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Review

A COMPARATIVE ANALYSIS OF KEY FACTORS INFLUENCING COMPLIANCE IN MEDICAL SOLID WASTE MANAGEMENT IN HEALTHCARE FACILITIES: A META-ANALYSIS OF STUDIES IN INDONESIA VS. OTHER SOUTHEAST ASIAN COUNTRIES

Hasina Paradiba Syahrial[1], **Ermi Girsang**[2], **Sri Wahyuni Nasution**[3]
[1,2,3] Master's Program in Public Health, Universitas Prima Indonesia
Jl. Sampul No. 3, Sei Putih Barat, Medan Petisah, Medan, North Sumatra, Indonesia
E-mail: hasinaparadiba@gmail.com

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ABSTRACT

A Comparative Analysis of Key Factors Influencing Compliance in Medical Solid Waste Management in Healthcare Facilities: A Meta-Analysis of Studies in Indonesia vs. Other Southeast Asian Countries. *Medical solid waste management is a crucial global challenge for healthcare systems due to therisk of nosocomial infections and the resulting environmental impacts. Although Indonesiahas strict regulations, implementation in the field still faces obstacles such as lack of training, inadequate infrastructure, and low awareness among healthcare workers. This contrasts withseveral other Southeast Asian countries that have successfully implemented integrated auditsystems and comprehensive training programs. This study aims to identifyand analyze key factors (knowledge and attitudes) influencing compliance with medical solid waste management inIndonesia and compare it with other Southeast Asian countries.This study used a meta-analysisdesign with a Comparative Systematic Review approach. Secondary data was obtained from asystematic search of PubMed, Scopus, ScienceDirect, and Google Scholar databases for articles published between 2018 and 2025. The analysis showed a significant relationship between staff knowledge and medical waste management compliance. Meanwhile, staff's positive attitudes consistently correlated with higher compliance across both geographic regions, with nosignificant difference in the strength of the effect. Knowledge and attitudes are the main determinants of medical waste management compliance. The dominance of knowledge in Indonesia indicates a gap in technical understanding that needs to be addressed. In general, Jcountries with more integrated monitoring and training systems show more stable compliancerates. The Indonesian government and healthcare facility managers are advised to improve ongoing technical training programs and strengthen internal audit systems.*

INTRODUCTION

Medical solid waste (healthcare waste) represents one of the most serious challenges within healthcare service systems, particularly in developing countries. This type of waste poses substantial risks to public health and the environment if not properly managed, including the

transmission of nosocomial infections, bloodborne diseases, and contamination of soil and water. The World Health Organization (WHO) estimates that approximately 10–25% of total healthcare facility waste is classified as hazardous, including infectious waste, sharps, and pharmaceutical waste, all of which require special and stringent management [17,26].

In Indonesia, the management of medical solid waste has been regulated through various policies, including the Minister of Health Regulation on healthcare facility waste management [27–33]. Nevertheless, the implementation of these regulations in practice continues to face numerous challenges [1,4–6,14,30]. Many healthcare facilities have not fully complied with the established standards due to limited infrastructure, inadequate training of healthcare personnel, weak supervision, and low awareness of the importance of safe and compliant medical waste management [2].

Compliance with medical solid waste management is influenced by multiple interrelated factors, including government policies, the availability of waste treatment facilities, the competence and training of healthcare workers, the utilization of technology, as well as the perceptions of communities and stakeholders [3]. Insufficient understanding of the risks associated with medical waste, along with stigma surrounding waste handling, often constitutes a major barrier to the implementation of proper and safe waste management practices in healthcare facilities [4,18].

Several countries in Southeast Asia, such as Malaysia, Thailand, and the Philippines, have demonstrated relatively better experiences in medical waste management. This success has been supported by stricter regulations, consistent law enforcement systems, continuous training programs, and the utilization of information technology for monitoring and reporting medical waste. Comparisons with these countries are essential to identify best practices that may be adapted to the Indonesian context [7,8,10,11,21–23].

Based on this background, the research questions of this study include: what key factors influence compliance with medical solid waste management in healthcare facilities in Indonesia; how these factors compare with those in other Southeast Asian countries; and what challenges and opportunities are encountered in efforts to improve compliance with medical solid waste management across the region.

MATERIALS AND RESEARCH METHODS

This study is a secondary research employing a meta-analysis design with a comparative systematic review approach. Meta-analysis was conducted to quantitatively synthesize and analyze findings from relevant primary studies in order to obtain more robust and precise effect size estimates. A comparative approach was applied to examine differences in the strength of influence of key factors—particularly healthcare workers' knowledge and attitudes—on compliance with medical solid waste management between studies conducted in Indonesia and those from other Southeast Asian countries. The research process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological transparency and validity.

The data used in this study were secondary data obtained through a systematic literature search of national and international scientific databases, including PubMed, Scopus, ScienceDirect, and Google Scholar. Selected articles consisted of quantitative studies with analytic designs published between 2018 and 2025 and meeting the inclusion criteria based on the PICOS framework (Population, Exposure, Comparison, Outcome, and Study Design). The data collection process comprised article identification, title and abstract screening, full-text eligibility assessment, and extraction of quantitative data in the form of Odds Ratios (ORs) or raw data that could be recalculated.

Data analysis was conducted quantitatively using meta-analytic methods supported by statistical software capable of effect size pooling. Measures of association were expressed as pooled Odds Ratios (PORs) with 95% confidence intervals. Heterogeneity among studies was

assessed using the Chi-square (Q) test and the I^2 statistic to determine the use of fixed-effect or random-effects models. Furthermore, comparative analyses were performed between the Indonesian group and other Southeast Asian countries, along with meta-regression analyses to identify potential moderator factors influencing variability in study outcomes. The results are presented in the form of tables and forest plots to facilitate interpretation.

RESEARCH RESULTS AND DISCUSSION

Results of Quantitative Data Extraction

Table 1. Results of Effect Size Data Extraction for Key Factors

No.	Key Factors	Indonesian Studies (OR, 95% CI)	Southeast Asian Studies (OR, 95% CI)
1.	Good Knowledge	3.79 [1.80, 7.96]	4.26 [1.60, 11.33]
2.	Positive Attitude	6.78 [4.61, 9.95]	8.44 [3.53, 20.18]

Figure 1. Comparison of Effect Sizes

The forest plot shows that the vertical line at an Odds Ratio (OR) value of 1 represents the no-effect condition, while all OR values in the analysis are positioned above 1, indicating that the examined factors contribute to an increased likelihood of compliance or appropriate behavior in medical waste management. Confidence intervals (CIs) that do not cross the value of 1 indicate statistically significant results. Overall, knowledge was found to play an important role in improving compliance in both study regions, with a slightly stronger effect observed in Southeast Asian countries. However, positive attitude demonstrated a more dominant influence than knowledge in determining compliance with medical solid waste management.

Results of Comparative Meta-Analysis

Table 2. Knowledge Factor

Parameter	Indonesia	Southeast Asia
Number of Studies	9	9
Pooled Odds Ratio (95% CI)	3.79 [1.80, 7.96]	4.26 [1.60, 11.33]
I^2 (Heterogeneity)	76% (High)	90% (Very High)
p-value	<0.00001	<0.00001

The analysis results indicate that good knowledge is consistently a significant factor in improving compliance with medical solid waste management across all study regions, both in Indonesia and in other Southeast Asian countries. Comparatively, the effect size of knowledge appears slightly greater in Southeast Asia (OR = 4.26) than in Indonesia (OR = 3.79), suggesting that individuals with good knowledge in Southeast Asia have a higher likelihood of compliance. However, the wider confidence interval (CI) observed in Southeast Asia [1.60–11.33] compared with Indonesia [1.80–7.96] reflects a greater degree of

uncertainty. This finding is consistent with the high to very high heterogeneity (I^2 = 76–90%), indicating substantial variability among studies, which may be attributable to differences in study design, operational definitions of knowledge and compliance, population characteristics, study periods, and intervention contexts across countries. Therefore, the pooled effect estimates should be interpreted with caution, and further analyses—such as subgroup analysis or meta-regression—are required to identify the underlying sources of heterogeneity.

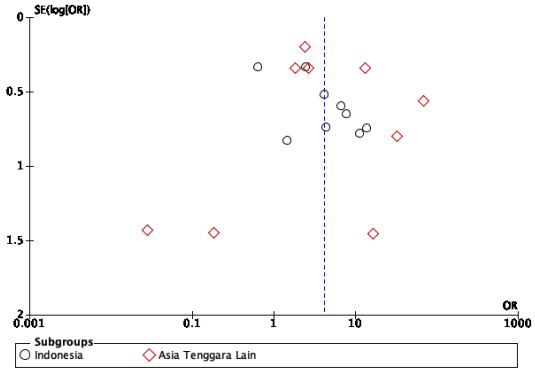

Figure 2. Forest Plot of the Knowledge Factor

In the forest plot for the knowledge factor, the pooled Odds Ratio (POR) for other Southeast Asian countries was 4.26 [1.60, 11.33], indicating a slightly greater effect compared with Indonesia, which showed a POR of 3.79 [1.80, 7.96]. These findings indicate that good knowledge significantly improves compliance in both regions, with a marginally stronger effect observed in Southeast Asia. Both subgroups demonstrated high heterogeneity, suggesting substantial methodological or clinical differences among studies, particularly within the Southeast Asian subgroup.

Table 3. Attitude Factor

Parameter	**Indonesia**	**Southeast Asia**
Number of Studies	9	9
Pooled Odds Ratio (95% CI)	6.78 [4.61, 9.95]	8.44 [3.53, 20.18]
I^2 (Heterogeneity)	0% (Low)	92% (Very High)
p-value	<0.00001	<0.00001

The most prominent finding of this analysis is the marked difference in heterogeneity across regions. In the Indonesian subgroup (I^2 = 0%), results from nine studies demonstrate very high consistency, indicating that the finding that a positive attitude increases compliance with medical solid waste management by 6.78 times is uniformly supported across all studies. In contrast, in the subgroup of other Southeast Asian countries (I^2 = 92%), results from nine studies exhibit substantial variability; therefore, the pooled odds ratio (POR) of 8.44 must be interpreted with considerable caution. This high level of heterogeneity suggests the presence of strong moderating factors, such as differences in study design, socio-cultural contexts, regulatory systems, and variations in the operational definitions of attitude, which contribute to the wide divergence of findings across studies in the Southeast Asian region.

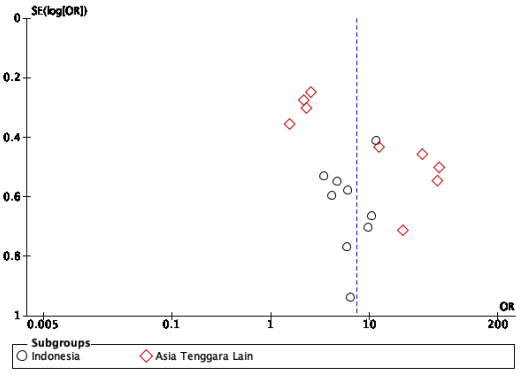

Figure 3. Forest Plot of the Attitude Factor

Comparative analysis indicates that a positive attitude plays a more dominant role in promoting compliance in other Southeast Asian countries, with a pooled odds ratio (POR) of 8.44 [3.53, 20.18], compared with Indonesia, which showed a POR of 6.78 [4.61, 9.95]. Both results are statistically significant, suggesting a greater emphasis on internal factors—such as motivation and attitude—in the context of compliance within Southeast Asian studies. However, it should be noted that the Indonesian subgroup exhibited perfect homogeneity, whereas the Southeast Asian subgroup demonstrated very high heterogeneity, indicating the presence of substantial unexplained differences among studies conducted in Southeast Asia.

Table 4 : Analysis of the Strength of Key Factors

Intervention Priority	Indonesia	Southeast Asia	Assessment
Most Dominant	Attitude (POR = 6.78) I^2 (Heterogeneity): 0%	Attitude (POR = 8.44) I^2 (Heterogeneity): 92%	Attitude is the most dominant factor driving compliance in both regions. The effect is stronger in Southeast Asia.
Less Dominant	Knowledge (POR = 3.79) I^2 (Heterogeneity): 76%	Knowledge (POR = 4.26) I^2 (Heterogeneity): 90%	Knowledge ranks second but remains a statistically significant factor influencing compliance.

The results of the comparative meta-analysis demonstrate a consistent prioritization of determinant factors influencing compliance with medical solid waste management in both Indonesia and other Southeast Asian countries. The attitude factor exhibited substantially higher Odds Ratio values than the knowledge factor, indicating that attitude is the most dominant determinant of compliance in both regions. Nevertheless, the effect sizes of both attitude and knowledge tended to be greater in Southeast Asia than in Indonesia. These findings underscore that the dominance of attitude represents a regionally consistent pattern, as reflected by the high pooled Odds Ratios for attitude in Indonesia (POR ≈ 6.78) and Southeast Asia (POR ≈ 8.44), highlighting attitude formation as the primary priority for interventions aimed at improving compliance.

This study has several limitations that warrant consideration, particularly the high level of heterogeneity ($I^2 > 50\%$) observed in most analyses, especially within the Southeast Asian subgroup. This condition indicates that pooled estimates—especially for the attitude factor in Southeast Asia—should be interpreted with caution. The stark contrast in heterogeneity between Indonesia ($I^2 = 0\%$) and Southeast Asia ($I^2 = 92\%$) represents an important finding, suggesting that methodological and contextual conditions in Indonesian studies are relatively homogeneous, whereas studies conducted across Southeast Asia are highly heterogeneous. Such heterogeneity may be attributable to differences in the operational definitions of attitude and compliance, variations in study design and measurement instruments (questionnaire-based assessments versus observational methods), as well as differences in regulatory enforcement systems and occupational safety cultures across countries.

The quantitative analysis further demonstrates that both key factors—good knowledge and positive attitude—have a significant influence on compliance with medical waste management in Indonesia as well as in other Southeast Asian countries. All Odds Ratio (OR) values exceeding 1 confirm a positive association between these factors and compliant behavior. However, positive attitude shows a stronger effect size than knowledge, both in Indonesia (OR = 6.78) and Southeast Asia (OR = 8.44), while the influence of knowledge is comparatively lower (Indonesia OR = 3.79; Southeast Asia OR = 4.26). These findings indicate that although knowledge is an essential prerequisite, attitude plays a more dominant role in driving compliant behavior in medical waste management.

The findings of this study are consistent with numerous studies and systematic reviews based on the Knowledge–Attitude–Practice (KAP) model, which posit that knowledge and attitude are positively associated with medical waste management practices. Several observational studies in Southeast Asia have also shown that good knowledge tends to result in better practices; however, this effect is often strengthened by attitude, individual motivation, and institutional support. The World Health Organization (WHO) emphasizes that the success of healthcare waste management is determined not only by cognitive aspects but also by policies, continuous training, adequate infrastructure, and effective monitoring systems. Studies conducted in Indonesia further indicate that interventions focusing solely on improving knowledge, without parallel improvements in facilities and without approaches targeting attitude change and workplace safety culture, have not been sufficient to optimally enhance compliance. Therefore, more comprehensive strategies incorporating managerial interventions and infrastructural support are required.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the comparative meta-analysis of studies conducted in Indonesia and other Southeast Asian countries, it can be concluded that healthcare workers' knowledge and attitudes have a significant influence on compliance with medical solid waste management in healthcare facilities. Positive attitude emerged as the most dominant determinant of compliance in both regions, demonstrating a stronger effect size than knowledge in Indonesia as well as in Southeast Asia. Differences in compliance levels across countries are influenced by variations in facility availability, training systems, regulatory strength, and institutional support, with countries implementing stricter regulations, consistent audit mechanisms, and adequate infrastructure showing more stable compliance. These findings highlight that improving compliance requires an integrated approach that not only enhances knowledge but also prioritizes the formation of positive attitudes, supported by strengthened systems, policies, and institutional frameworks. Therefore, policymakers are encouraged to reinforce the consistent implementation of medical waste management regulations through routine supervision, integration of health and environmental policies, and sufficient budgetary and infrastructural support. Healthcare facility management should focus on behavior-based training programs, the establishment of internal monitoring systems, and the development of a collective culture of compliance through interprofessional collaboration. Future research should employ more robust study designs, explore contextual and moderating factors affecting compliance, and promote regional collaboration to develop cross-country databases that support evidence-based policymaking in medical solid waste management.

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