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Nurse Compliance with Medical Waste Management Protocols: An Observational Study at Indonesian Hospitals

Setia Megawati Hutajulu[1,*], Arifah Devi Fitriani[1] and Nuraini[1]

[1]*Faculty of Public Health, Institut Kesehatan Helvetia, Medan, Indonesia*

Abstract:

Introduction: Medical waste management in hospitals is influenced by nurses' compliance with sorting, as the initial steps in waste handling from the source. Nurse adherence to waste management protocols has the potential to prevent infection risks and environmental contamination. This study aims to identify the predominant factors influencing nurses' compliance with medical waste management protocols in hospitals across Indonesia.

Methods: This quantitative study employs a cross-sectional design. The research was conducted at three hospitals in Deli Serdang Regency, which share similar characteristics and have obtained research approval. The data analysis was performed using multiple logistic regression analysis.

Results: The study findings indicate that the knowledge variable has a significant effect on medical waste management, with a *p*-value of 0.019 and an odds ratio of 1.560. The perception variable also demonstrates a significant influence, with a *p*-value of 0.037 and an odds ratio of 1.229. The workload variable exhibits a significant impact, with a *p*-value of 0.045 and an odds ratio of 1.348. Meanwhile, the training variable shows a highly significant and strong effect, with a *p*-value of 0.009 and an odds ratio of 35.918.

Discussion: Nurses who had undergone training demonstrated better knowledge, skills, and a higher sense of responsibility in following the medical waste management protocols. The improvement reflects the effectiveness of training in forming technical competencies and work attitudes that comply with hospital environmental safety and health standards.

Conclusion: Training is a key factor influencing nurses' compliance. There is a need to enhance training programs to improve the quality of medical waste management by providing nurses with accurate knowledge, practical skills, and an understanding of procedures and standards.

Keywords: Nurse compliance, Medical waste management, Workload, Facilities, Hospital environmental safety, Technical competencies, Health care services.

*Address correspondence to this author at the Faculty of Public Health, Institut Kesehatan Helvetia. P.O. Box: 20124, Medan, Indonesia; Tel/Fax: ++061 42084106; E-mail: hsetiamegawati@gmail.com

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1. INTRODUCTION

The policy of medical waste management in hospitals has been implemented in the regulations of the Minister of Health Regulation Number 7 of 2019 concerning Hospital Environmental Health [1], the Regulation of the Minister of Health of the Republic of Indonesia Number 18 of 2020 concerning Management of Medical Waste in Health Service Facilities Article 6 stages of waste management including: reduction and sorting, internal transportation, temporary storage and internal processing [2]. However,

nurses' compliance with the applicable protocols still shows quite significant variations in various regions of Indonesia. This phenomenon is reflected in the practice of mixing medical and non-medical waste in several health service facilities [3]. Another research found that the level of nurses' compliance in separating medical and non-medical waste is low [4].

Regional disparities in the availability of health resources, such as infrastructure, training, and managerial oversight, are thought to influence healthcare workers' compliance behavior. Several previous studies have identified that human resource (nurse) behavior is a critical determinant of the effectiveness of solid medical waste management [5]. However, most of these studies have not examined in depth how regional disparities mediate the relationship between nurse behavior and compliance with medical waste management protocols. Based on this context, this study offers novelty by highlighting factors influencing nurse compliance in medical waste management through an approach that considers regional disparities and healthcare resources. Given that facilities differ across hospitals, particularly those located within districts, it is hoped that this study will provide a more relevant empirical contribution to strengthening policies based on local contexts.

Medical waste refers to residual waste generated from healthcare activities, which categorizes it as hazardous and toxic waste. Waste containing hazardous chemicals, such as medical chemicals, infectious waste, and radioactive waste, has the potential to pollute the environment and cause long-term impacts [6]. Concerning research conducted in Zimbabwe, it has been explained that poorly managed medical waste—particularly when disposed of in open dumping sites—can lead to pollution of water, air, and soil, thereby causing environmental and human health damages [7]. Proper and safe management of medical waste is essential to prevent the transmission of infections and diseases. Contamination from medical waste can result in disease transmission to healthcare workers, patients, and the surrounding community. Previous studies have found that infectious and non-infectious waste are often disposed of together in the same location [8]. This practice does not comply with the standards for safe medical waste management. Implementing safe management practices helps minimize these risks and protect the health of all involved parties [9].

Medical waste management is regulated by national and international regulations. In Indonesia, medical waste management is governed by Government Regulation No. 101 of 2014 concerning the Management of Hazardous and Toxic Waste, the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.56/Menlhk-setjen/2015 regarding the procedures and technical requirements for the management of hazardous and toxic waste from healthcare facilities, and the Regulation of the Minister of Health No. 18 of 2020 concerning the management of medical waste in healthcare facilities based on regional jurisdiction [1, 10, 11]. These regulations stipulate that medical waste must be managed in accordance with established standards to prevent risks to human health and the environment.

Healthcare services, whether in hospitals, community health centers, or outpatient clinics, place full responsibility on nurses for the handling and management of medical waste. Various studies indicate that nurses' compliance with established protocols remains inconsistent and not yet optimal. Field findings reveal instances of healthcare practices that do not meet standards, such as the mixing of medical waste with non-medical waste due to errors in disposal by nurses, such as disposing of medical waste into non-medical waste containers [5, 12]. Research in one healthcare clinic found that during patient care, nurses often forget to separate medical waste because of a lack of supervision [3]. A study conducted at a hospital in Delhi discovered that only 41.02% of nurses possessed adequate knowledge of biomedical waste management, and they lacked the necessary skills to properly handle the waste [13].

Nurses play a strategic role in the management of medical waste as an integral component of a safe, effective, and sustainable healthcare system. Their compliance with medical waste management protocols within hospitals is critical to ensuring safety, health, and environmental sustainability. Compliance refers to the extent to which nurses adhere to procedures, protocols, and standards established by regulations and hospital policies related to waste handling. These protocols encompass various stages, including waste segregation, packaging, storage, transportation, and final treatment of hazardous and toxic waste [1, 9]. The level of compliance significantly influences the prevention of nosocomial infection transmission, worker protection, and environmental pollution prevention.

However, in reality, the level of nurses' compliance with medical waste management protocols still exhibits variability, and recent studies indicate the presence of significant challenges. Previous research suggests that human resource behavior has a substantial impact on the effectiveness of solid medical waste management. This behavior encompasses the level of knowledge, attitude, and positive actions related to solid medical waste, which in turn contributes to optimal management practices, including waste reduction, storage, collection, treatment, and transportation of solid medical waste [14].

Factors contributing to non-compliance include a lack of adequate knowledge and understanding of the importance of proper medical waste management, as well as the absence of interventions related to waste management procedures [15]. Additionally, high workload and time pressure during duty often lead nurses to neglect strict adherence to established protocols [16]. Limitations in facilities and supporting equipment, such as appropriate trash bins, personal protective equipment, and efficient waste transportation systems, also play a role in the low levels of compliance [17].

Considering that medical waste management is crucial for safeguarding public health and protecting the environment, it is essential to conduct research on medical waste management with diverse research focuses. Previous studies have examined various aspects, including the factors influencing the generation of medical waste

[18], strategies for solid medical waste management in hospitals [14], as well as investigations into nurses' knowledge and attitudes toward waste management [3, 5], and nurses' compliance in infection prevention [16].

However, there is a lack of empirical data regarding nurses' compliance with waste management protocols in hospitals, particularly in Indonesia. Previous research has predominantly focused on the general knowledge and attitudes of healthcare workers, with limited studies specifically assessing the factors influencing compliance and the practical implementation in the field. Therefore, further research is necessary to comprehensively identify the determinants and obstacles faced by nurses in adhering to medical waste management protocols. This study aims to identify the dominant factors influencing nurses' compliance with medical waste management protocols in Indonesian hospitals.

The urgency of this study is rooted in the pressing need to enhance medical waste management as part of efforts to improve healthcare quality, protect the public from exposure to disease, and preserve environmental health. Consequently, this research is vital for providing valid data that can serve as a reference for developing effective waste management policies in hospitals and designing targeted training programs for nurses and other healthcare providers.

2. MATERIALS AND METHODS

2.1. Research Design and Type of Study

The study was conducted in Deli Serdang Regency, North Sumatra Province, one of the 33 regencies and cities in Indonesia, from March to August 2024. This research is an observational study employing a quantitative approach with a descriptive nature. The design utilized is a cross-sectional study, whereby data collection was carried out at a single point in time to assess nurses' compliance levels with medical waste management protocols in three hospitals located within Deli Serdang Regency.

2.2. Population and Sample

The population in this study consisted of all nurses working in service units across three hospitals in Deli Serdang Regency. The research was conducted in three hospitals that share similar characteristics and had obtained research approval. These characteristics include: private hospitals, fully accredited, located in the same district. Hospital “X” has a bed capacity of 324, Hospital “Y” has a bed capacity of 327, and Hospital “Z” has 320 beds. Hospitals “X”, “Y”, and “Z” have wastewater treatment plants. Hospital “X” uses an autoclave, Hospital “Y” uses an incinerator and autoclave, and Hospital “Z” uses a third-party wastewater treatment service.

A total of 210 nurses who were directly involved in patient care participated in the study. The sample was selected using purposive sampling. This technique was chosen based on the following considerations: the nurses' work system is based on morning, afternoon, and night shifts. Furthermore, the researchers' limited resources, funding, and time constraints were also considered.

The inclusion criteria were as follows: participants who have been working for at least six months, voluntarily willing to participate as research respondents until completion, assigned to provide patient care, and not experiencing illness or on leave at the time of data collection. The exclusion criteria were as follows: 1) Nurses experiencing health issues that could affect participation or research outcomes; 2) Nurses currently on sick leave or other extended leave; 3) Nurses who are unwilling to continue participation voluntarily until the study's completion; 4) Nurses who do not meet the minimum work experience criterion of at least six months; 5) Nurses not providing direct patient care during the research period. This participant selection process ensures greater transparency and adherence to research standards

Using Slovin’s formula with a 5% margin of error, a sample size of 137 nurses was determined to ensure data representativeness. However, 16 participants were excluded from the sample due to not meeting the criteria, such as unwillingness to participate, transfer to other units, or nearing retirement. Consequently, the total number of respondents in the study was 121 nurses.

2.3. Data Collection Techniques

Data were collected directly from respondents using closed-ended questionnaires. The weaknesses of data collection using questionnaires include the possibility of bias, respondent honesty, and limitations in data collection, and non-complex variables are limited to the observed variables. This weakness was overcome by providing an explanation of the questionnaire to respondents, accompanying respondents while filling out the questionnaire, and conducting validity tests on small samples. The questionnaires were distributed to the participants, along with an explanation of the study's objectives, instructions for completion, and the voluntary nature of their participation until the study's conclusion. Respondents were free to choose whether to participate in the study or withdraw at any point. The research received approval from the Health Research Ethics Committee of the College of Health Science “Maluku Husada”, with registration number RK. 120/KEPK/STIK/I/2024.

2.4. Research Instrument

The research instrument consisted of a questionnaire used to measure nurses’ knowledge, perceptions, facilities, workload, training, and compliance related to medical waste management. The instrument was developed based on relevant guidelines for medical waste management, such as standards from the Ministry of Health and the World Health Organization (WHO). Knowledge variables were measured using 17 question items such as: containers, waste sources, color, type of waste, and transportation. 3 answer options: agree, no opinion, don't know. Knowledge was categorized: good score 40-51, sufficient score 29-39, and less than 17-28. Perception variables were measured with 17 question items, including: waste collection, waste separation, disposal, and waste safety. 3 answer options

were: “agree”, “no opinion” and “don't know”. Perception was categorized into 3 categories: good score 40-51, sufficient score 29-39 and less than 17-28.

The measurement of the facility variables referred to in this study is the facilities available in the hospital, such as: waste containers, types of waste, symbols on containers, personal protective equipment for officers, disinfectants, transportation routes, and waste processing equipment. The answer choices are “yes”, “sometimes” and “none”. Facility categories: complete with a score of 30-39, lacking with a score of 15-29, and not available with a score of less than or equal to 14. The workload variable consists of 10 question items, and 2 answer choices: “yes” and “no”. Workload is measured by tasks completed, difficulty, time, and frequency. Workload is categorized into low, with a score of 10-20, and high, with a score of 21-30. Training consists of 7 items, including socialization and participation. There are 2 answer choices, namely “yes” and “no”. The training category never with a score of less than 9, and the category ever with a score of 9-14.

Compliance consists of 17 question items. The questionnaire included indicators of compliance covering aspects such as waste segregation, the use of personal protective equipment, packaging, and waste storage. There are three answer options: “always,” “sometimes,” and “no.” Compliance is categorized as compliant (a score greater than or equal to 25) and non-compliant (a score less than 25). The reliability of the instrument was tested through a pilot study involving 20 samples outside the main population, resulting in a Cronbach's alpha of ≥ 0.80.

To address potential sources of bias in research. First, selecting samples randomly without distinguishing status to reduce selection bias. Second, using instruments that have been tested for reliability. Third, ensuring participant anonymity and confidentiality reduces social desirability bias, encouraging honest responses and authentic behavior during observation.

2.5. Data Analysis

Data obtained from observations and questionnaires were analyzed descriptively, including frequency distributions, mean values, as well as minimum and maximum scores to depict the characteristics of the variables under study. Measurement of knowledge, perception and compliance variables was measured using a questionnaire consisting of 17 question items, 13 facility items, 10 workload items, and 7 training variable items. The questionnaire was compiled by researchers adopting from previous literature and tested for validity. The uncategorized x variable is displayed in mean, median, mode, minimum and maximum values (Table **1**). The compliance variable is made into 2 categories according to the requirements of logistic regression analysis, namely: non-compliant score 1-25 and compliant score range 26 - 51. The relationships among variables—namely knowledge, perception, facilities, workload, training, and compliance—were examined using multiple logistic regression analysis. Logistic regression is useful for estimating the influence of independent variables on the dependent variable [19, 20]. Prior to conducting the regression analysis, variables that met the criterion of $p < 0.25$ were selected, and those variables were then analyzed collectively. The decision to include variables was based on a significance level of $p < 0.05$, and the dominant variables were identified based on the odds ratio values.

The study established the following hypotheses to be tested:

H1: Knowledge influences nurses' compliance with medical waste management protocols

H2: Perception influences nurses' compliance with medical waste management protocols

H3: Facilities influence nurses' compliance with medical waste management protocols

H4: Workload influences nurses' compliance with medical waste management protocols

H5: Training influences nurses' compliance with medical waste management protocols

These five hypotheses were then analyzed for the variables that predominantly influence nurses' compliance with medical waste management protocols in hospitals.

3. RESULTS

Table **2** presents the research results based on the demographic characteristics of the respondents, including age, gender, education level, and years of service.

Based on the results of the frequency distribution analysis of the research sample characteristics related to medical waste management in hospitals, the following overview was obtained. In terms of age, the majority of respondents were between 45 and 55 years old, totaling 66 individuals (54.6%), followed by the 34–44 years age group with 46 individuals (38.0%), and the 23–33 years age group with 9 individuals (7.4%).

Table 1. Research variable description.

Variable	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Knowledge	29.32	28	25	7.145	19	51
Perception	34.17	32	30	8.707	18	51
Facilities	23.01	26	26	7.047	14	34
Workload	19.75	20	15	4.482	15	26
Training	1.47	1.00	1	0.501	1	2
Compliance	24.32	21	21	8.042	17	51

Note: Source: primary data, 2024.

Regarding gender distribution, most respondents were female, totaling 89 individuals (73.6%), while male respondents numbered 32 (26.4%). Based on education level, 57 respondents (47.1%) had a Diploma III degree, followed by 43 Bachelor's (S1) graduates (35.5%), and 21 Master's (S2) graduates (17.4%). In terms of years of work experience, most respondents had been employed for 11–20 years, totaling 70 individuals (57.9%), followed by the 1–10 years group with 30 individuals (24.8%), and the 21–30 years group with 21 individuals (17.4%). These data indicate that the majority of respondents are mid- to long-term experienced personnel, predominantly female, with educational backgrounds of Diploma III and Bachelor's degrees.

Table 2. Characteristics of respondent (n= 121).

Characteristics	Frequency	Percentage (%)
Age (years)	-	-
23 – 33	9	7.4
34 – 44	46	38
45 – 55	66	54.6
Gender	-	-
Men	32	26.4
Women	89	73.6
Education	-	-
Diploma III	57	47.1
Bachelor	43	35.5
Master	21	17.4
Years of service (years)	-	-
1 – 10	30	24.8
11 – 20	70	57.9
21 – 30	21	17.4

Note: Source: primary data, 2024.

Based on Table **1**, the results of descriptive statistical analysis of the variables related to medical waste management in hospitals are as follows: for the knowledge variable, the mean score was 29.32 with a median of 28 and a standard deviation of 7.145, indicating a moderate level of variability in respondents' knowledge. The minimum score was 19, and the maximum score reached 51, reflecting a wide range of knowledge levels. The perception variable had an average score of 34.17 with a median of 32 and a standard deviation of 8.707, suggesting generally high perceptions that are quite widely dispersed, with scores ranging from 18 to 51. The facilities variable had a mean score of 23.01, a median of 26, and a standard deviation of 7.047, indicating a perception leaning towards moderate to high regarding the available facilities, with the lowest score being 14 and the highest 34. The workload variable had an average score of 19.75 with a median of 20 and a standard deviation of 4.482, reflecting a perception of a moderate workload, with scores ranging from 15 to 28. For training, the mean was 1.47 and the mode was 1, indicating that the majority of respondents had not yet participated in training. The compliance variable showed an average score of 24.32 with a median of 21 and a standard deviation of 8.042, suggesting a relatively high and variable level of compliance, with scores spanning from 17 to 51.

Based on Table **3**, the results of the logistic regression analysis identifying factors influencing medical waste management in hospitals are as follows: the knowledge variable has a B coefficient of 0.445, a standard error of 0.198, and a significance value of 0.019. These findings indicate that knowledge has a statistically significant effect on medical waste management, with an odds ratio of 1.560 (95% CI: 1.077–2.258). Additionally, the perception variable demonstrates a significant influence (B = 0.206; p = 0.037), with an odds ratio of 1.229 (95% CI: 1.013–1.491).

The facilities variable has a coefficient of 0.340, indicating that its effect is not statistically significant (p = 0.098). The workload variable also demonstrates a significant effect (p = 0.045), with an odds ratio of 1.348 (95% CI: 1.006–1.807). In contrast, the training variable shows a highly significant and strong influence (p = 0.009), with an odds ratio of 35.918 (95% CI: 1.454–525.789). The facilities variable was excluded from the regression analysis due to its non-significant value; subsequently, a second-stage analysis was conducted to identify the most significant and dominant variable. The results of the second-stage analysis are presented in Table **4**.

Table **4** presents the results of the logistic regression analysis after the removal of the facility variable from the model. The findings indicate that the knowledge variable has a significance value (Sig.) of 0.038, demonstrating a statistically significant association with medical waste management.

Table 3. Results of stage 1 logistic regression test.

Variable	B	S.E	Sig.	Exp (B)	95% C.I for Exp (B)	
					Lower	Upper
Knowledge	0.445	0.198	0.019	1.560	1.077	2.258
Perception	0.206	0.099	0.037	1.229	1.013	1.491
Facilities	0.340	0.206	0.098	1.405	0.938	2.102
Workload	0.299	0.149	0.045	1.348	1.006	1.807
Training	3.581	1.369	0.009	35.918	1.454	525.789

Note: Source: primary data, 2024.

Table 4. Results of stage 2 logistic regression test.

Variable	B	S.E	Sig.	Exp (B)	95% C.I for Exp (B)	
					Lower	Upper
Knowledge	0.408	0.196	0.038	1.503	1.024	2.207
Perception	0.185	0.091	0.042	1.203	1.007	1.438
Workload	0.442	0.136	0.001	1.556	1.192	2.033
Training	3.685	1.338	0.006	39.854	2.895	548.575

Note: Source: primary data, 2024.

Specifically, knowledge is associated with an odds ratio of 1.503 (95% CI: 1.024–2.207). Additionally, the perception variable also shows a significant effect (p = 0.042), with an odds ratio of 1.203 (95% CI: 1.007–1.438). The workload variable exerts a moderately strong and statistically significant influence (B = 0.442; p = 0.001), with an odds ratio of 1.556 (95% CI: 1.192–2.033). Furthermore, the training variable demonstrates a highly significant and substantial impact (B = 3.685; p = 0.006), with an odds ratio of approximately 39.854 (95% CI: 2.895–548.575). These results suggest that increased knowledge, positive perceptions, manageable workload, and intensive training are key factors that significantly enhance the effective and controlled management of medical waste in hospitals. Consequently, efforts to improve staff competency and training are recommended as primary strategies to promote safe and standards-compliant medical waste management practices.

4. DISCUSSION

4.1. Respondent Characteristics

The analysis of the respondents' characteristics indicates that the majority of the nurses are female, accounting for 73.6%. In terms of age, most respondents are between 45 and 55 years old, representing 54.6%. Additionally, the majority possess a Diploma III in Nursing as their educational background, comprising 47.1% (57 respondents). Furthermore, most respondents have work experience ranging from 11 to 20 years, totaling 57.9% (70 respondents). These characteristics suggest that the majority of the respondents are experienced nurses with an adequate level of education in the field of nursing.

Individual characteristics influence nurses' knowledge, perceptions, and understanding of their work. Those with higher educational attainment tend to have broader insights into both knowledge and perceptions. Research indicates that a nurse's level of education affects their compliance in managing medical waste. This is attributed to differences in the level of knowledge, procedural understanding, and academic experience they possess, which directly impact their ability to adhere to proper medical waste management standards. A study conducted by Aziza *et al*. demonstrates that higher education levels enhance understanding of safety protocols and waste management procedures, thereby increasing nurses' compliance with these protocols [21].

Years of experience as a nurse influence compliance in medical waste management, although research findings vary depending on the context and other contributing factors. Several studies indicate that nurses with longer tenure tend to exhibit better behaviors in managing medical waste [8]. This is because extended work experience allows nurses to better understand and become accustomed to proper medical waste management procedures. A study conducted at Sundari General Hospital in Medan found a positive correlation between years of service and nurses' behavior in segregating medical waste, with a significance level of 0.043 [22]. Additionally, research in hospitals in Aceh demonstrated that years of experience have a significant relationship with medical waste management, with a p-value of 0.019. This underscores that work experience can enhance nurses' understanding and compliance with correct procedures in medical waste management [23].

However, not all studies have found a significant relationship between years of service and compliance in medical waste management. For example, research conducted at Muhammadiyah Hospital in Selogiri and Tangerang Regency Hospital did not reveal a significant association between years of experience and nurses' behavior in managing medical waste. This suggests that other factors, such as knowledge, attitude, and training, also play a crucial role in determining nurses' adherence to proper waste management procedures [5]. While years of experience may contribute to increased compliance, other factors such as knowledge, perceptions, and training are equally important. Therefore, efforts to improve nurses' compliance should include regular training, enhancement of knowledge, and the development of positive perceptions regarding the importance of correct medical waste management.

4.2. Compliance with Medical Waste Management Protocols

Medical waste, as a byproduct of health care activities, has the potential to pose risks of infection, injury, and environmental contamination if not managed systematically. This management process encompasses various stages, including collection, segregation, temporary storage, transportation, and final disposal [24]. Nurses serve as the frontline responsible for segregating waste according to its type and characteristics, including infectious waste, pathological waste, pharmaceutical waste, and sharps waste [25]. Previous research reported that 80% of medical waste was mixed with non-medical waste [26]. Inadequate waste segregation can lead to increased generation of medical waste [15].

The Standard Operating Procedures (SOP) for medical waste management require all healthcare personnel, including nurses, to understand and implement the principles of the 3Rs (Reduce, Reuse, Recycle) that are relevant, as well as to adhere to the technical guidelines established by the government [1]. Nurses hold a central position in direct patient care and play a vital role in promoting a culture of cleanliness and environmentally friendly practices. Enhancing nurses' capacity contributes to the achievement of an effective and sustainable medical waste management system, while also supporting the attainment of the Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-being) and Goal 12 (Responsible Consumption and Production).

The analysis results indicate that nurses' knowledge of medical waste management is significantly related to their level of compliance, meaning that the higher the nurses' knowledge, the greater the likelihood of their adherence to proper waste management procedures. Awareness among healthcare workers regarding the implementation of medical waste management policies is at an average level [13]. Consistent with previous research, factors that motivate nurses to adhere to protocols include a good understanding of the risks associated with medical waste, awareness of the importance of maintaining personal and environmental health, and supervision and reinforcement from hospital management [14]. Additionally, other studies identify primary causes of unsafe medical waste management as limited funding, weak regulatory enforcement, lack of knowledge and awareness among healthcare personnel and waste management workers, and insufficient participation in decision-making processes [7]. Adequate knowledge among nurses supports proper medical waste segregation practices [4].

In addition, a positive perception of the importance of waste management also has a significant influence. This indicates that a favorable perception can enhance nurses' compliance levels in managing medical waste safely and in accordance with established standards. When staff regard waste management as an important and supportive aspect, they tend to take more responsibility and demonstrate greater discipline in executing procedures. Healthcare professionals hold varying perspectives on how to safely handle medical waste [27]. Hospitals must foster awareness and cultivate a unified perception among staff regarding waste management in compliance with the regulations set by the Ministry of Health of the Republic of Indonesia. This can be achieved through effective communication. Individuals with knowledge of waste management and disposal practices tend to exhibit tangible differences through their behaviors [28].

Nurse workload has a significant and moderate influence, indicating that an appropriate workload can support effective waste management practices. Controlled workload impacts the staff's ability to manage waste effectively. When staff are not overburdened with tasks, they are better able to focus and carry out waste management processes accurately. Management must ensure the equitable distribution of duties and workload to prevent disruptions in waste management. Excessive workload hampers medical waste management and recycling efforts [29]. A major challenge in medical waste management is the limitation of capacity and resources [30].

Managerial aspects must be taken seriously to improve efficiency and compliance. If the nurse-to-patient ratio is adequate, nurses can perform their duties following proper medical waste management standards, including sorting, use of personal protective equipment, packaging, and storage.

However, the findings of this study indicate that facility availability does not significantly influence nurses' compliance. While facility support is crucial, in reality, inadequate facilities—such as containers that do not meet standards, are lined with plastic, and have limited availability or stock of personal protective equipment—are often encountered. This research also revealed that, currently, there are no dedicated facilities for waste transportation routes. As observed in a study at Tuban Hospital in West Java, medical waste transportation processes lack a designated route to the final disposal site. Instead, the waste is transported along the same routes used by visitors to access the hospital [31].

Strong institutional support and effective management practices tend to enhance nurses' motivation and perception of the importance of compliance with waste management standards and protocols, thereby contributing to increased levels of compliance. Conversely, disparities in support and suboptimal management practices can reduce motivation and increase the likelihood of non-compliance.

The results of this study differ from previous research. The availability of facilities has a significant influence on nurses' behavior in sorting medical waste [22]. One of the essential requirements for effective medical waste disposal is the commitment of hospitals and government authorities to develop the necessary infrastructure and facilities [32]. A similar condition was observed in Gonibeduu's study, which found that only 25% of available facilities included covered containers for medical waste transportation [33].

Training is a dominant variable influencing nurses' compliance. Nurses who have participated in training demonstrate a highly significant and substantial impact, emphasizing that training is essential in enhancing nurses' adherence to medical waste management protocols. The research revealed that not all nurses have received training in waste management, aligning with previous research conducted at Padang Sidempuan Hospital [34]. In accordance with the recommendations of the Indonesian Ministry of Health and as stipulated in the Minister of Health Regulation No. 9 of 2019, all personnel involved in medical waste management are required to undergo training [1]. A recent study by Bannour *et al*. indicates that training has a significant positive effect on the practice of proper medical waste management among healthcare workers [35]. The external validity of nurses'

compliance with medical waste management protocols in a hospital in Indonesia is influenced by several factors, including sample characteristics, research location, and methodology used. Therefore, the research results are only applicable to the hospital in the research location.

5. STUDY LIMITATION

This study focused on nurses who had received training and those who had not. Potential biases, including selection bias, may have arisen, as participants who had received training may have higher motivation and commitment to competency improvement. Observer bias is also a concern, as assessments of knowledge, skills, and responsibility are subjective and susceptible to researcher perception.

The tendency for high OR values is assumed to be due to uncontrolled confounding factors in the study, such as the differing motivations of each nurse and the culture of the three hospitals, which were not examined in the model.

The primary limitations of this study include constraints related to time and resources, which restricted the scope of data collection, as well as difficulties in objectively measuring aspects of work attitude and sense of responsibility through quantitative methods. Additionally, external variables such as differing work environments and institutional cultures may influence the results and were not fully controlled within the scope of this research.

Areas for further exploration in future research include the development of more objective assessment methods for evaluating nurses' competencies and work attitudes, as well as longitudinal studies to assess the sustainability of competency improvements post-training. Additionally, subsequent studies could expand the population scope to evaluate the effectiveness of training across various hospital settings with differing characteristics, and to examine the long-term impact of training on medical waste management and its environmental implications.

CONCLUSION

Source segregation of waste by nurses is a fundamental step in medical waste management, as it minimizes the risk of cross-contamination and optimizes subsequent handling processes. Efforts to improve the effective management of medical waste should be evaluated, and hospitals must focus on enhancing staff knowledge, perceptions, and workload management to prevent excessive burden, and provide quality and ongoing training. These measures will help ensure that waste management is carried out in accordance with safety and environmental standards, thereby minimizing risks to public health and the environ-ment. Enhancing competency through training and optimal workload management is highly recommended to support safe and standards-compliant waste management practices within hospital settings. The findings of this study are expected to serve as a foundation for developing strategies to improve compliance with medical waste management protocols in Indonesian healthcare facilities.

Suggestions for further research include utilizing a sequential mixed-method (qualitative-quantitative) research design or data triangulation methods to gain a more comprehensive and in-depth understanding of nurses' compliance levels. This approach allows for the integration of multiple data sources, such as interviews, direct observation, and medical records, thereby increasing the validity and reliability of research results. The use of data triangulation is expected to reduce potential bias and provide a holistic description of the factors influencing nurses' compliance in carrying out their duties.

To gain a more comprehensive understanding, it is recommended that future research develop analytical models that include controls for additional potentially influential variables, such as hospital culture, hospital leadership support, and staff-to-patient ratios. This further study is essential to improve the accuracy of health policy intervention planning in health care facilities.

AUTHORS' CONTRIBUTIONS

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

LIST OF ABBREVIATIONS

3R	=	Reduce, Reuse, and Recycle
CI	=	Confidence Interval
SDGs	=	Sustainable Development Goals
SOP	=	Standard Operating Procedures
WHO	=	World Health Organization

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research received approval from the Health Research Ethics Committee of the College of Health Science "Maluku Husada", Indonesia with registration number RK. 120/KEPK/STIK/I/2024.

HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committee and with the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

Written informed consent was obtained from all participants prior to the commencement of this study.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article will be available from the corresponding author [S.M.H] upon reasonable request.

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None.

CONFLICT OF INTEREST

The author(s) declare no conflict of interest, financial or otherwise.

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