

Assessment of Knowledge and Practice of Biomedical Waste Management Among Health Workers at Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria

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ABSTRACT

Background: Biomedical waste management (BMWM) has emerged as a major public health, occupational safety, and environmental concern worldwide. Healthcare facilities generate substantial quantities of hazardous waste, including infectious materials, sharps, pathological waste, pharmaceutical residues, and chemical waste. When improperly managed, these wastes expose healthcare workers, patients, waste handlers, and communities to infectious diseases, toxic substances, and environmental pollution. Healthcare workers play a central role in ensuring proper biomedical waste segregation, handling, transportation, treatment, and disposal. Therefore, understanding their knowledge and practices is critical for improving compliance with recommended waste management standards.

Aim: The study aimed to determine the knowledge of health workers regarding biomedical waste management and assess biomedical waste management practices among health workers at Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi, Anambra State, Nigeria.

Methods: A descriptive cross-sectional survey design was employed among 255 healthcare workers selected through stratified random sampling. Data were collected using a structured self-administered questionnaire and an observational checklist. Descriptive statistics including frequencies and percentages were used to summarize data, while inferential statistics (Chi-square test) examined associations between relevant variables at a significance level of $p < .05$.

Results: The findings indicated that 64.7% of respondents had received formal training on biomedical waste management. Most respondents (84.3%) recognized biomedical waste management as the responsibility of all healthcare workers, while 90.2% correctly identified the appropriate disposal method for used syringes. More than half (54.9%) reported always segregating waste appropriately. However, 39.2% had experienced needle-stick injuries, and a significant proportion failed to report such incidents. Observational findings revealed moderate compliance with waste management protocols, particularly regarding color-coded bins and sharps disposal, but identified deficiencies in personal protective equipment utilization and

infrastructure. Significant associations were found between knowledge and practices ($\chi^2=14.82$, $p=.002$); and professional category and practices ($\chi^2=12.56$, $p=.041$).

Conclusion: Healthcare workers at NAUTH demonstrated relatively good knowledge of biomedical waste management; however, gaps remain in practical implementation and institutional compliance. Continuous training, infrastructure improvement, and strengthened monitoring systems are required to ensure effective biomedical waste management and protect occupational and environmental health.

Keywords: Biomedical waste management, Knowledge, Practices, Healthcare workers, Waste segregation, Waste disposal, Occupational safety.

INTRODUCTION

Biomedical waste management has become an increasingly important component of healthcare delivery globally due to the growing complexity of healthcare services and the rising volume of hazardous waste generated by healthcare facilities. Healthcare institutions produce various categories of waste during patient diagnosis, treatment, immunization, laboratory investigations, and research activities. While a significant proportion of healthcare waste is comparable to domestic waste, approximately 15–25% is classified as hazardous because it contains infectious, toxic, radioactive, or chemical materials capable of causing harm to humans and the environment¹.

Biomedical waste includes infectious waste, pathological waste, sharps, pharmaceutical waste, chemical waste, cytotoxic materials, radioactive substances, and contaminated plastics generated during healthcare activities. Improper management of these wastes poses serious occupational, environmental, and public health risks. Healthcare workers who handle biomedical waste are particularly vulnerable to injuries and infections resulting from accidental exposure to contaminated materials. Such exposure may lead to transmission of blood-

borne pathogens including hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV) through needle-stick injuries and contact with contaminated sharps².

Globally, healthcare waste management has gained considerable attention due to its implications for sustainable healthcare systems and environmental protection. The WHO (2020) emphasizes that healthcare waste management should encompass waste minimization, segregation, collection, transportation, treatment, and final disposal. These processes require strict adherence to established guidelines and standards to prevent adverse health outcomes. The COVID-19 pandemic further highlighted the importance of biomedical waste management as healthcare facilities experienced unprecedented increases in waste generation, particularly personal protective equipment (PPE), testing materials, and vaccination-related waste³. (Nosheen et al., 2022).

International frameworks have been developed to guide countries in implementing safe biomedical waste management practices. The WHO Safe Management of Wastes from Health-Care Activities remains the most widely adopted global guideline, providing protocols for waste categorization, color-coded segregation, safe transportation, treatment technologies, and environmentally sound disposal methods. The Basel Convention regulates transboundary movement of hazardous waste and promotes environmentally sound management practices, while the International Labour Organization (ILO) focuses on occupational safety measures for healthcare workers handling hazardous waste. These frameworks collectively emphasize prevention of occupational injuries, environmental contamination, and disease transmission through effective waste management systems.

Despite the existence of these guidelines, implementation challenges remain particularly pronounced in low- and middle-

income countries (LMICs). Many healthcare facilities in Africa, Asia, and Latin America lack adequate infrastructure, trained personnel, and financial resources required for effective biomedical waste management. Studies across LMICs reveal widespread deficiencies in waste segregation, collection, transportation, treatment, and final disposal practices. Infectious waste is frequently mixed with general waste, while outdated incineration technologies contribute to environmental pollution and occupational health hazards^{4,5}. (Chisholm et al., 2021; Mitiku et al., 2022).

In Nigeria, biomedical waste management remains a significant public health concern despite the existence of several policy frameworks and regulatory instruments. The National Healthcare Waste Management Policy, the Federal Ministry of Health Guidelines, the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act, and the Environmental Impact Assessment (EIA) Act collectively provide the legal and institutional framework for healthcare waste management. However, evidence suggests that implementation and enforcement remain suboptimal because of inadequate infrastructure, insufficient funding, limited staff training, weak regulatory oversight, and poor compliance with established waste management protocols⁶. (Awodele et al., 2016).

Research conducted in various parts of Nigeria has documented persistent challenges in biomedical waste management. Okechukwu⁷ reported that although healthcare workers in Abuja demonstrated awareness of biomedical waste segregation protocols, actual compliance remained low due to inadequate availability of color-coded bins and PPE. Similarly, Sabo et al.⁸ reported that although primary healthcare workers in Gwadabawa Local Government Area of Sokoto State demonstrated awareness of biomedical waste management, compliance with recommended waste management practices was suboptimal, underscoring the need for continuous training, adequate

resources, and stronger institutional support. Ezeoke et al.⁹ reported that although healthcare workers at the University of Nigeria Teaching Hospital, Enugu, had good knowledge of healthcare waste management, appropriate waste management practices were poor, highlighting the need for regular training and continuous supervision. These findings suggest that while knowledge may be relatively adequate, translating knowledge into practice remains a major challenge.

Healthcare workers constitute the cornerstone of biomedical waste management systems because they generate, segregate, handle, transport, and dispose of waste during routine healthcare activities. Their knowledge, attitudes, and practices significantly influence the effectiveness of waste management programs. According to the Knowledge-Attitude-Practice (KAP) framework, healthcare workers who possess adequate knowledge and positive attitudes toward biomedical waste management are more likely to engage in safe waste handling practices. Conversely, inadequate knowledge, negative attitudes, and poor institutional support may result in unsafe behaviors that increase occupational and environmental risks.

Occupational hazards associated with poor biomedical waste management are extensive and include needle-stick injuries, exposure to infectious agents, chemical toxicity, respiratory complications, and psychosocial stress. Needle-stick injuries remain among the most common occupational hazards experienced by healthcare workers globally. Exposure to contaminated sharps places healthcare personnel at increased risk of acquiring blood-borne infections, particularly hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV). Improper segregation, handling, and disposal of sharps significantly increase the likelihood of occupational exposure and subsequent disease transmission^{1,10} (World Health Organization [WHO], 2020; Bouya et al., 2020). In Nigeria, poor segregation practices and inadequate availability of puncture-

resistant containers have been linked to increasing rates of sharps-related injuries among healthcare workers.

Beyond occupational health concerns, ineffective biomedical waste management has significant environmental implications. Open dumping, uncontrolled burning, and poorly managed incineration systems release hazardous pollutants into air, soil, and water sources. Such practices contribute to environmental degradation, ecosystem disruption, and community exposure to toxic substances. Consequently, biomedical waste management is increasingly recognized as a critical component of environmental sustainability and the achievement of Sustainable Development Goals (SDGs), particularly those related to health, sanitation, and responsible consumption and production.

Training and capacity building have been identified as essential strategies for improving biomedical waste management among healthcare workers. Studies consistently demonstrate that healthcare workers who receive structured training are more likely to adhere to waste segregation protocols, utilize PPE appropriately, and comply with institutional guidelines. Furthermore, training programs contribute to behavior change by reinforcing positive attitudes and strengthening accountability regarding waste management responsibilities. However, training alone may not be sufficient unless accompanied by adequate infrastructure, supervision, and institutional commitment.

Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi, serves as a major tertiary healthcare institution in southeastern Nigeria. The hospital provides specialized healthcare services and functions as a teaching and research center, generating substantial quantities of biomedical waste from clinical, laboratory, and academic activities. Given the volume and diversity of waste generated within the institution, effective biomedical waste management is essential for safeguarding healthcare workers, patients, and the surrounding

environment. Despite the importance of this issue, there remains limited empirical evidence regarding healthcare workers' knowledge and biomedical waste management practices within the institution. This study was therefore conducted to assess healthcare workers' knowledge regarding biomedical waste management and evaluate biomedical waste segregation and disposal practices at NAUTH, Nnewi. Findings from this study are expected to contribute to the evidence base required for designing targeted interventions, strengthening institutional policies, and improving compliance with biomedical waste management standards within healthcare settings.

Study Aims

The study aimed to determine the knowledge of health workers regarding biomedical waste management and biomedical waste management practices among health workers at Nnamdi Azikiwe University Teaching Hospital, Nnewi.

MATERIALS AND METHODS

Study Design

The study adopted a descriptive cross-sectional survey design. This design was considered appropriate because it enabled the assessment of healthcare workers' knowledge and biomedical waste management practices at a single point in time. Cross-sectional studies are widely used in public health research to investigate associations between knowledge, attitudes, and practices and to provide baseline information for intervention planning.

Study Area

The study was conducted at Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi, Anambra State, Nigeria. NAUTH is a federal tertiary healthcare institution that serves as a referral center for the southeastern region of Nigeria. The hospital comprises several departments including internal medicine, surgery, obstetrics and gynecology, pediatrics, laboratory services, pharmacy units, and nursing departments.

The institution also functions as a teaching hospital for undergraduate and postgraduate healthcare training.

Study Population

The target population consisted of healthcare workers directly or indirectly involved in biomedical waste generation and handling. These included doctors, nurses, laboratory scientists, pharmacists, cleaners, sanitary officers, and waste handlers. According to hospital records, the estimated workforce relevant to biomedical waste management activities was approximately 2,700 personnel.

Sample Size Determination

The sample size was calculated using Yamane's formula for finite populations, resulting in a minimum sample size of 255 respondents. This sample size was considered adequate for ensuring representative participation across different professional categories within the hospital.

Sampling Technique

A stratified random sampling technique was employed. Healthcare workers were first stratified according to professional categories, including doctors, nurses, laboratory personnel, pharmacists, and waste

handlers. Proportionate allocation was then used to determine the number of respondents selected from each category, after which simple random sampling was applied to select participants. This approach minimized sampling bias and ensured adequate representation of all professional groups.

Statistical Analysis

Statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 25 for analysis. Descriptive statistics of frequency and percentage means was used to summaries demographic variables, knowledge variables and practices. Inferential statistics using Chi-square test examined associations between knowledge and practices, and between professional category and practices.

RESULTS

This section presents the findings obtained from the analysis of data collected from 255 health workers at Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi.

Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of respondents are presented in Table 1.

Table 1: Socio-Demographic Characteristics of Respondents (n = 255)

Variable	Category	Frequency (f)	Percentage (%)
Age (Years)	18–25	45	17.6
	26–35	98	38.4
	36–45	62	24.3
	46–55	35	13.7
	56 and above	15	6.0
Gender	Male	102	40.0
	Female	153	60.0
Professional Category	Doctor	55	21.6
	Nurse/Midwife	90	35.3
	Laboratory Scientist/Technician	40	15.7
	Pharmacist	25	9.8
	Cleaner/Sanitary Officer	30	11.8
	Others	15	5.8
Years of Experience	Less than 1 year	30	11.8
	1–5 years	105	41.2
	6–10 years	75	29.4
	More than 10 years	45	17.6
Educational Qualification	SSCE/WAEC	20	7.8
	OND/NCE	25	9.8

	B.Sc./HND	80	31.4
	MBBS/B.NSc./Pharm.D	105	41.2
	M.Sc./Ph.D.	25	9.8

Table 1 shows that the majority of respondents were aged 26–35 years (38.4%), followed by those aged 36–45 years (24.3%). Respondents aged 56 years and above constituted the smallest proportion (6.0%). Female respondents accounted for 60.0% of participants, while males constituted 40.0%. Regarding professional categories, nurses and midwives represented the largest group (35.3%), followed by doctors (21.6%) and laboratory scientists/technicians (15.7%). Most respondents had between one and five years of work experience (41.2%), while 17.6% had more than ten years of experience. Concerning educational qualifications, 41.2% possessed professional degrees

(MBBS, B.NSc., or Pharm.D), while 31.4% held B.Sc. or HND qualifications. These findings indicate that respondents were generally well educated and professionally trained, suggesting a workforce capable of understanding and implementing biomedical waste management protocols.

Knowledge of Biomedical Waste Management among Respondents

Respondents' knowledge regarding biomedical waste management was assessed using questions on training, responsibility for waste management, awareness of health risks, color coding, and appropriate disposal procedures.

Table 2: Knowledge of Biomedical Waste Management among Respondents (n = 255)

Variable	Response	Frequency (f)	Percentage (%)
Received Formal training	Yes	165	64.7
	No	90	35.3
BMWM responsibility	Everyone	215	84.3
	Cleaners only	40	15.7
Correct disposal of used syringes	Sharp-proof container	230	90.2
	Recapping/Breaking	25	9.8
Awareness of health hazards associated with BMWM	Yes	240	94.1
	No	15	5.9
Knowledge of colour-coded waste segregation system	Yes	195	76.5
	No	60	23.5

Table 2 reveals a generally high level of knowledge regarding biomedical waste management among respondents. 64.7% had received formal training on biomedical waste management, while 35.3% had never received such training. 84.3% correctly identified biomedical waste management as the responsibility of all healthcare workers rather than cleaners alone. Furthermore, 90.2% correctly identified puncture-resistant sharps containers as the recommended method for syringe disposal. Most respondents (94.1%) were aware of the health hazards associated with poor biomedical waste management, indicating a

high level of awareness regarding occupational and environmental risks. Knowledge of color-coded segregation systems was slightly lower, with 76.5% demonstrating correct understanding. This finding suggests that although general awareness is high, some technical aspects of biomedical waste management require reinforcement through additional training and supervision.

Biomedical Waste Segregation and Disposal Practices among Respondents

Respondents' biomedical waste segregation and disposal practices were evaluated

through questions on waste segregation frequency, reporting of injuries, final disposal methods, and use of safety procedures.

Table 3: Biomedical Waste Segregation and Disposal Practices among Respondents. (n = 255)

Variable	Response	Frequency (f)	Percentage (%)
Frequency of waste segregation	Always	140	54.9
	Sometimes	95	37.3
	Rarely/Never	20	7.8
Experienced needle-stick injury	Yes	100	39.2
	No	155	60.8
Reporting of injury (n = 100)	Reported	40	40.0
	Not Reported	60	60.0
Knowledge of final disposal method	Yes	180	70.6
	No	75	29.4
Routine use of PPE during waste handling	Yes	190	74.5
	No	65	25.5

Table 3 shows that slightly more than half of respondents (54.9%) reported always segregating biomedical waste according to established guidelines. Approximately 37.3% practiced segregation occasionally, while 7.8% rarely or never segregated waste appropriately.

The prevalence of needle-stick injuries among respondents was notable, with 39.2% reporting previous exposure. Alarming, only 40.0% of affected respondents officially reported such injuries, while 60.0% failed to report incidents, potentially increasing risks of untreated occupational exposure.

Regarding disposal methods, 70.6% correctly identified the hospital's final waste disposal method, while 29.4% demonstrated inadequate knowledge. Most respondents

(74.5%) reported consistent use of personal protective equipment during waste handling, although approximately one-quarter failed to use PPE regularly.

These findings suggest that while biomedical waste management practices are generally acceptable, substantial gaps remain in injury reporting, PPE compliance, and consistent waste segregation.

Observed Biomedical Waste Management Infrastructure and Practices

In addition to self-reported responses, an observational checklist was used to evaluate existing biomedical waste management infrastructure and compliance within hospital departments.

Table 4: Observed Biomedical Waste Management Infrastructure and Practices

Observational Indicator	Compliance (%)
Identification and use of colour-coded bins	50.2
Knowledge of needle-stick injury procedures	49.8
Appropriate use of sharps containers	47.1
Staff responsibility toward waste management	45.5
Careful handling of biomedical waste	43.9
Appropriate use of PPE	41.6
Availability of waste collection containers	40.8
Proper waste labeling and signage	38.4
Waste storage facilities	36.9
Chemical waste disposal procedures	32.5

Table 4 presents observational findings regarding biomedical waste management infrastructure and practices within NAUTH. The highest compliance was observed in the

use of color-coded waste bins (50.2%) and knowledge of needle-stick injury procedures (49.8%).

The use of sharps containers was satisfactory in many departments (47.1%), while staff responsibility toward waste management scored 45.5%. Compliance with PPE use was relatively moderate at 41.6%.

However, weaknesses were identified in waste storage facilities, waste labeling systems, and chemical waste disposal procedures. These deficiencies suggest that although healthcare workers possess adequate knowledge, infrastructural limitations may hinder effective implementation of biomedical waste management guidelines.

The observational findings therefore corroborate questionnaire responses indicating a gap between knowledge and actual practice.

Relationships Between Selected Variables and Biomedical Waste Management Practices

Inferential statistical analysis was conducted using Chi-square test to determine statistically significant relationships between knowledge of Biomedical Waste Management Practices and the level of practice; and between professional category and the level of practice.

Table 5: Relationship between Knowledge and Biomedical Waste Management Practices

Variables	χ^2	p-value
Knowledge vs Practice	14.82	0.002
Professional Category vs Practices	12.56	0.041

The Chi-square test revealed a statistically significant relationship between knowledge and biomedical waste management practices ($\chi^2 = 14.82$, $p = .002$). Since the p-value was less than the 0.05 level of significance, the null hypothesis was rejected. This finding indicates that healthcare workers with higher knowledge levels were significantly more likely to engage in appropriate biomedical waste management practices. The result also revealed a statistically significant association between professional category and biomedical waste management practices ($\chi^2 = 12.56$, $p = .041$). This indicates that biomedical waste management practices differed significantly among healthcare worker categories. Differences may be attributable to varying levels of training, professional responsibilities, frequency of waste exposure, and institutional roles.

DISCUSSION

The present study assessed healthcare workers' knowledge of biomedical waste management (BMWM) and evaluated biomedical waste management practices at Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi. The findings provide important insights into the strengths and gaps in biomedical waste management

within a tertiary healthcare institution and contribute to the growing body of evidence on healthcare waste management in Nigeria and other low- and middle-income countries (LMICs).

The study revealed that the majority of respondents were young adults aged between 26 and 35 years, accounting for 38.4% of participants. This finding suggests that the workforce at NAUTH is predominantly composed of early-career professionals who are actively engaged in clinical and support services. Younger healthcare workers may be more receptive to modern biomedical waste management guidelines and institutional training programs because of recent professional education and exposure to current healthcare standards. Female respondents constituted 60.0% of the study population, reflecting the predominance of women in nursing and allied healthcare professions. Similar gender distributions have been reported in studies conducted among healthcare workers in Nigeria, Ethiopia, and Bangladesh, where females represented a substantial proportion of the healthcare workforce^{5,11} (Mitiku et al., 2022; Islam et al., 2025). Nurses and midwives formed the largest professional category in the study. This finding is unsurprising

because nurses typically constitute the largest healthcare workforce group and are directly involved in patient care activities that generate biomedical waste. Their prominent role in waste generation and handling underscores the importance of ensuring adequate knowledge and compliance with biomedical waste management protocols. The majority of respondents possessed tertiary-level education, including professional degrees such as MBBS, Bachelor of Nursing Science (B.NSc.), and Doctor of Pharmacy (Pharm.D). High educational attainment among respondents is expected to facilitate comprehension of biomedical waste management principles and increase adherence to recommended practices. However, education alone may not necessarily translate into safe practices unless supported by institutional infrastructure and continuous training.

One of the primary aims of this study was to determine healthcare workers' knowledge regarding biomedical waste management. The findings demonstrated generally high levels of knowledge among respondents. Approximately two-thirds (64.7%) had received formal training on biomedical waste management, while a substantial majority correctly identified biomedical waste management as the responsibility of all healthcare workers rather than cleaners alone. The high level of awareness observed in this study is consistent with findings reported by Ezeoke et al.⁹ who found that healthcare workers in Enugu State possessed good knowledge regarding biomedical waste segregation and disposal procedures. Similarly, Diwan et al.¹² reported high levels of biomedical waste management knowledge among healthcare workers in India following regular institutional training programs. The finding that 90.2% of respondents correctly identified puncture-resistant sharps containers as the recommended disposal method for used syringes is particularly encouraging. Improper disposal of sharps remains one of the leading causes of occupational injuries among healthcare

workers worldwide. Adequate knowledge regarding sharps disposal therefore plays a crucial role in reducing the risk of needle-stick injuries and blood-borne infections. Furthermore, more than 94% of respondents demonstrated awareness of health hazards associated with biomedical waste exposure. This finding indicates widespread recognition of the occupational and environmental risks associated with poor biomedical waste management. Comparable findings have been reported by Woromogo et al.¹³ who observed high awareness of biomedical waste hazards among healthcare workers in Cameroon. Despite these encouraging findings, gaps remained in respondents' understanding of technical aspects of biomedical waste management, particularly color-coded waste segregation systems. Approximately one-quarter of respondents demonstrated inadequate knowledge of color coding. Similar deficiencies have been reported in previous studies conducted in Nigeria and Ethiopia, suggesting that healthcare workers often possess general knowledge of biomedical waste management while lacking detailed understanding of segregation protocols⁵. The observed knowledge gaps highlight the need for regular refresher training programs focusing on practical aspects of biomedical waste management, including waste categorization, segregation, transportation, treatment, and disposal.

The second aim of this study was to assess biomedical waste management practices in the form of waste segregation and disposal practices among healthcare workers. Although respondents generally demonstrated satisfactory knowledge, the findings revealed notable deficiencies in practical implementation. Only 54.9% of respondents reported always segregating biomedical waste according to recommended guidelines. While this finding suggests moderate compliance, it also indicates that nearly half of the workforce fails to consistently adhere to segregation protocols. Effective waste segregation is the foundation of biomedical waste management because it

prevents contamination of general waste streams and facilitates appropriate treatment and disposal. Chisholm et al.⁴ concluded that healthcare facilities in many LMICs continue to struggle with proper waste segregation because of inadequate infrastructure, weak enforcement mechanisms, and insufficient training. One of the most concerning findings of this study was the high prevalence of needle-stick injuries among healthcare workers. Approximately 39.2% of respondents reported experiencing at least one needle-stick injury during their professional practice. This finding is consistent with previous studies indicating that occupational exposure to sharps remains a major challenge in healthcare settings. Bouya et al.¹⁰ reported that healthcare workers exposed to needle-stick injuries face increased risks of hepatitis B, hepatitis C, and HIV infection. Similarly, Ogoina et al.¹⁴ reported that 44.7% of healthcare workers in two tertiary hospitals had experienced needle stick injuries, with house officers and nurses being the most affected occupational groups. Under-reporting of occupational exposures limits access to post-exposure prophylaxis, counseling, and medical monitoring, thereby increasing the likelihood of adverse health outcomes. Similar patterns of underreporting have been documented in several African healthcare settings, where stigma, fear of blame, lack of awareness, and inadequate reporting systems contribute to poor incident documentation. The study also found that approximately three-quarters of respondents routinely used personal protective equipment (PPE) while handling biomedical waste. Although this level of compliance is encouraging, it falls short of WHO recommendations that advocate universal PPE use during waste handling activities. The remaining quarter of respondents who reported inconsistent PPE use represent a significant occupational health concern. The observational assessment provided objective evidence regarding biomedical waste management practices and infrastructure within the hospital environment. The findings revealed

moderate compliance with several key indicators, including the use of color-coded bins, sharps containers, and knowledge of needle-stick injury procedures. The availability and utilization of color-coded bins indicate institutional efforts to support waste segregation. Color-coded systems are internationally recognized as essential components of biomedical waste management because they facilitate waste identification and reduce cross-contamination. The observed compliance level is consistent with findings reported by WHO¹, which emphasizes color coding as a critical element of healthcare waste management systems. However, the observational assessment also identified important infrastructural deficiencies. Compliance with PPE use, waste labeling, waste storage, and chemical waste disposal procedures was relatively low. These deficiencies may undermine the effectiveness of biomedical waste management programs even when healthcare workers possess adequate knowledge. Previous studies have highlighted the importance of institutional infrastructure in promoting compliance with biomedical waste management guidelines. Chisholm et al.⁴ observed that healthcare facilities lacking adequate infrastructure often experience lower compliance rates despite having knowledgeable staff. Similarly, Niman et al.¹⁵ demonstrated that governance quality and infrastructural support significantly influence biomedical waste management outcomes. The findings therefore suggest that improving biomedical waste management requires not only staff training but also sustained investments in infrastructure, equipment, and institutional oversight.

The study revealed a statistically significant relationship between healthcare workers' knowledge and biomedical waste management practices ($\chi^2 = 14.82$, $p = .002$). This finding indicates that respondents with higher knowledge levels were more likely to engage in safe waste management practices. The result supports the Knowledge-Attitude-

Practice (KAP) model, which proposes that knowledge serves as a foundation for behavior change and compliance with health-related practices. Similar findings have been reported by Ezeoke et al.⁹, Mitiku et al.⁵ and Diwan et al.¹², all of whom found significant associations between knowledge and compliance with biomedical waste management standards. This finding reinforces the importance of educational interventions and continuous professional development programs aimed at improving healthcare workers' understanding of biomedical waste management principles.

The significant association between professional category and biomedical waste management practices indicates that compliance varies across different healthcare professions. Differences in professional training, job responsibilities, and frequency of waste exposure may explain these variations. For example, nurses and laboratory personnel are typically more involved in daily waste handling activities than physicians, which may influence their level of compliance. Similarly, cleaners and waste handlers may face unique challenges related to resource availability and training opportunities. This finding underscores the importance of profession-specific training programs tailored to the responsibilities and exposure risks of different categories of healthcare workers.

The findings of this study have several implications for healthcare administration, occupational health, environmental management, and policy development. First, healthcare institutions should prioritize regular biomedical waste management training programs for all categories of staff. Such programs should emphasize practical aspects of waste segregation, sharps disposal, injury reporting, and PPE utilization. Second, healthcare facilities should strengthen occupational health systems to ensure timely reporting, documentation, and management of needle-stick injuries and other occupational exposures. Third, hospital administrators should invest in biomedical waste management infrastructure, including

color-coded bins, sharps containers, PPE supplies, waste storage facilities, and environmentally sound disposal technologies. Finally, policymakers and regulatory agencies should strengthen monitoring and enforcement mechanisms to ensure compliance with national healthcare waste management guidelines.

Limitations of the Study

Despite its strengths, the study has some limitations. The cross-sectional design limits causal inference and self-reported practices may be subject to social desirability bias.

CONCLUSION

The study demonstrated that healthcare workers at Nnamdi Azikiwe University Teaching Hospital possess generally good knowledge regarding biomedical waste management. Most respondents understood the health risks associated with biomedical waste and demonstrated awareness of recommended waste handling procedures. Despite satisfactory knowledge levels, practical compliance remained suboptimal. Significant proportions of respondents reported inconsistent waste segregation, inadequate injury reporting, and irregular use of personal protective equipment. Observational findings further revealed infrastructural deficiencies that may hinder effective implementation of biomedical waste management guidelines. The study established significant relationships between knowledge and professional category; and biomedical waste management practices, emphasizing the importance of educational, behavioral, and institutional factors in promoting compliance. Improving biomedical waste management within healthcare facilities therefore requires a multifaceted approach involving continuous training, infrastructure development, effective supervision, occupational health support systems, and strengthened policy implementation.

Declaration by Authors

Ethical Approval: Ethical approval for the study was obtained from the Research Ethics

Committee, Faculty of Health Sciences, Nnamdi Azikiwe University. Participation was voluntary, informed consent was obtained from all respondents, and confidentiality of information was maintained throughout the study.

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