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Original Article

Knowledge, Attitude, and Practices on Biomedical Waste Management Among Healthcare Workers at Kibungo Level Two Teaching Hospital, Rwanda

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Abstract

Background: Biomedical waste (BMW) poses health and environmental risks, especially in low- and middle-income countries like Rwanda, where resources and training are limited. This study assessed healthcare workers' knowledge, attitudes, and practices (KAP) regarding biomedical waste management at Kibungo Level Two Teaching Hospital in Rwanda.

Methods: A cross-sectional quantitative study was conducted among 158 healthcare workers using a self-administered questionnaire. Participants were selected through stratified random sampling. Data were analysed using SPSS version 25, employing descriptive and inferential statistics.

Results: 58.23% of participants had moderate to high knowledge of biomedical waste (BMW) management, while 13.27% had limited awareness. The majority (84.25%) held positive attitudes. Regarding practices, 26.18% demonstrated good practices, 54.39% fair, and 19.43% poor. Participants aged 25–34 were less likely to manage BMW effectively compared to those aged ≥30 (AOR = 0.374, 95% CI = 0.14–0.991), and females were less likely than males (AOR = 0.53, 95% CI = 0.4–0.73). Better knowledge was observed among healthcare professionals, particularly nurses and allied health workers, and those with longer professional experience.

Conclusion

The study reveals disparities in BMW management practices influenced by age, gender, profession, and experience. Younger individuals and females are less likely to manage BMW effectively, while healthcare professionals and those with more experience exhibit higher levels of knowledge and better practices. Targeted training and policy interventions are needed to enhance BMW management across all demographic groups.

Keywords: Biomedical Waste Management, Knowledge, Attitude, and Practices, Healthcare Workers, Infection Control, Kibungo Hospital

Introduction

Biomedical waste (BMW) refers to waste generated during the diagnosis, treatment, or immunization of humans or animals and poses significant health and environmental risks if not managed properly (M et al., 2024). Familiar sources include hospitals, clinics, laboratories, and research facilities (Bansod & Deshmukh, 2023). Proper BMW management is essential to prevent infections, injuries, and contamination of the environment (Capoor & Parida, 2021). Globally, improper disposal of biomedical waste has led to serious public health concerns, such as outbreaks of diseases from reused syringes and injuries to waste pickers. For instance, in Afghanistan in 2018, syringes from a polio vaccination campaign were discarded in a landfill, where individuals scavenging for recyclable materials were injured and exposed to potential infections (Nuripuoh et al., 2022). Similarly, in India in 2019, unsafely disposed healthcare waste contributed to the circulation of reused syringes on the black market, resulting in a hepatitis B outbreak that affected approximately 240 people (Borowy, 2020).

Low- and middle-income countries (LMICs) often face significant challenges in managing biomedical waste (BMW) due to inadequate infrastructure, limited resources, and insufficient training. In Africa alone, an estimated 2 million tons of biomedical waste are generated annually, yet only about 20% is managed safely. Contributing factors include underfunded healthcare systems, poor staff training, and limited awareness of existing policies and legislation related to medical waste management (Chisholm et al., 2021). Effective BMW management requires that healthcare workers understand and apply color-coded segregation systems and adhere to standardized disposal procedures. They must know the associated risks of poor waste management and recognize the importance of complying with biomedical waste management (BMWM) guidelines. Most importantly, they should implement these practices consistently within their facilities (Aravind et al., 2023).

However, studies across countries have identified persistent gaps in healthcare workers' knowledge, attitudes, and practices (KAP) regarding BMWM. In Karnataka, India, a study revealed that only 43% of public healthcare staff could correctly sort and dispose of medical waste. Younger staff, males, lab technicians, pharmacists, and support personnel performed particularly poorly, while doctors, though aware of BMWM regulations, struggled with specific practices like sorting and color-coding. Despite these shortcomings, healthcare workers generally held a positive attitude towards proper waste disposal (Golandaj & Kallihal, 2021).

In the Philippines, a KAP study among nurses and medical technologists found that although participants had a reasonable understanding of some disposal procedures, both groups faced challenges in handling human tissue and medication waste. Interestingly, nurses demonstrated better practices in managing certain waste types, whereas medical technologists performed better in disposing of human tissue (Aldeguer et al., 2021). Similarly, research conducted in Nigeria at Yusuf Dantaho Memorial Hospital highlighted a disconnect between knowledge and practice. While nurses, doctors, and lab staff exhibited some awareness of proper disposal techniques, ward attendants and cleaners had the least knowledge. Even those with moderate knowledge failed to follow correct procedures consistently (Musa et al., 2023).

A study by (Letho et al., 2021) further revealed that although most healthcare workers (74.4%) acknowledged the importance of BMWM and use of personal protective equipment (98.2%), their understanding of specific practices such as storage times (37.6%) and waste segregation (61.3%) was limited. This led to widespread improper waste handling, including incorrect transport and segregation (Letho et al., 2021). Other regional studies reinforce these findings. For example, Ethiopian hospitals demonstrated poor waste separation at the source and inadequate treatment practices (Debere et al., 2013). In Kenya, administrators' lack of formal training programs and lack of prioritization contributed to low awareness and poor disposal practices among staff (Nkonge Njagi et al., 2012). In South Africa, Makhura et al. (2016) also reported deficient knowledge of medical waste management among healthcare professionals (Makhura et al., 2016).

Rwanda has made notable advancements in healthcare service delivery; however, biomedical waste management faces challenges. A study conducted in a district hospital revealed that while healthcare personnel demonstrated good knowledge regarding waste management protocols, actual practices were often inadequate (Rutayisire et al., 2019). Moreover, awareness and training among healthcare workers varied significantly, indicating potential gaps in knowledge, attitudes, and practices related to biomedical waste management. While Rwanda has made notable strides in healthcare delivery, challenges in effective biomedical waste management persist. Given the limited evidence on healthcare workers' knowledge, attitudes, and practices regarding biomedical waste, this study focuses on assessing these factors at Kibungo Level Two Teaching Hospital. The findings aim to guide targeted training and inform policy strategies for improving biomedical waste management in Rwanda.

Methods

Study design and setting

This study employed a quantitative cross-sectional design conducted at Kibungo Level Two Teaching Hospital, an urban government referral hospital located in Ngoma District, Eastern Province, Rwanda. The hospital serves

a population of approximately 404,048 and has a capacity of 312 beds, offering specialized services across several districts.

Study Population

The target population included 260 healthcare workers, such as doctors, nurses, midwives, allied health professionals like lab scientists, anaesthetists, physiotherapists, and cleaners with at least six months of experience at the hospital. Workers with less than six months of experience or those not involved in biomedical waste management were excluded.

Sample size

Slovin's formula was used to calculate the sample size, based on a confidence level of 95% and a margin of error (e) of 0.05. This formula is commonly applied when working with a finite population (Adam, 2020). Given a total population of 260 healthcare workers at Kibungo Hospital, the sample size was calculated as follows:

$$n = \frac{N}{1 + N(e)^2}$$

Where

n: sample size

N: target population (260)

e: acceptable sampling error (0.05)

Calculation becomes:

$n = \frac{260}{1+260(0.05)^2}$= 157.57

n=158 population sample

Stratum-wise Sample Size Distribution Based on Proportional Allocation

Stratum	Total Population Size (N)	Proportion of Each Stratum: The population in the stratum is divided by the total population	Sample Size per Stratum: Sample size multiplies the proportion of each stratum
Nurses	**99**	**0.3808**	**60**

Doctors	**20**	**0.0769**	**12**
Midwives	**26**	**0.1**	**16**
Cleaners	**80**	**0.3077**	**49**
Allied Health Workers	**35**	**0.1346**	**21**
Total			**158**

Sampling Technique

The hospital setting was selected purposively due to its relevance to the study objectives. A stratified random sampling technique was employed to obtain a representative sample across different professional categories within the hospital. This method involves dividing the population into homogeneous subgroups (strata) based on specific characteristics and selecting a random sample from each stratum (Afful-Dadzie et al., 2023). In this study, the participants were grouped into five strata regarding their jobs: medical doctors, nurses, midwives, Allied health workers (anesthetists, laboratory scientists, dental therapists, physiotherapists, Radiologists, and ophthalmology technicians), and cleaners. A systematic random sampling was used to select from the list of each group according to their availability due to their shift.

1. **Sampling Interval (k):**

The sampling interval was calculated using the formula:

$K = \frac{N}{n} = \frac{260}{158} = 1.65 = k \approx 2$

Where:

N = Total population (260)

n = Desired sample size (158)

2. Random Starting Point:

A random starting point between 1 and the sampling interval (k) was selected. In this study, the starting point was **1**.

3. **Selection of Participants:**

From the random starting point, every second individual in the list within each stratum was selected until the

required sample size for that stratum was reached. For instance, 60 nurses were selected and administered the questionnaire.

Data Collection Instrument

Data were collected at Kibungo Level Two Teaching Hospital using a structured, self-administered questionnaire adapted from a validated study (Olaifa et al., 2018). The tool included closed-ended questions on demographics, and healthcare workers' knowledge, attitudes, and practices regarding biomedical waste management. The original tool was in English and translated in Kinyarwanda to facilitate some participants to understand questions. Participants were approached individually at their workstations and completed the questionnaire during their shifts. Informed consent was obtained prior to participation.

Data Collection Procedure

Data collection began after receiving approval from the MKU/Rwanda Institutional Review Board and permission from Kibungo Level Two Teaching Hospital management. The researcher collected data for one month in 2024, meeting participants at their workstations. The study's purpose and significance were explained, and informed consent was obtained. Questionnaires were administered individually, allowing participants to complete them independently. Questions were welcomed during completion, and privacy and confidentiality were maintained, with participants identifying themselves using only their initials.

Reliability and validity of instruments

A previously validated questionnaire was utilized to ensure reliability and validity in assessing healthcare workers' knowledge, attitudes, and practices regarding biomedical waste management at Kibungo Level Two Teaching Hospital. Reliability was confirmed through internal consistency measures, with Cronbach's alpha scores of 0.75 for knowledge, 0.83 for attitude, and 0.86 for practice. Validity was established through expert review, alignment with Rwanda's biomedical waste management guidelines, and a pilot test involving 10 healthcare workers. These steps ensured the tool accurately and consistently measured the intended KAP constructs in the study context.

Data Analysis

Data were analyzed using SPSS version 25. Descriptive statistics summarized participants' demographics and assessed their knowledge, attitudes, and practices (KAP) regarding biomedical waste management. The questionnaire included four sections:

Section A: Collected demographic data (age, gender, marital status, education, and job designation).

Section B: Assessed knowledge using 16 items on a 5-point scale, categorized as high (4–5), moderate (3), or low (0–2), based on Kumar et al. (2015).

Section C: Measured attitudes through four Likert-scale items, with reverse scoring for negative items. A total score ≥3 indicated a positive attitude.

Section D: Evaluated practices with 22 items, categorized as good (15–22), fair (11–14), or poor (≤10) based on the proportion of correct practices reported.

Ethical Consideration

Ethical standards were followed in conducting this study to ensure the integrity and protection of all participants. Before data collection, approval was obtained from the Institutional Ethical Review Board (IRB), which reviewed and approved the study protocol to ensure compliance with ethical guidelines, including respect for participants' rights, confidentiality, and safety. The IRB emphasized the importance of informed consent, requiring that all participants be fully informed about the study's purpose, procedures, potential risks, and benefits before participating. Consent forms were developed following IRB guidelines and signed by participants to confirm their voluntary involvement. The study also adhered to strict confidentiality measures to protect participant anonymity, ensuring no identifying information was disclosed or misused. In addition, the study followed the IRB's guidelines for minimizing potential harm, providing clear procedures for addressing any concerns or discomfort that participants might experience. Throughout the research process, the IRB continued to monitor the study to ensure that ethical standards were upheld and that participant protection was prioritized.

Results

Socio-demographic characteristics of respondents

Table 1 summarizes the demographic Characteristics of Participants. Among the 158 participants, the majority (57.59%) were aged 25–34, indicating a predominantly young and professionally active group. Females comprised 57.59% of the sample, slightly outnumbering males (42.41%). Most respondents were single (56.33%), followed by married (39.87%) and divorced (3.80%). Regarding education, 63.92% had tertiary-level qualifications, reflecting a well-educated sample. Primary and secondary education levels accounted for 24.05% and 12.03%, respectively. Most participants were relatively new to the workforce, with 32.91% having 1–3 years of experience and 29.11% having 6 months to 1 year. Fewer respondents had 3–6 years (18.35%) or over 6 years

(19.62%) of experience. Regarding professional roles, nurses represented the largest group (37.97%), while healthcare and non-health professionals accounted for 31.01%, showing a diverse participant profile.

Table 1 Socio-demographic characteristics of respondents in Kibungo Hospital

Study variables	Category	Frequency (F)	F %
Age of respondent	18-24	31	19.62
	25-34	91	57.59
	>35	36	22.78
Gender	Male	67	42.41
	Female	91	57.59
Marital status	Single	89	56.33
	Married	63	39.87
	Divorced	6	3.8
Education level	Primary	38	24.05
	Secondary	19	12.03
	Tertiary	101	63.92
Working experiences	6 months - 1 year	46	29.11
	>1 years - 3 years	52	32.91
	> 3 years - 6 years	29	18.35
	> 6 years	31	19.62
Designation	Nurse	60	37.97
	Other health professionals	49	31.01
	Non-health professional	49	31.01

Knowledge of Health workers about medical waste

Table 2 presents the frequency and percentage of responses from healthcare workers regarding their knowledge of medical waste identification, handling, and disposal. The majority of respondents demonstrated strong knowledge and awareness about medical waste management. Most (96.20%) could identify medical waste, and 97.47% were familiar with its criteria. Additionally, 94.94% recognized the importance of sorting medical waste during collection, and 97.47% understood why sorting is necessary. A significant proportion of respondents (91.77%) knew the risks of handling medical waste, and 89.24% knew the specific risks. However, only 79.75%

knew the proper disposal procedures for liquid waste, and 81.01% had received formal training on medical waste handling. Knowledge about disposing of expired blood units and human tissue remains was lower, with only 55.06% and 74.68% reporting adequate knowledge. Most (90.51%) knew the color-coding system for medical waste disposal, but fewer (49.37%) knew the correct disposal procedures for expired medicines. Furthermore, while 79.75% disagreed with throwing blood waste into domestic waste, a small minority (20.25%) believed it was acceptable. 62.66% of respondents reported receiving supervision on medical waste handling, but 37.34% did not. Similarly, 77.85% disagreed with disposing of expired medicines in domestic waste, while 22.15% accepted this practice.

Table 2 Respondents' knowledge about medical waste

Study variables	**Category**	**Frequency**	**F %**
Are you able to identify the nature of medical waste?	Yes	152	96.2
	No	6	3.8
Do you know the criteria for identifying medical waste?	Yes	154	97.47
	No	4	2.53
Do you identify the need to sort medical waste during collection?	Yes	150	94.94
	No	8	5.06
Do you know the reason behind sorting medical waste?	Yes	154	97.47
	No	4	2.53
Do you know the reasons why waste should be sorted at the site?	Yes	149	94.3
	No	9	5.7
Are you aware of the risks of dealing with medical waste?	Yes	145	91.77
	No	13	8.23
Do you know the risks associated with medical waste?	Yes	141	89.24
	No	17	10.76
Do you know adequate disposal procedures for liquid waste?	Yes	126	79.75
	No	32	20.25
Have you ever received any formal training on medical waste handling?	Yes	128	81.01
	No	30	18.99
Do you know adequate disposal procedures for expired blood units and by-product waste?	Yes	87	55.06
	No	71	44.94

Do you know adequate disposal procedures for human tissue remains?	Yes	118	74.68
	No	40	25.32
Do you know the color coding of medical waste disposal bags/containers?	Yes	143	90.51
	No	15	9.49
Do you know adequate disposal procedures for expired medicines?	Yes	78	49.37
	No	80	50.63
Is domestic waste not an adequate disposal procedure?	Yes	32	20.25
	No	126	79.75
Do you receive any form of supervision on the way you handle waste	Yes	99	62.66
	No	59	37.34
Do you believe that throwing expired medicine into domestic waste is not an adequate disposal procedure?	Yes	35	22.15
	No	123	77.85

Respondents' attitudes concerning biomedical waste management

Table 3 highlights healthcare workers' attitudes toward biomedical waste management and safety aspects. The survey assessed four variables, with responses categorized as Agree/Strongly Agree, Neutral, or Disagree/Strongly Disagree. A significant portion of respondents (68.35%) disagreed with the statement that waste segregation at the source increases the risk of injury to waste handlers, suggesting they view segregation as safe. However, 31.64% agreed it could increase risk, possibly due to improper sorting or lack of protective measures. Regarding sharps containment, most respondents (75.31%) agreed it is crucial for safe waste management, indicating strong awareness of the risks associated with improper disposal. A large majority (79.11%) agreed that Hepatitis-B immunization helps prevent hospital-acquired infections, though 20.88% disagreed, possibly due to a lack of awareness or underestimation of its importance. On reporting needle stick injuries, 77.85% of respondents agreed that it adds extra work, while 20.88% disagreed, suggesting that most healthcare workers do not find injury reporting burdensome.

Table 3: **Respondents' attitudes concerning biomedical waste management**

Study variables	Agree/ Strongly Agree	Neutral	Disagree/ Strongly Disagree

	n	%	n	%	n	%
Segregation of waste at source increases the risk of injury to waste handlers	50	31.64	0	0	108	68.35
Containment of sharps does not help in the safe management of hospital waste	119	75.31	0	0	39	24.68
Hepatitis-B immunization prevents transmission of hospital-acquired	125	79.11	0	0	33	20.88
Reporting needle stick injuries is an extra burden at work	123	77.85	2	1.26	33	20.88

Respondents' practices concerning Biomedical waste management

Most respondents reported following proper biomedical waste management practices in healthcare facilities. Most (84.18%) sort medical waste during collection, and 87.97% separate sharp and blunt waste. Most respondents (60.76%) use trolleys to transport waste, with 86.08% cleaning the trolleys after each use. Personal protective equipment (PPE) usage is high, with 91.14% of respondents using gloves, goggles, and masks. However, 45.57% feel that there are insufficient personnel to manage the waste effectively.

Using color-coded plastic bags for infectious and non-infectious waste is widely practiced, with 97.06% and 94.85% adherence. However, practices like collecting liquid waste in non-leak-proof bags (44.94%) and improper handling of human tissue remains (46.84%) still pose challenges. Most respondents (82.28%) reported that their hospital has furnaces for waste disposal, but 12.66% noted that hospital visitors are exposed to medical waste. Additionally, 34.18% of respondents stated that waste is sometimes stored in open areas, potentially leading to environmental contamination. While 63.29% of hospitals manage waste internally, 80.38% rely on external services for disposal.

Table 4: Respondents' practices concerning Biomedical waste management

Study variable	Category	Freq	Freq %

Do you sort medical waste during collection?	Yes	133	84.18
	No	25	15.82
Do you separate sharp waste from blunt waste?	Yes	139	87.97
	No	19	12.03
Do you move medical waste using trolleys?	Yes	96	60.76
	No	62	39.24
Do you clean the waste trolley directly after each collection?	Yes	136	86.08
	No	22	13.92
Do you ever use personal protection tools (gloves, safety goggles, face masks) when handling medical waste?	Yes	144	91.14
	No	14	8.86
Do you think the number of people employed to handle waste in the hospital is adequate?	Yes	86	54.43
	No	72	45.57
Do you use special plastic bags to collect medical waste?	Yes	136	86.08
	No	22	13.92
Do you use red plastic bags to collect infectious medical waste?	Yes	132	97.06
	No	4	2.94
Do you use black plastic bags to collect noninfectious medical waste?	Yes	129	94.85
	No	7	5.15
Do you collect liquid waste in bags that prevent leakage?	Yes	87	55.06
	No	71	44.94
Do you collect blood waste in bags that prevent leakage?	Yes	99	62.66
	No	59	37.34
Do you collect human tissue remains in separate bags to prevent leakage?	Yes	84	53.16
	No	74	46.84
Do you collect liquid waste together with other waste?	Yes	34	21.52
	No	124	78.48
Do you collect blood waste together with others in ordinary bags?	Yes	21	13.29
	No	137	86.71
Do you collect human tissue remains together with other wastes in ordinary bags?	Yes	22	13.92
	No	136	86.08
	Yes	29	18.35

Do you collect expired medicines together with other waste?	No	129	81.65
Do you dispose of liquid waste into the sewage system after processing?	Yes	27	17.09
	No	131	82.91
Does the hospital have furnaces for the incineration of medical waste?	Yes	130	82.28
	No	28	17.72
Are hospital visitors exposed to medical waste?	Yes	20	12.66
	No	138	87.34
Do you gather medical waste in open areas within the hospital for temporary storage before being transferred outside the hospital?	Yes	54	34.18
	No	104	65.82
Does the hospital have standard storage facilities for temporarily storing medical waste?	Yes	99	62.66
	No	59	37.34
Does the hospital depend on the city cleaning authority to move and dispose of medical waste outside the hospital?	Yes	58	36.71
	No	100	63.29
Does the hospital dispose of medical waste outside using its vehicles?	Yes	31	19.62
	No	127	80.38

Overall Scores of Knowledge, Attitudes, and Practices of Healthcare Workers Regarding Biomedical Waste Management

Table 5 presents the overall scores of healthcare workers' knowledge, attitudes, and practices related to biomedical waste management at Kibungo Hospital. Knowledge levels were categorized based on a 5-point scale: high (4–5 points), moderate (3 points), and low (0–2 points). The findings revealed that 58.86% of respondents (93 out of 158) had a high level of knowledge, 27.87% (44 respondents) had moderate knowledge, and 13.27% (21 respondents) demonstrated low knowledge, indicating a generally good understanding among most participants but also highlighting some knowledge gaps. In terms of attitudes, most respondents (84.25%) exhibited a positive attitude toward biomedical waste management, while 15.75% had a negative attitude. Attitude scores were based on responses to four items on a 5-point Likert scale, where a score of 3 or more indicated a positive attitude. This suggests that most healthcare workers not only understood the importance of biomedical waste management but also approached it with a constructive mindset. Regarding practices, the study assessed participants' self-reported

actions using 20 items scored as either 1 (Yes) or 0 (No). The results showed that 54.39% (86 participants) had fair biomedical waste management practices, 26.18% (41 participants) demonstrated good practices, and 19.43% (31 participants) had poor practices. While most healthcare workers performed at least adequately, the findings suggest the need for improved practical compliance and consistent reinforcement of safe waste management behaviors.

Table 5: Overall Scores of Knowledge, Attitudes, and Practices of Healthcare Workers Regarding Biomedical Waste Management

Category	Level	Number	Percentage (%)
Knowledge Level	High	93	58.86
	Moderate	44	27.87
	Low	21	13.27
	Total	**158**	**100.00**
Level of Attitudes	Positive (≥ 3 scores)	133	84.25
	Negative (< 3 scores)	25	15.75
	Total	**158**	**100.00**
Biomedical Waste Management Practice	Fair	86	54.39
	Good	41	26.18
	Poor	31	19.43
	Total	**158**	**100.00**

Bivariate Analysis of Respondents' Demographics and Their Knowledge Levels on Biomedical Waste Management

Bivariate analysis using the Chi-square test examined the association between respondents' sociodemographic characteristics and their knowledge of biomedical waste management. The results revealed significant associations between knowledge levels and several variables: age ($P < 0.001$), gender ($P = 0.046$), marital status ($P < 0.001$), work experience ($P = 0.001$), and designation ($P < 0.001$). However, no significant association was found between educational level and biomedical waste management knowledge ($P > 0.05$).

Table 6 Bivariate Analysis of selected demographic characteristics of respondents and biomedical waste management knowledge.

Study Variable	Categories	Biomedical Waste Management Knowledge						
		Low level		Moderate		High level		p-value
		N	%	n	%	n	%	
Age of respondent	18-24	7	22.58	15	48.39	9	29.03	**<0.001**
	25-34	14	15.38	35	38.46	42	46.15	

	>35	7	19.44	13	36.11	16	44.44	
Gender	Male	19	28.36	21	31.34	27	40.3	**0.046**
	Female	10	10.99	47	51.65	34	37.36	
	Single	11	12.36	46	51.69	32	35.96	
Marital status	Married	7	11.11	27	42.86	29	46.03	**<0.001**
	Divorced	2	33.33	3	50	1	16.67	
	Primary	24	63.16	9	23.68	5	13.16	
Education level	Secondary	3	15.79	11	57.89	5	26.32	0.42
	Tertiary	1	0.99	13	12.87	87	86.14	
	6 months - 1 year	15	32.61	20	43.48	11	23.91	
Working	>1 years - 3 years	9	17.31	27	51.92	16	30.77	**0.001**
experiences	> 3 years - 6 years	3	10.34	9	31.03	17	58.62	
	> 6 years	1	3.23	4	12.9	26	83.87	
	Nurse	2	3.33	11	18.33	47	78.33	
Designation	Other health professionals	4	8.16	27	55.1	18	36.73	**<0.001**
	Non-health professional	2	4.08	31	63.27	16	32.65	

Bivariate Analysis of Knowledge and attitudes among the respondents on Biomedical waste Management.

Table 7 presents the relationship between respondents' knowledge levels and overall attitudes, categorized as positive or negative. The Chi-square analysis revealed a statistically significant association between knowledge and attitudes ($\chi^2 = 13.29$, $p = 0.021$). Among those with low knowledge, the majority (69.23%) exhibited negative attitudes, whereas only 7.56% had positive attitudes. Respondents with moderate knowledge displayed a more balanced distribution, though negative attitudes slightly prevailed. In contrast, a substantial majority (74.52%) of highly knowledgeable individuals demonstrated positive attitudes, while only 9.62% held negative views. These findings suggest that higher knowledge levels are significantly associated with more positive attitudes toward biomedical waste management.

Table 7. Relationship between Knowledge and Attitudes among respondents on Biomedical Waste Management.

	Overall scores of Attitudes				Chi-square	*p-value*
	Negative		Positive			
	N	%	N	%		
Knowledge						
Low level	36	69.23	8	7.56		
Moderate	11	21.15	19	17.92	13.29	**0.021**
High level	5	9.62	79	74.52		
Total	52	100	106	100		

Bivariate Analysis of Knowledge Levels and Practices in Biomedical Waste Management

Table 8 presents the association between respondents' knowledge levels and their biomedical waste management practices, categorized as Poor, Fair, or Good. The Chi-square test revealed a highly significant association ($\chi^2 = 23.27$, $p < 0.001$). Among respondents with low knowledge, over half (53.5%) demonstrated poor practices, and only 10.8% showed good practices, highlighting a strong link between low knowledge and poor behaviour. Those with moderate knowledge were mainly associated with fair practices (73.1%), with fewer achieving good (32.4%) or poor practices (25.6%). In contrast, individuals with high knowledge levels predominantly engaged in good practices (56.8%), while only 20.9% had poor practices. These findings indicate that higher knowledge significantly improves biomedical waste management practices.

Table 8. Relationship between knowledge level and practices among the respondents on Biomedical Waste Management

Study variable	Level of Practices						Chi-square	p-value
	Poor		Fair		Good			
	n	%	n	%	N	%		
Knowledge								
Low level	23	53.5	15	19.2	4	10.8		
Moderate	11	25.6	57	73.1	12	32.4	23.27	**<0.001**
High level	9	20.9	6	7.7	21	56.8		
Total	43	100	78	100	37	100		

Bivariate Analysis of attitudes and practices among the respondents on the Biomedical Waste Management

Table 9 presents a cross-tabulation of attitudes and the overall score of biomedical waste management practices, categorized as Poor, Fair, or Good. The Chi-square test results, with a p-value of less than 0.001, indicate a highly significant association between attitudes and practice quality. Among individuals with negative attitudes, 69.2% were associated with poor practices, while only 13.8% demonstrated good practices, showing a clear correlation between negative attitudes and poor practices. In contrast, individuals with positive attitudes exhibited a more favourable distribution. Only 30.8% of those with positive attitudes had poor practices, while 78.4% were linked to good practices. This demonstrates a strong association between positive attitudes and high-quality practices. The Chi-square value of 152.25, with a p-value of <0.001, confirms that attitudes significantly influence the quality of biomedical waste management practices, suggesting that this association is not due to random chance.

Table 9. Relationship between the attitudes and practices among the respondents on Biomedical Waste Management.

Study variable	**Level of Practices**							
	Poor		**Fair**		**Good**		**Chi-square**	***p-value***
	N	**%**	**n**	**%**	**n**	**%**		
Attitudes								
Negative	27	69.2	45	54.9	8	21.6	152.25	**<0.001**
Positive	12	30.8	37	45.1	29	78.4		
Total	39	100	82	100	37	100		

Multivariate Analysis

A binary logistic regression was conducted with categorized practices as the dependent variable. Respondents who did not sort medical waste were coded as 0, while those who sorted biomedical waste were coded as 1. The independent variables included in the logistic regression model were age, gender, marital status, designation, and working experience. The 95% confidence interval and adjusted and crude odds ratios (OR), are presented in Table 12. Univariate logistic regression revealed that all independent variables, except education level, were significantly associated with respondents' knowledge of biomedical waste management. Significant changes in the crude OR were observed when these variables were included in the multivariate model, as shown in Table 10. The results indicated that respondents aged between 25 and 34 years (AOR = 0.374, 95% CI = 0.14-0.991) were less likely to manage biomedical waste compared to those aged 30 years and older. Additionally, females (AOR

= 0.53, 95% CI = 0.4-0.73) were less likely to manage biomedical waste than males. Respondents with a designation in nursing or other health professions were more likely to know about biomedical waste management than those with non-health-related professions. Furthermore, respondents with longer working experience were more likely to know about biomedical waste management than those with minimal experience.

Table 10: Binary logistic regression of practice as a dependent variable (0 = poor practice; 1 = good practice) with demographic factors as predictors.

Study variables	COR	AOR	95% CI	
			Lower	Upper
Respondents age group				
18-24	1.42	1.45	0.41	5.08
25-34	0.29	0.374*	0.14	0.991
>= 35		**Ref**		
Gender				
Male		**Ref**		
Female	0.78	0.53*	0.4	0.73
Marital status				
Single		**Ref**		
Married	1.47*	0.94	0.564	1.56
Divorced	1.58	0.67	0.166	2.72
Designation				
Nurse	2.06*	2.78	1.059	7.31
Other health professionals	0.9	1.17	0.431	3.18
Non-health professional			**Ref**	
Working experiences				
6 months - 1 year			**Ref**	
>1 years - 3 years	2.32*	1.83*	1.296	2.57
> 3 years - 6 years	4.37*	4.19*	2.514	6.97
> 6 years	4.15*	3.94*	1.773	8.74

Multinomial Logistic Regression Analysis of Factors Associated with Biomedical Waste Management Practices

Table 11 presents findings from a multinomial logistic regression analysis exploring factors associated with biomedical waste sorting practices. It compares respondents who sorted biomedical waste every time or sometimes with those who never sorted it. Individuals aged 25-34 years were significantly less likely to sort biomedical waste every time (AOR = 0.74, 95% CI: 0.42–0.91) compared to those aged ≥35 years. However, no significant differences were observed for individuals aged 18-24 years in either the "sort every time" (AOR = 1.45, 95% CI: 0.62–3.38) or "sort sometimes" (AOR = 1.24, 95% CI: 0.53–2.89) categories when compared to those aged ≥35 years. This suggests that younger age groups may adopt waste sorting practices inconsistently or face barriers to full compliance. Gender emerged as a significant factor. Females were less likely to sort biomedical waste every time (AOR = 0.62, 95% CI: 0.35–0.79) or sometimes (AOR = 0.72, 95% CI: 0.44–0.92) compared to males. These findings highlight a gender gap in waste management practices, with males showing higher compliance in consistently sorting waste.

Marital status did not significantly influence biomedical waste sorting practices. Married individuals were no more likely to sort waste every time (AOR = 1.14, 95% CI: 0.89–1.56) or sometimes (AOR = 1.06, 95% CI: 0.81–1.42) compared to single respondents. Similarly, divorced individuals did not show significant differences in either category when compared to singles. This suggests that marital status does not substantially impact waste sorting behaviours. Working experience emerged as a critical determinant of biomedical waste sorting practices. Respondents with 1-3 years of experience were significantly more likely to sort waste every time (AOR = 2.36, 95% CI: 1.45–3.56) or sometimes (AOR = 2.18, 95% CI: 1.32–3.21) compared to those with less than one year of experience. This trend became even stronger for respondents with 3-6 years of experience, who were nearly four times as likely to sort waste every time (AOR = 3.92, 95% CI: 2.48–6.11) and more than three times as likely to sort sometimes (AOR = 3.11, 95% CI: 2.01–5.02). Respondents with more than six years of experience showed the strongest associations, being almost five times as likely to sort waste every time (AOR = 4.68, 95% CI: 2.94–7.54) and four times as likely to sort sometimes (AOR = 4.07, 95% CI: 2.41–6.94) compared to those with less than one year of experience. These findings emphasize the critical role of accumulated experience and familiarity with waste management protocols in promoting consistent sorting behaviours.

Table 11. Multinomial logistic regression analysis of practice as a dependent variable (0 = poor practice; 1 = good practice) with demographic factors as predictors.

Variable	Sorting waste Every Time vs None/rarely	Sorting waste Sometimes vs None/rarely

	AOR	95% CI	AOR	95% CI
Respondents' Age Group				
18–24 years	1.45	0.62-3.38	1.24	0.53-2.89
25–34 years	0.74*	0.42-0.91	0.81	0.47-1.17
≥35 years (Ref)	-	-	-	-
Gender				
Female	0.62*	0.35-0.79	0.72*	0.44-0.92
Male (Ref)	-	-	-	-
Marital Status				
Married	1.14	0.89-1.56	1.06	0.81-1.42
Divorced	0.71	0.35-1.84	0.79	0.41-1.92
Single (Ref)	-	-	-	-
Working Experience				
1–3 years	2.36*	1.45-3.56	2.18*	1.32-3.21
3–6 years	3.92*	2.48-6.11	3.11*	2.01-5.02
>6 years	4.68*	2.94-7.54	4.07*	2.41-6.94
<1 year (Ref)	-	-	-	-

Ref= >Reference group, *=>p -value=0.001, AOR= Adjusted Odds Ratio

Discussion

The study's findings on biomedical waste management knowledge, attitudes, and practices provide valuable insight into factors influencing effective waste handling in healthcare settings. Most respondents demonstrated high levels of knowledge, with many scoring between 80% and 100% of the total possible knowledge score. This is consistent with global literature, such as Rao (2018), which reported high BMWM knowledge among healthcare workers (Rao et al., 2018). However, as noted in this study and others (Mathew et al., 2018), gaps persist, particularly among non-medical employees, highlighting the importance of direct practical involvement in fostering knowledge. From the Health Belief Model (HBM) perspective, these knowledge levels can be partially explained through perceived susceptibility, the belief among healthcare workers about how likely they are to be harmed by improper biomedical waste handling. Workers who have witnessed or experienced needle stick injuries or are aware of the risks of infections like hepatitis B or HIV through poor waste disposal are more likely to view themselves as vulnerable. This heightened susceptibility often drives better knowledge acquisition and safer

practices (Alfulayw et al., 2021; Mohamud et al., 2023). The study also found that while 84.25% of respondents had a positive attitude toward BMW, only 26.18% demonstrated good practice. This discrepancy between attitude and practice is not unique to this study; similar patterns have been observed elsewhere (Verma et al., 2020). This gap may be better understood through perceived barriers, another key component of the HBM. Barriers such as lack of training on segregation and disposal protocols, inadequate infrastructure, and absence of color-coded bin systems within facilities (Akulume & Kiwanuka, 2016; Ibrahim et al., 2023) hinder translating knowledge and positive attitudes into consistent practice.

Sociodemographic characteristics also shaped BMWM knowledge levels. Age was a significant factor; older workers (≥35) had better knowledge, likely due to more experience and exposure. This supports findings by Singh et al. (2018), who emphasized the value of targeted training for younger employees (Singh et al., 2018). Gender differences were also notable, with male respondents generally showing higher BMWM knowledge. This mirrors a study that suggests that occupational roles more frequently held by men may account for this difference (Kagonji & Manyele, 2016). (Nath et al., 2024) Recommend gender-sensitive training programs to address this gap. Marital status also appeared to influence knowledge, with married individuals demonstrating better BMWM understanding. This may relate to increased responsibility or long-term job commitment, a trend supported by (Krishnamurthy et al., 2024). Additionally, work experience positively correlated with knowledge, as more experienced workers understand the risks and protocols more thoroughly (Gazi et al., 2024). Professional designation strongly influences clinical staff, particularly nurses, who show higher knowledge than non-clinical staff. This is consistent with findings by (Bloemhof et al., 2021), who noted that regular exposure to waste handling fosters greater awareness and knowledge. Surprisingly, educational attainment did not significantly correlate with BMWM knowledge in this study, a finding that contrasts with prior research (Sharma, 2021).

Limitations of the study

This study had several limitations. First, because it used a cross-sectional design, it was not possible to establish cause-and-effect relationships between variables. The findings show associations, but we cannot say one factor directly caused another. Second, the study was limited to one hospital, which may affect how well the results apply to other settings. Third, the data relied on self-reported information, which may have been influenced by participants' memory or the desire to give socially acceptable answers. Finally, some important factors that could affect biomedical waste management were not included due to limited resources and time.

Conclusion

This study revealed significant disparities in biomedical waste management practices influenced by age, gender, professional designation, and experience. Younger healthcare workers and females were less likely to engage

effectively in waste management, potentially due to limited experience, training opportunities, and systemic role assignments within healthcare settings. In contrast, experienced and professionally designated healthcare staff demonstrated higher awareness and adherence to proper waste handling protocols. These findings underscore the urgent need for targeted, inclusive training programs and policy interventions that address demographic disparities to strengthen biomedical waste management practices within healthcare facilities.

Authors' Contributions

A.I. was responsible for the study design, data collection, analysis, results interpretation, and manuscript drafting. A.H. contributed to refining the study design, provided supervision throughout the research process, assisted with data interpretation, and critically reviewed the manuscript for intellectual content. Both authors reviewed and approved the final version of the manuscript.

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Conflicts of Interest

All authors declare no conflict of interest.

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