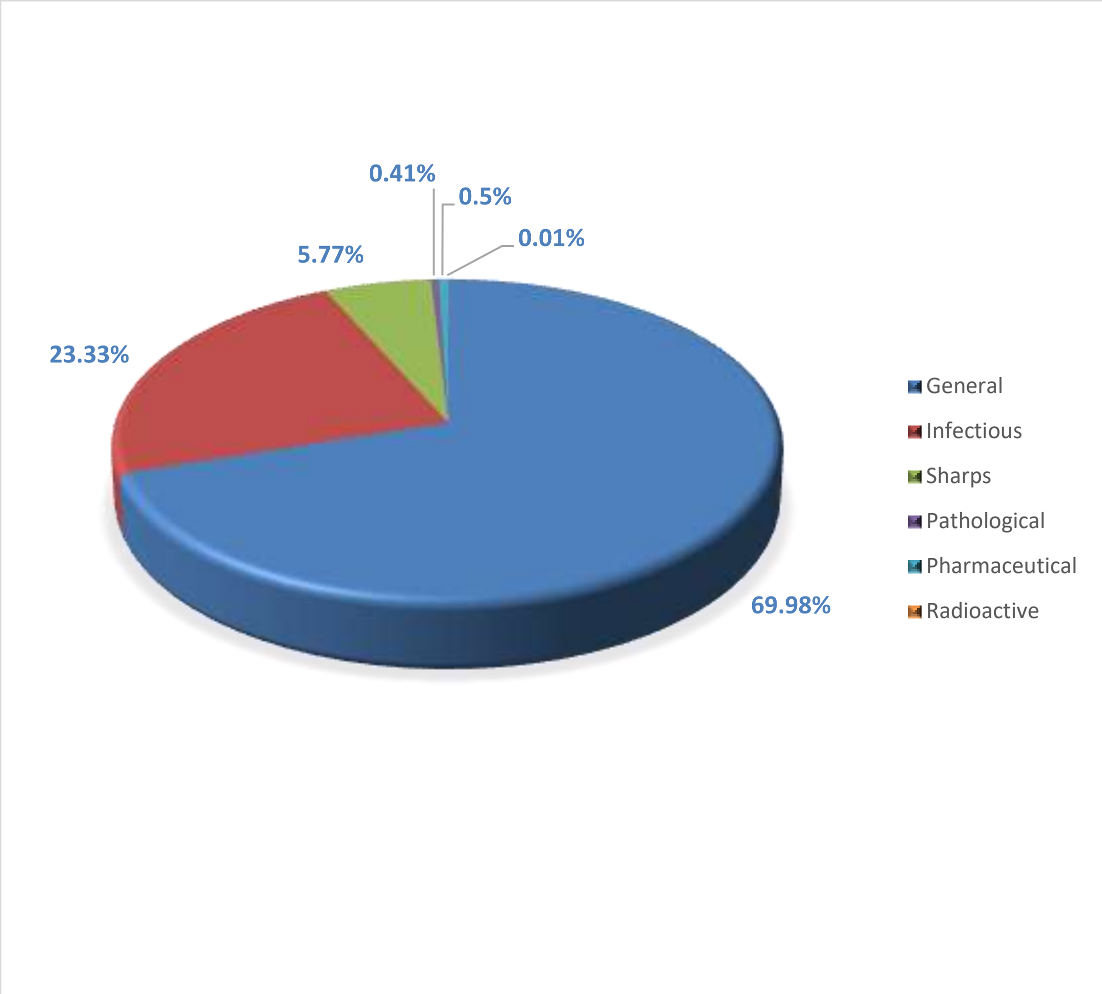


Figure 4.24: Composition of medical wastes generated from General Hospital New Extension Minna (H2)

4.4.2.3 *Results of the composition of medical wastes in IBB Specialized Hospital, (H3)*

The composition analyses of MW generated from H3, Figure 4.25 Shows that, the main components of medical wastes in the hospital were; general (39.09%), infectious (35.00%), sharps (13.39%), pathological (6.04%), pharmaceutical (6.15 %) and radioactive (0.33 %). The hazardous wastes consisted (60.91%) which is higher than the value for non-hazardous wastes (39.09%).

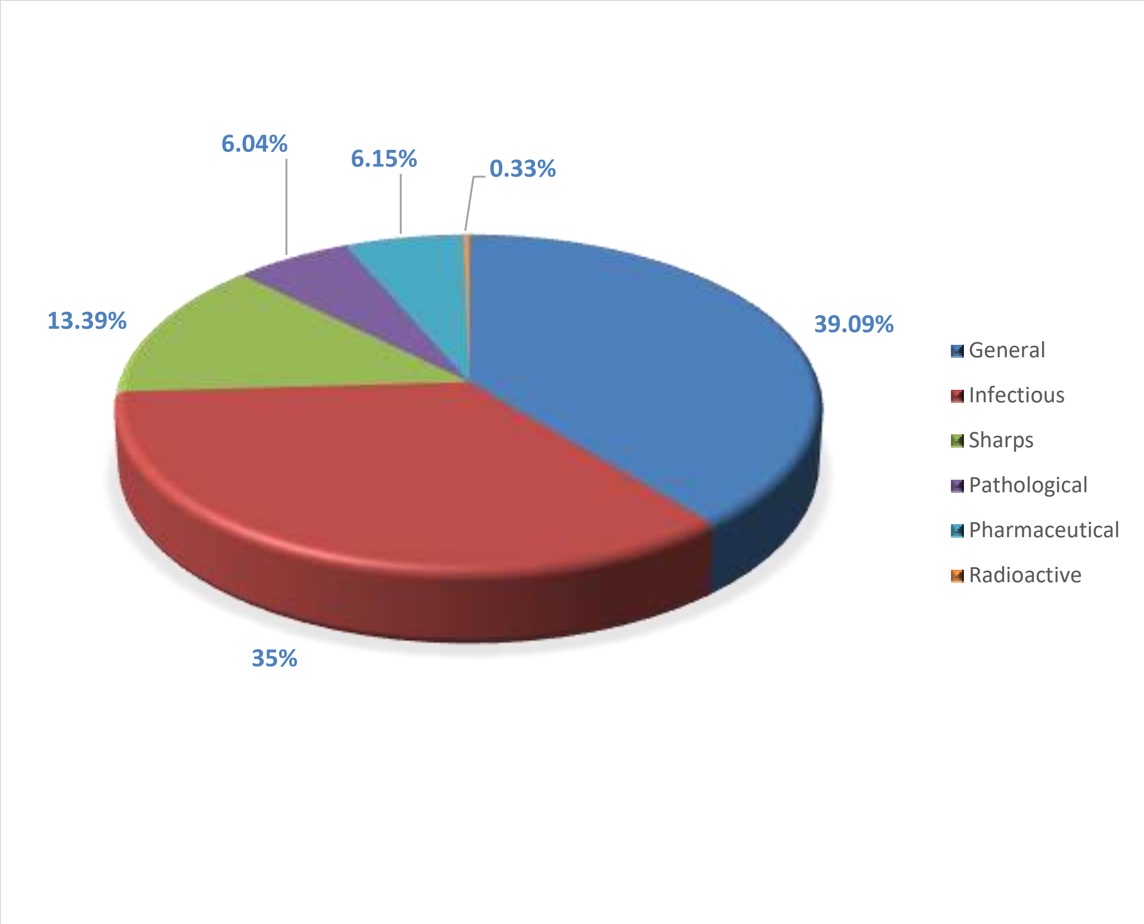


Figure 4. 25: Composition of medical wastes generated from IBB Specialized Hospital (H3)

4.4.2.4 *Results of the composition of medical wastes generated by General Hospital Bida (H4)*

The composition of MW generated from H4, Figure 4.26, indicates that, the main components of medical wastes were; general (71.45%), infectious (15.51%), sharps (8.55%), pathological (2.13%), pharmaceutical (2.28 %) and radioactive (0.08 %). The non-hazardous wastes (71.45%) has a higher value than the hazardous wastes (28.55%).

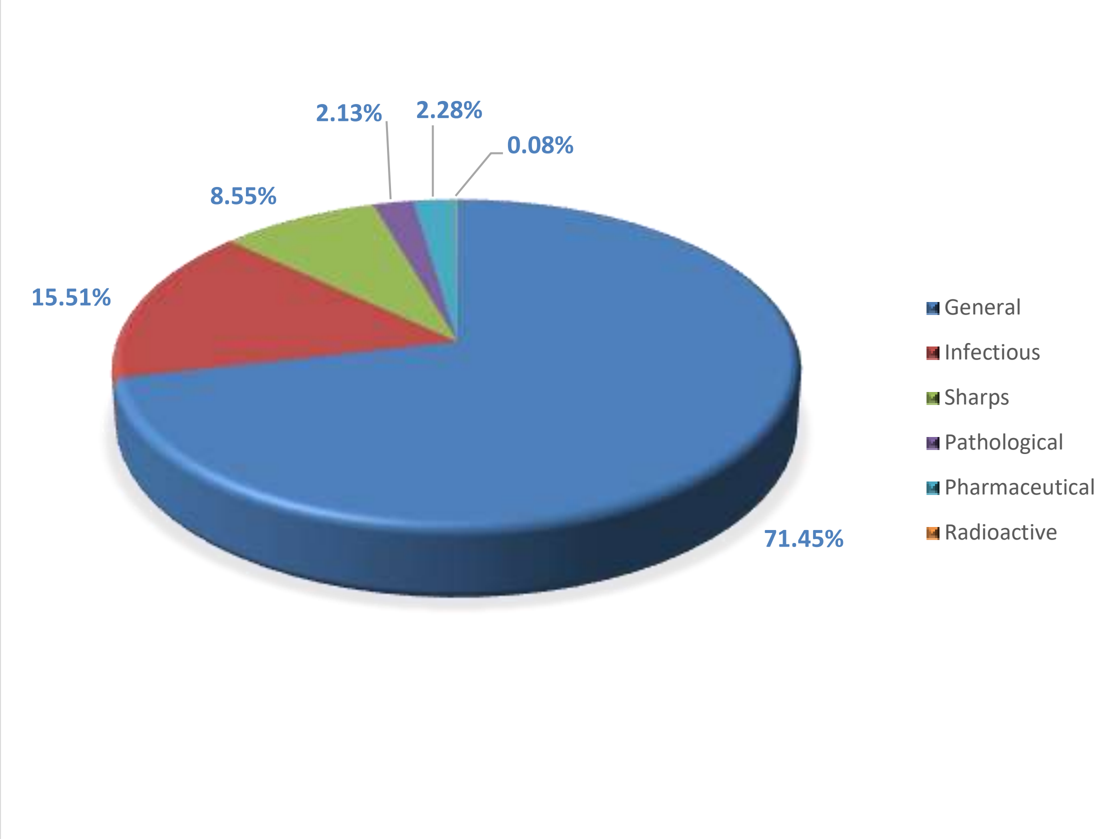


Figure 4.26: Composition of medical wastes generated from General Hospital Bida (H4)

4.4.2.5 ***Results of the composition of medical wastes generated by General Hospital Suleja (H5)***

The composition of MW generated from H5 as presented in Figure 4.27, indicates that, the main components of the medical wastes in H4 were; general (38.24%), infectious (38.39%), sharps (16.61%), pathological (3.21%), pharmaceutical (3.41 %) and radioactive (0.14 %). This gave the total percentage of non-hazardous wastes (38.24%) which was lower than that of the hazardous wastes (61.76%). From the forgoing, the percentage of the infectious waste generated by this healthcare facilities were almost the highest.

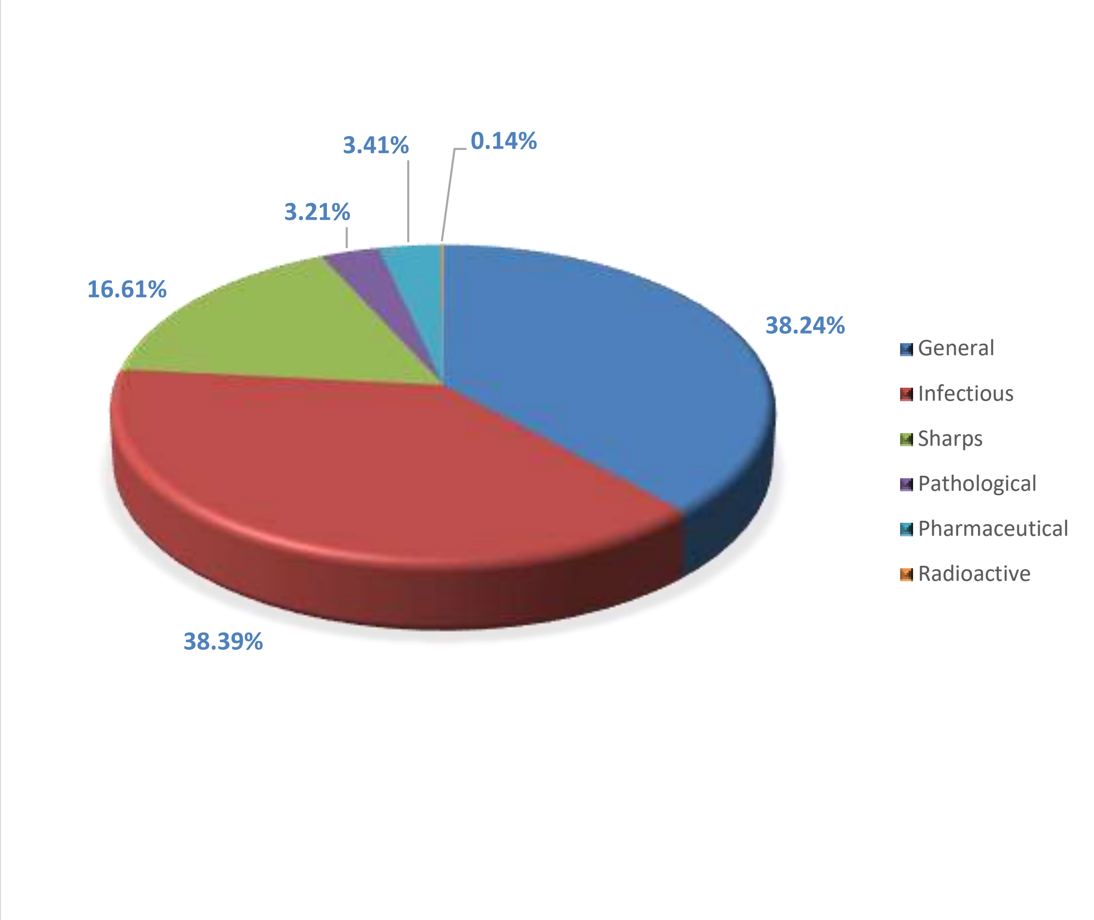


Figure 4.27: Composition of medical wastes generated from General Hospital Suleja (H5)

4.4.2.6 *Results of the composition of medical waste generated by General Hospital, Kontagora (H6)*

The results of the composition analyses of MW generated from H6 presented in Figure 4.28, shows that, the main components of hazardous wastes stream in H6 were general (38.24%), infectious (35.99%), sharps (16.47%), pathological (3.68%), pharmaceutical (4.27 %) and radioactive (0.22 %) while, non-hazardous wastes were 39.37%), a value lower than that of the hazardous wastes (60.63%).

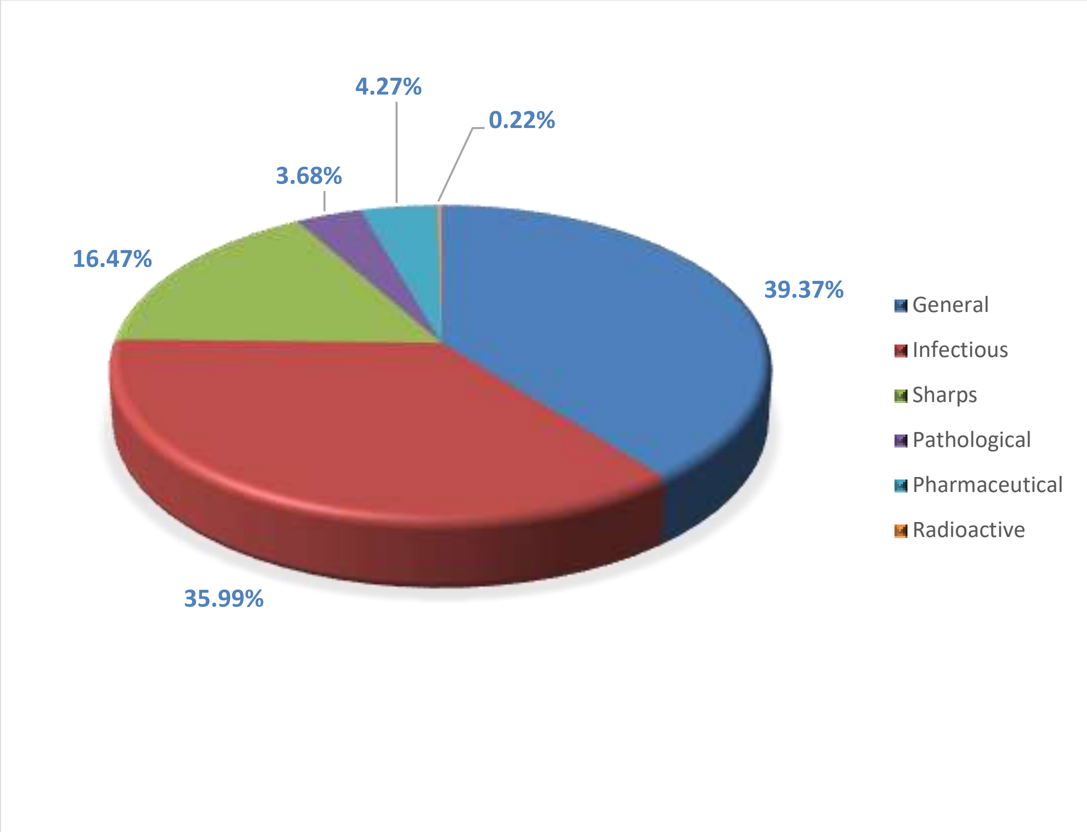


Figure 4.28: Composition of medical wastes generated from General Hospital, Kontagora (H6)

4.4.2.7 *Results of the composition of medical waste generated by General Hospital Wushishi (H7)*

The results of composition analysis of MW generated from H7 presented in Figure 4.29, indicates that, non-hazardous wastes constituted 40.33% while the main components of hazardous wastes were infectious (36.89%), sharps (18.42%), pathological (3.31%), pharmaceutical (0.8 %) and radioactive (0.25 %). This means that the non-hazardous wastes (40.33%) were lower than the hazardous wastes (59.67%).

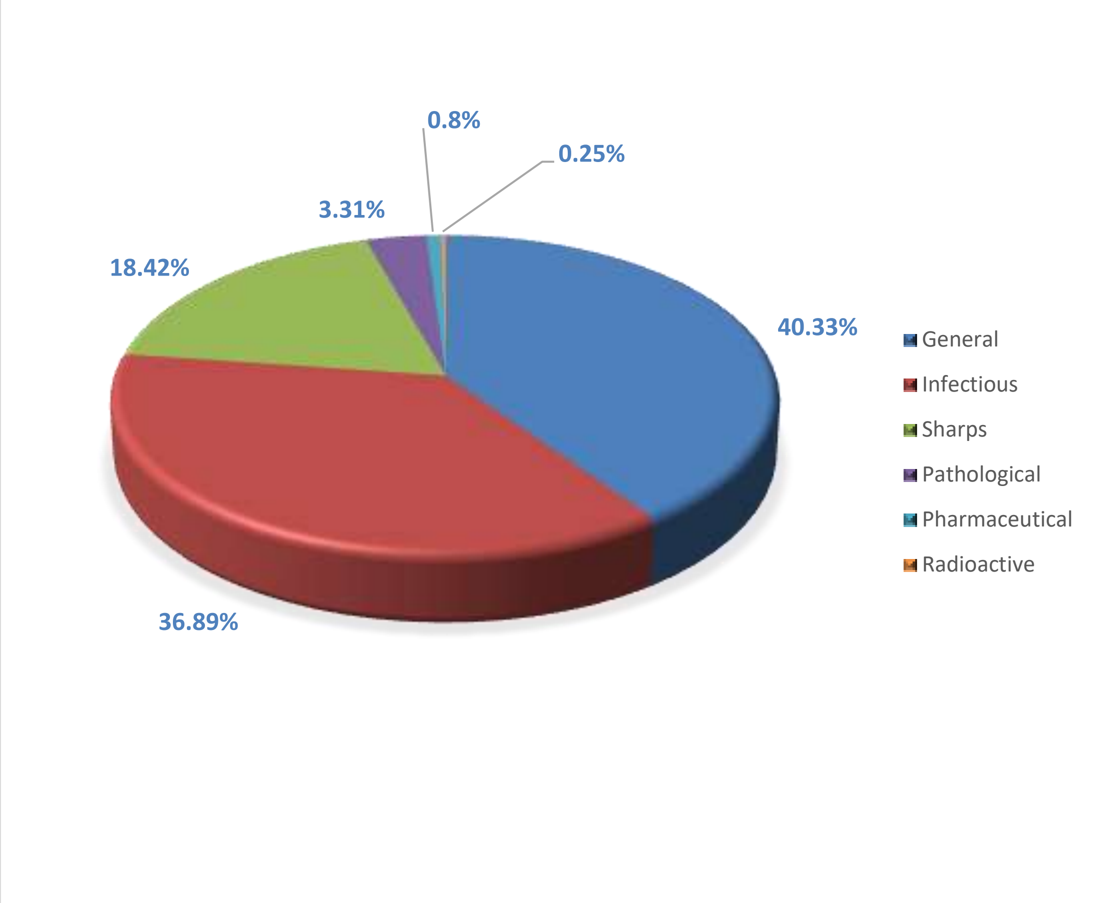


Figure 4.29: Composition of medical wastes generated from General Hospital Wushishi (H7)

4.4.2.8 ***Results of the composition of medical waste generated by Standard Hospital Minna (H8)***

The results of composition analysis of MW generated from H8, Figure 4.30, reveals that, the main components of hazardous wastes stream were general (38.24%), infectious (34.13%), sharps (16.14%), pathological (3.05%), pharmaceutical (3.52 %) and radioactive (0.4 %). The non-hazardous wastes constituted 42.76% of the total wastes generated while the total hazardous constituted 57.24%, a value higher than the value for the total non-hazardous waste.

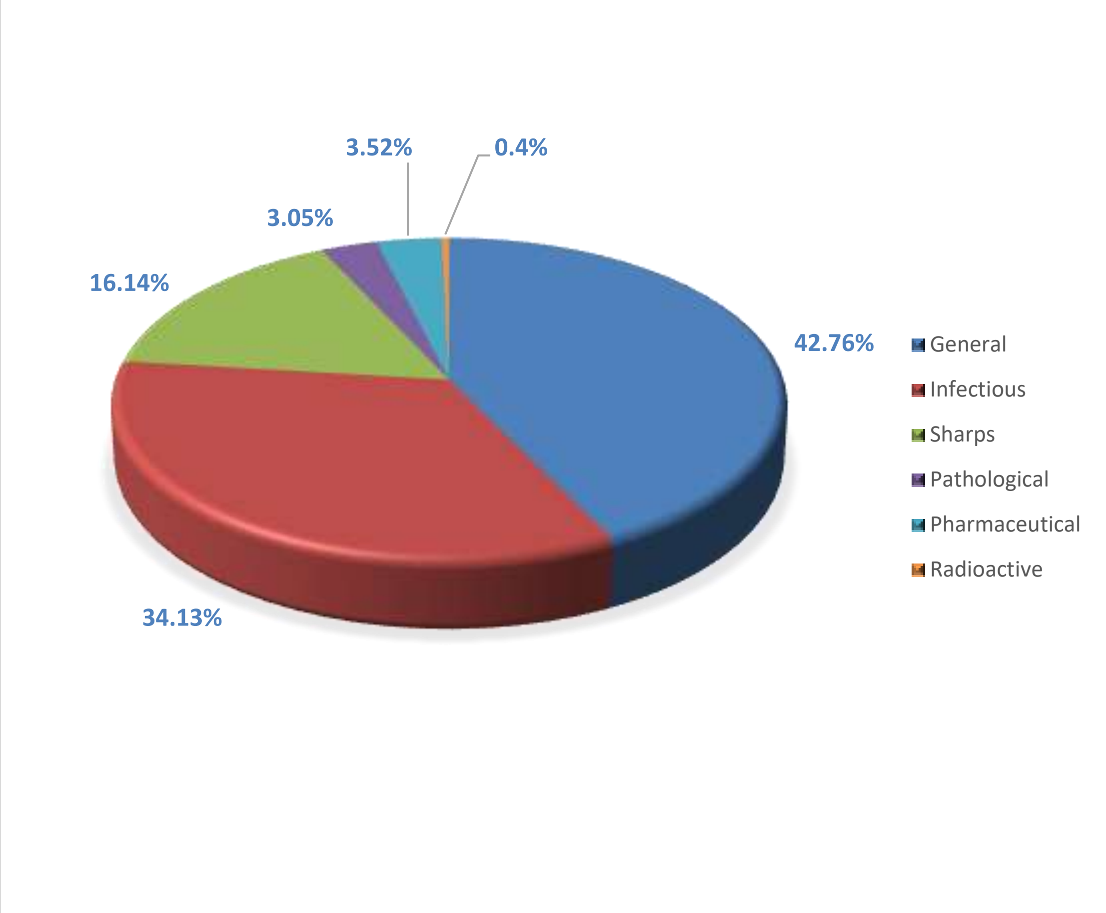


Figure 4. 30: Composition of medical wastes generated from Standard Hospital Minna (H8)

4.4.2.9 *Results of the composition of medical waste generated by Maharaba Hospital Bida (H9)*

Results of composition analysis of MW generated from H9 presented in Figure 4.31, reveals that, the main components of hazardous wastes stream were general (38.24%), infectious (17.34%), sharps (3.8%), pathological (1.43%) and pharmaceutical (1.66%) giving a total of 24.23% for the hazardous wastes while the total non-hazardous wastes constituted 75.77% of the total wastes generated.

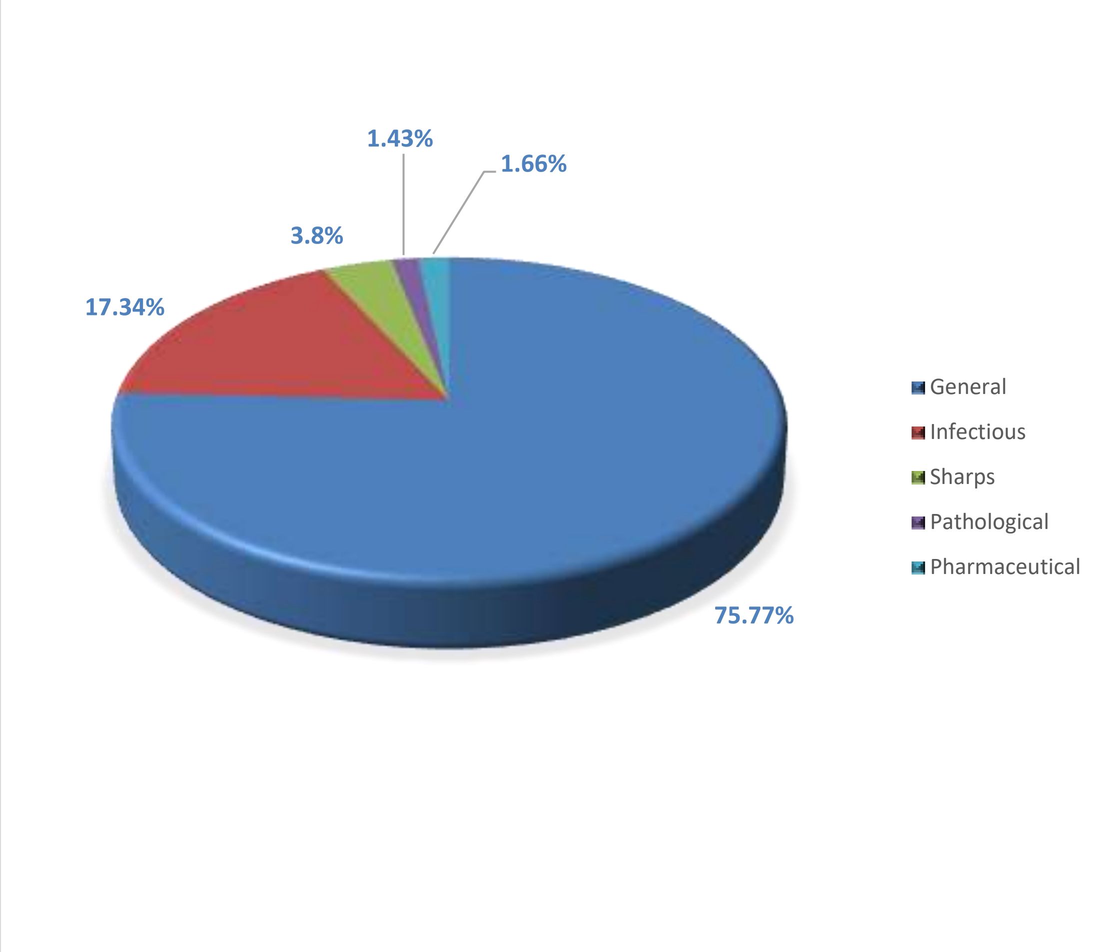


Figure 4. 31: Composition of medical wastes generated from Maharaba Hospital Bida (H9)

4.4.2.10 *Results of the composition of medical waste generated by Al- Azeez Hospital, Kontagora (H10)*

The results of composition analysis of MW generated from H10, Figure 4.32, shows that, non- hazardous wastes were 81.58% whereas, the main components of hazardous wastes stream were infectious (13.27%), sharps (2.52%), pathological (1.21%) and pharmaceutical (1.42 %) which constituted 18.42% of the total wastes generated and this represents the percentage hazardous wastes generated.

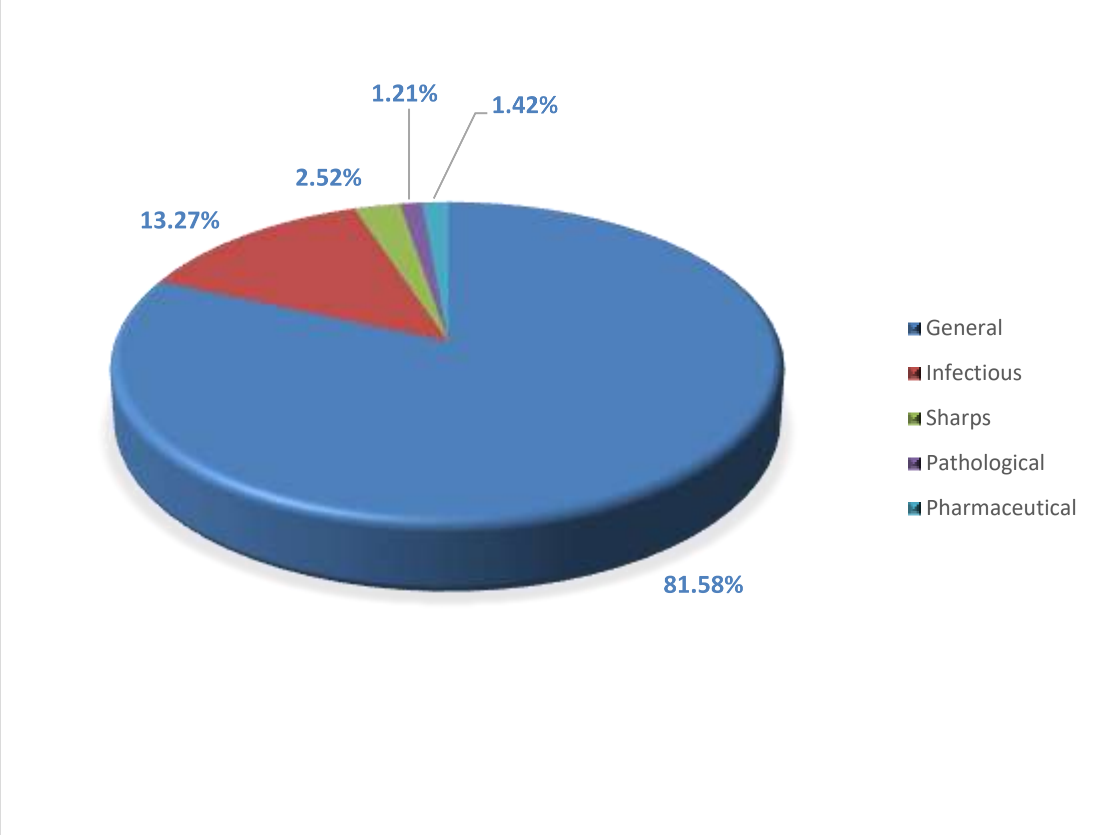


Figure 4. 32: Composition of medical wastes generated from Al- Azeez Hospital, Kontagora (H10)

4.4.3 Medical waste generated from selected hospitals in the study area

The average total healthcare wastes generation rates were calculated by dividing the total volume of hospital wastes collected during a week by seven. The figure obtained was the daily average of healthcare wastes generation rate as indicated in Table 4.8. On daily basis the number of patients treated in the hospitals varies. The daily average hazardous and non-hazardous wastes calculated was shown in Figures 4.33 and 4.34. These amounts of wastes generated in the hospitals depend number of beds, number of inpatients and outpatients, location and socioeconomic status of the patients handled in the given healthcare facility.

Table 4.8 Hazardous Wastes Generated kg/day in the Selected Hospitals of the Study Area

Hospitals code	General	Infectious	Sharps	Pathological	Pharmaceutical	Radioactive
H1	130.32	100.46	44.61	14.44	17.43	0.36
H2	350.14	116.71	28.86	2.06	2.49	0.05
H3	44.46	39.8	15.23	6.87	7	0.37
H4	57.43	12.47	6.87	1.71	1.83	0.07
H5	30.25	30.37	13.14	2.54	2.7	0.11
H6	48.5	44.34	20.29	4.54	5.26	0.27
H7	6.57	6.01	3	0.54	0.13	0.04
H8	6.44	5.14	2.43	0.46	0.53	0.06
H9	3.19	0.73	0.16	0.06	0.07	
H10	7.44	1.21	0.23	0.11	0.13	

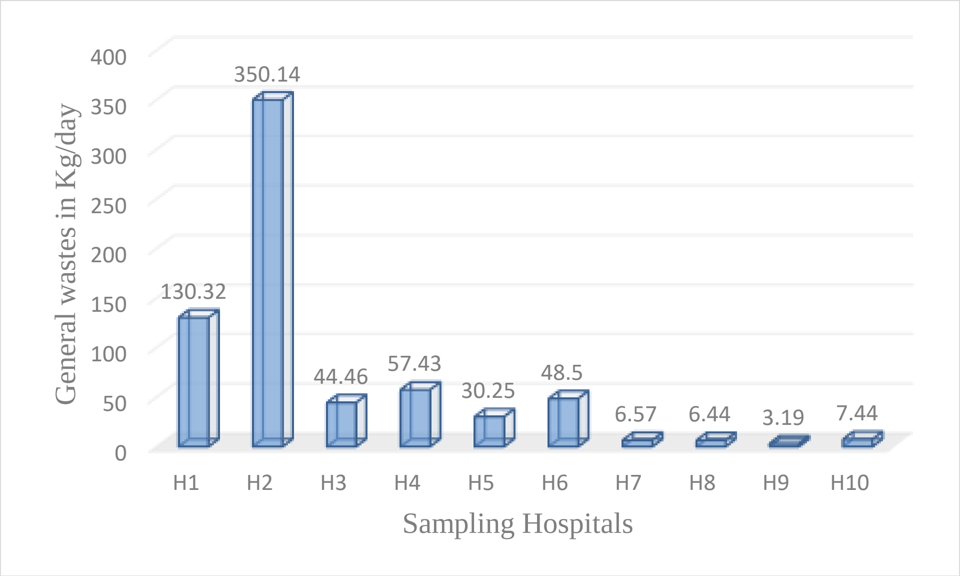


Figure 4.33: Average quantity of general wastes produced per day in the selected hospitals of the study area

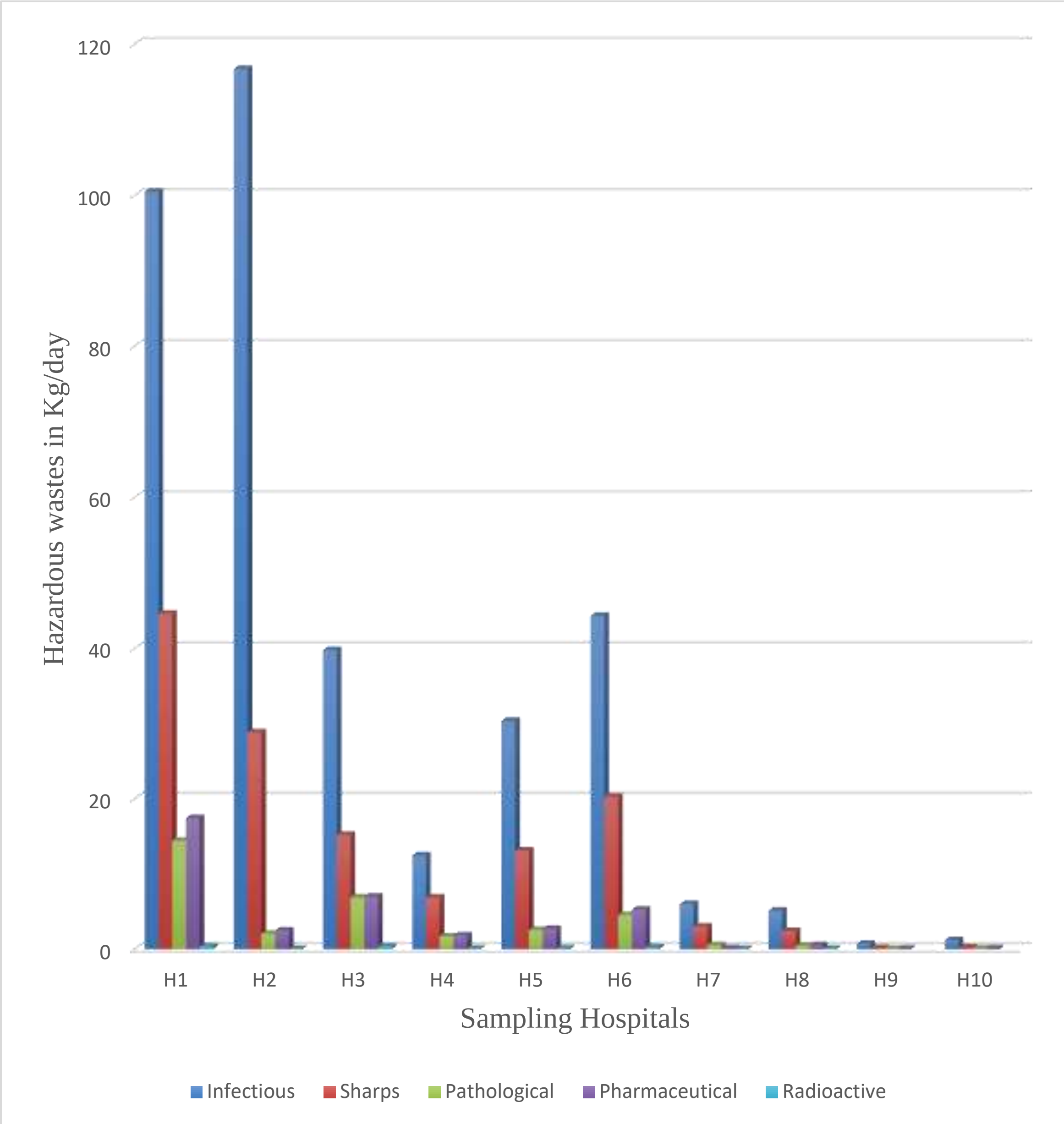


Figure 4 .34: Average Quantity of hazardous wastes produced per day in the selected hospitals of the study area

4.4.3.1 *Comparison of public versus private hospitals on healthcare wastes composition and generation rates of the study area*

Based on the composition percentages of healthcare wastes generated in public hospitals, 54.7, 28.7, 10.8, 2.7, 3 and 0.1% were general, infectious, sharps, pathological, pharmaceutical and radioactive wastes respectively while in private hospitals, 60.1, 24.9, 10, 2.6, 2.2 and 0.2%, respectively. However, the compositions of healthcare wastes are almost similar in the public and Private hospitals except general wastes 54.7% in the public hospitals, but 28.7% in the private hospitals on the other hand, infectious hospital wastes 60.1%, in public hospitals while 24.9% in the private's hospitals respectively (Figure 4.35 and 4.36).

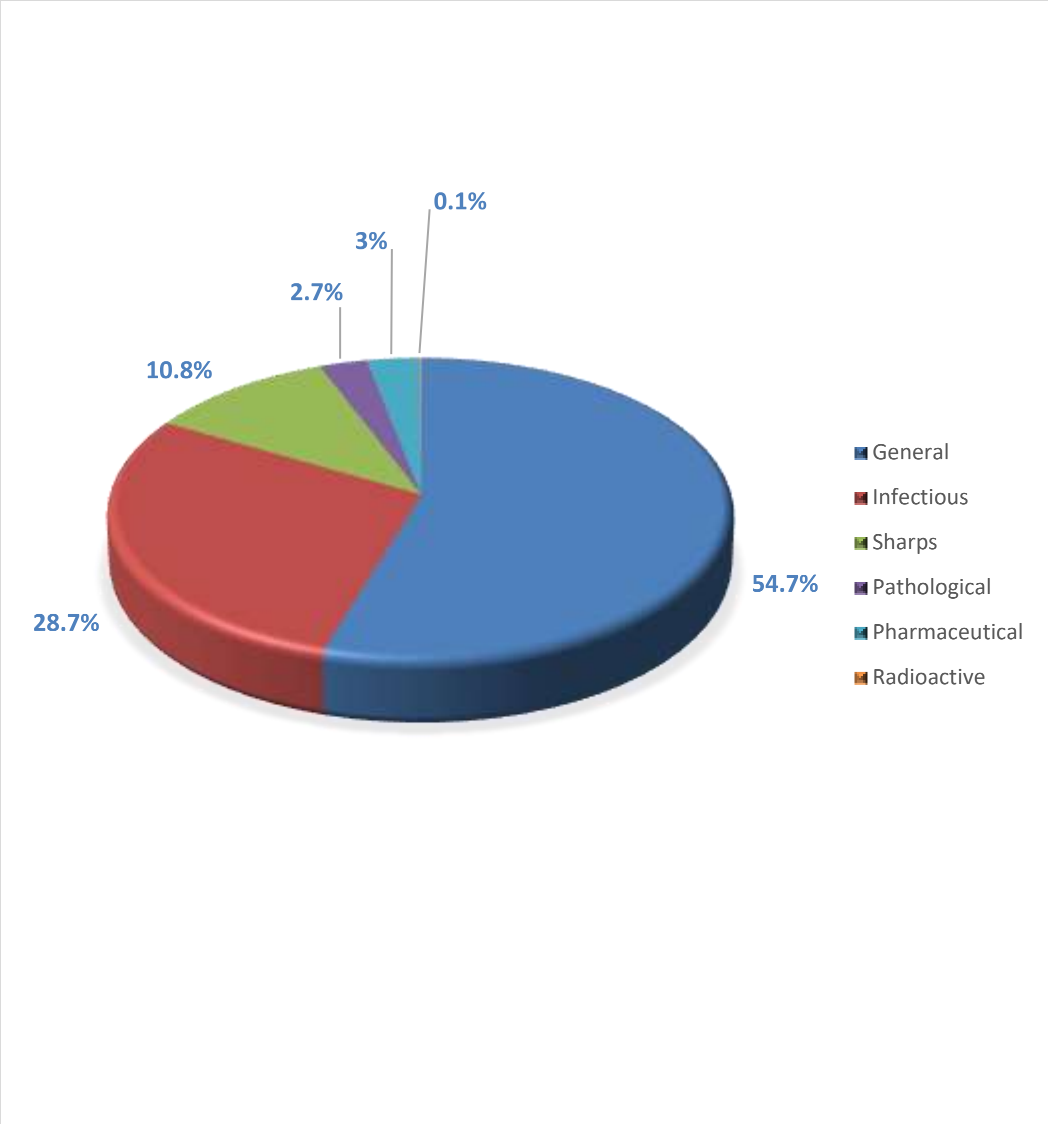


Figure 4.35: Composition of healthcare waste in the selected public hospitals

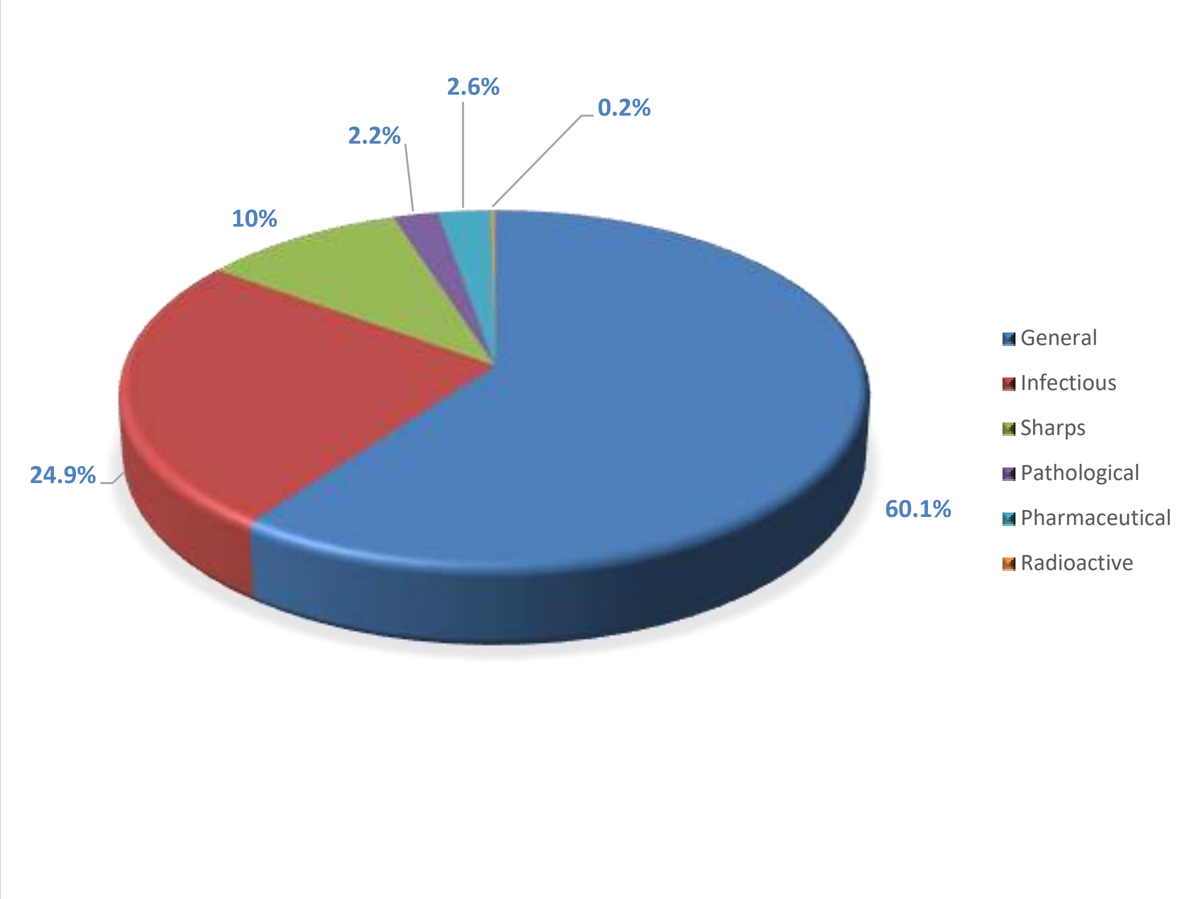


Figure 4.36: Composition of healthcare waste in the selected private hospitals

4.4.4 Medical wastes generated according to total number of beds

According to the findings of this study, the average MW generation rate of the hazardous waste were 0.53 kg/bed/day and general wastes were 0.44 kg/bed/day in all the hospitals selected. Thus, the total average generation rate of MW was 0.97kg/bed/day (Table 4.9). Similarly, in the public hospitals the average generation rate of general wastes was 0.54 kg/bed/day and the private hospitals was 0.2 kg/bed/day (Table 4.9), with the significance statistical variations of ($P < 0.05$). Also, in the case of hazardous MW in the public hospitals, the average generation rate was 0.71 kg/bed/day while 0.10 kg/bed/day for the private hospitals, which were statistically different at $P \leq 0.05$.

Table 4. 9: The Average Quantity of General and Hazardous Waste Generated kg/bed/day

Code	Number of beds	Hospitals waste composition in Kg/bed/day					
		General	Infectious	Sharps	Pathological	Pharmaceutical	Radioactive
H1	296	0.44	0.34	0.15	0.05	0.06	0.001
H2	187	1.87	0.39	0.15	0.11	0,11	0.003
H3	100	0.44	0.41	0.15	0.07	0.07	0.004
H4	100	0.57	0.12	0.07	0.02	0.02	0.0007
H5	140	0.22	0.22	0.09	0.02	0.02	0.0008
H6	250	0.19	0.18	0.08	2.00	0.02	0.001
H7	87	0.08	0.07	0.03	0.006	0.007	0.0004
H8	50	0.13	0.1	0.05	0.009	0.01	0.001
H9	20	0.16	0.04	0.009	0.003	0.004	
H10	24	0.31	0.05	0.01	0.004	0.006	
Average	**125.4**	**0.441**	**0.192**	**0.0789**	**0.2292**	**0.02411**	**0.00149**

4.4.5 Medical wastes generated according to total number of inpatients and outpatients

According to the results of this study, the average generation rate of the general wastes based on the number of inpatients in all the selected hospitals for this study was 0.43kg/patient/day while that of the hazardous wastes was 0.69kg/inpatient/day (Table 4.11). Similarly, in the public hospitals, the average generation rate of hazardous wastes was 0.92 kg/patient/day while that of the private hospitals was 0.13kg/patient/day (Table 4.11). These values are significantly different from one another (at $P \leq 0.05$). Also, the average generation rate of non- hazardous MW in the public hospitals was 0.58 kg/patient/day while that of the private hospitals was 0.08 kg/patient/day. These proportions varies significantly from one another ($P \leq 0.05$).

Furthermore, the generation rate for the sum of inpatients and outpatients' averages total of MW estimated in kg/patient/day in all the selected hospitals was 0.25kg/patient/day. The value for the hazardous wastes was 0.17kg/patient/day while that of the non-hazardous wastes was 0.079 kg/patient/day (Table 4.10). Additionally, the average rate of the total hazardous wastes generation rate in all the selected hospitals was (0.53kg/bed/day), and (0.69 kg/inpatient/day) while for the sum of inpatients and outpatients was 0.17kg/patient/day. This means that, medical wastes composition and generation rate in all the selected hospitals were mostly directly influence by the number of inpatients than number of beds and outpatients.

Table 4.10: Composition Based on the Number of Inpatients (Results are expressed in kg/bed/day with their Standard Deviation (SD) and Percentages

Hospital code	Medical wastes composition in kg/patient/day						
	General	Infectious	Sharps	Pathological	Pharmaceutic	Radioactive	Average hazardous wastes (%)
H1	0.87±0.25	0.67±0.14	0.31±0.15	0.11±0.07	0.12±0.04	0.002±0.001	58.20
H2	1.90±0.43	0.66±0.06	1.13±0.38	0.81±0.2	0.83±0.16	0.10±0.15	65.00
H3	o.12±0.04	0.11±0.03	0.04±0.03	0.02±0.01	0.02±0.02	0.001±0.0005	61.40
H4	0.62±0.18	0.13±0.03	0.52±0.3	0.02±0.02	0.02±0.03	0.0008±0.0005	52.70
H5	0.16±0.05	0.2±0.18	0.07	0.01±0.003	0.01±0.002	0.0006±0.0003	64.50
H6	0.31±0.15	0.28±0.04	0.13±0.04	0.03±0.01	0.03±0.03	0.002±0.001	60.40
H7	0.05±0.03	0.05±0.03	0.02±0.01	0.004±0.002	0.005±0.003	0.0003±0.0002	61.30
H8	0.03±0.009	0.02±0.01	0.01±0.003	0.001±0.0003	0.003±0.001	0.0002±0.0001	53.30
H9	0.09±0.03	0.14±0.05	0.03±0.02	0.01±0.02	0.01±0.009		67.90
H10	0.11±0.03	0.12±0.05	0.02±0.01	0.01±0.003	0.01±0.005		59.30

H1 = General Hospital Minna, H2 = General Hospital new extension Minna, H3 = IBB Specialist Hospital Minna, H6= General Hospital Kontagora, H7= General Hospital Wushishi, H8= Standard Hospital Minna, H9= Maraba (Aisha Usman Hospital Bida and H10= Al-Azeez Hospital Kontagora

Table 4.11: Types of Medical Wastes based on the total Number of In and Out - Patients in the Selected Hospitals in the Study Area

Medical wastes composition in kg/patient/day						
General	Infectious	Sharps	Pathological	Pharmaceutic	Radioactive	Average hazardous wastes (%)
0.06±0.02	0.04±0.028	0.04±0.01	0.006±0.004	0.008±0.002	0.0002±0.0001	55.29
0.63±0.18	0.29±0.11	0.07±0.02	0.05±0.03	0.05±0.02	0.0008±0.0003	42.24
0.03±0.009	0.02±0.014	0.01±0.008	0.004±0.002	0.004±0.003	0.0002±0.002	56.01
0.02±0.01	0.04±0.03	0.02±0.009	0.006±0.004	0.006±0.003	0.0002±0.0002	78.31
0.02±0.02	0.02±0.01	0.008±0.006	0.002±0.001	0.002±0.003	0.00007±0.0002	61.59
0.07±0.02	0.07±0.02	0.03±0.03	0.007±0.002	0.008±0.002	0.0004±0.0002	62.24
0.02±0.009	0.02±0.01	0.008±0.003	0.001±0.0003	0.002±0.001	0.0003±0.0002	61.01
0.006±0.002	0.004±0.002	0.002±0.001	0.0004±0.0002	0.0005±0.0003	0.0002±0.0001	54.2
0.003±0.001	0.008±0.002	0.002±0.001	0.0006±0.0002	0.0008±0.0004	0.0144±0.0001	79.17
0.004±0.002	0.006±0.003	0.001±0.002	0.0006±0.0001	0.0007±0.0002		67.48

H1 = General Hospital Minna, H2 = General Hospital new extension Minna, H3 = IBB Specialist Hospital Minna, H6= General Hospital Kontagora, H7= General Hospital Wushishi, H8= Standard Hospital Minna, H9= Maraba (Aisha Usman Hospital Bida and H10= Al-Azeez Hospital Kontagora

4.5 Approaches for Achieving Better Medical Waste Management

Already, the findings of this study have demonstrated that, current practice of linear MW management system (take, make, use, waste dispose model is unsustainable path due to higher risk of pathogens being present in the waste capable of causing environmental pollution, transmission of infection and means of spreading diseases such as skin, intestinal and respiratory infections, typhoid, fever, hepatitis, HIV and Cancer agent) thus, urgent and united action is required to correct this.

The transition from current practice of linear economy to a circular economy development model which works to reduce waste before it is produced, but also treats waste as a resource which is essential, holistic and integrated sustainable waste management. The system consists take, make, use, return, recycle, repair/ treat, reuse or buried Figure 4.37. Thus, with these practice hazardous MW would be reduced to zero level. Most importantly, the transition to a circular economy and according to its principles which provided a means to significantly address several issues of the Sustainable Development Goals (SDGs), notably SDG 3, 9, 11 and 12

CIRCULAR ECONOMY

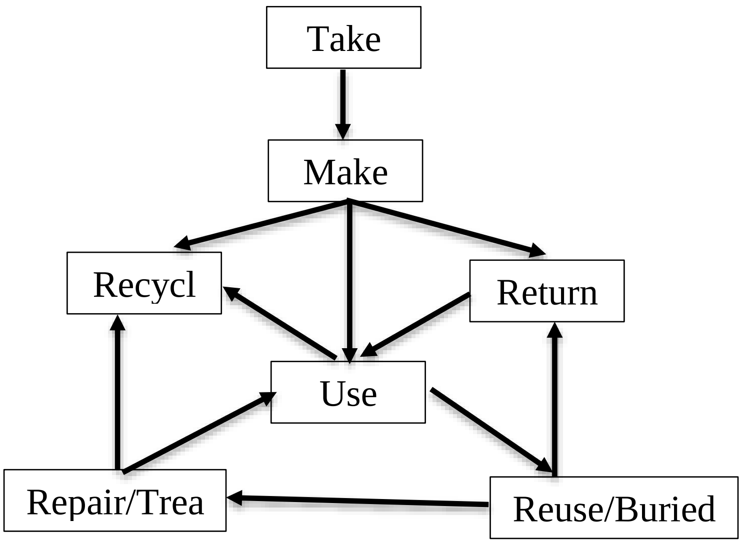


Figure 4.37**:** Circular economy medical waste management

4.6 Review of the Main Findings in this Study

Table 4.12: Summary of the Main Findings in all the Selected Hospitals

S/N	Objectives/Research question	Main findings
I	Examination of the current practices of medical waste management in Niger State.	In all surveyed hospitals, standard healthcare waste segregation practice was absence. Consequently, hazardous wastes are mixed with the general waste and burned in an open surface
II	Determination of the characteristics of hospital wastewater	The wastewater treatment plant was not available in all the hospital selected and wastewater quality parameters (pH, BOD, COD, TSS, DO, TC and FC analyses are above the permissible limit by the WHO (1996) and NESRSA (2011)
III	Investigation of morbidity in children (≤ 10 years) within the medical waste disposal and treatment of the study area.	Living in close proximity to wastes disposal sites, use of open surface/pits burning as well as low combustion single-chamber incinerators all can be major underlying factors in poor children health conditions since they enhance skin infections, respiratory and intestinal infections
IV	Determination of the compositions of solid medical wastes and generation rate.	The generation rate of hazardous MW in kg/bed/day in the public hospitals is greater than the generation rate in the private hospitals.

4.7 Discussions

This examination of current medical waste management practices, characterization of wastewater, examination of the morbidity of children exposed to the medical waste were implemented and to collect data on healthcare waste from relevant stakeholders in the selected hospitals in the study area. To achieve all these and the Sustainable Development Goals in respect of sustainable MW management, the need to move modern societies towards circular economies (CE) is germane. The idea of having materials labelled as waste, only to be disposed into the environment is against the principle of circular economy. With the promotion of circular economy systems around the globe which are more regenerative, will gradually relegate the traditional linear economies currently practised by most medical facilities to the background if not totally eliminated. The findings of this study reveals that, MW management practices was purely linear economy system (Take-Make-Use-Waste).

4.7.1 The practice of current medical waste management systems

The segregation of MW at the generation point is the first key factor among the waste management practices in the world. This study reveals that, there was no proper medical waste segregation practice using standard colour code containers and labels according to the international hazard symbols in all the selected hospitals (Plate III). The study findings similar to those submissions in Somaliland by Di- Bella *et al.* (2012), Nigeria by Afon *et al.* (2017) and Ethiopia by Sisay *et al.* (2017); Ahmed (2017) noticed that, according to WHO standards there were not real applications/usage of coloured bags or containers used at the two hospitals studied in Gaza Strip just as it is the case in this current study. Others similar findings by Ali *et al.* (2017); Hassan *et al.* (2018); Ankita *et al.* (2019); Yazie *et al.* (2019); Karki *et al.* (2020). The finding in this study is however, different from the results of the study conducted in Lagos, Nigeria by Olufunsho (2016) who found that, medical wastes were segregated by the use of standard colour code containers and labels according to WHO in his studied hospitals in Lagos. In addition, it was established in the current study in the selected hospitals that pathological wastes particularly human body parts and placentas were segregated from the point of generation and usually given to the patients' relatives to be buried in various homes. More so, it was observed that the current system in all the selected hospitals is that there was no WHO standards application in medical waste segregation practices indicating that the implementation of healthcare waste segregation is still a big challenge in Niger State and even the country in general. Thus, in this study, hazardous and non-hazardous hospitals waste were collected and disposed of at the same point which increased the quantity of hazardous waste generated capable of polluting the air, soil, surface and underground water as well as posed higher public risks Plate III and IV. Similar findings were reported by (Esubalew, 2015); (WHO, 2018a); Ahmed *et al*. (2018); Karki *et al*. (2020). However, it was reported that implementation of segregation of waste policies reduced hazardous waste generation in hospitals to a large extent (Esubalew, 2015).

Improper temporary waste storage facilities were seen to be in use in all the selected hospitals in this study. In these hospitals, mixed medical waste (hazardous and non-hazardous) were kept in open containers and on surfaces temporarily for about 2- 4 days, without proper supervision before final disposal (Plate V). This could attract rodents, dogs, cats and insects which could potentially contaminate the environment and transmission of difference type's diseases to the general public. The mixed wastes can contain harmful agents (microbiological pathogens, hazardous chemicals, sharp and radioactive substances) that can transmit diseases and cause injury to those exposed to such sites (Singh *et al.*, 2012; Yazie *et al*., 2019; Ghimire, 2020)

In this study, these containers were usually kept in the front of hospitals or at the back yards of the hospitals used as temporary storage facilities Plate V. In other studies, similar practices of healthcare waste substandard temporary storage practices existed as reported in Nigeria, South Africa, Ethiopia, Libya (Esubalew, 2015) and in Sudan (Hassan *et al*., 2018). Similar findings were reported by Áli *et al*. (2017); Afon *et al*. (2017); Puspalata, 2018; Yazie *et al*. (2019). This implies that, in developing countries, use of improper temporary medical waste storage facilities to create environmental pollution that could affect the lives of patients, healthcare workers as well as the general public. This study also, reveals that, a private hospital amongst the selected hospitals (Standard Hospital, Minna) stored their wastes in an attachment to the fence of the hospital with the roof over it which prevents unauthorized peoples access Plate V (c).

In addition, it was also observed that, all the waste storage facilities are substandard compared to those required by the WHO and others best practices globally, in this case, wastes storage site are not protected from the effects of the weather; sun, rain while animals, rats, dogs, cats, flies and birds have free access due to lack of proper and special built waste storage areas was apparent in all the selected hospitals in the study area. This could also contribute to the health risks for healthcare workers, patients, visitors and the neighbouring community. Similar findings were reported in Ghana by (Asante *et al*., 2014); (Áli *et al*., 2017); (Afon *et al*., 2017), in Edo and Kano in Nigeria by Stephen and Elijah (2011) and Umar and Mohammed (2014) respectively. In the forgoing, these situations were incompatible with WHO regulations.

In the current study, it was observed that, most common treatment and disposal methods of hospitals waste practiced by all the selected hospitals were burning in open surface, open fire pit and one chamber incinerator Plate VII. Similarly, NISEPA that has the responsibility of proper wastes management equally used surface burning for the treatment of its medical as well as domestic wastes. It was reported that, the used of aforementioned methods pose serious environmental pollution and health risk (Ngwuluka *et al.*, 2009; Puspalata, 2018; Yazie *et al*. (2019). In this study, none of the hospitals burns its wastes completely, thus, significantly producing high smoke that releases air pollutants to the environment known as fly ash. The Bottom and Fly Ash may pose significant health risks and environmental pollution through consumption of locally produced meat, eggs, and dairy products, consumption of fish from local waterways that are contaminated by air pollutants, and dermal contact with contaminated soils. These persistent pollutants that can bioaccumulate into food, a result of the deposition of toxic emissions onto plants and soil with subsequent ingestion by farm animals, or, in the case of fish contamination, from deposition directly into water bodies or onto soil and runoff into surface waters, wells with subsequent uptake in fish and human being (food chain). The exposure can be important for dioxins, furans and other emissions if: Food is grown near the incinerator/open surface burning, animals are raised on fields near the open surface burning, lakes, ponds, or other surface drinking water sources have a local catchment area, subsistence fishers or farmers in the area obtain most of their food from local sources and children play in dirt subjected to significant atmospheric deposition. Similar findings reported by Puspalata, 2018; Yazie *et al*. (2019).

In all the selected hospitals in this study, burning and burial sites are located inside the hospitals except IBB Specialist Hospital (H3) that burns its waste opposite outside to the hospital. Therefore, from the forgoing the current practices of healthcare waste treatment in all the selected hospitals in the study area could expose the whole environment to higher risks of accruing chronic and acute health problems. Such practices reported in Jos Metropolis Hospital, Nigeria by Longe (2012) and Imo State, Nigeria by Etusim (2013).

Also, in Ethiopia by (Esubalew, 2015), Bauchi and Kebbi states in Nigeria as reported by (Abayomi and Tolulope, 2017), in South-East Asia Region by WHO (2017) and (Ahmed *et al.*, 2018). Others similar findings in U. S and British by (Environmental Review of Incineration Technologies (ERIT), 1986), U.S. EPA (2007) established that substances from MW incinerators/open surface burning can influence male proliferation Chemicals and can also straightforwardly influence the testicles where sperm begins in which the quantity of sperm can be lessened or some sperm can be harmed or be inevitably convey poisons legitimately to the egg which causes contaminations. What is more poisons can assault the male sensory system, or endocrine framework, by influencing the hormones. Thus, giving birth to defective children as a result of exposures to toxins by men. Likewise, prior examinations have connected chlorinated hydrocarbons to female bosom disease or cancer of breast.

On the other hand, a different practice by the Lagos State wastes management agency, LAWMA which collects hospital wastes and uses hydroclave for their treatment as reported by Olufunsho (2016). Treatment of infectious wastes before burning was not done in all the hospitals selected in this study. A similar result was reported by Sisay *et al.* (2017) in the Hawassa University, in the Southern Ethiopian hospital. Others similar findings were reported in Ghana by (Asante *et al.*, 2014), in Edo and Kano in Nigeria by Stephen and Elijah (2011) and Umar and Mohammed (2014) respectively.

The specific National Healthcare Waste Management Policies and Guidelines in Nigeria is still at the drafting stage. Therefore, specific national medical wastes management policies and guidelines documents are not yet available in the country. In addition, the Niger State Ministry of Health and all the selected hospitals in this study, none of them has developed its own medical wastes management strategic plans and written instructions manual for the standard management of MW practices. This implies that there was no organized structure established to guide and monitor healthcare waste management practices in the state. This observation has been corroborated by the reports of Olufunsho (2016); Sisay *et al.* (2017); Olaniyi *et al*. (2018); Hassan *et al*. (2018); Katusiim (2018); Yazie *et al*. (2019); Karki *et al*. (2020). However, a different finding by Abayomi and Tolulope (2017), reported that, about 52.20% of the healthcare facilities sampled from Cross River, Nigeria possesses guidelines for HCW management while 38.21% from Bauchi states, Nigeria also possesses guidelines for HCW management. Also, a similar report indicated that there were rules and regulations guiding MW disposal, but these rules were not implemented (Supriya and soma, 2017).

Medical waste management is a hazardous activity therefore, workers should be trained before handling wastes and the training should be on regular basis (Annette *et al.*, 2013; Hassan *et al*., 2017; Yazie *et al*., 2019). The concept of global best practices in medical wastes management requires workers who receive continuous training on the job (WHO, 2004). This study ascertained that, all the hospitals studies (99%) have not provided trainings related to specific field of medical wastes management to medical doctors, nurses, paramedical and waste handlers. This might be the main factor for the improper practices and precautionary measures in handling healthcare waste thus, exposing themselves, pollute the environment as well as the public health risk. Similar findings reported by Adekunle *et al.* (2018) shows that, most of the healthcare workers in district hospitals in Kwazulu-Natal did not receive training on medical wastes management. Also, a report from Northern Jordan indicates that, doctors and other personnel have not been provided with the training on medical waste management in about 29% of the hospitals (Abdulla *et al.*, 2008). Others similar reported findings by Ali *et al*. (2017); Sutha (2018); Hassan *et al*. (2018). However, the report of Abayomi and Tolulope (2017) showed that about 67.18 and 53.19% of the healthcare workers from Cross River and Imo states received trainings on management of MW respectively. Also, the reports Birpinar *et al.* (2009) and Kumari *et al*. (2013) respectively showed that, in Istanbul, Turkey, 98% of healthcare workers attended training courses on medical waste management while in every department in China hospitals.

In all the surveyed hospitals in this study, mixed wastes were collected and transported in wheel barrow or open plastic or bins/metal buckets at the generation source without labelling. The wastes were scattered on the surrounding treatment and disposal sites due to the use of substandard waste containers. The findings of this study agreed with the findings in Edo and Kano in Nigeria by Stephen and Elijah (2011) and Umar and Mohammed (2014) respectively. Other similar report in less developed countries Iran by Bazrafshan and Mostafapoor (2011) and Ali *et al*. (2017) which reported improper use of facilities in the collection and transportation of hospital wastes management in their study area. These practices could contribute to the health risk of healthcare providers, patients, visitors and the neighbouring residents. These practices are different from the findings reported in India by UNEP (2009) and Esubalew (2015) which stated that, standard containers were used for the collection of hazardous wastes with proper covers and labelling's. The differences in practices may be associated with the level of awareness of the healthcare professionals and decision makers in the study area.

Furthermore, the results from the interviews conducted with the head of departments, units and patients in all the selected hospitals as well as residents living closed to the hospitals in the study area. The study reveals that, the proportion of healthcare workers adequately perceived the health and environmental risks of handling MW was very low. This result is similar to the study reported by Omofunmi *et al*. (2016); Ali *et al*. (2017)

and Hassan *et al*. (2018) that the majority of MW operators were not aware of the level of risk associated with handling MW in private hospitals in Nigeria. This is a cause for concern and it is important that, they are appropriately equipped to deal safely with MW. These results reflect the non-exposure to MW management courses during undergraduate training or non-exposure to in-service training at the hospitals on specific MW management. This deficiency could also be linked with absence of medical waste management policies, guideline manual and strategic plans in the selected hospital in the study area. Furthermore, in regards to the patients interviewed across the selected hospitals indicates that, they fairly perceived health implications of hospital wastes but, adequately perceived the health risk of black smoke released from surface burning of hospital wastes inside the hospitals. Similarly, in the case of the residents living close to hospitals and disposal sites indicates that, the existing surface burning of hospital wastes profoundly contributed to the air pollution within and around the hospital due to the thick smoke released by the processe. The majority of residents said that, they have to temporarily vacates their houses during the burning processes particularly those who are asthmatic.

Poor healthcare waste management in Taiwan in 2003 led to a severe outbreak of acute respiratory syndrome that forced the authorities to take more serious measures in managing healthcare wastes (TEPA, 2003). Furthermore, similar cases were reported in the United Kingdom, France, Japan, Sweden and Italy by (Prüss *et al*., 2005). Finally, the results of this research indicates that, MW management practices Figure 4.11 is not in line with the global best practices. Generally, the absence of these key factors like the national medical waste policies, hospital waste strategic plans management, poor attention to staff training as well as absence of separate budget to healthcare wastes management have immensely affected the healthcare development in Niger State.

4.7.2 Characteristics of Hospital wastewater

The raw wastewater quality in each hospital is an essential factor considered for designing wastewater treatment in the system. Proper attention has to be focused on staff training and flow of wastewater in hospitals. The study on wastewater quality parameters (pH, BOD, COD, TSS, DO, TC and FC) indicated severe pollution of hospital raw wastewater in the selected hospitals. The results of wastewater analysis of the selected hospitals reveales that all the hospitals in the state (both public and private) are not equipped with any form of wastewater treatment plant. The total absence of hospital wastewater treatment plants might lead to the spread of chemical and microbiological contaminants in the environment. In this study, the mean pH values of 6.9 obtained are within the acceptable limit of 5-9 and 6.5 – 9.8 set by WHO (1996) and NESREA (2011) respectively. Other studies WHO (1996) showed that, the pH values of their samples were 7.4 and 7.6 respectively which were also within the WHO limits pH: 5-9, (WHO, 1996).

The high concentrations of BOD obtained for H1 (85.8) and H7 (92.7) whereas, for COD: H1 (214), H7 (242.5), H8 (341.4), H9 (297) and H10 (373.1) mg/L respectively were obtained which are higher than the respective WHO BOD: 30 and NESREA 30 while WHO COD: 60mg/L and NESREA 50 mg/L respectively. Those values are not safe for discharge in to surface water, wells and agriculture purposes these are in accordance to the WHO and NESREA standard set limits for the maximum concentration of BOD in effluent discharge into surface water and well is 30 mg/L for agricultural purposes is 100 mg/L while the COD limit in effluent discharge into surface water and wells is 60 mg/L by WHO and 50 mg/L by NESREA respectively and this calls for special interventions. The findings in some of the hospitals in the current study accord with these results in literature. Different values were obtained for different hospitals in this study because, generally, values of hospital wastewater BOD and COD vary due to differences in their medical services (WHO, 1996). In some studies, the BOD values of 240 mg/L and 272.98 mg/L have been reported (Gautam *et al*., 2007). Similarly, the results of COD in hospital raw wastewater of 792, 628 and 629 mg/L respectively were reported (Emmanuel *et al.*, 2007). All these results are higher than the findings of current study. According to the WHO and NESREA standard set limits for the maximum concentration of BOD in effluent discharge into surface water and well is 30 mg/L for agricultural purposes is 100 mg/L while the COD limit in effluent discharge into surface water and wells is 60 mg/L by WHO and 50 mg/L by NESREA respectively. The DO values of the samples obtained in this study ranging from 1.3 lower limit (H4) to 3.7 mg/L upper value (H5) Figure 4.17. These values are too low and have implications in water quality. In this case these values obtained are thus unacceptable according to the standards. This therefore, implies that the oxygen level is too low for microbial activities which mean that pollution level is high

The concentrations of TSS in most of the hospitals in this study were more than the 100 mg/L permissible limit set by the WHO (1996) and NESREA (2011). Similar studies which investigated wastewater samples of some government hospitals obtained TSS concentrations in the range of 120-400 mg/L (WHO, 1996). These higher values of TSS obtained in the current study indicates that, these wastewaters are not safe for discharge into surface water, wells and agricultural irrigation dams. The results of this study show that, the mean TC and FC values in most of the studied hospitals are within the permissible limits of 1000, 400 MPN/100 mL respectively set by the WHO (1996) and NESREA (2011). High TC (72334.7 MPN/100 mL) and FC (60334 MPN/100 mL) concentrations were obtained in H2 indicating higher bacterial contaminations. Accordingly, these hospital effluents are not fit for discharge into surface water, wells and agricultural waters. These values obtained for this hospital are quite different from the respective TC and FC values of 99.57, 97.45, reported by (Majlesi and Yazdanbakhsh (2008).

4.7.3 Morbidity in Children (≤ 10 years) within the Medical Waste Disposal and Treatment Vicinities of the Study Area.

The assessment of medical wastes management of hospital healthcare facilities that practices improper wastes disposal methods. Thus, such a situation exposes residents (particularly children) close to hospitals in developing countries in great risk of contamination. The submission on health problems associated with proximity to a MW disposal site by Vrijheid (2000) includes the specific symptoms such as irritation of the skin, nose, eyes, gastrointestinal and respiratory problems. Whereas non-specific symptoms includes headaches, allergies, fatigue and psychological problems.

The results of living in vicinity to an improper healthcare wastes treatment and disposal sites in this study revealed that the risk ratio (RR) was (0.25 - 0.18) for skin infection in children, this implies that, exposed groups have common cases for skin infection than unexposed children. Also, stated by Bailie *et al.* (2005), usually, skin infections are common among the children and significant cause of morbidity in children, especially living in proximity to improper medical waste disposal sites.

The risk ratio (RR) for respiratory infection was 0.44 – 0.31 in children living in proximity to a poor hospital wastes disposal and treatment sites. This indicates that, exposed children living close to a poor hospital healthcare wastes disposal and treatment sites suffer two and a half (2½) times more from respiratory related symptoms compared to unexposed children living far away from such sites. The p – value of ≤ 0.05 indicates that, it is statistically significant. Similar findings reported by Peter, (2011) that risks ratio

(RR) of children living in proximity to a poor hospital wastes disposal site was (2.19-5.73) for respiratory infection (3½) times more than unexposed children. Other submission by (Ozonoff *et al.*,1987; Girón *et al*., 2009) indicates that, larger cases of respiratory symptoms in children, as well as irregular heartbeat, history of heart problems, cases of anaemia and other blood disorders in people neighbouring several hazardous waste disposal sites such sites when compared with control children living far away from such sites.

Furthermore, living in proximity to an improper healthcare wastes treatment and disposal sites in this study revealed that, the risk ratio (RR) for intestinal symptoms in children was 0.27 – 0.19 meaning that, children within the exposed group were more than two and little above suffer more likely from intestinal infections than unexposed children living far away from such dump sites. The result is also statistically significant p – value of ≤ 0. 05. The higher risks ratio (RR) of intestinal symptoms (1.34 - 7.60) was reported by (Peter 2011) which indicates a 3-times likelihood for intestinal symptoms in exposed compared to unexposed children, indicates that, it is statistically significant. Others reported cases reveals that, intestinal infections are globally called endemic and constitute the greatest single worldwide cause of illness and disease (Mehraj *et al.,* 2010). On the other hand, Gazon (2003) and Steketeer (2003) mentioned that intestinal infections occur to all ages; with children having the worst morbidity and mortality. Similarly, a study by Fogwe and Ndifor (2010) investigated intestinal worms in children (aged 5 to 9 years) in the city of Douala, Cameroon living in proximity to poor hazardous wastes disposal sites were most affected (88.9%) as opposed to adults.

However, MW treatment and disposal in all the hospitals selected in the study area in aforementioned involve the use of open dumps, open surface burning and substandard incinerator while hospital raw wastewater is flushed to pits and drainages. In addition, visibly black smoke and fly ash from the open surface burning and substandard incinerator, through mass air movements deposit pollutants around the households which could lead to environmental pollutions and public health crisis particularly amongst children. In this study therefore, hospital wastes treatment enhance morbidity in children and other adults. The findings of this study were similar with their reports that open surface burning and substandard incinerator can pollute the environment (Zhao *et al*., 2010; Auta and Morenikeji, 2013; Mohajer *et al*., 2013). Therefore, the findings and recommendations of this research maybe useful for all hospitals in Niger State and the country at large.

4.7.4 Compositions and Generation Rate of Hospital Medical Wastes

Composition analysis of medical waste generated is the basic fundamental step in the development of a strategic plans for management of MW. The results obtained in all the selected hospitals in this study shows that, 0.97kg/bed/day was the average total medical wastes generation rate. The generation rate values recorded in this study were similar with the generation rate in their studied in Nigeria estimated between 0.562 to 0.670 kg/bed/day and as high as 1.68 kg/bed/day Abahand and Ohimain, (2011.). Other similar findings were the generation rate in Edo, Nigeria (0.81 kg/bed/day) by Stephen and Elijah (2011), Ghana (1.2kg/ bed/ day) by (Asante *et al*., 2014), Ethiopia (1.5 ±0.6 kg/ bed/day) by Esubalew (2015), Sana'a city, Yemen (0.7 kg/bed/day) by (Gawad *et al.*, 2016).

In addition, in relation to number of inpatients. The average total medical wastes generation rate in this study was 1.12kg/patient/day while in the case of hazardous healthcare wastes, the generation rate was 1.05 kg/inpatient/bed/day. Similar close results were obtained in a Teaching Hospital in Nigeria 0.62 kg/patient/day at the outpatient units and 0.81 kg/patient/day in the in-patient wards in Edo, State (Stephen and Elijah, 2011), in hospitals of Sana'a city, Yemen; 0.8 kg/patient/day and 2.3 kg/patient/day of non-hazardous wastes (Gawad *et al*., 2016).

The total generation rates of the number of in and outpatients' term of kg/patient/day was not significantly different between the public and the private hospitals in Niger State (Figure 4.35 and 4.36). Therefore, this study concluded that, the number of inpatients available at a particular time influenced the MW generation rate in all the selected hospitals in the study area. This is because, the MW generation rates of inpatients in terms of kg/bed/day were significantly higher when compared to the generation rates of total number of in and outpatient in terms of kg/patient/day. This is owing to the fact that, large hospital size, various type of services provided and social economy factors of patients these can make a significant contribution to the MW generation rate.

The amount of MW generated in each hospital was affected by several major issues which includes: the income level and number of patients present at the time of the measurement, the number of beds, type of services offered and hospital location. According to these factors, the percentage of hazardous wastes generation rate of each hospital was determined. This research (Table 4.8 and 4.9) has established that, categories of MW components in the selected hospitals were composed of general, infectious, sharps, pathological and Pharmaceutical wastes. Thus, compositional analyses of hospitals waste indicates that, the total percentage of average hazardous waste components generated in each of the hospital based on the number of inpatient /bed/days were; H1: 58.21, H2: 65.01, H3: 61.41, H4: 52.70, H5: 64.49, H6: 60.36, H7: 61.33, H8: 53.27, H9: 67 and H10: 57.26% respectively. These percentages of hazardous wastes in both inpatients and the sum of (in and outpatients) Tables 4.8 and 4.9 were significantly above the 10-25%

threshold set by WHO (2018a). Similar findings were reported by Esubalew, (2015) in Iran hazardous hospital healthcare waste was (29%), South Africa 39%, Tanzania (67%) and Ethiopia 70% by (Yazie *et al*., 2019). All of these reports, the hazardous wastes generated was above the limit (10-25%) set by WHO. However, improper segregation of different types of MW materials by healthcare workers and wastes handlers were the major reason for the high percentage of hazardous waste in all the selected studied hospitals as well as hospitals of developing countries. These deficiencies were linked with total absence of medical wastes policies, guidelines and strategies plans.

Non-significant variations between dry and wet seasons of hospital wastes compositions and generation rate in all the hospitals studied. The one-way ANOVA test between variables shows that, hazardous MW was significantly higher in public hospitals than in private hospitals ($P < 0.05$). This is because, the services charges in the public hospitals is significantly lower, the higher number of beds, inpatient and outpatient as well as the various type of services are provided in the public hospitals. As a result, more hazardous MW were generated in public than private hospitals.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Hospital medical wastes poses risk to the environment and public health due to the presence of hazardous substances in the hospital healthcare wastes generated. Despite these facts, it has attracted little attention in the state as well as within the spectrum of environmental risks and public health research. From the studied hospitals, it was observed that, the segregation/sorting, handling, storage, treatment, transportation and disposal of solid medical wastes by all the selected hospitals in the study were ineffective in protecting the environment from contamination thus creating public health risks. The reasons for these were not far-fetched from the total absence of medical wastes management policies and strategic especially for handling hazardous hospital wastes which were mixed with the non-hazardous ones.

The common use of low combustion single-chamber incinerators, open surface burning and open pits burning for the treatment of the generated healthcare wastes in the study area has already exposed the entire population of the hospital communities to substances released from such practice that are expected to cause a number of serious health effects as well as environmental risks in the study area. The study on wastewater quality parameters (pH, BOD, COD, TSS, DO, TC and FC analyses are above the permissible limit by the WHO (1996) and NESRSA (2011). These chemicals and toxic materials indicated severe pollution of hospital raw wastewater capable of surface and underground water contamination. This study also revealed that, all the hospitals in the state (both public and private) were not and of course are still not equipped with any form of wastewater treatment plant thus releasing unfit healthcare wastewater directly to the environment.

Living in close proximity to wastes disposal sites, use of open surface burning, open pits burning as well as low combustion single-chamber incinerators all can say be the major underlying factors in poor children health conditions since they enhance skin infections, respiratory and intestinal infections (Peter, 2011). The total commitment shown by the parents of the children and other residents interviewed close to the hospitals towards the success of this study confirms the environmental and public health risks that requires urgent need for better medical wastes practice.

The average generation rates of hazardous hospital medical wastes in the public hospitals studied were 0.71kg/bed/day and 0.92kg/patient/day while those of the private hospitals were 0.10kg/bed/day and 0.13kg/patient/day respectively. Similarly, the average rate of the total hazardous wastes generated by the inpatients and outpatients in this study was 0.25 kg/patient/day. All these values gave the percentage values of the hazardous components of the total healthcare wastes above 50% in all the selected hospitals which are all values above the 10 - 25% threshold set by the WHO (2005) and WHO (2013). Thus, these figures indicates that, all the hospitals in the study area generates wastes whose environmental qualities are of great challenge. This is however, more prominent in the public hospitals than the private healthcare facilities. Therefore, it is pertinent to take into consideration all measures of healthcare waste generation parameters in order to reliably and effectively quantify the wastes generation rates for different types of composition of wastes from the healthcare facilities in the study area most especially that of the general position of the Focus Group Discussion (FGD) which rated the current medical wastes management practices in the state far below the standards.

5.2 Recommendations

In the light of the field observations and the findings of this study, the following recommendations have been made;

i. That the Ministry of Health should ensure the use of comprehensively developed policies, strategic plans and guidelines for sustainable MW management in healthcare facilities in the state. In this wise, every hospital or health care facility should be made comply by way of having developed waste management committees.

ii. In order to meet the WHO standards and achieve sustainable development goals in medical waste management, proper training of healthcare workers is necessary. Thus, the roles of all healthcare workers and waste handlers in basic healthcare facilities and waste management plan should be given a special attention at all levels.

iii. All the hospitals must have standard treatment systems for hospital raw wastewater with the capability of removing contaminants. These could be achieved by the provision of adequate training courses related to the operations of wastewater treatment systems for the personnel of the hospitals.

iv. This study also suggests the use of alternative technologies to incineration for medical waste treatment. The use of incinerators/open surface burning for the treatment of MW should be completely phased out to completely avoid the hazards it poses to the environment and health. Thus, the use of environmentally friendly treatment technologies such as electron beam sterilization (autoclave, microwave, plasma torch, thermal deactivation, electro-thermal deactivation), hydro-claving. The use of these technologies should be taken into consideration.

v. Provision of hospital healthcare waste storage and treatment areas in every hospital. In this case, all hospitals need to identify appropriate and well-ventilated areas designated as waste storage treatment areas equipped with clearing facilities and screens for protection against flies and rodents. This can be achieved right from designing stage in the construction of a hospital by allocating a special space for waste management.

vi. Also, simple medical waste promotion and intervention programmes can reduce morbidity in children and other public health risks should be taken into consideration.

vii. Establishment of clear guidelines that lay emphasis on the reduction of the use of products that generate hazardous MW. In this case, the replacement of mercury based diagnostic tools with digital and electronic technology is necessary.

viii. Approach the federal government, the international organizations such as the WHO, UNEP, GMO and others such as the World Bank and Global Alliance for Vaccines and Immunization (GAVI) for financial, technical and expertise supports that would bring about proper policy development, implementation and monitoring in the health sector.

ix. Another recommendation by this study is the transition from linear to circular economy in the management of medical waste which could provide a significant opportunity to reduction of environmental impacts and health risks of the current practice and yield substantial environmental and health benefits aimed at achieving the SDGs.

5.3 Strengths of this Study/Contribution to Knowledge

One of the key strengths of this study is the use of mixed methods such as physical measurements, questionnaires administration, laboratory samples analysis, focus group discussions, interviews and observations to measure, examine and understand the inherent problems. The second strength is in the ability of the study to harness the services of all the categories of healthcare workers and waste handlers in the selected hospitals for data gathering. Therefore, this research could be useful in policy development, strategic planning and guidelines for the management of MW in healthcare facilities in Niger State in particulars and the country as a whole.

In addition, this research has added some knowledge to the healthcare waste management in the study area by:

i. Determining the level of awareness and knowledge.
ii. Determining the contribution of solid and liquid hospitals waste to environmental pollution and public health risks.
iii. Precisely determining the healthcare waste composition and generation rates in the study area.
iv. Suggesting comprehensive medical waste management systems

5.4 Contribution to Knowledge

i. From this study, it was observed that, 100% of the disposed wastes were not segregated and were dumped on open surfaces
ii. 100% of the studied hospitals did not have standard temporary storage of healthcare wastes
iii. 100% of the studied hospitals utilized open surface and open pits burning systems for the treatment of the generated healthcare wastes
iv. This study revealed that, all the hospitals (100%) in the state were not and of course are still not equipped with any form of wastewater treatment plant thus releasing unfit healthcare wastewater directly to the environment.

v. BOD of wastewater while the highest concentrations were measured for two hospitals (H1 and H8) with 86 and 97 mg/L respectively permissible limits of 30 mg/L given by WHO, (2004) and NESREA (2011) respectively

vi. The high concentrations of BOD obtained for H1 (85.8) and H7 (92.7) whereas, for COD: H1 (214), H7 (242.5), H8 (341.4), H9 (297) and H10 (373.1) mg/L respectively were obtained which are higher than the respective WHO BOD: 30 and NESREA 30 while WHO COD: 60mg/L and NESREA 50 mg/L respectively. Those values are not safe for discharge in to surface water, wells and agriculture purposes

vii. The results obtained from 60% of selected hospitals in this study shows that DO values ranging from 1.30 to 2.30 mg/L are too low 60%. In this case these values obtained are thus unacceptable according to the standards. This therefore, implies that the oxygen level is too low for microbial activities which mean that pollution level is high

viii. The concentrations of TSS in most of the hospitals in this study were more than the 100 mg/L permissible limit set by WHO (1996) and NESREA (2011)

ix. This study indicates that, exposed children living close to a poor hospital healthcare wastes disposal and treatment sites suffer two and a half (2½) times more from skin infections, respiratory and intestinal infections related symptoms than the unexposed children living far away from such sites.

x. The results obtained in all the selected hospitals in this study show that, 0.97kg/bed/day was the average total medical wastes generation rate.

xi. In all the selected hospitals, the percentage hazardous components of the total healthcare wastes were above 50 which are all values above the 10 - 25% threshold set by WHO (2005) and WHO (2013).

5.5 Suggestion for Further Research

i. Further studies should consider impacts of intervention measures which case evaluation of the effectiveness of measures taken on healthcare waste storage, collection in the study area should be carried out.

ii. It is also suggested that further research on this topic in the study area should contents, the investigation of environmental and health implications of bottom and fly ash of hospitals incinerators and surface open burning of medical wastes

iii. It is also suggested that assessment of surveillance and monitoring systems in occupational exposure to medical waste under a variety of conditions in developing countries including the study area be vigorously undertaken.

iv. It is the suggestion of this study that further work on this subject in the study area should take into consideration, the empirical risk assessment tools for chronic low-level exposures to the use of substandard incinerators in developing countries.

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Appendix (A)

Survey questionnaire for medical waste management

DEPARTMENT OF GEOGRAPHY

FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA, NIGE STATE

Dear Sir/Madam,

The aim of this study is to examine Environmental and Health Implications of Management of Medical Wastes in selected Hospitals in Niger State, Nigeria

1. This questionnaire is designed to collect data and will be limited to scientific research purposes only. The answers you gave will be treated with maximum confidentiality and will not be used for any purpose other than scientific research.

2. Read each statement carefully and then specify that you know only one answer that you are comfortable with or prefer.

3. I hope to answer all the questions with credibility and not leave any of them unanswered to achieve the goal of the study, where the results will be analysed, which could serve as reference materials for the formulation of policies. We do appreciate the questionnaire will take some of your valuable time; however, it will provide a wealth of helpful information to improve medical waste management in Niger State. Any further information and the final outcome of the research will be available upon your request. To this end, we would like to thank you in advance for your valued and kind consideration.

ABUBAKAR ABUBAKAR

(Principal Researcher) 08051664027

SUPERVISORY TEAM:

MAJOR SUPERVISOR: **Dr. M.A. Emigilati**

CO-SUPERVISOR: **Dr. T. I. Yahaya**

CO-SUPERVISOR: **Prof. M. M. Ndamitso**

Appendix (B)
Survey questionnaire for medical waste management

Part I

Hospital Name:

Identifying Data

Name [optional]______________________________

Designation / Position__________________

Gender: Male □female □

Profession / Field of Work: Doctor □ Pharmacy □Nurse □Laboratory Technician □ Admin □ waste collector □

Department______________________ Length of service in hospital _____________

current position_______________________

Number of beds in the hospital ....Quantity of waste produced from hospital / Day or /month • ....

The highest department records the largest amount of medical waste---------

1. Age group to which you belong: □Less than 19 years □ Between 19-29 years □ Between 30-39 years □ Between40-50 years □ Over 50 years

2. Level of education: □ Uneducated □Certificate of Primary, Preparatory, Secondary School

□Diploma □ University Degree □ Above () Specify / ... ..

Part II

Organization and Planning

1.Presence of Hospital's Waste Management Manual of Procedures or Standard Operating Procedures on medical Waste Management in the hospital? □ A □SDA □ DA

2.There is a medical waste management Department in the ministry and hospitals? □ A □SDA □ DA

3. If yes, does the waste management staff/team have scientific qualifications specialized in the management of medical waste? □ A □SDA □ DA

4. Presence of an organized Health Care Waste Management Committee (HCWM) □ A □SDA □ DA

5. If yes, does the waste management committee have scientific qualifications specialized in the management of medical waste □ A □SDA □ DA

6. Presence of Hospital Waste Management Plan □ A □SDA □ DA

7. Hospital Waste Management Plan is regularly updated □ A □SDA □ DA

7. Are there waste management responsibilities include in the job descriptions of hospital supervisory staff (Head of hospital, Department Heads, Medical Doctors, Matron/senior nursing officer? Hospital engineer, infection control officer, pharmacist, laboratory supervisor, etc)? □ A □SDA □ DA

8. How much does the hospital spend in waste treatment and / or disposal in a month? --

9. Has your hospital done a waste audit / assessment over the last three years? □ A □SDA □ DA

10. Is there currently an internal system for auditing / assessing the medical waste generated by the hospital? □ A □SDA □ DA

Part III

Waste Management Policies

1. Are you aware of any legislation existing policies application to Health Care Waste Management □ A □SDA □ DA

2. Recycling is being practiced in the hospital □ A □SDA □ DA

3. Does your hospital practice segregation & sorting? □ A □SDA □ DA

. Safe packaging and adequate labelling of waste being practiced □ A □SDA □ DA

5. Appropriate colour-coded receptacles/bins/bags are provided □ A □SDA □ DA

6. Are there sanctions for non-compliance on Waste Management policies □ A □SDA □ DA

7. Does your hospital have a programme in place to eliminate the use of mercury containing products? Please elaborate. □ A □SDA □ DA

8. Does your hospital have a policy of reducing or phasing out PVC packaging and containers? □ A □SDA □ DA

Part IV

Staff Development

1. Are there training modules developed on Health Care Waste Management □ A □SDA □ DA

2. Are you received training in medical waste management: □ A □SDA □ DA

3. If yes, where did you receive training? ....

4. Duration of training: □ Less than 1week □ 2-3 weeks □ other set by ....

5. The new staff member is trained for the management of medical waste before receiving his / her job: □ A □SDA □ DA

Part V

Waste Storage Facility and Waste Management Records

1. Presence of a designated waste storage facility within the hospital's premises? □ A □SDA □ DA

2. The waste is stored in the hospital temporarily: □ A □SDA □ DA If yes, you can answer questions 3-9

3. The storage area inside the hospital is suitable in terms of ventilation, size, safe, lighting and easy access □ A □SDA □ DA

4. The place to store medical waste in the hospital is only accessible to the staff Concerned □ A □SDA □ DA

5 Storage facilities are properly marked with signage/warning signs? □ A □SDA □ DA

6. Presence of Daily Waste Collection Monitoring Records

a. Daily Waste segregation records b. Monitoring of Weight of Daily Waste Collection c. Monitoring of Daily Waste Transportation

7. Presence of Monthly Waste Collection Monitoring Records

a. Monthly waste segregation records b. Monitoring of Weight of Monthly Waste Collection c. Monitoring of Monthly Waste Transportation

Part VI

Waste Processing

1. You have knowledge about the medical waste management process □ A □SDA □ DA

2. Types of waste produced from the department □ General □ Pathological □ Pressurized containers □ Infectious □ Pharmaceutical □ Radioactive □Sharps □ Chemical waste

3. Containers and bags are available in sufficient numbers within the departments □ A □SDA □ DA

4. Are you have knowledge of the colour code used in the medical waste system □ A □SDA □ DA

5. Containers and bags available conform to the colours specified in the code □ A □SDA □ DA

6. Containers for hazardous medical wastes are identified and distinguished from general waste: □ A □SDA □ DA

7. Medical waste is separated in each department □ A □SDA □ DA

8. Are you have a knowledge of the capacity that the medical waste bags must be filled □ A □SDA □ DA

9. The bags are filled with more than one capacity □ A □SDA □ DA

10. Wastes are not remained in a place of generation more than one day □ A □SDA □ DA

11. Medical waste or part of it is treated within the hospital □ A □SDA □ DA

12. If yes, what methods are used to treat medical waste within the hospital (on-site) a. Incinerator, b. Delay to decay c. Open fire pit/Surface d. Chemical disinfection e. Autoclave f. Microwave g. Pyrolysis f. Others, please specify

13. Waste Treatment (off-site) a. Delay to decay b. Chemical disinfection c. Autoclave d. Microwave e. Pyrolysis f. Open fire pit/Surface g. Others, please specify

14. Waste Collection and Transport (on-site) a. Collection is done daily b. Twice in a week c. Three time in a week d. once in a week

15. Medical waste are transported inside the hospital building using □Hand □ Wheeled trolleys or Cart □ A □SDA □ DA

16. Waste Collection and Transport (off-site) a. Collection of hospital waste is done regularly (frequency 1, 2, and 3time in a week) b. Waste collection is done by a private company accredited transporter or carrier c. Waste collection is done by the NISEPA d. Waste collection is done by the health care facility (waste generator)

17. Medical waste are transferred from the hospital building to the storage area using: □ Hand □ Cart □ I do not know

18. Vessels used for the transport of a sharp waste are perforated □ A □SDA □ DA

19. In the case of liquid medical waste, precautions are taken to prevent leakage of fluids from the bags (such as placing a bag inside a bag) □ A □SDA □ DA

20. What is your method of Waste Disposal a. Sanitary landfill (privately owned/ operated) b. Sanitary landfill (LG/state operated) c. Controlled Dumpsite (privately owned/operated) d. Controlled Dumpsite (LG/state operated) e. Others, please specify---

21. Does your hospital equipped with wastewater treatment plant? □ A □SDA □ DA

. If yes, what type of treatment system? ……………………….…..

22. Where is the final disposal area of hospital wastewater? ---------------------

Part VII

Health and Safety Practices

1. Do you wear gloves when dealing with medical waste □ A □SDA □ DA Sometimes □Rarely. If yes, please answer question 2

2. Do you use the same glove more than once? □ Yes / Always □ No □ Sometimes□ Rarely

3. Do you wear a special dress while performing your work □ Yes / Always □ No □ Sometimes□ Rarely

4. Are your clothes protective, so that needles are not easily penetrated □ Yes Protective □ No Protective □ I do not know?

5. Do you have an injury resulting from dealing with medical waste □ A □SDA □ DA

7. Have you registered the injury: □ A □SDA □ DA

8. Have you been vaccinated before starting work in the hospital □ A □SDA □ DA

9. Do you receive vaccinations periodically during work in the hospital □ A □SDA □ DA

APPENDIX C

Survey questionnaire for morbidity in children

Part I

Community Name:

Identifying Data

Name [optional]______________________________

Occupation ___________________

Gender: Male □female □

Number of months or years in the area ______________

1.Number of children ....

2.Gender: Male □female □

3.Age group to which he/she belong: □Less than 1years □ Between 2-5 years □ Between 6-10years

4. Any child suffering from: (a) Skin infection (b) Respiratory infection (c) Intestinal infection.

5. How long for the 4a-c above. □ Since birth □Less than 1years □ Between 2-5 years □ Between 6-10years

APPENDIX D

Post hoc tests results for wastewater parameters analysis from the study area

Extract from post-hoc points

Duncan H1

Parameter	N	1	2
DO	3	1.6000	
Ph	3	7.4700	
BOD	3	85.7667	
TSS	3	212.6000	
COD	3	214.0000	
FC	3	409.0000	
TC	3		4.4067E3
Sig.		.837	1.000

.

H2

Duncan

Parameter	N	1	2	3
DO	3	1.7667		
pH	3	7.2733		
BOD	3	10.2000		
COD	3	23.0667		
TSS	3	48.9667		
FC	3		6.0334E4	
TC	3			7.2335E4
Sig.		.867	1.000	1.000

H3

Duncan

Parameter	N						
		1	2	3	4	5	6
COD	3	.0033					
BOD	3	1.6333	1.6333				
DO	3		3.6000	3.6000			
pH	3			5.1833			
TSS	3				99.0667		
FC	3					3.0333E2	
TC	3						3.1220E2
Sig.		.165	.099	.176	1.000	1.000	1.000

H4

Duncan

Parameter	N						
		1		3	4	5	6
COD	3	.0667					
BOD	3		1.1000				
DO	3		1.3333				
pH	3			7.6000			
TSS	3				12.1733		
FC	3					3.2043E2	
TC	3						4.0297E2
Sig.		1.000	.547	1.000	1.000	1.000	1.000

H5

Duncan

Parameter	N	1	2	3	4	5	6	7
BOD	3	1.8333						
DO	3		3.6667					
pH	3			7.3000				
COD	3				43.1333			
TSS	3					2.5200E2		
TC	3						2.5593E2	
FC	3							5.2037E2
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000

H6

Duncan

Parameter	N	1	2	3	4	5
FC	3	.0033				
BOD	3		.6333			
TC	3		1.0667			
COD	3			3.4333		
DO	3			3.6333		
pH	3				7.4067	
TSS	3					11.2667
Sig.		1.000	.158	.503	1.000	1.000

H7

Duncan

Parameter	N	1	2	3	4	5	6
TC	3	.0067					
FC	3	.0133					
DO	3		2.3333				
pH	3			7.1700			
BOD	3				97.1667		
TSS	3					1.5427E2	
COD	3						2.4137E2
Sig.		.992	1.000	1.000	1.000	1.000	1.000

H8

Duncan

Parameter	N	1	2	3	4	5	6
FC	3	.0000					
BOD	3		1.0000				
DO	3		1.2667				
TC	3			6.2333			
pH	3				8.0567		
TSS	3					73.3000	
COD	3						3.4137E2
Sig.		1.000	.381	1.000	1.000	1.000	1.000

H9

Duncan

Parameter	N				
		1	2	3	4
FC	3	.0033			
BOD	3	.5000			
TC	3	3.2000	3.2000		
DO	3	3.5667	3.5667		
pH	3		9.1500		
TSS	3			62.6667	
COD	3				2.9700E2
Sig.		.346	.115	1.000	1.000

H10

Duncan

Parameter	N						
		1	2	3	4	5	6
BOD	3	.3000					
DO	3	1.5000					
pH	3		7.4733				
TSS	3			2.5850E2			
COD	3				3.7307E2		
FC	3					4.0043E2	
TC	3						5.1440E2
Sig.		.284	1.000	1.000	1.000	1.000	1.000