

# Systematic Study of Risk-Based Medical Waste Management in Teaching Hospitals

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**Background:** Teaching hospitals are highly complex due to the integration of service, education, and research functions, resulting in a larger and more varied volume of hazardous medical waste. A risk-based management approach is crucial to mitigate occupational health impacts and environmental pollution. **Objective:** This systematic review aims to analyze risk-based medical waste management practices, operational indicators that determine waste generation, and control strategies in teaching hospitals. **Methods:** This study used the Systematic Literature Review (SLR) method following the PRISMA protocol. Article searches were conducted in Scopus, ScienceDirect, and Taylor & Francis databases for publications from 2021–2026, resulting in 9 primary articles for synthesis. **Results:** Risk analysis based on Failure Mode and Effects Analysis (FMEA) showed that the waste transfer stage and direct exposure to body fluids were critical points with the highest risks. In the laboratory area, risks were dominated by chemical and ergonomic hazards. Medical waste generation was strongly correlated with hospital operational indicators such as Bed Occupancy Rate (BOR), Bed Turnover Rate (BTOR), duration of hospitalization, and infection rates (HAIs). For final treatment, incineration is the optimal choice based on a multi-criteria decision-making (MCDM) for large capacities, while a combination of chemical disinfection and pyrolysis offers the most environmentally friendly option based on a Life Cycle Assessment (LCA). Human factors, particularly training frequency, have been shown to be a key predictor of staff sorting compliance. **Conclusion:** Medical waste management in teaching hospitals requires an integrated management system that combines periodic risk assessments, sustainable treatment technologies, and continuous staff training.

**Keywords:** Teaching Hospital; Medical Waste Management; Risk-Based Management; FMEA.

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## 1. Introduction

Improved healthcare services in various countries have led to an increase in the number of healthcare facilities, including teaching hospitals that simultaneously serve as service, educational, and research facilities. These activities generate large amounts of medical waste with diverse characteristics, ranging from infectious waste, sharp objects, pharmaceutical waste, chemical waste, to radioactive waste [1]. The World Health Organization states that approximately 85% of healthcare facility waste is classified as non-hazardous waste, while the remaining 15% is classified as hazardous waste, which can pose a risk of infection, injury, environmental pollution, and public health problems if not managed properly [2].

Medical waste management is a global concern because its impact is not only felt in the hospital environment, but also on the wider community and the ecosystem surrounding the health facility. WHO reports that every year there are around 16 billion injections used worldwide and some of them are still disposed of unsafely, increasing the risk of transmitting diseases such as hepatitis B, hepatitis C, and HIV [2]. In addition, the practice of open burning and low-temperature medical waste processing is still found in various developing countries and can produce hazardous emissions such as dioxins, furans, and particulates that pollute the air [3][4]. This condition shows that medical waste management is not only a

technical operational issue, but is also closely related to occupational safety, public health, and environmental sustainability.

In recent years, the amount of medical waste has increased significantly, especially after the COVID-19 pandemic [5]. The use of personal protective equipment, disposable medical devices, disinfectants, and laboratory waste has increased sharply in various healthcare facilities. Previous studies on healthcare waste have shown that the healthcare sector produces large amounts of waste and requires more structured management policies, particularly in the aspects of segregation, storage, transportation, and disposal of hazardous waste [6]. Research by Kaposi et al. on university hospitals shows that teaching hospitals have a higher volume of hazardous waste than general hospitals due to the high level of clinical, research, and laboratory activities [7].

Teaching hospitals have more complex characteristics than other healthcare facilities [8]. In addition to providing medical services to patients, teaching hospitals also serve as places for medical student practice, laboratory research, and medical technology development. This complexity results in a higher variety of waste produced and requires a risk-based management system so that each type of waste can be handled according to its level of danger [8]. A risk-based approach is one of the most widely developed strategies because it is able to identify sources of danger, levels of exposure, and potential impacts of medical waste so that the management process can be carried out in a more targeted and safe manner [9].

Internationally, medical waste management still faces various challenges. The WHO and UNICEF reported that in 2021, only around 61% of hospitals worldwide had adequate basic healthcare waste management services [2]. This figure is even lower in countries with limited resources and conflict-prone areas. Hospital waste production across continents also demonstrates differences in waste management capacity between developed and developing countries, both in terms of infrastructure, technology, and regulations [10]. This demonstrates that medical waste management remains a global challenge that requires strengthening ongoing monitoring and risk management systems.

In Indonesia, medical waste management also faces various challenges. The growth in the number of hospitals, improvements in healthcare services, and the use of single-use medical devices have led to a continuous increase in the volume of medical waste each year. Although the government has issued various regulations regarding the management of hazardous and toxic waste from healthcare facilities, implementation in the field remains suboptimal. Some hospitals still experience obstacles in the waste sorting process, limited processing facilities, minimal staff training, and inadequate oversight of high-risk waste management [11][12]. These conditions can increase the potential for environmental pollution and the risk of exposure for healthcare workers and the surrounding community.

A risk-based approach is considered one concept capable of addressing these challenges because waste management focuses not only on final disposal but also on identifying risks from the time the waste is generated [13]. This system encompasses hazard identification, risk assessment, risk control, and periodic evaluation of all stages of medical waste management. Through this approach, hospitals can prioritize control measures based on the level of waste risk, allowing available resources to be used more effectively and efficiently.

Several previous findings also indicate that implementing waste audits and appropriate management technologies can help improve the effectiveness of medical waste management in hospitals. Slutzman et al. explained that waste audits can help healthcare facilities understand waste production patterns and determine waste reduction strategies more accurately [14]. In addition, the development of waste treatment technologies such as autoclaves, microwave treatment, and non-incinerator technologies is starting to be widely developed as more environmentally friendly alternatives to conventional incineration [15].

Based on these conditions, a systematic review of risk-based medical waste management in teaching hospitals is necessary to obtain a comprehensive overview of waste management practices, the risk factors encountered, the control strategies employed, and the challenges of their implementation. This review is expected to serve as a basis for developing a safer, more effective, and more sustainable medical waste management system in teaching hospitals, while also supporting efforts to protect public health and preserve the environment.

## **2. Literature Review and Problem Statement**

### **Medical Waste Management in Hospitals**

Medical waste management is a series of activities carried out to handle waste generated from healthcare activities to prevent negative impacts on human health and the environment. Medical waste includes infectious waste, sharp objects, pharmaceutical waste, chemical waste, pathological waste, and radioactive waste, which require special handling according to their level of danger. In practice, medical waste management includes the processes of segregation, collection, temporary storage, transportation, processing, and final disposal. Good management aims to prevent the risk of disease transmission, reduce environmental pollution, and ensure the safety of healthcare workers, patients, and the public. Therefore, every healthcare facility, especially hospitals, is required to implement a medical waste management system that complies with applicable health and environmental standards.

### **Risk-Based Approach in Medical Waste Management**

A risk-based approach is a management method that emphasizes the identification, analysis, and control of risks that may arise during the medical waste management process. This approach is carried out by identifying the sources of hazards originating from each type of waste, assessing the likelihood of exposure, and estimating the potential impact on humans and the environment. Through risk management, hospitals can determine treatment priorities based on the level of danger so that available resources can be utilized more effectively and efficiently. Implementing a risk-based approach also supports the creation of a work safety culture, improves regulatory compliance, and helps hospitals reduce the potential for workplace accidents, nosocomial infections, and environmental pollution due to improper waste management.

### **Risk-Based Medical Waste Management in Teaching Hospitals**

Teaching hospitals have more complex characteristics than typical hospitals because they provide healthcare services and also conduct education, training, and research. These diverse activities generate a wider variety of types and volumes of medical waste, necessitating an integrated, risk-based management system. Risk-based medical waste management in teaching hospitals involves identifying waste sources, assessing the risk level of each type of waste, implementing appropriate control procedures, and periodically evaluating the effectiveness of the system. This approach enables teaching hospitals to manage waste more safely, prevent exposure to hazardous materials, improve the safety of academics and healthcare workers, and support the creation of a healthy, safe, and sustainable hospital environment.

## **3. Method**

This study used a systematic literature review method to identify, analyze, and synthesize various research findings on risk-based medical waste management in teaching hospitals [16]. This method was chosen because it provides a comprehensive overview of research developments, medical waste management approaches, and the various challenges and risk control strategies that have been implemented in healthcare facilities, particularly teaching hospitals.

The article search process was carried out systematically by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process. The PRISMA approach was used to ensure that the process of identifying, screening, selecting, and determining articles was carried out in a transparent and structured manner, thereby improving the quality of the resulting study. The PRISMA stages in this study included the process of identifying articles, screening articles, assessing eligibility, and determining the final articles used in the study [17].

A literature search was conducted in several international databases, namely Scopus, ScienceDirect, and Taylor & Francis. Article searches were conducted using a combination of keywords tailored to the research topic, namely "Risk Management", "Risk Based", "FMEA", "Risk Analysis", "Risk Assessment", "Medical Waste", "Healthcare Waste", "Hospital Waste", "Clinical Waste", "University", "Teaching Hospital", and "Academic Medical Center". These keywords were combined using the Boolean operators AND and OR to obtain articles that were in line with the research focus [18].

Inclusion criteria for this study included scientific articles published between 2021 and 2026, articles in English, research addressing risk-based medical waste management, and research conducted in hospitals, teaching hospitals, or healthcare facilities with similar characteristics. Articles that were review articles, articles without full access, articles on inappropriate topics, and articles that did not address risk aspects in medical waste management were excluded from the selection process.

Based on the initial search results, 129 articles were obtained from various databases. Next, articles that did not align with the research title and theme, those not in English, and those that were not fully accessible were eliminated. After the screening stage, the remaining articles were reanalyzed based on their suitability for content and research context. In the final stage, nine articles met the inclusion criteria and were used as primary sources in this literature review.

The data obtained were then analyzed descriptively and qualitatively by grouping the research findings based on key themes, such as types of medical waste, waste management methods, risk management approaches, waste treatment technologies, and barriers to implementing medical waste management in teaching hospitals. The analysis results were then compiled narratively to provide a comprehensive overview of risk-based medical waste management practices in teaching hospitals.

#### **4. Results and Discussion**

Based on the article identification and selection process using the PRISMA flow, nine articles met the inclusion criteria and were used in this study. These articles, from various countries, discussed risk-based medical waste management in hospitals and healthcare facilities with characteristics similar to teaching hospitals.

The study results indicate that medical waste management is influenced by various factors, such as waste segregation systems, processing methods, risk management implementation, facility availability, healthcare worker competency, and institutional policies regarding hazardous waste control. Furthermore, several studies have highlighted challenges that remain frequently encountered in medical waste management, ranging from high volumes of infectious waste, limited processing technology, to the risk of environmental pollution and exposure for healthcare workers. Table 1 presents the results of the research synthesis.

**Table 1.** Research Synthesis Results

No	Author (Year)	Country	Method	Risk Method	Outcome
1	Ghaffari et al. (2026)	Finland	Life Cycle Assessment (LCA)	Environmental impact evaluation includes Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), and Abiotic Depletion Potential (ADP).	The combination of chemical disinfection and pyrolysis of residual materials (PRM) is the best scenario and can reduce GWP by up to 77%.
2	Dadashi et al. (2024)	Iran	Direct observation, interviews, questionnaires, and quantitative approaches	Failure Mode and Effects Analysis (FMEA) through Risk Priority Number (RPN) calculations	The waste transfer stage carries the highest risk level. Lack of training and limited staffing are the main causes of risk.
3	Devebakan et al. (2025)	Türkiye	Time series data analysis using TRAMO/SEATS	Bayesian Model Averaging (BMA), Augmented-ARDL, and Fourier Todo-Yamamoto test	Bed Occupancy Rate (BOR) and Number of Days Hospitalized (NDH) have a positive effect on the amount of medical waste. There is a two-way causal relationship between Bed Turnover Rate (BTOR) and waste volume.
4	Yeoh et al. (2024)	Australia	Quantitative studies through sorting, weighing waste, and statistical analysis	Greenhouse Gas (GHG) Emission Estimates	The largest waste sources are cellulose materials and disposable aprons. Recycling sterile plastic wrap can save up to 10 kg of CO <sub>2</sub> e per year.
5	ALMashaqbeh & ALKhamisi (2023)	Oman	Questionnaire survey and interviews using Likert scale	Exponential Weighted Geometric Mean-FMEA (EWGM-FMEA)	The highest risk comes from exposure to blood and body fluids in medical workers with an RPN value of 1409.757.
7	Alshammari et al. (2021)	Qatar	Cross-sectional study using audits, checklists, evaluation sheets, and interviews	FMEA and risk matrix through RPN calculation	Chemical and ergonomic hazards are the highest in laboratories. Implemented controls

No	Author (Year)	Country	Method	Risk Method	Outcome
					can significantly reduce the severity and likelihood of these risks.
8	Kaposi et al. (2024)	Hungary	Descriptive statistical analysis	Spearman correlation analysis and robust regression	The amount of medical waste is increasing by 2.11% per year. Healthcare-associated infections and diaper use are strongly correlated with the increase in hazardous waste.
9	Çetin et al. (2025)	Türkiye	Cross-sectional observational study through waste weighing for 45 days and questionnaires	Correlation analysis, regression, and Chi-square test	As many as 15% of staff still misclassify hazardous waste. Training has been shown to significantly improve waste classification compliance.
10	Kalan et al. (2025)	Türkiye	Literature review, expert opinion, and decision matrix	Hybrid Multi-Criteria Decision-Making (MCDM) using CRITIC, PROMETHEE, TOPSIS, and EDAS methods	Incineration was determined to be the best medical waste treatment method, followed by autoclaving, microwaves, and landfills.

Overall, the findings from these ten articles highlight that medical waste risk management relies heavily on the identification of occupational hazards and the selection of integrated disposal methods. Based on an evaluation using the Failure Mode and Effects Analysis (FMEA) method, the waste transfer stage and direct worker exposure to blood and body fluids are the highest risk contributors that must be immediately mitigated in hospital environments. Furthermore, chemical hazards and the threat of ergonomic injuries dominate safety risks, particularly in teaching laboratories. In terms of waste treatment strategies, comprehensive findings regarding the best methods are available. A Life Cycle Assessment (LCA) study demonstrated that a combination of advanced sorting, chemical disinfection (as an alternative to autoclaving), and pyrolysis of residual materials is the most environmentally friendly method, capable of reducing global warming potential by up to 77%. However, a multicriteria decision-making (MCDM) analysis applied to a high-capacity university hospital recommended incineration as the most optimal disposal method due to its large processing capacity, ability to process a wide variety of waste, and potential for energy recovery.

On the other hand, these literature findings also reveal that the surge in hazardous medical waste generation is largely driven by operational patient dynamics and human compliance factors. Operational

metrics such as Bed Occupancy Rate (BOR), bed turnover, length of stay, number of healthcare-associated infections (HAIs), and diaper usage have been shown to significantly increase the volume of medical waste. Invasive units such as operating rooms, intensive care units (ICUs), and emergency departments are also recorded as producing hazardous waste far above the average for other units. From a human resources perspective, incorrect sorting processes by medical staff remain a major weakness, exacerbating the risk of disease exposure and environmental burden. Interestingly, research has clearly demonstrated that the frequency of waste management training is the strongest predictor of improved waste classification accuracy, while length of experience or tenure does not guarantee that staff have a good or up-to-date understanding of medical waste management regulations.

## Discussion

### Risk Identification and Analysis in Medical Waste Management

In identifying and evaluating health, safety, and environmental (HSE) hazards in medical waste management, healthcare facilities and educational laboratories generally adopt a systematic risk assessment approach such as the Failure Mode and Effects Analysis (FMEA) method (AlShammari et al., 2021; Dadashi et al., 2024). The FMEA method measures the level of operational risk by calculating the Risk Priority Number (RPN), which is the product of three main parameters: the probability of failure (occurrence), the severity of the impact (severity), and the ability to detect (detection) (Dadashi et al., 2024). To overcome the limitations of the conventional FMEA method, such as the possibility of repeating RPN values, a modified approach, namely the Exponential Weighted Geometric Mean-FMEA (EWGM-FMEA) combined with the Analytic Hierarchy Process (AHP), is used to prioritize waste hazards more accurately so that corrective actions can be taken immediately (AlMashaqbeh & AlKhamisi, 2023).

Based on risk analysis in hospitals, the waste transfer phase was identified as the operational phase with the highest risk level (Dadashi et al., 2024). When evaluated specifically based on the type of hazard using the EWGM-FMEA method in teaching hospitals, occupational hazard threats in the form of direct exposure of healthcare workers to patient blood and body fluids ranked highest with an RPN value of 1409.757 (AlMashaqbeh & AlKhamisi, 2023). In addition, other high-level operational risks include autoclave leaks, contaminated water for immunocompromised patients, and failure to use Personal Protective Equipment (PPE) when staff handle infectious waste (AlMashaqbeh & AlKhamisi, 2023).

In educational biomedical laboratory environments, the types of hazards faced by staff and students are diverse, but chemical and ergonomic hazards are the most common. Chemical and ergonomic hazards each account for the highest percentages, at 31% in hematology laboratories and 25% in microbiology laboratories (AlShammari et al., 2021). Ergonomic risks are often associated with musculoskeletal injuries due to poor posture or repetitive movements while working in the laboratory, while chemical hazards include spills, exposure to toxic materials, and improper storage of flammable materials (AlShammari et al., 2021). Meanwhile, biological hazards (exposure to infection) account for approximately 15.4% to 18.75% of the total hazards, which can lead to the spread of disease due to the unsafe handling of blood specimens or microbiological agents (AlShammari et al., 2021).

Misidentification and classification of waste pose a serious threat in the medical waste management chain. An observational study conducted by Ceti et al. (2025) in a university hospital microbiology laboratory found that as much as 15% of hazardous waste was still misclassified by medical workers, particularly expired pharmaceutical waste, cytotoxic drug vials, and fluorescent lamps. These misclassification errors not only lead to inappropriate final disposal but also significantly increase the risk of cross-infection among staff, sharps injuries, and environmental contamination (Cetin et al., 2025).

The high level of hazards and incidents of errors in waste management are rooted in operational factors and human resource (HR) weaknesses. An FMEA evaluation indicates that inadequate personnel training, low awareness, staff shortages (HR limitations), and a lack of accuracy are the main causal contributors to the high risk (Dadashi et al., 2024). This is reinforced by regression analysis findings, which confirmed that training frequency was the strongest predictor ( $R^2 = 0.72$ ) in determining staff compliance with waste classification, while length of service (experience) did not guarantee accurate medical waste sorting (Çetin et al., 2025). Therefore, mandatory, regular training programs are crucial for improving compliance with protective procedures, considering that 66.6% of healthcare workers reported being exposed to medical waste risks due to inadequate management systems (Çetin et al., 2025).

### **Factors Influencing the Generation of Medical Waste and Its Impact on the Environment**

The increase in medical waste in hospitals is influenced by various operational factors in healthcare services, particularly high patient care volumes, the use of single-use medical devices, and the increasing need for infection control in healthcare facilities. Teaching hospitals have more complex characteristics than general hospitals because, in addition to providing healthcare services, these institutions also conduct clinical education, laboratory research, and student internships. These conditions tend to produce larger and more diverse volumes of medical waste, particularly infectious and hazardous waste.

The results of research by Devebakan et al. (2025) show that the increase in the amount of medical waste is closely related to hospital service indicators, such as Bed Occupancy Rate (BOR) and Number of Days Hospitalized (NDH). The higher the bed occupancy rate and the longer the patient is treated, the greater the amount of medical waste produced. The study also found a two-way causal relationship between Bed Turnover Rate (BTOR) and the amount of medical waste. The high patient turnover in hospital services leads to an increase in the use of disposable medical devices, sterilization materials, personal protective equipment, and other medical materials, which then contributes to the increase in the volume of medical waste.

The increase in medical waste is also influenced by the high production of infectious waste in hospitals. Kaposi et al. (2024) found that the amount of medical waste increases by 2.11% annually and is strongly associated with high cases of Healthcare Associated Infections (HAIs). The higher the number of healthcare-associated infections, the greater the use of personal protective equipment, sterilization materials, medical diapers, and other disposable supplies. The study showed that the use of medical diapers is one of the largest contributors to hazardous waste in hospitals. These findings illustrate that the modern healthcare system, which is increasingly oriented towards infection prevention, has also significantly increased medical waste production.

In addition to being influenced by healthcare service activities, the characteristics of the type of waste produced are also a concern in risk-based medical waste management. Yeoh et al. (2024) Research shows that the most dominant medical waste comes from cellulose-based materials and disposable aprons. This waste mostly originates from operating rooms and medical procedures that use large quantities of sterile materials. The use of disposable materials is considered to improve patient safety and reduce the risk of cross-infection, but on the other hand, it results in significant waste generation. This situation presents a challenge for hospitals because the increasing volume of waste must be balanced with a safe and sustainable management system.

The ever-increasing production of medical waste has a significant impact on the environment, primarily through increased carbon emissions and environmental pollution. Medical waste management, which still relies on conventional incineration methods, can produce greenhouse gas emissions, hazardous particulates, dioxins, and other toxic compounds. Yeoh et al. (2024) explained that medical plastic waste,

particularly sterile plastic packaging, is a significant contributor to carbon emissions in hospitals. The study showed that recycling sterile plastic packaging can reduce emissions by approximately 10 kg CO<sub>2</sub>e per year. These results demonstrate that waste reduction strategies and the reuse of certain materials can help reduce the environmental impact of healthcare activities.

A study on the environmental impact of medical waste was also conducted by Ghaffari et al. (2026) using a Life Cycle Assessment (LCA) approach. The study evaluated the environmental impact of several medical waste treatment methods based on indicators such as Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), and Abiotic Depletion Potential (ADP). The results showed that the combination of chemical disinfection and pyrolysis of residual materials was the most effective waste treatment alternative because it was able to reduce global warming potential by up to 77%. These findings indicate that the choice of waste treatment technology has a significant impact on the environmental sustainability of hospitals.

Environmental evaluation approaches such as Life Cycle Assessment and Greenhouse Gas Emission estimation are increasingly being used in modern medical waste management because they provide a comprehensive overview of the environmental impacts resulting from each stage of waste management. Through this approach, hospitals can identify the largest emission sources, determine more environmentally friendly treatment methods, and develop more targeted waste reduction strategies. As institutions with large-scale service and research activities, teaching hospitals require waste management systems that are not only safety-oriented but also consider environmental sustainability.

### **Risk-Based Medical Waste Management Strategies and Technologies**

In medical waste management, hospitals use various processing methods such as incineration, autoclaving, microwaves, and pyrolysis to handle infectious and hazardous waste generated from healthcare activities (Kalan et al., 2025). The choice of waste treatment method needs to be tailored to the conditions and needs of the hospital because each method has its own advantages and disadvantages. Research by Kalan et al. (2025) shows that incineration remains the primary choice because it can process large amounts of waste and can be used for various types of medical waste. In addition, the incineration process can also generate energy again. However, research by Ghaffari et al. (2026) explains that the combination of chemical disinfection and pyrolysis methods is more environmentally friendly because it can reduce the potential for global warming by up to 77%. These results indicate that hospitals are starting to need waste treatment technology that is not only effective but also safer for the environment.

Successful medical waste management depends not only on processing technology but also on risk control during the waste handling process in hospitals. Research by AlShammari et al. (2021) explains that risk control is carried out through several steps, such as the use of personal protective equipment (PPE), the implementation of standard operating procedures (SOPs), the use of Biosafety Cabinets (BSCs), and the provision of special cabinets for hazardous chemicals. The use of these facilities has been shown to reduce the risk of exposure to infectious materials and chemicals in hospital laboratories. Furthermore, special protection is also needed for healthcare workers who are more vulnerable to exposure to medical waste, such as laboratory staff, pregnant women, and healthcare workers with weakened immune systems.

The human factor also plays a significant role in the success of medical waste management. Mistakes in sorting and classifying waste are still common in hospitals, such as pharmaceutical waste or cytotoxic waste being disposed of in general waste bins (Çetin et al., 2025). This situation can increase the risk of environmental pollution and disease exposure for healthcare workers. Research by Çetin et al. (2025) shows that regular training significantly impacts staff compliance in classifying medical waste. Healthcare workers who receive regular training have a higher level of waste sorting accuracy than those who rarely

receive training. Therefore, hospitals need to implement ongoing education and training programs to ensure all healthcare workers understand proper medical waste management procedures.

Safe and sustainable medical waste management requires a collaborative effort between the use of appropriate technology, the implementation of risk controls, and increased compliance among healthcare workers. Hospitals are not only required to reduce the risk of infection and workplace accidents, but also need to consider the environmental impact of the waste they produce. Ghaffari et al. (2026) explain that an environmentally friendly approach can be implemented through waste reduction at the source, the reuse of certain materials, and the development of safe recycling systems. Furthermore, hospitals also need to conduct regular monitoring and evaluation through waste audits and supervision of waste management procedures so that any mishandling errors can be promptly corrected (Çetin et al., 2025). By implementing an integrated system, medical waste management in teaching hospitals can be safer, more effective, and support environmental sustainability..

## 5. Conclusion

Based on the results of a systematic review of 9 articles, risk-based medical waste management in teaching hospitals is influenced by various factors, including high patient occupancy rates, length of stay, use of single-use medical devices, and increased need for infection control. These conditions contribute to an increase in the volume of medical waste, particularly infectious and hazardous waste, which has the potential to negatively impact human health and the environment if not managed properly. The complexity of activities in teaching hospitals, which include health services, education, and research, also results in an increasingly diverse variety of waste products, necessitating a more structured and risk-oriented management system.

The study also shows that implementing a risk-based approach through methods such as Failure Mode and Effect Analysis (FMEA), Life Cycle Assessment (LCA), and Multi-Criteria Decision-Making (MCDM) can help hospitals identify hazard sources, assess risk levels, and prioritize the most effective controls. Furthermore, improving the competency of healthcare workers through training, implementing a standardized waste sorting system, and utilizing safer and more environmentally friendly waste processing technologies have been shown to improve the effectiveness of medical waste management. Therefore, teaching hospitals need to develop an integrated, adaptive, and sustainable medical waste management system to support the creation of safe, efficient, and responsible healthcare services that protect public health and environmental sustainability.

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