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Knowledge and Practice of Healthcare Waste Management among Healthcare Workers in Maiduguri Metropolis

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Abstract

This study investigates the knowledge and practices of healthcare waste management (HCWM) among healthcare workers (HCWs) in Maiduguri Metropolis, Borno State, Nigeria. Using a cross-sectional survey of 318 HCWs across five major healthcare facilities, the study assesses their knowledge of HCWM regulations, waste segregation, disposal methods, and PPE use, and observes their actual practices related to these areas. The findings reveal discrepancies between knowledge and practice, with some HCW groups exhibiting higher knowledge levels but gaps in practical application. The study highlights the need for targeted training, improved infrastructure, and stricter policy enforcement to enhance HCWM in the region.

Keywords

Healthcare Waste Management, Healthcare Workers, Healthcare Facility/Hospital, Segregation, Knowledge, Practice, Waste Disposal, Hazard, Segregation, Maiduguri Metropolis Borno State

1. Introduction

Proper management of healthcare waste is essential for safeguarding public health and preventing infections. This includes proper procedures for collecting, storing, transporting, and disposing of waste in order to avoid complications associated with direct exposure to these waste products, which could pose risks to patients, medical professionals, and the wider community [1]-[3] (WHO 2017; Abbas *et al.*, 2018; Patwary *et al.*, 2019). Adequate disposal of healthcare waste is vital in curbing the transmission of diseases and minimizing harm to the environment. Healthcare waste encompasses all discarded materials from medical institutions,

research centers, and laboratories [4] (Tudor *et al.*, 2010). Healthcare waste management (HCWM) encompasses actions ranging from waste creation to final disposal. It covers waste creation, characterization, quantification, storage, management, collection, transportation, and disposal [5] (Tudor *et al.*, 2015). Because improperly managed healthcare waste has the potential to cause disease and harm, it has become a serious public health problem worldwide [5] (Tudor *et al.*, 2015).

Healthcare waste is waste produced by healthcare personnel while doing healthcare tasks in health facilities. In the course of providing healthcare services, healthcare personnel generate a variety of trash. Medical waste, chemical waste, radioactive waste, cytotoxic waste, pharmaceutical waste, and general garbage. Sharps, laboratory and related trash, human tissues, and corpses used for study are all examples of medical waste [1] [2] [6] (WHO 2017; Abbas *et al.*, 2018; United Nations Environment Programme, 2018) Each categorization must be handled following the criteria. These criteria typically involve; physical characteristics such as solid, liquid or sharp waste, and volume of waste generated, chemical composition such as presence of pharmaceutical, disinfectants and radioactive materials, biological characteristics such as presence of infectious agents like viruses, bacteria, fungi. The origin and source of the waste, health risks such as toxicity and injury, handling and disposal requirements as well as the type of regulation are all among the specific criteria that helped HPCN to categories healthcare waste for proper handling, transportation and disposed safely and effectively minimize public health and environmental risks.

The health risks linked to human exposure to healthcare-related hazardous wastes have amplified health concerns about the sustainable handling of such waste [5] [7] [8] (Da Silva *et al.*, 2012, Ferreira and Veiga, 2013; Tudor *et al.*, 2015). In Nigeria, healthcare waste is categorized into infectious and non-infectious types. Infectious waste according to the National Environmental Standards and Regulations Enforcement Agency [9] (NESREA) 2020, encompasses materials like cultures of infectious agents, pathological remains or waste (such as human tissue, organs, or body fluids), surgical or autopsy remnants contaminated with infectious materials, sharp objects (like needles, syringes, lancets, and scalpel blades), discarded human blood and its by-products, pleural fluid, semen, vaginal secretions, vomit, feces or urine and certain laboratory discards like cultures, stocks, and growth media [9] [10] (WHO, 2018; NESREA, 2020) Infectious waste generation rates normally depend on the size of the hospital, the number of patients coming to that particular facility, the number of beds available, segregation steps, and the kind of care provided to the patients [11] (Coker *et al.*, 2019). Non-infectious waste refers to general waste produced during the routine administrative and maintenance tasks of healthcare facilities, similar to typical household refuse [12] (FEPA, 2004). A small percentage of infectious waste (10% - 25%) is being generated but due to poor management of health waste by healthcare workers, the non-infectious are being contaminated by the infectious waste hence constituting a larger proportion of infectious waste being generated [13] (Kumar *et al.*, 2013).

There is a notable deficiency in both knowledge and implementation of healthcare

waste management practices aligned with the Healthcare Waste Management Plan (HCWMP), especially in developing countries [14]-[16] (Ali *et al*., 2018; Melekogu and Aktas, 2020; WHO, 2020). The types and volumes of healthcare waste produced, along with facility practices related to sustainable healthcare waste management (HCWM) techniques, such as waste sorting and recycling, often lack comprehensive research and documentation [17] [18] (Smith and Johnson, 2019; Wang *et al*., 2020). Despite the evident health risks linked to improper HCW handling, such mismanagement is observed in numerous countries globally, Nigeria included [19] [20] (Oke, 2018; Farzadika *et al*., 2019). Alarmingly, an estimated 10% - 25% of healthcare waste is hazardous, carrying potential health threats if not managed correctly [20] (Farzadika *et al*., 2019). Recent statistics from the World Health Organization (WHO) indicate that unsafe injection practices continue to be a significant source of infection. In 2022, it was estimated that 1.2 million new hepatitis B virus (HBV) infections occurred globally, many of which were attributed to contaminated syringes and unsafe injections. This highlights the critical need for stringent safety measures to prevent the reuse of syringes and other medical instruments [21] (WHO, 2024). Moreover, data from the International Safety Centre's (ISC) 2022 [22] report shows that needle stick and sharps injuries remain a persistent issue, with healthcare workers frequently exposed to potential blood borne pathogen transmission through contaminated needles [22] (International Safety Centre, 2022). Furthermore, improper disposal of healthcare waste can contaminate both ground and surface water sources [23] (Singh *et al*., 2008) and may even be linked to cancer cases [24] (Karademir, 2014). Issues such as typhoid fever, cholera, skin ailments, malaria, and gastroenteritis have been linked to poor collection, treatment, and disposal of waste [25] (Chukwuezie, 2009).

Healthcare workers play an important role in improving basic care in both rural and urban areas by delivering healthcare services. Healthcare waste management knowledge and practice among the healthcare workers are critical in ensuring successful healthcare waste management practices [26] [27] (Zerihun and Debebe 2019; Sharma *et al*., 2020). Therefore, this research aims at assessing the knowledge and practice of healthcare waste management among healthcare workers in Maiduguri metropolis of Borno State Nigeria.

Conceptual Framework

Overview: This study adopts a composite conceptual framework that integrates elements from the Socio-Ecological Model (SEM), Institutional Theory, Governance Theory, and the Resource-Based View (RBV) to investigate the determinants of healthcare waste management (HCWM) practices in Maiduguri Metropolis. This integrative framework captures the multi-level interactions between policy systems, institutional dynamics, and individual behaviors that influence HCWM effectiveness. It reflects the understanding that healthcare waste management is a complex, system-dependent phenomenon requiring analysis across multiple levels of influence—ranging from macro-level governance structures to micro-level individual practices.

Theoretical Underpinnings

1) Socio-Ecological Model (SEM): SEM posits that behavior is influenced by multiple levels of interaction—intrapersonal, interpersonal, organizational, community, and policy/environmental. HCWM behaviors are shaped not only by personal knowledge and attitudes but also by institutional norms, community perceptions, and policy enforcement.

2) Institutional Theory: Institutions—defined as formal rules and informal norms—shape the behavior of actors within them. Compliance with HCWM protocols is mediated by organizational culture, role expectations, and institutional incentives or penalties.

3) Governance Perspective: Effective HCWM requires governance mechanisms that ensure accountability, transparency, and regulatory enforcement. Weak or fragmented governance structures can undermine the policy-practice nexus.

4) Resource-Based View (RBV): Organizations require critical resources—such as funding, human capital, infrastructure, and technology—to implement HCWM. Where these are lacking, even the best-intentioned policies and training programs will fail.

Framework Components: The framework is structured around five interconnected layers, each representing a critical domain of influence:

1. ***Policy and Regulatory Environment*** **(*Macro-Level*)**

Key Elements: national HCWM policies and legislation (e.g., Federal Ministry of Health (FMoH) HCWM Guidelines)

- State-level adaptation and institutional bylaws
- Enforcement mechanisms (monitoring, sanctions)
- Alignment with WHO and Basel Convention protocols

Hypothesis: A well-defined, enforced, and contextually adapted policy environment positively influences institutional behavior and individual compliance with HCWM practices.

2. ***Institutional Capacity and Organizational Culture*** **(*Meso-Level*)**

Key Elements:

- Availability of waste management infrastructure (e.g., color-coded bins, incinerators)
- Training and capacity-building programs for staff
- Internal protocols and standard operating procedures
- Leadership commitment and infection control oversight
- Workplace norms, role clarity, and staff engagement

Hypothesis: Institutions with adequate resources, clear protocols, and strong leadership are more likely to support compliant HCWM practices among their staff.

3. ***Resource Availability*** **(*Cross-Cutting Dimension*)**

Key Elements:

- Budgetary allocation for HCWM
- Procurement and maintenance of waste handling equipment
- Availability and accessibility of PPE and segregation tools
- Human resources: trained personnel and appropriate staff deployment

Hypothesis: The availability and consistent provisioning of resources are necessary conditions for effective HCWM, mediating the impact of knowledge and policy.

4. *Individual Knowledge, Attitudes, and Practices* (*Micro-Level*)

Key Elements:

- Awareness of HCWM policies and risks
- Training history and competence
- Attitudinal disposition toward HCWM tasks
- Behavioral compliance (segregation, use of PPE, reporting)

Hypothesis: Individual knowledge and motivation are necessary but insufficient for HCWM compliance; their effect is moderated by institutional and resource-related factors.

5. *Community and Environmental Feedback* (*External Interface*)

Key Elements:

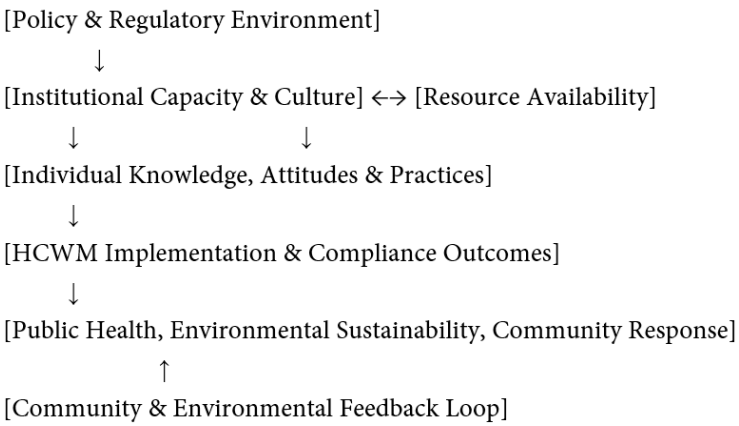
- Public perception of medical waste
- Informal waste disposal practices
- Media and civil society advocacy
- Environmental consequences (e.g., contamination, disease outbreaks)

Hypothesis: Community engagement and environmental feedback loops can stimulate institutional accountability and policy refinement.

Interrelationships: The model posits the following causal pathways:

- Policy environment sets the formal expectations, but its effectiveness depends on institutional readiness and resource sufficiency.
- Institutional capacity and culture mediate how policies are implemented and how individual behavior is shaped.
- Resource availability underpins all levels and is a precondition for translating policy and training into practice.
- Individual behavior is influenced by knowledge but sustained through organizational support and cultural reinforcement.
- Community and environmental factors serve as feedback mechanisms, potentially driving systemic change or policy reform when HCWM failures result in visible harm.

Visual Representation (Conceptual Diagram)



Arrows represent direct or mediating influences across levels.

Framework Application in the Study: This conceptual framework informs both the data collection strategy and analytical approach of the study. It guides the construction of research instruments, enabling a multi-level assessment of how regulatory, institutional, and behavioral dynamics intersect to influence HCWM outcomes in Maiduguri metropolis. By capturing the interdependence of these dimensions, the framework enhances the study's explanatory power and practical relevance for policy and system reform by:

- Capturing macro-micro linkages between policy, institutional performance, and individual behavior;
- Evaluating barriers to HCWM from both structural and behavioral perspectives;
- Recommending targeted interventions that align with systemic weaknesses identified across the layers.

Conclusion

The proposed conceptual framework offers a theoretically grounded, multidimensional lens for understanding and improving HCWM practices in Maiduguri Metropolis. It emphasizes that effective HCWM is not solely a matter of individual knowledge but a function of aligned policies, institutional commitment, available resources, and broader environmental dynamics. This grounding is essential for designing sustainable, context-specific interventions and for informing public health policy at both state and national levels.

2. Material and Methods

2.1. Type of Study

The research is a cross-sectional descriptive survey conducted using purposeful sampling to divide the population into homogenous units and group similar healthcare workers into one group to facilitate comparisons [28] [29] (Creswell, J.W. and Poth, C.N. 2016; Etikan *et al.*, 2016). A convenient sampling procedure was used to select the healthcare workers because they carry out their activities in different healthcare facilities. The five hospitals in Maiduguri Metropolis selected include: University of Maiduguri Teaching Hospital (UMTH) (a tertiary referral and teaching hospital), State Specialist Hospital (a state-owned secondary-level facility), Maryam Abatcha Women and Children Hospital (a specialized maternal and pediatric facility), Muhammad Shuwa Memorial Hospital (a general secondary-care hospital), and Federal Neuro-Psychiatric Hospital (a specialized federal facility for mental health care). These hospitals were chosen based on facility size, accessibility, diversity in service provision and waste generated, patient volume, and their central roles in the health system within the Maiduguri metropolis. The intent was to capture perspectives from both general and specialized service providers, across secondary and tertiary care levels. However, while this sampling approach facilitated data collection and allowed access to a variety of healthcare worker roles, the lack of randomization presents limitations in terms of generali-

zability. The study did not reflect healthcare waste management knowledge and practices across all facilities, especially in rural or less-resourced settings in Borno State or other regions in Nigeria. The research was conducted from July 2024 to September 2024.

2.2. Study Population

The sample size consisted of 318 healthcare workers selected across different professional cadres within these facilities of State Specialist Hospital, Muhammad Shuwa Memorial Hospital, Maryam Abatcha Women and Children Hospital Maiduguri, Federal Neuro-Psychiatric Hospital and University of Maiduguri Teaching Hospital (UMTH) who agreed and consented to participate in the study and must have worked in these hospitals for more than 6 months, aged 18 years and above and must have had direct dealings with waste generation, segregation, storage, transportation, and final disposal of medical wastes. Those who didn't meet up the stipulated criteria mentioned were excluded. The healthcare workers include the medical doctors, Nurses/midwifes, Radiographers, Physiotherapists, Pharmacists, Medical Laboratory Scientists, Technicians/Technologists, Health Assistants.

Yamane's formula $n = N/(1 + Ne^2)$ was used to determine the sample size [30] (Yamane, T. 1973). A validated structured questionnaire was administered to 318 healthcare workers. This way, 53 Medical Doctors, 56 Medical Laboratory Scientists, 52 Nurses/midwives, 46 Pharmacists, 42 Radiographers, 25 Physiotherapists, 24 Technicians/Technologists and 20 Health Assistants were selected.

2.3. Ethical Considerations

The researcher obtained ethical authorization from the public health review board of the National Open University to guarantee that the study was carried out appropriately. Before distributing any questionnaires, the participants were told the purpose of the research. The researcher also secured ethical approval from the Health Research Ethics Committee of the Borno State Ministry of Health and Human Services and the University of Maiduguri Teaching Hospital Research and Ethics Committee and informed consent from each participant regarding general data protection regulations. As a result, participants were also informed that the study was optional and that only those who gave their permission participated in the survey. The acquired data was safeguarded against unauthorized access to preserve participant privacy and confidentiality.

2.4. Methods and Instruments

The study used a robust combination of descriptive and inferential statistical techniques, primarily through SPSS, to analyze the relationships between knowledge, practice, and professional characteristics. Including p-values, confidence intervals, and correlation coefficients enhances the statistical rigor and validity of the findings, ensuring that results are not only descriptive but also inferential and generalizable

within the study context. A well-validated survey questionnaire divided into three sections covers the socio demographics of healthcare workers, knowledge and practice of healthcare waste management. Data gathered from the questionnaire underwent analysis and interpretation employing both descriptive and inferential methods. Initially, the data were coded using the Statistical Package for the Social Sciences (SPSS) version 25. Subsequently, this coded data was processed using the SPSS 25.0 software. The results on knowledge and practice were codded with numbers (1 for correct answer and 0 for wrong answer). Based on codes the knowledge and practice will be categorized into good (≥70% correct responses), fair (50% - 69% correct responses) and poor (<50% correct responses). The demographic characteristics of the respondents were presented in frequency and percentage.

Software Used: Data collected from 318 healthcare workers were entered and analyzed using IBM SPSS Statistics (Version 15). SPSS was chosen for its reliability in handling categorical data and for performing both descriptive and inferential statistics.

1) Descriptive Statistics: Frequencies and Percentages were computed for: Sociodemographic variables (e.g., age, gender, professional group), work-related characteristics (e.g., years of experience, qualification) and knowledge and practice variables. This provided an overview of the sample and the distribution of responses across key indicators.

2) Knowledge Scoring and Categorization: A composite knowledge score was generated based on correct responses to knowledge-related items. Scores were categorized into: Good Knowledge: ≥75% correct responses, Fair Knowledge: 50–74% correct responses, and Poor Knowledge: <50% correct responses. This classification enabled analysis of trends and patterns in knowledge levels across demographic and professional groups.

3) Inferential Statistics

a) Chi-square (χ^2) Test of Independence: used to assess associations between categorical variables, such as professional group versus knowledge level, professional group versus HCWM practices, and knowledge level versus use of PPE, waste segregation, availability of color-coded containers, etc.

P-values were reported, with $p < 0.05$ considered statistically significant. For example: A statistically significant association was found between professional category and knowledge level ($\chi^2 = 15.64$, df = 6, $p = 0.017$), indicating that doctors, medical laboratory scientists and nurses had significantly better knowledge than other groups.

b) Cramer's V: used alongside chi-square for effect size when significant associations were detected with the interpretation of 0.10 = small effect, 0.30 = moderate effect and 0.50 = large effect.

c) Correlation Analysis: Spearman's rho (ρ coefficient) was used to assess the correlation between knowledge and practice scores, as the data were ordinal and non-parametric. For example: $\rho = 0.42$, $p < 0.001$, suggesting a moderate positive correlation between knowledge and HCWM practices.

4) Confidence Intervals: 95% Confidence Intervals (CI) were calculated for proportions and means to provide an estimate range and strengthen reliability. For example: Proportion of HCWs with good knowledge = 56.6%, 95% CI [51.3%, 61.7%].

5) Reliability Testing: Cronbach's Alpha was used to test the internal consistency reliability of knowledge and practice items in the questionnaire. For example: Knowledge scale $\alpha = 0.81$; Practice scale $\alpha = 0.70$ where α is the alpha coefficient. Values above 0.70 indicate acceptable reliability.

3. Results

3.1. Demographic Characteristics of Respondents

Table 1 summarizes the demography of respondents with a total of 318 healthcare workers. The majority 173 (54.4%) are males while 145 (45.6%) are females. A good number of the respondent 123 (38.7%) are within the age group of 24 - 29 years, 101 (31.8%) within 30 - 35 years, 83 (26.1%) are either 36 years or above while 11 (3.4%) are within 18 - 23 years. With regards to qualification, 264 (83%) have a bachelor's degree while 37 (11.6%) and 17 (5.3%) have diploma and certificate respectively. The majority 145 (45.6%) have 0 - 4 years working experience, 90 (38.3%) have 5 - 8 years' experience, while 45 (14.2%) and 38 (11.9%) have an experience of over 11 years and 9 - 12 years respectively. Based on profession, 56 (17.6%), 53 (16.7%), and 52 (16.4%) are Medical Laboratory Scientist, Doctors, and Nurses/Midwives respectively. Pharmacist and Radiographers constitute 46 (14.5) and 42 (13.2) respectively. Physiotherapist and Technician/Technologist constitute 25 (7.9%) and 24 (7.5%) respectively while Health assistants constitute the least with 20 (6.3%).

Table 1. Socio-demographic characteristics of respondents.

Variable		Frequency (n = 318)	Percentage (%)
Male		173	54.4
Female		145	45.6
Age	18 - 23 years	11	3.40
	24 - 29 years	123	38.70
	30 - 35 years	101	31.80
	36 years and above	83	26.1
Qualification	Certificate	17	5.3
	Diploma	37	11.6
	Bachelor's Degree	264	83
Years of working experience	0 - 4 years	145	45.6
	5 - 8 years	90	28.3
	9 - 11 years	38	11.9
	12 years and above	45	14.2

Continued

Profession	Doctors	53	16.7
	Nurses/midwives	52	16.4
	Radiographers	42	13.2
	Medical Laboratory Scientists	56	17.6
	Physiotherapists	25	7.9
	Pharmacists	46	14.5
	Technicians/Technologists	24	7.5
	Health Assistants	20	6.3
Place of Work/Departments	Medical and Surgical ward	20	6.3
	Medical Laboratory	83	26.1
	Critical Care Unit	7	2.2
	Accident and Emergency ward	21	6.7
	Community Health/medicine	21	6.6
	Obstetrics and Gynecology ward	19	6.0
	Pharmacy department	62	19.5
	Radiology Department	45	14.2
	Physical Therapy Department	24	7.5
	Pediatrics ward	16	5.0

Source: Field Work, 2024.

3.2. Knowledge of Healthcare Waste

Table 2 summarizes the knowledge of health care waste management of respondents with the majority 250 (78.6%) aware of the regulation of HCWM while 68 (21.4%) unaware of the regulation of HCWM. The majority 297 (93.4%) are aware that medical waste handling requires PPEs while 21 (6.6%) are unaware. A good number of the respondent 233 (73.3%) agreed that general/domestic waste is among the various categorization of HCW while 196 (61.6%) pathological waste, 210 (66%) radioactive waste, 227 (71.4%) pharmaceutical waste, 270 (84.9%) sharps and the majority 272 (85.5) infectious waste. Equally a significant proportion of the respondents are aware that diseases that can be transmitted through HCW include HIV 264 (83%) and 297 (93.4%) hepatitis B and C. With regards to medical waste segregation, 212 (66.7%) are aware that HCW can be segregated at the point of collection/generation while 69 (21.7%) before disposal and 37 (11.6%) don't know.

The majority 219 (68.9%) are aware that sharps are disposed in yellow or white puncture proof container/box while 29 (9.1%) purple plastic bag, 53 (16.7%) red biodegradable plastic bag/bin and 17 (5.3%) brown container or plastic bag. Based on the knowledge of respondents on the disposal of infectious waste, 191 (60.06%), 32 (10.06%), 10 (3.15%), and 08 (2.52%) are aware of disposing in red biodegradable plastic bag/bin, yellow plastic bag/bin, purple container or plastic bag/bin and brown or black bag/bin respectively while 77 (24.21%) don't know. There is a var-

ied understanding of how to dispose of cytotoxic waste, with the majority 118 (37.11%) aware of using purple container or plastic bag/bin while 90 (28.30%), 47 (14.7%), 34 (10.70%) and 29 (9.11%) don't know, yellow bin/bag, red biodegradable plastic bag/bin, and brown or black bag/bin respectively. For disposal of chemical/pharmaceutical waste, the majority 173 (54.40%) of respondents correctly identify the brown/black plastic bag/bin as the proper method of disposal while 88 (27.67%), 28 (8.81%), 17 (5.35%) and 12 (3.77%) chose I don't know, yellow container or plastic bag/bin, purple container or plastic bag/bin, and red biodegradable container or plastic bag/bin respectively. The majority 161 (50.60%) are aware that the maximum time for medical waste to be kept in the hospital is 48 hours while 52 (16.40%) are unaware, 105 (33%) do not know this guideline, which can lead to improper HCWM practices.

Table 2. Knowledge of waste management among healthcare workers in Maiduguri metropolis.

S/No.	Statement	Responses	Frequency (n = 318)	Percentage (%)
1	Are you aware of the regulation on medical waste management?	Yes	250	78.6
		No	68	21.4
2	Medical waste handling policy requires PPE	Yes	297	93.4
		No	21	6.6
3	Healthcare waste can be categorized into the following	General waste	233	73.3
		Pathologic waste	196	61.6
		Radioactive waste	210	66
		Pharmaceutical waste	227	71.4
		Infectious waste	272	85.5
		Sharps	270	84.9
4	Disease(s) that can be transmitted through healthcare waste include	HIV	264	83
		Hepatitis B&C	297	93.4
5	Medical waste can be segregated at	Point of collection/generation	212	66.7
		Before disposal	69	21.7
		I don't know	37	11.6
6	Sharps are disposed in	Purple container/plastic bag	29	9.1
		Red biodegradable plastic bag/bin	53	16.7
		Yellow container/box	219	68.9
		Brown container/plastic bag	17	5.3
7	Infectious wastes are disposed in	Purple container/plastic bag	10	3.15
		Red biodegradable plastic bag/bin	191	60.06
		Yellow container/box	32	10.06
		Brown container/plastic bag	8	2.52
		I don't know	77	24.21

Continued

8	Cytotoxic wastes are disposed in	Purple container/plastic bag	118	37.11
		Red biodegradable plastic bag/bin	34	10.70
		Yellow container/box	47	14.78
		Brown container/plastic bag	29	9.11
		I don't know	90	28.30
9	Chemical/Pharmaceutical wastes are disposed in	Purple container/plastic bag	17	5.35
		Red biodegradable plastic bag/bin	12	3.77
		Yellow container/box	28	8.81
		Brown container/plastic bag	173	54.40
		I don't know	88	27.67
10	The maximum time for medical waste to be kept in the hospital is 48 hours?	Yes	161	50.60
		No	52	16.40
		I don't know	105	33

Source: Field Work, 2024.

3.3. Summary Knowledge Score of Healthcare Workers on HCWM in Maiduguri Metropolis

The summary knowledge score was established based on the data generated from the second principle and categorized as Good, Fair, or Poor. A common approach adopted was to score knowledge levels based on correct responses and then classify them into three categories: Good Knowledge: ≥70% correct responses, Fair Knowledge: 50% - 69% correct responses and Poor Knowledge: <50% correct responses.

Table 3 summaries the knowledge score of respondents with the majority having good knowledge on HCWM regulations 78.6% and 93.4% with PPE awareness. Waste categorization had 84.9% aware of sharps waste, and 85.5% infectious waste, Pharmaceutical Waste 71.4% and General Waste 73.3% while a good number 83% are aware that improper waste disposal can transmit diseases like HIV infection and 93.4% hepatitis B and C. Fair knowledge of HCWM were noted with the distribution of 66.7% aware of waste segregation, while waste categorization had 66% radioactive waste and 61.6% pathological waste. Fair number of respondents had 68.9% sharps, 60.6% infectious and 54.4% chemical/pharmaceutical waste disposal knowledge.

Poor knowledge was noted among the respondents with 37.11% cytotoxic waste disposal and some waste segregation method.

The overall summary score revealed that the majority (56.6%) have good knowledge of HCWM. A significant proportion (33%) have fair knowledge, indicating room for improvement while 10.4% have poor knowledge, particularly in cytotoxic waste disposal and some waste segregation practices. This provides a clear understanding of knowledge gaps that need to be addressed through

targeted training and awareness programs to improve overall HCWM compliance.

Table 3. Summarize the HCWM knowledge levels/scores among healthcare workers in Maiduguri metropolis of Borno State. Source: Field work.

Knowledge Levels/Scores	Number of Respondents	Percentage (%)	Key Areas of Strength/Weakness
Good Knowledge	180	56.6	Awareness of HCWM regulations (78.6%) PPE importance (93.4%) Sharps waste disposal (84.9%) Infectious waste disposal (85.5%) Disease transmission (HIV-83%, Hepatitis B&C-93.4%)
Fair Knowledge	105	33.0	Waste segregation (66.7%) Pathological waste (61.6%) Radioactive waste (66%) Pharmaceutical waste (71.4%) General waste categorization (73.3%) Sharps disposal (68.9%) Infectious waste disposal (60.06%) Chemical/pharmaceutical waste disposal (54.4%) Storage time knowledge (50.6%)
Poor Knowledge	33	10.4	Cytotoxic waste disposal (37.11%) Some knowledge gaps in waste segregation and disposal

3.4. The Practices of Healthcare Waste Management among Healthcare Workers in Maiduguri Metropolis

Table 4 summarizes the attitude and practices of respondents with a total of 226 (71.1%) have specific color-coded containers for waste disposal while 92 (28.9%) do not have. The majority 267 (84%) had a specific area for healthcare waste disposal while 51 (16%) had no specific area for waste disposal. A good number of the respondents 229 (72%) had waste bins that are covered and foot operated while 89 (28%) had none. With regards to posters to guide users displayed near waste bins, 168 (52.8%) had posters displayed to guide users while a near-equal split 150 (47.2%) had no posters displayed to guide users near waste bins indicating a significant visual education and guidance gap.

The majority 209 (65.7%) agree that transportation of healthcare wastes is done during non-busy hours while 109 (34.3%) do not. Based on infectious and general waste transported separately, 215 (67.6%) affirmed that infectious and general (non-infectious) wastes are transported separately while 103 (32.4%) do not. Similarly, majority 232 (73%) of the respondents appropriately use the PPE while 86 (27%) do not appropriately use the PPE.

Table 4. Practices of healthcare waste management among healthcare workers in Maiduguri metropolis (Source: Field Work, 2024).

S/No.	Statement	Responses	Frequency (n = 318)	Percentage (%)
1	Do you have specific color-coded containers for waste disposal?	Yes	226	71.1
		No	92	28.9
2	Do you have specific area for healthcare waste disposal?	Yes	267	84
		No	51	16
3	Are waste bins covered and foot operated?	Yes	229	72
		No	89	28
4	Are posters to guide users displayed near waste bins?	Yes	168	52.8
		No	150	47.2
5	Is transportation of healthcare waste done during non-busy hours?	Yes	209	65.7
		No	109	34.3
6	Are infectious and general waste transported separately?	Yes	215	67.6
		No	103	32.4
7	Do you appropriately use the PPE?	Yes	232	73
		No	86	27

Table 5. Relationships between demographic/work-related variables and knowledge of healthcare waste management (Source: Field Work, 2024).

Variables	Categories	Awareness of HCWM regulations (%)	Awareness of PPE use (%)	Awareness of waste segregation (%)	Correct sharps disposal (%)	Correct infectious waste disposal (%)
Gender	Male: 54.4%	79.2% (137)	94.2% (163)	67.1% (116)	70.5% (122)	61.3% (106)
	Female: 45.6%	77.9% (113)	92.4% (134)	66.2% (96)	67.6% (98)	58.6% (85)
Age Group (Years)	18 - 23 (3.4%)	72.7% (8)	90.9% (10)	63.6% (7)	63.6% (7)	54.4% (6)
	24 - 29 (38.7%)	77.2% (95)	92.7% (114)	65.9% (81)	68.3% (84)	57.7% (71)
	30 - 35 (31.8%)	78.2% (79)	94.1% (95)	67.3% (68)	71.3% (72)	60.4% (61)
	36+ (26.1%)	81.9% (68)	95.2% (79)	68.7% (57)	72.3% (60)	62.7% (52)
Qualifications	Bachelor's (83%)	79.2% (209)	94.3% (249)	67.0% (177)	70.8% (187)	61.7% (163)
	Diploma (11.6%)	75.7% (28)	91.9% (34)	65.8% (24)	66.2% (25)	56.8% (21)
	Certificate (5.3%)	73.3% (12)	88.2 (15)	63.2% (10)	61.1% (10)	50.0% (8)
Work Experience (Year)	0 - 4 yrs (45.6%)	76.6 (111)	92.4% (134)	65.5% (95)	67.5% (98)	56.5% (82)
	5 - 8 yrs (38.3%)	78.9% (71)	94.4% (85)	67.8% (61)	70.0% (63)	59.1% (53)
	9 - 12 yrs (11.9%)	81.6% (31)	95.0% (36)	69.2% (26)	72.1% (27)	63.2% (24)
	11+ yrs (14.2%)	82.2% (37)	70.5% (32)	70.5% (32)	74.1% (34)	64.8% (30)
Profession	Medical Lab. Scientists (17.6%)	80.4% (45)	95.5% (53)	69.6% (39)	72.3% (41)	64.2% (36)
	Doctors (16.7%)	81.1% (43)	96.2% (51)	70.25% (37)	73.6% (39)	66.0% (350)
	Nurses/Midwives (16.4%)	79.6% (41)	94.2% (49)	68.0% (35)	71.2% (37)	63.5% (33)
	Pharmacists (14.5%)	78.3% (36)	93.5% (43)	67.4% (31)	70.0% (32)	60.9% (28)

Continued

	Radiographers (13.2%)	76.2% (32)	92.9% (39)	66.7% (28)	68.2% (28)	58.5% (24)
	Physiotherapists (7.9%)	75.0% (19)	91.7% (22)	64.0% (16)	66.7% (16)	55.0% (14)
	Technicians (7.5%)	74.2% (18)	90.3% (22)	63.8% (15)	65.2% (15)	53.8% (14)
	Health Assistants (6.3%)	72.0% (14)	88.0% (16)	60.0% (12)	62.5% (12)	50.0% (10)

The results presented in Table 5 revealed that:

- Higher education levels and work experience correlate with better HCWM knowledge, particularly among those with a bachelor's degree or over 11 years of experience.
- Doctors, nurses, and medical laboratory scientists demonstrate the highest HCWM awareness.
- Younger respondents (18 - 23 years) and health assistants show the lowest knowledge levels, indicating a need for targeted training programs.
- Gender differences are minimal, though male respondents show slightly higher awareness across most categories.

The table provides insights into gaps in HCWM knowledge and highlights areas for improvement through training and policy enforcement.

Table 6. Showing relationship between demographic/work related variables and the various practices of HCWM (source: field work).

Variables	Categories	Use of Color-Coded Bins (%)	Designated Waste Disposal Area (%)	Use of Covered Foot-Operated Bins (%)	Posters For Waste Guidance (%)	Waste Trans-ported during Non-Busy Hours (%)	Separate Infectious and General Waste (%)	Proper PPE Usage (%)
Gender	Male (54.4%)	72.3% (125)	85.0% (147)	73.4% (127)	54.3% (94)	66.5% (115)	68.2% (118)	74.0% (128)
	Female (45.6%)	69.7% (101)	82.8% (120)	70.3% (102)	51.0% (74)	64.5% (94)	66.8% (97)	71.7% (104)
Age Group (years)	18 - 23 (3.4%)	63.6% (7)	72.7% (8)	63.6% (7)	45.5% (5)	54.5% (6)	59.1% (6)	63.6% (7)
	24 - 29 (38.7%)	70.7% (87)	83.7% (103)	71.5% (88)	50.4% (62)	65.0% (79)	67.5% (83)	72.4% (89)
	30 - 35 (31.8%)	71.3% (72)	85.1% (86)	72.3% (73)	53.5% (54)	66.3% (67)	68.3% (69)	74.3% (75)
	36+ (26.1%)	74.7% (62)	86.7% (72)	74.7% (62)	55.4% (46)	67.5% (56)	69.9% (58)	76.5% (63)
Qualification	Bachelor's (83%)	72.3% (191)	85.2% (225)	73.1% (193)	54.2% (143)	66.9% (174)	68.6% (181)	74.2% (196)
	Diploma (11.6%)	68.1% (25)	82.3% (31)	69.6% (26)	50.3% (19)	64.5% (24)	66.1% (25)	71.4% (27)
	Certificate (5.3%)	64.7% (11)	78.6% (13)	64.7% (11)	47.1% (8)	60.1% (10)	62.5% (10)	68.4% (12)
Work experience (years)	0 - 4 (45.6%)	69.0% (100)	82.8% (120)	70.3% (102)	50.3% 73)	64.2% (93)	65.5% (95)	70.7 (102)
	5 - 8 (38.3%)	71.1% (64)	84.4% (76)	72.2% (65)	52.2% (47)	65.8% (59)	67.7% (61)	73.3% (66)
	9 - 12 (11.9%)	74.4% (28)	86.8% (33)	75.0% (28)	56.6% (21)	68.1% (26)	70.4% (27)	76.5% (29)
	11+ (14.2%)	75.5% (34)	87.8% (39)	76.7% (35)	57.8% (26)	69.4% (31)	72.1% (32)	78.4% (35)
Profession	Medical Lab Scientists (17.6%)	74.1% (41)	86.5% (48)	75.0% (42)	55.3% (31)	67.3% (38)	69.6% (39)	76.8% (43)
	Doctors (16.7%)	75.5% (40)	87.1% (46)	76.4% (41)	56.6% (30)	68.4% (37)	71.2% (38)	78.1% (42)

Continued

Nurses/Midwives (16.4%)	73.1% (38)	85.7% (44)	74.0% (39)	54.9% (29)	66.7% (35)	68.3% (36)	75.4% (39)
Pharmacists (14.5%)	71.7% (33)	84.4% (39)	72.2% (33)	52.3% (24)	65.1% (30)	67.9% (31)	73.9% (34)
Radiographers (13.2%)	70.2% (30)	83.3% (35)	71.4% (30)	51.4% (22)	64.5% (27)	66.5% (28)	72.6% (31)
Physiotherapists (7.9%)	68.0 (17)	81.6% (20)	69.6% (17)	49.2% (12)	62.5% (15)	64.0% (16)	70.4% (18)
Technicians (7.5%)	67.0% (16)	80.5% (19)	68.3% (16)	48.5% (11)	61.8% (14)	62.9% (15)	69.2% (17)
Health Assistants (6.3%)	65.0% (13)	79.0% (16)	66.7% (13)	46.0% (9)	60.0% (12)	61.5% (12)	67.0% (13)

Table 6 summarized the relationship between demographic/work-related variables and the various practices of HCWM among HCW in Maiduguri metropolis of Borno state. The table revealed that:

- Higher education, work experience, and professional roles correlate with better HCWM practices.
- Doctors, Medical laboratory scientists, and Nurses/midwives have the highest compliance.
- Younger respondents and health assistants show lower adherence, indicating the need for targeted training.
- PPE usage is the highest among those with extensive experience.
- These further highlights areas for improvement, particularly in training and waste management infrastructure.

Table 7. Relationship between knowledge (good, fair and poor) and the various practices of HCWM among healthcare workers in Maiduguri metropolis. Source: Field work.

HCWM Practices	Good Knowledge (%)	Fair Knowledge (%)	Poor Knowledge (%)
Use of Color-Coded Containers for Waste Disposal	85	65	30
Having a Specific Area for Waste Disposal	90	70	40
Display of Posters Near Waste Bins	70	50	20
Transportation of HCW During Non-Busy Hours	75	55	35
Segregation of Infectious and General Waste	80	60	30
Appropriate Use of PPE	85	65	40

Table 7 revealed that:

- Workers with Good Knowledge (≥70% correct answers) practice proper HCWM more consistently compared to those with fair or poor knowledge.
- Fair Knowledge workers (50% - 69%) have moderate adherence, but improvement is needed in waste segregation and PPE usage.
- Poor Knowledge workers (<50%) show significantly lower compliance, indicating the need for targeted training interventions.
- This reinforces the importance of HCWM training programs to bridge knowledge gaps and healthcare infrastructure funding and improve compliance with best practices.

Table 8. Relationship between professional group and knowledge level of HCWM (chi-square test).

Professional Group	Good Knowledge	Fair Knowledge	Poor Knowledge
Doctors	30	15	8
Nurses/Midwives	28	20	4
Medical Laboratory Scientists	27	18	3
Pharmacists	15	20	11
Radiographers	12	17	13
Physiotherapists	8	7	10
Technicians	8	12	4
Health Assistants	6	10	4

Chi-square result: χ^2 = [calculated value], df = 12, p = 0.017.

Table 8 shows statistically significant association between professional group and knowledge level.

Table 9. Correlation between knowledge and practice scores (Spearman's rho).

Variable 1	Variable 2	Spearman's rho	p-value	Interpretation
Knowledge Score	Practice Score	0.42	< 0.001	Moderate Positive Correlation

Table 10. 95% confidence intervals (CI) for knowledge categories.

Knowledge Category	Proportion (%)	95% CI Lower Bound	95% CI Upper Bound
Good	56.6	51.3	61.7
Fair	33.0	28.2	38.2
Poor	10.4	7.4	14.4

Table 11. Relationship between professional group and practice level of HCWM.

Professional Group	Good Practice	Fair Practice	Poor Practice
Doctors	32	13	8
Nurses/Midwives	30	18	4
Medical Laboratory Scientists	28	16	4
Pharmacists	16	19	11
Radiographers	14	17	11
Physiotherapists	14	6	5
Technicians/Technologist	10	10	4
Health Assistants	8	9	3

The table above (Table 11) shows statistically significant association between professional group and practice level.

Table 12. 95% confidence interval (CI) for practice categories.

Practice Category	Proportion (%)	95% CI Lower Bound	95% CI Upper Bound
Good	59.1	54.0	64.2
Fair	30.8	26.3	35.3
Poor	10.1	7.1	14.1

3.5. Summary of Major Findings on Knowledge Application in HCWM

The summary of major findings on knowledge application in HCWM, focusing on practical outcomes revealed that while a majority of healthcare workers demonstrated basic awareness of healthcare waste regulations, this knowledge does not consistently translate into best practices across facilities (Tables 9-12).

Regulatory Awareness: 78.6% of respondents were aware of national or institutional HCWM regulations. However, gaps still existed, as 21.4% remained unaware, reflecting inconsistent dissemination of policy information across healthcare tiers.

PPE Knowledge and Use: 93.4% acknowledged that personal protective equipment (PPE) is necessary when handling medical waste. Despite this, only 73% reported consistent use of PPE in practice, indicating a knowledge-practice gap, likely due to PPE unavailability or weak enforcement.

Waste Categorization Awareness: Most respondents recognized multiple categories of HCW, with over 85% correctly identifying infectious and sharp wastes. However, knowledge of proper disposal methods for specialized waste (e.g., cytotoxic, pharmaceutical) was less consistent, as reflected in mixed responses regarding appropriate container color codes.

Segregation Practices: While 66.7% knew that waste should be segregated at the point of generation, only 71.1% reported having color-coded containers in their workplaces. This disparity suggests that knowledge is sometimes constrained by facility limitations, such as inadequate supplies or infrastructure.

Disposal Timeframe Awareness: Only 50.6% of respondents were aware that medical waste should not exceed 48 hours within the facility. A significant proportion (49.4%) either lacked this knowledge or were unsure, indicating a potential risk for prolonged waste retention and contamination.

Overall Knowledge versus Practice Link: Cross-tabulation of knowledge levels with practical actions indicated that those with good knowledge levels (62.9%) were more likely to engage in correct practices (e.g., PPE use, proper segregation, and transportation protocols). Conversely, fair or poor knowledge was often associated with inconsistent or unsafe waste handling practices.

Implication: These findings suggest that knowledge alone is not sufficient to ensure compliance with HCWM standards. Systemic issues such as supply shortages, lack of training, poor supervision, and inadequate infrastructure limit the application of that knowledge in practice.

4. Discussion

The present study provides critical insights into the knowledge and practice of healthcare waste management (HCWM) among healthcare workers (HCWs) in Maiduguri Metropolis. The findings revealed that a substantial proportion of healthcare workers (HCWs) in Maiduguri Metropolis possess a good level of knowledge on healthcare waste management (HCWM), particularly concerning existing regulations, the use of personal protective equipment (PPE), and waste categorization. However, a notable and concerning knowledge-practice gap persists, with several institutional, behavioral, and infrastructural barriers impeding the effective translation of knowledge into consistent, safe HCWM practices.

Despite high awareness levels especially among medical doctors, nurses/midwives, and medical laboratory scientists, actual compliance with best practices remains suboptimal across many cadres and facilities. This knowledge-practice gap aligns with global trends observed in low- and middle-income countries, where systemic, infrastructural, and behavioral factors compromise implementation despite awareness [1] (WHO, 2017; Abd El-Wahab *et al.*, 2021). Factors such as staff workload, institutional culture, and absence of rigorous supervision often erode good practices even in well-informed environments.

Our findings suggest that HCWs in high-contact roles (e.g., nurses, doctors) demonstrated better HCWM adherence compared to support personnel such as technicians and health assistants. These disparities likely reflect both educational exposure and varying levels of engagement with waste handling responsibilities. This is consistent with Okechukwu *et al.* (2020) [31], who observed higher HCWM knowledge and compliance among highly educated HCWs in Abuja.

The implementation of HCWM practices is further challenged by limited infrastructure. Only 71.1% of respondents confirmed the availability of color-coded containers, and just 52.8% reported the presence of posters to guide waste segregation, an important tool for reinforcing knowledge. Similarly, while 84% had designated waste disposal areas, issues such as uncovered bins, poor bin placement, and improper transportation persist. These gaps are not merely operational inconveniences but reflect broader structural inadequacies in hospital management systems.

The absence of appropriate HCWM infrastructure in some facilities contributes to a situation where healthcare waste is often mixed with general waste, stored in unsafe conditions, or disposed of via open dumping, a practice contrary to both national and international guidelines [33] [34] (Olayinka & Akinyemi, 2015; WHO, 2022). These findings reinforce the conclusions of earlier studies in Nigeria and other low-resource settings, which identified weak regulatory enforcement and inadequate budgeting as root causes of improper HCWM [35] [36] (Awosan *et al.*, 2016; Riformato *et al.*, 2022).

Workload emerged as a significant barrier to good HCWM practice. Overburdened staff often prioritize direct patient care over waste segregation, particularly

during peak hours. This aligns with findings by Okonkwo *et al.* (2019) [37], which highlight that under high workload conditions, HCWM tasks are frequently relegated or assigned to junior staff with limited training.

Attitudinal issues were also apparent. The lack of commitment among some cadres, especially those with less direct involvement in patient care (e.g., radiographers, physiotherapists), suggests that HCWM is not universally internalized as a core responsibility. Motivation appears tied to both professional identity and perceived institutional priorities. In facilities with stronger infection control oversight and supervisory structures, compliance rates were markedly higher, supporting the argument that leadership and institutional accountability are critical enablers of effective HCWM [34] [37] (Okonkwo *et al.*, 2019; WHO, 2022).

Although training is widely acknowledged as essential, this study found limited data on the nature, frequency, and reach of existing HCWM training programs. The uneven distribution of knowledge across professional groups suggests inconsistent access to continuing professional development (CPD). For example, while doctors, medical laboratory scientists and nurses often targeted by CPD programs, displayed strong knowledge, technicians, radiographers, and support staff did not. The finding that only half the respondents were aware of the 48-hour waste retention policy also suggests a breakdown in policy dissemination mechanisms.

These observations are supported by Sangkham (2020) [38], who emphasized the role of structured and inclusive training programs in improving HCWM compliance. Without institutionalized and equitable training interventions, knowledge gaps will persist, and practice discrepancies will widen.

Our study corroborates earlier research on the importance of professional background and educational level in shaping HCWM knowledge and behavior. For example, Madhukumar & Ramesh (2020) [39] found that professionals who regularly handle HCW, especially doctors, medical laboratory scientists and nurses were more proficient in using color-coded containers. Similar studies from India, Yemen, and Botswana [33] [40] [41] (Chaudhary *et al.*, 2014; Al Emad, 2021; Olayinka & Akinyemi, 2015) echo these findings, further suggesting that limited engagement with HCW and absence of enabling environments often result in poor practices.

Furthermore, our results add to the growing literature emphasizing the role of policy clarity, supportive infrastructure, and institutional accountability in strengthening HCWM systems [42] [43] (Nkonde *et al.*, 2023; Udayanga *et al.*, 2023). Poor awareness of chemical and pharmaceutical waste disposal procedures, as well as limited familiarity with sharps disposal protocols among certain cadres, poses serious health and environmental risks [44] (Wojtas *et al.*, 2023).

Another key strength of this study was that evaluating knowledge and practices related to waste management offered a valuable opportunity to generate insights, rekindle the consciousness of respondents on a relatively underexplored topic which is lacking in the hospitals. It equally recognizes the gaps between the exist-

ing knowledge and practice among the healthcare workers involved in waste management and the future desired state that should be reached.

5. Conclusions

This study revealed important insights into respondent's awareness, compliance, and gaps in waste management practices particularly in waste segregation, PPE use, and disposal of hazardous waste. The majority (56.6%) of healthcare workers demonstrated good knowledge of HCWM, particularly in areas such as awareness of regulations (78.6%), importance of PPE (93.4%), sharps waste disposal (84.9%), and infectious waste handling (85.5%). This was especially noted among medical doctors, medical laboratory scientists and nurses/midwives. Fair knowledge (33%) was observed in waste segregation, pharmaceutical waste disposal, and storage time regulations while a small proportion (10.4%) had poor knowledge particularly in the disposal of cytotoxic waste (37.1%) and some aspects of chemical waste disposal, indicating a need for targeted training in these areas. Practice of healthcare waste management showed that 84% of respondents had a specific area for healthcare waste disposal, while 71.1% had color-coded containers for waste segregation.

Only 52.8% had posters displayed near waste bins, indicating a gap in visual guidance and education on HCWM practices. 73% of healthcare workers used PPE appropriately, but a significant 27% did not, increasing the risk of occupational hazards. 67.6% confirmed that infectious and general wastes were transported separately, but 32.4% did not follow this crucial segregation guideline. A positive observation was that 65.7% agreed that waste transportation occurred during non-busy hours, which minimizes the risk of exposure. The relationship between knowledge and practice revealed that healthcare workers with good knowledge exhibited better HCWM practices compared to those with fair or poor knowledge. Poor knowledge was associated with inconsistent use of PPE, improper segregation of waste, and lack of adherence to disposal protocols. Training and capacity-building programs are essential to improve HCWM practices, particularly among those with fair and poor knowledge.

6. Recommendations

Improving HCWM in Maiduguri Metropolis requires a multipronged approach. Interventions should address both material and non-material drivers of poor practice. This includes:

1) **Baseline Assessment of Training Programs:** Healthcare institutions in Maiduguri Metropolis should first assess the current state of HCWM training—frequency, audience, content, and facilitators to identify gaps.

2) **Inclusive Training Design:** Future trainings must include all cadres of healthcare workers, especially non-clinical staff (e.g., health assistants, technicians, cleaners) who are actively involved in waste handling but are often excluded from CPD programs.

3) **Periodic Refresher Courses:** Regular refresher sessions should be instituted to reinforce HCWM protocols and update staff on policy changes. These should be tied to institutional goals for quality improvement.

4) **Evaluation and Feedback Mechanisms:** Each training program should include pre- and post-tests to assess knowledge gain, as well as follow-up evaluations to measure behavioral outcomes on the job.

5) **Integrated Policy Dissemination:** Training should be coupled with physical job aids (e.g., posters, color charts, checklists), as 47.2% of respondents indicated there were no visual aids near waste bins.

6) **Train-the-Trainer Models:** Facilities should adopt a train-the-trainer approach where selected HCWs are trained to mentor others, promoting sustainability and wider reach.

7) **Leverage Partnerships:** Collaborations with organizations like WHO, local NGOs, or state training institutions can provide both technical support and materials for standardized training delivery.

8) **Investing in Infrastructure:** Ensuring availability of color-coded bins, posters, PPE, and dedicated disposal sites.

9) **Strengthening Supervision:** Instituting active infection control committees and routine audits to enforce compliance.

10) **Policy Reinforcement:** Enhancing dissemination and visibility of HCWM guidelines across departments.

11) **Addressing Workload Issues:** Reviewing staff deployment and responsibilities to ensure HCWM is not deprioritized under pressure.

By integrating these strategies, healthcare institutions can bridge the knowledge-practice gap, reduce occupational and environmental hazards, and align HCWM systems with global best practices.

7. Suggestion for Further Research

The present study could only include a few of the healthcare facilities in the Maiduguri metropolis of Borno State. Therefore, the researchers recommend further research using other research methods to expand its scope to include many healthcare facilities in the state including Primary Healthcare Centers (PHCs) and private clinics. This will provide valuable insight to healthcare workers so that they can priorities occupational safety practices and disease prevention associated with poor Healthcare Waste Management Practices.

Respondents Permission

The respondents were informed and gave their permission to present and publish this study.

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Conflicts of Interest

The author states that none of his known conflicting financial interests or personal connections may have appeared to impact the work presented in this study.

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