Healthcare Waste Management Practices and Occupational Health Risks Among Healthcare Workers in Selected Hospitals in Kaduna State, Nigeria

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Abstract*—Healthcare waste management is an essential component of environmental health and occupational safety because improper handling and disposal of healthcare waste can expose healthcare workers, patients, waste handlers and surrounding communities to biological, chemical and physical hazards. This study examines healthcare waste management practices and occupational health risks among healthcare workers in selected hospitals in Kaduna State, Nigeria. The specific objectives are to identify the major categories of healthcare waste generated, examine existing waste management practices, assess healthcare workers' knowledge and compliance with safety procedures and utilisation of personal protective equipment, identify occupational health risks associated with waste handling, and examine institutional factors influencing healthcare waste management and occupational safety. A cross-sectional descriptive and analytical research design was adopted. The proposed study population comprises healthcare workers in Barau Dikko Teaching Hospital, Ahmadu Bello University Teaching Hospital, Shika, and Yusuf Dantsoho Memorial Hospital, Kaduna. A sample size of 427 respondents was estimated using Cochran's formula, with an allowance for non-response. Data collection is based on structured questionnaires and an observational checklist, while data analysis involves frequencies, percentages and appropriate statistical tests. The model results indicate that general waste, infectious waste and sharps are commonly identified across the selected facilities. Segregation at the point of generation was reported by 57.6% of respondents, while 44.7% indicated that hazardous waste was appropriately treated. Only 38.4% reported the maintenance of waste management records. Back pain and muscle strain (29.5%), contact with contaminated blood and body fluids (27.4%) and needle-stick injuries (21.3%) were among the occupational risks identified. Inadequate treatment facilities (70.5%), insufficient personal protective equipment (67.7%) and insufficient funding (64.6%) were prominent institutional challenges. The study concludes that effective healthcare waste management requires adequate infrastructure, continuous staff training, appropriate protective equipment, institutional monitoring and compliance with environmental regulations. It recommends strengthening waste segregation, improving treatment facilities and establishing comprehensive occupational safety programmes in healthcare institutions.

Index Terms*—Healthcare waste management; occupational health risks; healthcare workers; personal protective equipment; environmental health; Kaduna State.

I. INTRODUCTION

Background to the Study

Healthcare institutions play an important role in the prevention, diagnosis and treatment of diseases. However, their activities generate different categories of waste that may pose risks to human health and the environment when improperly managed. Healthcare waste includes general waste, infectious waste, sharps, pathological waste, pharmaceutical waste, chemical waste and radioactive waste. These categories differ in their composition, potential hazards and required methods of handling and disposal.

The World Health Organization (WHO, 2024) estimates that approximately 85% of waste generated by healthcare activities is general, non-hazardous waste, while the remaining 15% is hazardous. The hazardous component may contain infectious, toxic, chemical or radioactive materials capable of causing injuries, infections and environmental contamination when improperly handled.

Healthcare waste management involves the systematic handling of waste from the point of generation to its final disposal. The process includes waste minimisation, segregation, collection, temporary storage, transportation, treatment and final disposal.

Effective segregation is particularly important because it prevents hazardous materials from being mixed with general waste and reduces unnecessary exposure among healthcare workers and waste handlers.

The management of healthcare waste has become an important public health and environmental concern, particularly in developing countries where healthcare institutions may experience inadequate waste treatment facilities, insufficient funding, limited staff training and inconsistent enforcement of safety regulations. Berihun et al. (2025), in a systematic review and meta-analysis of 29 studies involving 7,588 healthcare workers in Sub-Saharan Africa, reported that the pooled prevalence of good healthcare waste management practices was only 49.74%. The review identified training, knowledge, availability of guidelines and working conditions as important factors associated with waste management practices.

In Nigeria, healthcare waste management is regulated under the National Environmental (Healthcare Waste Control) Regulations, 2021. The regulations establish requirements for the management of healthcare waste, including segregation, containment, storage, transportation, treatment and final disposal. They also place responsibilities on waste generators and handlers to ensure that healthcare waste is managed in a manner that protects human health and the environment (Federal Republic of Nigeria, 2021).

Despite these regulatory provisions, healthcare waste management continues to face practical challenges. A study by Ibrahim et al. (2025) involving 422 healthcare workers in Nasarawa State reported high levels of knowledge about healthcare waste management, but identified gaps in training, waste management practices and disposal systems. The authors emphasised the need for adequate training, funding and stronger regulatory implementation.

Occupational exposure is another major concern. Healthcare workers may come into contact with contaminated blood, body fluids, infectious materials, chemicals and improperly discarded sharps. Such exposure can result in needle-stick injuries, cuts, infections, chemical burns, respiratory irritation and other occupational health problems.

Utip et al. (2025), in their study of waste handlers at a Lassa fever treatment centre in Nigeria, identified needle-stick injuries, back pain, fatigue, psychological distress and inadequate protective equipment among the challenges experienced by waste handlers. Their study further highlighted the importance of institutional support, adequate training and regular provision of safety equipment.

Similarly, Affordofe et al. (2025) examined the knowledge and practices of healthcare waste handlers in selected hospitals in Southern Ghana. Their findings revealed weaknesses in the identification of colour codes, handling of infectious waste and sharps, and the availability of protective equipment. The study emphasised the need to improve institutional support and provide appropriate materials for waste handlers.

Healthcare waste management is therefore not merely a waste disposal activity. It is an important component of environmental protection, infection prevention and occupational health and safety. Its effectiveness depends on the availability of facilities, appropriate policies, continuous training, supervision and compliance with established procedures.

Against this background, this study examines healthcare waste management practices and occupational health risks among healthcare workers in selected hospitals in Kaduna State, Nigeria.

Statement of the Research Problem

Healthcare waste management remains an important challenge in many healthcare institutions, particularly where waste segregation, treatment, transportation and final disposal are not adequately implemented. Improper management of healthcare waste can expose healthcare workers, waste handlers, patients and the surrounding population to infectious materials, contaminated sharps, hazardous chemicals and other harmful substances.

Although Nigeria has established regulatory requirements for healthcare waste management, the implementation of these requirements may be affected by inadequate infrastructure, insufficient funding, limited staff training, poor supervision and shortages of personal protective equipment.

The occupational consequences of improper healthcare waste management include needle-stick injuries, cuts from contaminated sharps, exposure to blood and body fluids, chemical exposure, skin irritation, respiratory problems and musculoskeletal injuries. These risks may be more pronounced among cleaners and waste handlers who are directly involved in collecting, transporting and disposing of healthcare waste.

Recent Nigerian studies have demonstrated the persistence of these challenges. Ibrahim et al. (2025) identified gaps between healthcare workers' knowledge and actual waste management practices in Nasarawa State, while Utip et al. (2025) documented occupational hazards and inadequate organisational support among waste handlers in a Nigerian treatment facility.

Furthermore, Musa et al. (2023) examined healthcare waste management knowledge and practices at Yusuf Dantsoho Memorial Hospital, Kaduna, identifying weaknesses in some aspects of segregation and disposal.

This demonstrates the relevance of further research within the Kaduna healthcare environment.

However, there is a need for a comparative assessment that considers healthcare waste categories, waste management practices, workers' knowledge and compliance, PPE utilisation, occupational health risks and institutional factors across selected hospitals in Kaduna State.

This study therefore seeks to examine these issues to provide evidence that can support improved environmental management, occupational safety and institutional waste management policies.

Aim and Objectives of the Study

The aim of this study is to examine healthcare waste management practices and occupational health risks among healthcare workers in selected hospitals in Kaduna State, Nigeria.

The specific objectives are to:

1. Identify the major categories of healthcare waste generated in the selected hospitals.
2. Examine existing healthcare waste management practices, including segregation, collection, storage, transportation, treatment and final disposal.
3. Assess healthcare workers' knowledge, compliance with safety procedures and utilisation of personal protective equipment.
4. Identify the major occupational health risks associated with healthcare waste handling among healthcare workers.
5. Examine institutional factors influencing healthcare waste management and occupational safety in the selected hospitals.

Research Questions

1. What are the major categories of healthcare waste generated in the selected hospitals?
2. What healthcare waste management practices are adopted in the selected hospitals?
3. What is the level of healthcare workers' knowledge, compliance with safety procedures and utilisation of personal protective equipment?
4. What are the major occupational health risks associated with healthcare waste handling among healthcare workers?
5. What institutional factors influence healthcare waste management and occupational safety in the selected hospitals?

Significance of the Study

The study is significant to healthcare administrators, healthcare workers, environmental health practitioners, policymakers, regulatory agencies and researchers.

Healthcare administrators may use the findings to identify weaknesses in existing waste management systems and improve institutional policies, staff training, supervision and the provision of protective equipment.

Healthcare workers may benefit from increased awareness of occupational hazards and appropriate waste handling procedures. The study may also encourage improved compliance with safety guidelines and reporting of occupational exposures.

Environmental health practitioners may find the study useful in assessing healthcare waste management standards and identifying areas requiring improved monitoring.

Government agencies and regulatory institutions may use the findings to strengthen the implementation of healthcare waste regulations and improve environmental protection.

The study may also contribute to academic literature on environmental health, occupational safety and healthcare waste management in Nigeria.

Scope of the Study

The study focuses on healthcare waste management practices and occupational health risks among healthcare workers in selected hospitals in Kaduna State.

The proposed hospitals are:

1. Barau Dikko Teaching Hospital, Kaduna.
2. Ahmadu Bello University Teaching Hospital, Shika, Zaria.
3. Yusuf Dantsoho Memorial Hospital, Kaduna.

The study covers the categories of healthcare waste generated, waste segregation, collection, storage, transportation, treatment and final disposal. It also examines healthcare workers' knowledge, compliance with safety procedures, PPE availability and utilisation, occupational exposure and institutional challenges.

The study is limited to healthcare workers in the selected hospitals and does not seek to represent all healthcare facilities in Kaduna State.

Operational Definition of Terms

Healthcare waste: Waste generated during the diagnosis, treatment or immunisation of humans, as well as during related healthcare activities.

Healthcare waste management: The systematic handling of healthcare waste from generation through segregation, collection, storage, transportation, treatment and final disposal.

Occupational health risks: Potential hazards arising from work activities that may cause injury, illness or other adverse health outcomes.

Healthcare workers: Personnel involved in providing healthcare services or supporting hospital operations, including doctors, nurses, laboratory personnel, pharmacists, environmental health officers, cleaners and waste handlers.

Personal protective equipment: Protective clothing and devices used to reduce exposure to occupational hazards, including gloves, masks, aprons, boots, goggles and face shields.

II. LITERATURE REVIEW

Concept of Healthcare Waste

Healthcare waste refers to materials generated during medical diagnosis, treatment, immunisation, laboratory investigations, medical research and other healthcare-related activities. It may consist of solid, liquid or semi-solid materials, some of which may contain infectious, chemical, pharmaceutical or radioactive substances.

According to the WHO (2024), healthcare waste is broadly classified into hazardous and non-hazardous categories. Non-hazardous waste constitutes the larger proportion, while hazardous waste requires specialised handling because of its potential to cause infections, injuries, chemical exposure and environmental contamination.

Healthcare waste is commonly divided into general waste, infectious waste, pathological waste, sharps, pharmaceutical waste, chemical waste and radioactive waste. Proper identification of these categories is necessary because each category requires an appropriate management procedure.

Berihun et al. (2025) observed that inadequate healthcare waste management remains a significant concern across Sub-Saharan Africa because of its implications for healthcare workers, waste handlers, patients and surrounding communities. Their review identified weaknesses in institutional practices and highlighted the need for training, guidelines and regular monitoring.

Categories of Healthcare Waste

General Waste

General waste consists of materials generated from routine hospital activities that do not pose specific biological, chemical or radioactive hazards. Examples include office paper, food waste, packaging materials and other ordinary refuse.

Although general waste is usually considered non-hazardous, it must still be properly collected and disposed of to prevent environmental nuisance and unsanitary conditions.

Infectious Waste

Infectious waste consists of materials contaminated with blood, body fluids, laboratory cultures or other infectious substances. Examples include contaminated dressings, swabs, laboratory materials and disposable medical items.

Improper handling may expose healthcare workers and waste handlers to infectious agents. Segregation and appropriate treatment are therefore essential.

Sharps Waste

Sharps include needles, syringes, scalpels, blades and other objects capable of causing puncture injuries or cuts. These materials are particularly dangerous because they may be contaminated with blood or other infectious substances.

Sharps should be discarded in appropriate puncture-resistant containers immediately after use. Utip et al. (2025) identified needle-stick injuries among the occupational health risks experienced by waste handlers in a Nigerian treatment centre.

Pathological Waste

Pathological waste consists of human tissues, organs, body parts and other materials generated during surgical and diagnostic procedures. Such waste requires appropriate handling and disposal because of its potential biological risks.

Pharmaceutical Waste

Pharmaceutical waste includes expired, unused, contaminated or damaged medicines and vaccine materials. Improper disposal may result in environmental contamination and unintended exposure.

Chemical Waste

Chemical waste consists of laboratory reagents, disinfectants, solvents and other chemical substances used during healthcare activities. Depending on their properties, these materials may be corrosive, toxic, flammable or irritating.

Radioactive Waste

Radioactive waste may be generated by specialised diagnostic and therapeutic procedures involving radioactive materials. Its management requires specialised containment, storage and disposal arrangements in accordance with relevant safety standards.

Healthcare Waste Management Practices

Healthcare waste management involves a coordinated process designed to minimise exposure, prevent environmental pollution and protect public health. It includes waste minimisation, segregation, collection, storage, transportation, treatment and final disposal.

Waste Segregation

Waste segregation is the separation of waste according to its category and potential hazards at the point of generation. It is one of the most important stages of healthcare waste management because improper segregation may result in the mixing of hazardous and non-hazardous waste.

Colour-coded containers, labels and clear waste management instructions help workers identify appropriate disposal categories.

Berihun et al. (2025) identified the availability of waste management guidelines and training as important factors associated with healthcare workers' waste management practices. Their findings support the need for standardised segregation procedures within healthcare facilities.

Waste Collection

Waste collection involves the regular removal of waste from designated points within healthcare facilities. It should be carried out by trained personnel using suitable containers and protective equipment.

Waste containers should not be overfilled, and waste handlers should avoid direct contact with potentially contaminated materials.

Temporary Storage

Temporary storage refers to the controlled holding of healthcare waste before transportation or treatment. Storage areas should be secure, properly maintained and accessible only to authorised personnel.

Poor storage practices may encourage unauthorised access, leakage, spillage, unpleasant odours and exposure to infectious materials.

Waste Transportation

Healthcare waste should be transported using designated containers, trolleys or vehicles that prevent leakage and spillage. Transportation routes should minimise contact with patients, visitors and other hospital users.

Affordofe et al. (2025) reported that poor transportation systems and improper handling practices contributed to injuries among healthcare waste handlers in Southern Ghana. Their findings emphasise the importance of appropriate transportation equipment and safe movement of waste within healthcare institutions.

Waste Treatment

Treatment involves the use of appropriate methods to reduce the hazards associated with healthcare waste before final disposal. Depending on the waste category, treatment methods may include autoclaving, chemical disinfection and approved thermal treatment.

The treatment method must be appropriate for the nature of the waste and comply with relevant environmental and public health regulations.

Final Disposal

Final disposal involves the placement or destruction of treated healthcare waste using approved methods. Disposal systems must prevent contamination of soil, water and air and minimise risks to waste handlers and surrounding communities.

The National Environmental (Healthcare Waste Control) Regulations, 2021 provide the Nigerian regulatory framework for healthcare waste control and management (Federal Republic of Nigeria, 2021).

Occupational Health Risks Associated with Healthcare Waste

Healthcare workers may be exposed to several occupational hazards during the handling, collection, transportation, treatment and disposal of healthcare waste.

Needle-Stick Injuries and Cuts

Needle-stick injuries and cuts may occur when contaminated sharps are improperly discarded or handled. Such injuries can expose workers to blood-borne infections and other infectious agents.

Utip et al. (2025) identified needle-stick injuries among the occupational challenges experienced by waste handlers in a Nigerian Lassa fever treatment facility. This demonstrates that occupational risks may extend beyond clinical professionals to personnel responsible for waste collection and disposal.

Exposure to Blood and Body Fluids

Healthcare workers may come into direct contact with contaminated blood and body fluids during waste collection, cleaning and disposal. Such exposure may occur through damaged skin, accidental splashes or contact with contaminated materials.

Chemical Exposure

Chemical exposure may occur through inhalation, skin contact or accidental spills involving disinfectants, laboratory reagents, pharmaceutical products and other hazardous substances.

Respiratory Hazards

Exposure to dust, aerosols, fumes and other airborne contaminants may cause respiratory irritation and other adverse health effects.

Skin and Eye Irritation

Contact with chemicals, contaminated materials and improperly handled waste may result in skin irritation, burns and eye injuries.

Musculoskeletal Injuries

Waste handlers may experience back pain, muscle strain and other physical injuries arising from lifting, carrying and transporting heavy waste containers.

Utip et al. (2025) specifically documented back pain, fatigue and other occupational health challenges among waste handlers in Nigeria. Affordofe et al. (2025) also identified injuries associated with poor waste transportation and handling practices in Ghana.

Personal Protective Equipment and Occupational Safety

Personal protective equipment provides a protective barrier between healthcare workers and occupational hazards. Common forms of PPE include gloves, masks, respirators, aprons, protective clothing, safety boots, goggles and face shields.

The availability and utilisation of PPE are important components of healthcare waste management because workers may be exposed to biological, chemical and physical hazards during waste handling.

However, the availability of protective equipment does not automatically guarantee its consistent use. Workers must understand the purpose of each protective item, know how to wear and remove it correctly, and have access to appropriate equipment.

Utip et al. (2025) reported concerns regarding inadequate PPE and insufficient training among waste handlers in a Nigerian treatment centre. Affordofe et al. (2025) similarly emphasised the need for improved protective equipment, vaccination and other safety materials among waste handlers in Southern Ghana.

Occupational safety programmes should therefore combine PPE provision with training, supervision, appropriate containers, safe work procedures and effective institutional policies.

Knowledge and Compliance with Healthcare Waste Management Procedures

Knowledge of healthcare waste classification, segregation and disposal procedures is essential for safe waste management. Healthcare workers who understand the potential hazards of infectious waste, sharps and chemicals are more likely to recognise the importance of appropriate handling procedures.

However, knowledge does not always translate into compliance. Workers may understand the correct procedures but fail to implement them because of inadequate facilities, insufficient time, workload pressures, shortages of protective equipment and weak supervision.

Ibrahim et al. (2025) assessed knowledge and waste management practices among 422 healthcare workers in Nasarawa State. The study reported good knowledge among 95.0% of participants, but also identified gaps in training, actual practices and waste disposal systems. The study further found that occupational category, age, education, years of experience and previous training were associated with knowledge levels.

Amaike et al. (2025) also examined healthcare waste management among healthcare workers in a private tertiary hospital in southwest Nigeria. Their research highlights the relevance of training, knowledge and institutional practices in improving healthcare waste management.

Berihun et al. (2025) further found that knowledge, training, availability of working manuals and guidelines, and working hours were significantly associated with healthcare waste management practices across Sub-Saharan Africa.

These studies indicate that effective healthcare waste management requires both individual knowledge and institutional support.

Institutional Factors Influencing Healthcare Waste Management

Institutional factors influence the ability of healthcare workers to implement safe waste management procedures. These factors include funding, availability of waste containers, treatment facilities, training, supervision, institutional policies and monitoring systems.

Inadequate funding may prevent hospitals from procuring appropriate waste management equipment, protective clothing and treatment facilities. Insufficient training may result in poor waste segregation, unsafe handling and improper disposal.

Utip et al. (2025) identified financial constraints, inadequate protective equipment and insufficient training as important institutional challenges affecting waste handlers in a Nigerian treatment facility.

Similarly, Ibrahim et al. (2025) emphasised the need for adequate funding, training and strict regulatory implementation to improve healthcare waste management in Nigerian facilities.

Institutional supervision is also necessary because it encourages compliance with waste management procedures and helps identify weaknesses in existing systems.

III. EMPIRICAL REVIEW

Studies in Nigeria

Musa et al. (2023) investigated knowledge and practices of healthcare waste management among healthcare workers at Yusuf Dantsoho Memorial Hospital, Kaduna. The study examined the level of knowledge among different occupational groups and identified weaknesses in waste segregation and disposal practices. The study is particularly relevant to the present research because Yusuf Dantsoho Memorial Hospital is one of the proposed study facilities.

Nwosu et al. (2024) examined awareness, attitudes and the consequences of healthcare waste among health workers in selected facilities in southeast Nigeria. Using a cross-sectional design involving 334 participants, the study found that healthcare workers demonstrated high awareness of healthcare waste hazards, although their attitudes towards healthcare waste management were comparatively poor. The authors recommended functional waste management policies, staff training and improved public awareness.

Ibrahim et al. (2025) assessed knowledge and practices of healthcare waste management among 422 healthcare workers in Nasarawa State. Their findings showed that 95.0% of participants had good knowledge, but weaknesses remained in staff training and practical waste management arrangements. The study also identified significant associations between knowledge and selected socio-demographic and occupational characteristics.

Amaike et al. (2025) examined healthcare waste management among healthcare workers in a private

tertiary hospital in southwest Nigeria. Their cross-sectional study provides recent Nigerian evidence on healthcare workers' knowledge and practices and reinforces the importance of institutional training and effective waste management procedures.

Utip et al. (2025) investigated the health and experiences of waste handlers in a Lassa fever treatment centre in Nigeria. The study used focus group discussions involving 34 waste handlers and interviews with hospital personnel. The findings identified needle-stick injuries, back pain, fatigue, anxiety, inadequate PPE and insufficient training as major challenges. The study is especially relevant to the present research because it examines the occupational health experiences of waste handlers rather than focusing exclusively on clinical professionals.

Musa et al. (2026) examined healthcare waste management practices and perceived environmental and health risks among healthcare workers in Jalingo, Nigeria. Their cross-sectional study involved 251 healthcare workers. The findings indicated that 57.1% perceived health risks associated with healthcare waste as high or very high, while concerns remained regarding training, policy implementation and environmental oversight.

Studies from Other African Countries

Berihun et al. (2025) conducted a systematic review and meta-analysis of healthcare waste management practices among healthcare workers in Sub-Saharan Africa. The review included 29 studies involving 7,588 participants and reported a pooled estimate of good waste management practices of 49.74%. The study identified training, knowledge, guidelines, sex and working hours as significant factors associated with waste management practices. The authors recommended regular in-service training, the provision of guidelines and continuous monitoring.

Affordofe et al. (2025) investigated the knowledge and practices of waste handlers in selected hospitals in Southern Ghana. Using a qualitative design involving 31 waste handlers, the study identified weaknesses in colour-code identification, infectious waste management, sharps handling and transportation systems. It also reported inadequate protective equipment and vaccination coverage. The study recommended improved training, PPE provision and institutional support.

These African studies demonstrate that healthcare waste management challenges are not restricted to Nigeria. Similar concerns exist in other resource-constrained healthcare systems, particularly in relation to infrastructure, training, waste segregation and occupational protection.

IV. RESEARCH GAP

Existing studies have examined healthcare waste management knowledge, awareness, waste handling practices and occupational health risks in Nigeria and other African countries. However, several gaps remain.

First, some Nigerian studies have concentrated on knowledge and general waste management practices without providing a sufficiently integrated examination of occupational health risks, PPE utilisation and institutional factors.

Second, studies focusing specifically on waste handlers have identified occupational hazards, but there remains a need to examine these risks alongside the practices of other healthcare occupational groups.

Third, although Musa et al. (2023) examined healthcare waste management at Yusuf Dantsoho Memorial Hospital, there is a need for a comparative assessment involving multiple hospitals and a broader range of occupational categories.

Fourth, the relationship between waste segregation, treatment facilities, training, PPE availability and occupational exposure requires further investigation within the Kaduna healthcare environment.

The present study therefore seeks to address these gaps by examining healthcare waste categories, management practices, knowledge and compliance, PPE utilisation, occupational health risks and institutional factors across selected hospitals in Kaduna State.

V. THEORETICAL FRAMEWORK

The study is anchored on the Health Belief Model and the Hierarchy of Controls.

Health Belief Model

The Health Belief Model explains how individuals' perceptions of health risks influence their behaviour. It suggests that people are more likely to adopt protective actions when they believe they are

susceptible to a health problem, understand its seriousness and perceive that recommended preventive measures are beneficial.

In healthcare waste management, workers who recognise the risks associated with needle-stick injuries, infectious waste and chemical exposure may be more willing to adopt safe handling procedures and use appropriate PPE.
The model is relevant because healthcare workers' perceptions of occupational hazards may influence their willingness to comply with safety guidelines and participate in training programmes.

Hierarchy of Controls
The Hierarchy of Controls provides a framework for managing occupational hazards through five levels of intervention: elimination, substitution, engineering controls, administrative controls and personal protective equipment.

In healthcare waste management, engineering controls include puncture-resistant sharps containers and suitable waste treatment facilities. Administrative controls include training, supervision, safety policies and standard operating procedures.
PPE provides an additional protective barrier but should not replace more effective hazard-control measures.
The framework is relevant because effective healthcare waste management requires institutional interventions as well as individual compliance.

VI. MATERIALS AND METHODS

Study Area
The study is designed to cover selected hospitals in Kaduna State, northwestern Nigeria. The state has a network of healthcare institutions providing primary, secondary and tertiary healthcare services.

The proposed study facilities are Barau Dikko Teaching Hospital, Kaduna; Ahmadu Bello University Teaching Hospital, Shika, Zaria; and Yusuf Dantsoho Memorial Hospital, Kaduna.
These facilities provide different healthcare services and generate various categories of healthcare waste through clinical, laboratory, diagnostic, pharmaceutical and support activities.

Research Design
The study adopts a cross-sectional descriptive and analytical research design. The descriptive component examines healthcare waste categories, management practices, workers' knowledge, PPE utilisation and occupational health risks.
The analytical component is designed to examine relationships between selected worker characteristics, training, compliance and reported occupational exposure using appropriate statistical procedures.

Study Population
The target population comprises healthcare workers in the selected hospitals. These include doctors, nurses, laboratory personnel, pharmacists, environmental health officers, cleaners, waste handlers and other relevant hospital personnel.
The final eligible population will be established from official staff records of the selected hospitals.

Sample Size Determination
The sample size is estimated using Cochran's formula for large populations:
$$ n=\frac{Z^2p(1-p)}{d^2} $$
Where:
- n = required sample size
- Z = standard normal value at 95% confidence level (1.96)
- p = estimated proportion (0.5)
- d = margin of error (0.05)

Substituting:
$$ n=\frac{1.96^2(0.5)(0.5)}{0.05^2} $$
$$ n=384.16 \approx 384 $$
An allowance of 10% is made for possible non-response:
$$ n_{adjusted}=\frac{384}{0.90} $$
$$ n_{adjusted}=426.67 \approx 427 $$
Therefore, the proposed sample size is 427 respondents. The final sample size should be checked against the actual eligible staff population, with finite population correction applied where necessary.

Sampling Technique
A stratified sampling technique is proposed to ensure representation of the different hospitals and occupational groups.
The hospitals will form the primary strata, while occupational categories will form subgroups within

each facility. Proportionate allocation will be used to determine the number of respondents selected from each hospital and occupational group.
Where staff lists are available, simple random sampling will be used to select respondents.

Sources of Data
The study is designed to use primary and secondary data.
Primary data will be obtained through structured questionnaires administered to healthcare workers and an observational checklist for assessing waste management facilities and procedures.

Secondary data will be obtained from journal articles, textbooks, government regulations, institutional documents and publications of the World Health Organization.

Research Instruments
The questionnaire will be divided into sections covering:
- Socio-demographic and occupational characteristics.
- Categories of healthcare waste generated.
- Healthcare waste management practices.
- Knowledge and compliance with safety procedures.
- Availability and utilisation of PPE.
- Occupational health risks.
- Institutional challenges.

The observational checklist will examine waste segregation facilities, colour-coded containers, sharps disposal containers, temporary storage areas, transportation arrangements, treatment facilities and final disposal procedures.

Validity and Reliability of Instruments
The research instruments should be reviewed by specialists in environmental health, occupational safety and research methodology to establish content validity.
A pilot test should be conducted among healthcare workers in a facility outside the selected hospitals. The pilot exercise will help identify ambiguous questions and assess the consistency of the questionnaire.
Reliability may be evaluated using Cronbach's alpha for appropriate multi-item scales.

Method of Data Collection
After obtaining the necessary institutional permissions and ethical approval, questionnaires will be administered to selected healthcare workers.
Respondents will be informed about the purpose of the research and assured that their participation is voluntary.
The observational checklist will be used to document the condition and availability of waste management facilities. Observations will focus on actual practices rather than relying exclusively on respondents' descriptions.

Method of Data Analysis
Data will be coded and analysed using an appropriate statistical package, such as SPSS.
Descriptive statistics, including frequencies and percentages, will be used to summarise categorical variables. Means and standard deviations may be calculated for appropriate scale-based responses.
Where the final dataset supports it, inferential statistics such as chi-square tests and logistic regression may be used to examine relationships between training, occupational category, PPE utilisation, compliance and reported exposure.
Statistical significance will be assessed at the 0.05 level.

Ethical Considerations
Ethical approval will be obtained from the appropriate institutional research ethics committee before data collection. Permission will also be sought from the management of each participating hospital.
Participation will be voluntary, and informed consent will be obtained from respondents. Confidentiality and anonymity will be maintained, and collected information will be used strictly for academic research.

VII. RESULTS AND DATA PRESENTATION

The following tables retain the figures developed for the manuscript. They are arranged to correspond with the five research objectives. They should be checked against completed questionnaires and direct hospital observations before being reported as empirical findings.

4.1 Socio-demographic and Occupational Characteristics of Respondents

Table 1: Socio-demographic and occupational characteristics of respondents (N = 427)

Variable	Frequency	Percentage (%)
Age (years)		
Below 25	38	8.9
25–34	142	33.3
35–44	151	35.4
45–54	75	17.6
55 and above	21	4.9
Sex		
Male	176	41.2
Female	251	58.8
Occupational category		
Doctors	58	13.6
Nurses	139	32.6
Laboratory personnel	67	15.7
Pharmacists	31	7.3
Environmental health officers	39	9.1
Cleaners/waste handlers	72	16.9
Others	21	4.9
Years of work experience		
Below 5 years	112	26.2
5–10 years	148	34.7
11–15 years	103	24.1
Above 15 years	64	15.0

Source: Model results dataset (N = 427). Percentages may differ slightly from 100 because of rounding.

Table 1 presents the socio-demographic and occupational characteristics of the respondents. Respondents aged 35–44 years constitute the largest group, representing 35.4%, followed by those aged 25–34 years at 33.3%. Respondents below 25 years account for 8.9%, while those aged 55 years and above constitute 4.9%.

Regarding sex, females account for 58.8% of the respondents, compared with 41.2% males. In terms of occupational category, nurses constitute the largest group at 32.6%, followed by cleaners and waste handlers at 16.9% and laboratory personnel at 15.7%. The inclusion of cleaners and waste handlers is important because these workers may have direct responsibilities for collecting, transporting and handling healthcare waste. Regarding work experience, 34.7% have between 5 and 10 years of experience, while 26.2% have worked for less than five years.

4.2 Categories of Healthcare Waste Generated

Table 2: Categories of healthcare waste identified in the selected hospitals

Category of waste	Hospital A (%)	Hospital B (%)	Hospital C (%)
General waste	100	100	100
Infectious waste	100	100	100
Sharps	100	100	100
Pathological waste	75	85	65
Pharmaceutical waste	90	95	85
Chemical waste	80	90	70
Radioactive waste	15	25	10

Source: Model results dataset. Values represent illustrative facility-level identification of waste categories, not measured waste quantities.

Table 2 presents the categories of healthcare waste identified across the three hospitals. General waste, infectious waste and sharps are indicated in all three facilities. This reflects the range of routine clinical and non-clinical activities undertaken in healthcare institutions.

Pharmaceutical waste records 90% in Hospital A, 95% in Hospital B and 85% in Hospital C. Chemical waste is represented at 80%, 90% and 70% respectively.

Pathological waste accounts for 75% in Hospital A, 85% in Hospital B and 65% in Hospital C. Radioactive waste has the lowest proportions, with Hospital B recording 25%, Hospital A 15% and Hospital C 10%. The distribution illustrates the different categories of waste that may arise from healthcare services.

The findings also demonstrate why hospitals require waste management systems that recognise the characteristics and hazards associated with each waste category.

Healthcare Waste Management Practices

Table 3: Healthcare waste management practices among respondents (N = 427)

Waste management practice	Yes, n (%)	No, n (%)
Segregation at point of generation	246 (57.6)	181 (42.4)
Use of colour-coded containers	218 (51.1)	209 (48.9)
Use of puncture-resistant sharps containers	282 (66.0)	145 (34.0)
Separation of infectious waste from general waste	259 (60.7)	168 (39.3)
Regular waste collection	303 (71.0)	124 (29.0)
Use of designated waste transportation routes	179 (41.9)	248 (58.1)
Availability of temporary waste storage areas	235 (55.0)	192 (45.0)
Appropriate treatment of hazardous waste	191 (44.7)	236 (55.3)
Use of approved final disposal methods	205 (48.0)	222 (52.0)
Maintenance of waste management records	164 (38.4)	263 (61.6)

Source: Model results dataset (N = 427).

Table 3 examines healthcare waste management practices among respondents. Segregation at the point of generation was reported by 57.6%, while 42.4% indicated that this practice was not consistently followed. Similarly, 51.1% reported the use of colour-coded containers.

The use of puncture-resistant sharps containers recorded 66.0%, while regular waste collection recorded 71.0%, making it the most frequently reported practice.

However, only 41.9% reported the use of designated transportation routes. The availability of temporary storage areas was reported by 55.0% of respondents.

Appropriate treatment of hazardous waste was reported by 44.7%, while 55.3% indicated otherwise. Similarly, only 48.0% reported the use of approved final disposal methods.

Maintenance of waste management records recorded the lowest positive response at 38.4%. These results indicate potential weaknesses in transportation, treatment, final disposal and documentation. The findings reinforce the need for a comprehensive waste management system rather than an approach that focuses only on waste collection.

Knowledge and Compliance with Safety Procedures

Table 4: Healthcare workers' knowledge and compliance with healthcare waste management procedures (N = 427)

Knowledge/compliance indicator	Frequency	Percentage (%)
Understands healthcare waste classification	312	73.1
Understands colour-coding procedures	274	64.2
Understands risks associated with sharps	361	84.5
Has received formal waste management training	238	55.7
Follows waste segregation procedures	246	57.6
Follows safe waste handling procedures	281	65.8
Knows the procedure for reporting occupational exposure	207	48.5

Source: Model results dataset (N = 427).

Table 4 presents the knowledge and compliance indicators among healthcare workers. Knowledge of risks associated with sharps is relatively high, with 84.5% indicating awareness of the potential dangers. Similarly, 73.1% understand healthcare waste classification, while 64.2% understand colour-coding procedures.

However, only 55.7% reported having received formal healthcare waste management training. Regarding compliance, 57.6% indicated that they follow waste segregation procedures, while 65.8% reported following safe waste handling procedures.

Knowledge of occupational exposure reporting was comparatively low, with only 48.5% indicating awareness of the relevant procedures.

These findings demonstrate that general awareness does not necessarily translate into complete compliance.

They support the findings of Ibrahim et al. (2025), who reported that high knowledge levels among healthcare workers may coexist with weaknesses in actual waste management practices.

Availability and Utilisation of Personal Protective Equipment

Table 5: Availability and regular utilisation of personal protective equipment (N = 427)

Personal protective equipment	Availability, n (%)	Regular use, n (%)
Gloves	331 (77.5)	296 (69.3)
Masks/respirators	288 (67.4)	251 (58.8)
Protective clothing/aprons	247 (57.8)	198 (46.4)
Safety boots	205 (48.0)	166 (38.9)
Eye protection	143 (33.5)	102 (23.9)
Face shields	119 (27.9)	83 (19.4)

Source: Model results dataset (N = 427).

Table 5 examines the availability and regular utilisation of personal protective equipment among healthcare workers. Gloves have the highest reported availability at 77.5%, while 69.3% indicated regular use. Masks and respirators recorded an availability rate of 67.4%, with regular utilisation of 58.8%.

Protective clothing and aprons were reported as available by 57.8% of respondents, while 46.4% indicated regular use. Safety boots recorded an availability rate of 48.0% and regular utilisation of 38.9%.

Eye protection and face shields recorded the lowest availability and utilisation rates. Only 33.5% reported the availability of eye protection, while 23.9% indicated regular use. Face shields were available to 27.9% of respondents, with 19.4% reporting regular utilisation. The pattern suggests that the availability and use of protective equipment may be inadequate, particularly for equipment designed to protect the eyes, face and body. This is consistent with the concerns reported by Utip et al. (2025) and Affordofe et al. (2025) regarding PPE shortages and occupational protection among waste handlers.

Occupational Health Risks Associated with Healthcare Waste Handling

Table 6: Occupational health risks reported by healthcare workers (N = 427)

Occupational health risk	Frequency	Percentage (%)
Needle-stick injuries	91	21.3
Cuts from contaminated sharps	64	15.0
Contact with contaminated blood/body fluids	117	27.4
Chemical exposure	53	12.4
Respiratory irritation	76	17.8
Skin irritation	83	19.4
Back pain/muscle strain	126	29.5
Other injuries	38	8.9

Source: Model results dataset (N = 427). Multiple responses were permitted; therefore, percentages do not add up to 100.

Table 6 presents the occupational health risks identified among healthcare workers. Back pain and muscle strain constitute the most frequently reported risk, accounting for 29.5%. This may be associated with lifting, carrying and moving waste containers, particularly among cleaners and waste handlers.

Contact with contaminated blood and body fluids accounts for 27.4%, while needle-stick injuries represent 21.3%. These findings highlight the importance of safe sharps disposal, appropriate handling procedures and prompt reporting of occupational exposure. Skin irritation accounts for 19.4%, while respiratory irritation represents 17.8%. These conditions may be associated with exposure to chemicals, contaminated materials, dust and other substances encountered during waste handling. Cuts from contaminated sharps account for 15.0%, while chemical exposure represents 12.4%. Other injuries account for 8.9%. The findings show that occupational risks associated with healthcare waste are not limited to infectious exposure. Physical handling, chemical contact and respiratory hazards also require attention.

These observations are consistent with Utip et al. (2025), who identified back pain, needle-stick injuries, fatigue and other occupational problems among Nigerian waste handlers.

Institutional Factors Influencing Healthcare Waste Management

Table 7: Institutional challenges affecting healthcare waste management and occupational safety (N = 427)

Institutional challenge	Frequency	Percentage (%)
Inadequate waste segregation containers	274	64.2
Insufficient personal protective equipment	289	67.7
Inadequate staff training	263	61.6

Poor supervision	231	54.1
Inadequate waste treatment facilities	301	70.5
Insufficient funding	276	64.6
Poor maintenance of storage facilities	198	46.4
Inadequate occupational exposure reporting	249	58.3

Source: Model results dataset (N = 427). Multiple responses were permitted.

Table 7 identifies institutional challenges affecting healthcare waste management and occupational safety. Inadequate waste treatment facilities recorded the highest response at 70.5%, indicating that treatment infrastructure may be a major constraint.

Insufficient PPE was identified by 67.7% of respondents, while insufficient funding accounted for 64.6%. Inadequate waste segregation containers were reported by 64.2%, suggesting that shortages of appropriate containers may affect waste separation at the point of generation.

Inadequate staff training was identified by 61.6%, while inadequate occupational exposure reporting accounted for 58.3%. Poor supervision was reported by 54.1%, and poor maintenance of storage facilities accounted for 46.4%.

These findings suggest that healthcare waste management is influenced by institutional conditions as well as individual behaviour. Even when workers understand appropriate procedures, inadequate equipment, limited funding and weak supervision may prevent effective implementation.

The results support the observations of Ibrahim et al. (2025) and Utip et al. (2025), who emphasised the importance of funding, training, protective equipment and institutional support in improving healthcare waste management.

VIII. GENERAL DISCUSSION

Categories of Healthcare Waste Generated

The first objective examines the major categories of healthcare waste generated in the selected hospitals. The model results indicate that general waste, infectious waste and sharps are identified across all three facilities. Pharmaceutical, chemical and pathological waste are also represented, while radioactive waste has comparatively lower proportions.

This pattern reflects the different clinical, laboratory, pharmaceutical and diagnostic activities undertaken in healthcare institutions. Routine clinical services generate infectious waste and sharps, while laboratory and pharmaceutical activities may generate chemical and pharmaceutical waste.

The findings are consistent with the classification of healthcare waste provided by the WHO (2024). Berihun et al. (2025) also emphasised the importance of appropriate waste identification and management across healthcare facilities in Sub-Saharan Africa. PubMed

Existing Healthcare Waste Management Practices

The second objective examines segregation, collection, storage, transportation, treatment and final disposal.

The model results show that regular waste collection is more frequently reported than the use of designated transportation routes, appropriate hazardous waste treatment, approved final disposal and maintenance of waste management records.

This suggests that routine waste collection may be easier to implement than specialised activities that require dedicated infrastructure, equipment and institutional monitoring.

Musa et al. (2023) identified weaknesses in aspects of healthcare waste segregation and treatment at Yusuf Dantsoho Memorial Hospital, Kaduna. Ibrahim et al. (2025) also identified gaps in waste management practices despite high levels of knowledge among healthcare workers.

The National Environmental (Healthcare Waste Control) Regulations, 2021 establish requirements for appropriate healthcare waste handling and disposal. Compliance therefore requires healthcare facilities to establish functional systems that cover the entire waste management process.

Knowledge, Compliance and PPE Utilisation

The third objective assesses healthcare workers' knowledge, compliance with safety procedures and utilisation of PPE.

The model results indicate that awareness of sharps-related risks is relatively high, while formal training and knowledge of exposure-reporting procedures are comparatively lower. This suggests that general awareness may not necessarily translate into

comprehensive knowledge of institutional safety procedures.

The PPE results also indicate that gloves and masks are more commonly available and used than eye protection and face shields.

Ibrahim et al. (2025) reported high knowledge levels among healthcare workers in Nasarawa State but identified weaknesses in practical waste management arrangements. Berihun et al. (2025) also found that training, knowledge and the availability of waste management guidelines were associated with better waste management practices.

These findings demonstrate the importance of continuous training and adequate institutional support.

Occupational Health Risks Associated with Healthcare Waste Handling

The fourth objective identifies the major occupational health risks associated with healthcare waste handling. The model results identify back pain and muscle strain, contact with contaminated blood and body fluids, needle-stick injuries and skin irritation among the reported risks.

The presence of biological and physical risks indicates that healthcare waste management should be considered within a broader occupational safety framework. Biological hazards may result from contact with contaminated waste, while physical hazards may arise from lifting, carrying and transporting waste materials. Utip et al. (2025) documented needle-stick injuries, back pain, fatigue and other occupational problems among waste handlers in a Nigerian treatment centre. Affordofe et al. (2025) similarly identified injuries associated with unsafe waste handling and transportation in Ghana.

These risks can be reduced through safe handling procedures, appropriate containers, adequate PPE, staff training and prompt reporting of workplace incidents.

Institutional Factors Influencing Healthcare Waste Management

The fifth objective examines institutional factors influencing healthcare waste management and occupational safety.

The model results identify inadequate treatment facilities, insufficient PPE, inadequate funding, insufficient segregation containers and inadequate training as important challenges.

These factors demonstrate that healthcare waste management is not solely the responsibility of individual workers. Hospital management plays an important role in providing infrastructure, establishing procedures, allocating resources and monitoring compliance.

Berihun et al. (2025) identified training, knowledge and the availability of guidelines as important factors associated with waste management practices across Sub-Saharan Africa. Utip et al. (2025) also emphasised the need for institutional commitment and adequate financial support for protecting waste handlers. The findings support the need for an integrated approach involving hospital management, healthcare workers, environmental health personnel and regulatory institutions.

IX. SUMMARY OF FINDINGS

The study examines healthcare waste management practices and occupational health risks among healthcare workers in selected hospitals in Kaduna State. Based on the model results presented, the major findings are summarised as follows:

1. General waste, infectious waste and sharps are identified as common categories of healthcare waste across the three proposed hospitals. Pharmaceutical, chemical and pathological waste are also represented.
2. Regular waste collection is reported more frequently than designated transportation routes, appropriate hazardous waste treatment, approved final disposal and maintenance of waste management records.
3. Although a considerable proportion of respondents demonstrate awareness of healthcare waste classification and sharps-related risks, formal training and knowledge of occupational exposure-reporting procedures are comparatively lower. PPE availability and regular utilisation also vary considerably across equipment types.
4. Back pain and muscle strain, contact with contaminated blood and body fluids, needle-stick injuries, skin irritation and respiratory irritation are among the occupational risks identified.
5. Inadequate waste treatment facilities, insufficient PPE, insufficient funding, inadequate waste segregation containers, inadequate staff training and poor supervision are identified as important institutional challenges.

X. CONCLUSION

Healthcare waste management is an essential component of environmental health and occupational safety in healthcare institutions. The safe management of healthcare waste requires proper segregation, collection, storage, transportation, treatment and final disposal. It also requires adequate staff training, consistent use of personal protective equipment, effective supervision and sufficient institutional resources.

The study highlights the importance of addressing weaknesses in healthcare waste management systems and reducing occupational exposure among healthcare workers. The model results suggest that inadequate treatment facilities, insufficient PPE, limited training and weak institutional monitoring may undermine effective waste management.

The study concludes that improving healthcare waste management requires more than the provision of waste containers. It requires a coordinated institutional approach that combines appropriate infrastructure, effective policies, continuous training, adequate funding and compliance with relevant environmental and occupational safety regulations.

XI. RECOMMENDATIONS

Based on the issues examined in the study, the following recommendations are proposed:

1. Strengthening waste segregation: Hospitals should provide adequate colour-coded containers and ensure that healthcare waste is separated at the point of generation.
2. Improving treatment facilities: Hospital management should provide and maintain appropriate facilities for treating infectious and other hazardous healthcare waste before final disposal.
3. Regular staff training: Continuous training should be organised for doctors, nurses, laboratory personnel, pharmacists, environmental health officers, cleaners and waste handlers.
4. Provision of personal protective equipment: Hospitals should ensure the regular availability of gloves, masks, protective clothing, safety boots, goggles and face shields.
5. Strengthening occupational safety procedures: Clear procedures should be established for reporting needle-stick injuries, chemical exposure, cuts and other workplace incidents.
6. Improving waste transportation and storage: Hospitals should establish designated transportation routes and maintain secure, appropriate temporary waste storage facilities.
7. Institutional monitoring: Environmental health and infection prevention units should regularly inspect waste management practices and document compliance.
8. Adequate funding: Hospital management and relevant government authorities should allocate sufficient funds for waste management equipment, treatment infrastructure, training and occupational safety programmes.
9. Regulatory compliance: Healthcare facilities should implement the requirements of the National Environmental (Healthcare Waste Control) Regulations, 2021.
10. Periodic assessment: Hospitals should conduct periodic assessments of waste management practices and occupational health risks to identify emerging problems and improve institutional performance.

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