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Effectiveness of Implementing Hazardous and Toxic Waste (B3) Management Standards in Improving Knowledge, Attitudes, and Compliance in Hazardous Waste

Agus Riyadi[1*], Kusbaryanto[2]

[1,2] Departement of Hospital Administration and Manajemen, Universitas Muhamadiyah Yogyakarta

[1]dragusriyadi01@gmail.com
[2]koesbary@yahoo.co.id

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ABSTRACT

Background: Hazardous and toxic waste (B3) generated by hospitals poses significant risks to healthcare workers, patients, and the environment if not properly managed. Despite the implementation of waste management systems and training programs, staff compliance with standard operating procedures (SOPs) often remains suboptimal. This study aimed to evaluate the effectiveness of implementing hazardous and toxic waste management standards in improving knowledge, attitudes, and compliance among hospital staff.
Method: A mixed-methods approach with a quasi-experimental pretest–posttest control group design was employed. A total of 120 respondents were divided into intervention and control groups. Quantitative data were analyzed using paired t-tests and Wilcoxon tests, while qualitative data were analyzed thematically.
Result: The results showed significant improvements in the intervention group, with increases in knowledge and attitudes ($p < 0.0001$) and compliance ($p = 0.001$). However, the magnitude of change in compliance was smaller compared to knowledge and attitudes. Qualitative findings indicated that while training improved awareness and understanding, sustained compliance was strongly influenced by organizational factors, including monitoring, supervision, and institutional support.
Conclusion: In conclusion, training-based implementation of hazardous waste management standards is effective in improving knowledge and attitudes but insufficient to ensure consistent compliance. Strengthening organizational support through continuous monitoring and supervision is essential to promote sustainable behavioral change in healthcare settings.

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INTRODUCTION

Medical waste, particularly hazardous and toxic waste (B3), poses significant risks to healthcare workers, patients, and the environment due to its potential to contain infectious agents, toxic chemicals, and radioactive materials. The World Health Organization defines healthcare waste as all waste generated from healthcare facilities during diagnosis, treatment, or immunization activities, including sharps, infectious materials, pharmaceuticals, and chemical substances (Padmanabhan & Barik, 2019; Yang, Du, Sun, Meng, & Li, 2024). Improper management of such waste may lead to environmental contamination, occupational hazards, and increased risk of disease transmission, particularly in developing countries(Chisholm et al., 2021; Ndejjo et al., 2021).

Globally, medical waste management has become an increasing concern alongside the expansion of healthcare services and infection control practices. Evidence suggests that inadequate segregation, handling, and disposal of hazardous waste significantly contribute to environmental pollution and the spread of infectious diseases (WHO, 2024; Windfeld & Brooks, 2021; Woime, 2026). In low- and middle-income countries, this issue is further exacerbated by limited infrastructure, insufficient training, and weak regulatory enforcement (Chisholm et al., 2021).

In Indonesia, hazardous medical waste management remains a critical challenge. National data indicate that approximately 294.66 tons of medical waste are generated daily, while treatment capacity reaches only about 241.02 tons per day, leaving a substantial proportion untreated. The gap reflects limitations in both infrastructure and compliance with established standards. Although regulatory frameworks, such as the Minister of Health Regulation No. 18 of 2020, have been implemented, practical challenges in implementation at the healthcare facility level persist (Lelyana, 2024; Nurendra, Sentosa, Wibawa, Rahman, & Putri, 2023)

Hospitals, as primary generators of healthcare waste, are responsible for ensuring proper management practices. Approximately 15% of hospital waste is classified as hazardous and toxic (B3), including infectious, chemical, and pharmaceutical waste (Chartier et al., 2022). Improper handling of such waste may result in occupational exposure, environmental degradation, and broader public health risks (Deress, Jemal, Girma, & Adane, 2019). Previous studies have identified multiple contributing factors to suboptimal waste management practices, including inadequate training, low awareness, weak supervision, and limited organizational commitment to environmental safety (Akkajit, Romin, & Assawadithalerd, 2020; Khashaba, Hady, Gilany, & Denewar, 2023).

Training-based interventions have been widely applied to improve healthcare workers' knowledge and attitudes toward medical waste management. The Knowledge Attitude Practice (KAP) framework suggests that increased knowledge can influence attitudes and subsequently shape behavior (Launiala, 2021). Several studies have demonstrated that training significantly improves knowledge and attitudes among healthcare workers (Elsayed, Hassan, & Ahmed, 2025; Thirunavukkarasu, Raja, & Kumar, 2022). However, empirical findings also indicate inconsistencies, where improvements in knowledge and attitudes do not always translate into sustained compliance in practice (Baklouti, Ben Salem, & Kacem, 2025; Pawar & K A, 2024).

These inconsistencies suggest that behavioral change in healthcare settings is influenced not only by individual cognitive and affective factors but also by broader organizational and systemic conditions, including supervision, monitoring systems, workload, and institutional support (Amrutha & Geetha, 2021). Therefore, understanding the interaction between individual and organizational factors is essential to ensure sustainable compliance in hazardous waste management.

Despite the growing body of literature, several research gaps remain. First, many studies rely predominantly on quantitative approaches and lack qualitative insights to explore underlying

behavioral and organizational dynamics (Launiala, 2021). Second, limited studies have applied a mixed-methods design to comprehensively evaluate both measurable outcomes and contextual influences of training interventions (Khashaba et al., 2023). Third, there is insufficient evidence regarding the extent to which improvements in knowledge and attitudes lead to sustained compliance in real-world hospital settings, particularly in the Indonesian context.

Fatimah Islamic Hospital Cilacap has implemented hazardous and toxic waste management standards and conducted training programs for its staff. However, preliminary observations indicate that compliance with standard operating procedures (SOPs) remains suboptimal. This condition highlights the need to evaluate not only the effectiveness of training interventions but also the organizational factors influencing behavioral change.

Therefore, this study aims to evaluate the effectiveness of implementing hazardous and toxic waste (B3) management standards in improving knowledge, attitudes, and compliance among hospital staff using a mixed-methods approach. This study offers novelty by integrating quantitative and qualitative analyses to examine not only the effectiveness of training but also the organizational determinants of compliance, thereby providing a more comprehensive understanding of sustainable behavioral change in healthcare waste management.

METHOD

Research Design

This study employed a mixed-methods design, integrating both quantitative and qualitative approaches. The quantitative approach served as the primary method, while the qualitative approach was used to complement and enrich the interpretation of the findings. The quantitative component utilized a quasi-experimental design with a pretest–posttest control group approach. The study aimed to evaluate the effectiveness of training on hazardous and toxic waste (B3) management procedures in improving knowledge, attitudes, and compliance among healthcare and non-healthcare staff in managing hazardous medical waste.

The study population consisted of all healthcare and non-healthcare personnel involved in B3 waste management at Fatimah Islamic Hospital. A total of 120 respondents were selected using a purposive sampling technique and were equally divided into two groups: an intervention group ($n = 60$) and a control group ($n = 60$). The intervention group received structured training on B3 waste management procedures based on established standards, while the control group did not receive any intervention during the study period.

Quantitative data were collected using a structured questionnaire that had been tested for validity and reliability. The questionnaire measured respondents' knowledge, attitudes, and compliance regarding B3 waste management. Data collection was conducted twice, before (pretest) and after (posttest) the intervention. The qualitative phase involved key informants selected from participants in the quantitative phase, as well as supporting informants, including the head of the sanitation and waste management unit and the occupational health and safety (K3RS) officer. Qualitative data were collected through in-depth interviews using semi-structured interview guidelines to explore participants' experiences, perceptions, and challenges in implementing B3 waste management practices.

Quantitative data were analyzed using paired t-tests for normally distributed data and Wilcoxon signed-rank tests for non-normally distributed data to assess differences between pretest and posttest scores within groups. Comparative analysis between the intervention and control groups was performed using independent t-tests or Mann–Whitney U tests, as appropriate. Qualitative data were analyzed using thematic analysis to identify emerging themes

and patterns. This study has obtained ethical approval from the Ethics Committee of UNAIC (Universitas Al Irsyad Cilacap) with ethical clearance number No.688/280/03/61.

RESULTS AND DISCUSSION

Results

The management of hazardous and toxic waste (B3) is a critical component of hospital environmental safety systems. Improper medical waste management may lead to infectious disease transmission, environmental pollution, and increased health risks for healthcare workers and the surrounding community.

1. Knowledge of B3 Waste Management

Table 1. Pretest and Posttest Knowledge Scores

Group	Measurement	n	Mean ± SD	Min	Max
Control	Pretest	60	19.50 ± 2.182	14	23
Control	Posttest	60	19.57 ± 2.227	14	23
Intervention	Pretest	60	18.75 ± 2.039	14	22
Intervention	Posttest	60	20.25 ± 1.781	15	22

The control group showed only a slight increase in knowledge scores, whereas the intervention group demonstrated a more substantial improvement after the implementation of B3 waste management training

2. Attitude Toward B3 Waste Management

Table 2. Pretest and Posttest Attitude Scores

Group	Measurement	n	Mean ± SD	Min	Max
Control	Pretest	60	26.98 ± 3.317	20	35
Control	Posttest	60	27.13 ± 2.949	22	34
Intervention	Pretest	60	25.52 ± 3.793	19	35
Intervention	Posttest	60	33.27 ± 2.524	30	40

The intervention group experienced a marked increase in attitude scores compared to the control group, indicating improved perceptions toward proper B3 waste management.

3. Compliance with B3 Waste Management

Table 3. Pretest and Posttest Compliance Scores

Group	Measurement	n	Mean ± SD	Min	Max
Control	Pretest	60	19.70 ± 0.619	17	20
Control	Posttest	60	19.62 ± 1.151	16	22
Intervention	Pretest	60	24.57 ± 2.982	17	30

The compliance scores in the control group remained relatively unchanged, while the intervention group showed a slight but consistent improvement.

4. Statistical Analysis (Paired Test Results)

Table 4. Summary of Statistical Test Results

Variable	Group	Test Used	p-value	Interpretation
Knowledge	Control	Paired t-test	0.398	Not significant
Knowledge	Intervention	Wilcoxon	<0.0001	Significant
Attitude	Control	Paired t-test	0.331	Not significant
Attitude	Intervention	Wilcoxon	<0.0001	Significant
Compliance	Control	Paired t-test	0.510	Not significant
Compliance	Intervention	Wilcoxon	0.001	Significant

The statistical analysis indicates that no significant changes occurred in the control group across all variables ($p > 0.05$). In contrast, the intervention group showed significant

improvements in knowledge, attitudes, and compliance ($p < 0.05$), confirming the effectiveness of the implemented training program.

The qualitative findings were analyzed using a thematic approach based on in-depth interviews with key informants. The analysis identified five major themes reflecting the impact of implementing hazardous and toxic waste (B3) management standards on staff behavior and perceptions, as presented in Table 5.

Table 5. Thematic Analysis of Qualitative Findings on B3 Waste Management Implementation.

No	Theme	Description of Findings	Supporting Statement	Interpretation
1	Improvement in Knowledge	Staff demonstrated improved understanding of B3 waste classification, segregation procedures, and adherence to SOPs after training.	*"After the training, staff are more aware of how to classify and dispose of B3 waste properly according to the procedures."*	Training effectively strengthened the cognitive domain of staff, indicating that structured education is essential in improving knowledge of hazardous waste management.
2	Increased Risk Awareness	Staff showed greater awareness of occupational and environmental risks associated with improper waste handling.	*"Now staff are more careful because they understand the risks, both for their own safety and the environment."*	Increased risk perception reflects enhanced awareness, which is a key factor in influencing behavioral change in workplace safety practices.
3	Positive Attitude Change	Staff attitudes became more supportive and responsible toward proper B3 waste management practices.	*"Previously, some staff were less concerned, but now they are more responsible and follow the procedures more consistently."*	The intervention influenced the affective domain, suggesting that knowledge improvement contributes to more positive attitudes toward environmental safety.
4	Improved Compliance	Staff compliance improved, particularly in waste segregation, use of PPE, and adherence to disposal procedures.	*"Compliance has improved, especially in waste sorting and disposal according to the correct classification."*	Behavioral changes indicate that training combined with standard implementation can translate knowledge and attitudes into actual practice.
5	Importance of Monitoring and Evaluation	Continuous monitoring and supervision were identified as crucial to maintaining compliance and preventing relapse into previous practices.	*"Monitoring is very important. Without supervision, staff may return to previous habits."*	Sustained behavioral change requires reinforcement through monitoring systems, indicating that training alone is insufficient without institutional support.

Discussion

The findings of this study indicate that the implementation of hazardous and toxic waste (B3) management standards through structured training has a meaningful impact on improving staff knowledge, attitudes, and compliance in the intervention group, while no significant changes were observed in the control group. Quantitatively, the most notable improvement occurred in attitudes, followed by knowledge, whereas compliance showed a relatively smaller increase. This pattern suggests that behavioral change among healthcare workers does not occur simultaneously across domains, but rather develops progressively through different stages (Uloma, Nkem Benjamin, & Kiss, 2022).

The significant improvement in knowledge highlights the important role of training in strengthening the cognitive capacity of healthcare workers. Following the intervention, staff demonstrated a clearer understanding of waste classification, segregation procedures, the use of personal protective equipment (PPE), and the overall process of hazardous waste management. These findings are consistent with recent studies showing that training interventions can significantly enhance knowledge and awareness among healthcare workers ((Elsayed et al., 2025; Thirunavukkarasu et al., 2022; Windfeld & Brooks, 2021). In addition, the qualitative findings provide further support, as informants described how staff became more confident in applying standard operating procedures (SOPs) in their daily work. This indicates that the knowledge gained from training was not only theoretical but also began to be internalized in practice.

Alongside improvements in knowledge, this study found that changes in attitude were the most prominent among all variables. This suggests that the intervention was particularly effective in influencing the affective domain, including awareness, responsibility, and concern toward hazardous waste management. A positive attitude plays a crucial role in shaping safe work behavior, as it reflects an individual's willingness to comply with established procedures. Previous studies have also reported that healthcare workers with more positive attitudes toward waste management tend to demonstrate higher compliance (Islam, Rahman, & Karim, 2025; Ndejjo et al., 2021; Reddy, Kumar, & Sharma, 2024). In this study, qualitative findings revealed that staff became more cautious and responsible after understanding the risks associated with improper waste handling, highlighting the importance of risk perception in shaping behavior.

However, although compliance showed a statistically significant improvement, the magnitude of change was not as strong as that observed in knowledge and attitudes. This finding highlights a critical gap between what staff know, what they perceive, and what they actually do in practice. While knowledge and attitudes form an essential foundation for behavior, they do not automatically translate into consistent compliance. In real-world settings, behavior is shaped not only by individual factors but also by external conditions such as work routines, workload, availability of facilities, and organizational support systems (Baklouti et al., 2025; Chartier et al., 2022).

The qualitative findings in this study offer a deeper explanation of this gap. Informants emphasized that continuous monitoring and supervision are key factors in maintaining consistent compliance. Without regular oversight, staff may gradually return to previous habits, even when they already possess adequate knowledge and positive attitudes. This suggests that training alone is not sufficient to ensure sustained behavioral change. Instead, it needs to be supported by a structured system that includes routine supervision, clear policy enforcement, and a work environment that prioritizes safety (Amrutha & Geetha, 2021; Efendi, 2024; Haider, Fatima, Bakhsh, & Ahmed, 2019).

From a theoretical perspective, these findings generally align with the Knowledge Attitude Practice (KAP) model, which proposes that behavioral change begins with knowledge, influences attitudes, and is eventually reflected in practice. The pattern observed in this study follows this sequence, where improvements in knowledge were accompanied by changes in attitudes and subsequently followed by increased compliance. However, this study also shows that the relationship is not entirely linear. Changes in behavior, particularly in terms of consistent compliance, require more time and are influenced by broader contextual and organizational factors beyond individual cognition ((Launiala, 2021).

This study therefore contributes to the refinement of the KAP model by highlighting the importance of contextual and organizational dimensions in shaping behavior. In the context of healthcare settings, effective implementation of hazardous waste management standards requires not only educational interventions but also systemic reinforcement. The findings clearly indicate that organizational support particularly in the form of continuous monitoring, supervision, and

institutional commitment plays a decisive role in translating knowledge and attitudes into sustained practice (Khashaba et al., 2023; Pawar & K A, 2024).

This finding is consistent with the study by Deress et al., which demonstrated that although healthcare workers may possess adequate knowledge and positive attitudes toward medical waste management, optimal practices remain highly dependent on the availability of facilities, continuous training, and institutional support (Deress et al., 2019). Similar findings were reported by (Akkajit et al., 2020) who emphasized that organizational factors, including structured waste management systems and work experience, significantly contribute to the implementation of standard-compliant practices. Furthermore, the study by (Khashaba et al., 2023) highlighted that healthcare workers' behavior is not solely determined by individual factors, but is also shaped by organizational contexts such as workplace culture, policies, and institutional commitment to environmental safety. In addition, research by Pawar et al. indicated that a high level of knowledge does not automatically ensure consistent practice in the absence of reinforcement through continuous monitoring and evaluation systems. Therefore, the findings of this study reinforce the argument that KAP-based approaches need to be further developed by integrating structural and organizational dimensions as key determinants in promoting sustainable behavioral change within healthcare settings.

From a practical standpoint, this study emphasizes the need for a more comprehensive approach in improving B3 waste management practices in hospitals. Training programs should not stand alone but must be integrated with continuous monitoring and evaluation mechanisms. Without such reinforcement, improvements in knowledge and attitudes may not be fully reflected in daily practice. Therefore, strengthening institutional systems, promoting a culture of safety, and ensuring consistent supervision are essential steps to achieve sustainable compliance in hazardous waste management.

CONCLUSION

This study demonstrates that the implementation of hazardous and toxic waste (B3) management standards through structured training is effective in improving healthcare staff knowledge, attitudes, and compliance, particularly in the intervention group compared to the control group. The findings indicate that while knowledge and attitudes showed substantial improvement, changes in compliance were relatively more limited, highlighting a gap between understanding and actual practice. This suggests that behavioral change in waste management is not solely determined by cognitive and affective factors but is also influenced by organizational elements such as monitoring, supervision, and workplace culture. The results support the Knowledge Attitude Practice (KAP) model while also emphasizing the need for a more comprehensive approach that integrates training with continuous evaluation and institutional support to ensure sustainable compliance. Therefore, hospitals should strengthen not only educational interventions but also systemic reinforcement mechanisms to optimize the effectiveness of hazardous waste management practices.

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