Opportunities and Challenges in Sustainability
https://www.acadlore.com/journals/OCS

Strategies for Optimizing Medical Waste Management and Treatment Technologies in Jordanian Hospitals

Aseel Hendi[1], Jebril Al-hrinat[2], Abdullah M. Al-Ansi[3*], Manar Hazaimeh[4]

[1] Industrial Engineering Department, The Hashemite University, 1239 Zarga, Jordan
[2] Faculty of Education, Arab American University, 4312 Hebron, Palestine
[3] Collage of Commerce and Business Administration, Dhofar University, 211 Salalah, Oman
[4] Faculty of Education, Yarmouk University, 2662 Irbid, Jordan

[*] Correspondence: Abdullah M. Al-Ansi (aalansi@du.edu.om)

Received: 01-25-2024 **Revised:** 02-28-2024 **Accepted:** 03-15-2024

Citation: Hendi, A., Al-hrinat, J., Al-Ansi, A.M., & Hazaimeh, M. (2024). Strategies for optimizing medical waste management and treatment technologies in Jordanian hospitals. *Oppor Chall. Sustain.*, *3*(1), 35-49. https://doi.org/10.56578/ocs030103.

Abstract: Medical waste is recognized as a significant environmental and public health hazard due to its toxic and chemical constituents. In light of the varying standards for medical waste management within Jordan and comparisons with neighboring countries, this study aims to critically assess the existing management practices in Jordanian hospitals, utilizing a comprehensive database. The study further explores treatment technologies to enhance these practices. The effectiveness of Failure Mode and Effects Analysis (FMEA) in identifying and mitigating potential risks in the disposal process of infectious medical waste is also examined. Findings suggest that management procedures exhibit regional disparities influenced by factors such as the geographical location of the healthcare institution, its operational scale, and prevailing political circumstances. Moreover, the application of FMEA was found to significantly mitigate operational risks, as evidenced by reduced Risk Priority Number (RPN) values. Challenges identified include the need for increased resources, improved training, and enhanced systems for hazardous waste management. The study underscores the importance of public awareness in elevating medical waste management standards. These insights contribute to the broader discourse on environmental health and safety in medical waste management, advocating for systemic improvements in Jordanian healthcare facilities (HCFs).

Keywords: Medical waste management; Hospitals; Treatment technologies; Jordanian hospitals

1. Introduction

Infectious and cytotoxic medical waste could be generated due to healthcare procedures, such as expired drugs and mercury. This requires a comprehensive approach to healthcare waste management to reduce risks, whereas strategies for healthcare waste management include segregation, collection, storage, transportation, treatment, and disposal. These strategies should be implemented to protect healthcare workers and patients and reduce environmental contamination (Awodele et al., 2016; Cai & Du, 2021). Therefore, the World Health Organization (WHO) calls for treating hospital waste. Although many countries worldwide have enough awareness to correctly make medical waste a resource through treatment and disposal to minimize potential risks, improper disposal can cause health and environmental risks. Therefore, HCFs should take proper management of medical waste seriously. This helps prevent the spread of infectious diseases and protect the environment (Ali et al., 2017; Niyongabo et al., 2019; Singh et al., 2022). Despite Jordan being a small country with an open economy, middle-income, and limited natural resources (Karnouk et al., 2019), the World Bank has ranked Jordan as the number one provider of healthcare services in the region and the fifth worldwide health tourism destination (Darwazeh et al., 2021), because Jordan is committed to providing quality healthcare services, infrastructure, and technology while focusing on providing affordable healthcare to citizens.

Medical waste, a term encompassing all materials generated during patient care that could potentially pose a threat to human health, is a pressing concern within the healthcare industry (Kalantary et al., 2021). This category

of waste includes items such as discarded needles, syringes, bandages, and even disposable medical equipment (Kargar et al., 2020; Torkashvand et al., 2022). The improper disposal of medical waste can lead to serious consequences, including the spread of infections and diseases. HCFs are required to adhere to strict guidelines set forth by regulatory agencies in order to properly manage and dispose of medical waste in a safe and environmentally responsible manner. Failure to do so can not only harm the environment but also jeopardize public health. It is imperative for healthcare professionals to be vigilant in their handling of medical waste to ensure the safety of both patients and staff members alike.

The issue addressed in this research pertains to the notable surge in medical waste produced in HCFs, research institutes, and laboratories. This trash can be contaminated with infectious pathogens or other hazardous substances, particularly during the COVID-19 pandemic. The research demonstrates the need to effectively manage medical waste to minimize health hazards and save the environment. It also highlights the crucial treatment methods necessary to avoid the transmission of infectious diseases and safeguard public health and the environment. The study's objective is to assess the efficacy of medical waste management in hospitals in Jordan and explore the feasibility of implementing innovative waste treatment technologies. The findings of this study offer an essential understanding of the present condition of medical waste management in the nation.

Jordan faces numerous challenges in the management of medical waste, primarily due to a lack of proper infrastructure and regulations. Medical facilities often struggle with limited resources and capacity to effectively segregate, handle, store, and dispose of hazardous medical waste. Inadequate training among healthcare workers on safe disposal practices further complicates the situation. The absence of a centralized system for medical waste collection and treatment leads to haphazard disposal methods like open burning or dumping in landfills, posing serious health risks to both humans and the environment (Al-Ansi et al., 2023a; Goswami et al., 2021). Additionally, the growing healthcare sector in Jordan exacerbates the problem by generating increasing amounts of medical waste that strain existing waste management systems. Addressing these challenges requires improved governance, increased investment in appropriate technologies, enhanced public awareness campaigns, and stricter enforcement of regulations to ensure safe and sustainable management of medical waste in Jordan (Al-Ansi et al., 2023b; Ba Awain et al., 2023; Jaboob et al., 2024).

Many diseases have been found to be associated with improper handling and mismanagement of medical waste. A preliminary literature search showed that Jordan had little available literature. The literature search on Google Scholar was then broadened to include the terms “medical waste generation in Jordanian hospitals,” “medical waste treatment in Jordan,” “medical waste management in Jordan,” and “the FMEA method for healthcare waste risk assessment.” In addition, articles dealing with the same problem in neighboring countries were reviewed.

2. Literature Review

2.1 Medical Waste During the COVID-19 Pandemic

Expanding healthcare systems and services during the COVID-19 pandemic has increased medical waste for HCFs (Andeobu et al., 2022). Therefore, Jordan worked to improve and develop medical waste management by making an effective plan focused on providing better training for healthcare workers on proper waste management and disposal and increasing the number of waste disposal facilities. Additionally, Jordan implemented stricter regulations and sanctions to ensure compliance with the plan (Alzghoul et al., 2022). Thus, Jordan became one of the countries with advanced healthcare services in the Mediterranean Region; this has been achieved through the implementation of several initiatives, such as establishing healthcare centers and hospitals and implementing various health campaigns. As a result, the country has also seen an increase in healthcare professionals, particularly in rural and remote areas.

The effects of COVID-19 on Jordan's medical waste management were described in the article by Alzboon et al. (2022), which also examined the volume of waste generated in 54 facilities that produced medical waste in 2018 and 2020. The study found that the government's decisions on curfews and other things greatly influence medical waste. Medical waste generation in private hospitals and institutions that treated COVID-19 patients increased in 2020, whereas it decreased in government hospitals, HCFs, laboratories, and businesses. Hospitals in COVID-19 wasted three times as much when comparing 2020 to 2018 data. The implementation of stringent safety regulations and curfews is probably to blame for the rise in medical waste at private hospitals, which demonstrates the influence of government decisions on the generation of medical waste.

There are some countries that have adopted safety measures for managing healthcare waste, and the WHO has guidelines to help manage medical waste (Das et al., 2021). These measures include identifying and segregating hazardous healthcare waste, providing personal protective equipment for healthcare workers, and using proper disposal methods. Following these guidelines helps to protect healthcare workers and the environment from potentially hazardous materials.

2.2 Medical Waste Management in Jordan

Whereas Jordan provided primary healthcare through a network of health centers dispersed throughout all governorates and secondary and advanced healthcare through its hospitals or private hospitals, improving quality and obtaining accreditation in health centers to raise the number from 97 in 2017 to 147 in 2022, as well as computerizing health centers to raise the number from 142 in 2017 to 478 in 2022. However, about 4.7 tons of medical waste are produced daily in Jordan, with a daily production rate per bed of 2.69 kg (Abu Qdais et al., 2007). This is an alarming amount of waste, mainly because most of it is improperly recycled or disposed of. It can lead to environmental pollution, which can impact the health of local communities and ecosystems.

According to the health services will account for nine percent of Jordan's gross domestic product (GDP) in 2020, which is high compared to other nations. As shown in Table 1, Jordan has 14,779 beds available in private and public hospitals. This indicates that Jordan has a relatively high number of hospital beds per capita, especially in the public sector. Therefore, since COVID-19 has rapidly spread, more public and private hospitals have been opening, modernizing already-existing ones, extending health insurance coverage, and switching from antiquated traditional treatments to contemporary ones. As a result, Jordan's daily production of medical waste rose from 10 to 15 tons. Therefore, it is crucial to ensure that best practices for the disposal of medical waste are followed in order to protect Jordanian residents and hospital front-line staff from harmful and communicable diseases, including the spread of the novel coronavirus (United Nations Development Programme, 2020).

Table 1. Number of hospitals and hospital beds in 2017-2020 in Jordan

Facility Type	2017		2020	
	Number of Hospitals	Number of Hospital Beds	Number of Hospitals	Number of Hospital Beds
Private	62	4,496	67	7,242
Public	48	9,235	48	7,537
Total	110	13,731	155	14,779

2.3 Generation and Composition of Medical Waste

The generation and composition of medical waste are crucial aspects of HCFs' daily operations. Medical waste includes various materials like sharps, soiled dressings, discarded gloves, and other potentially infectious materials. The generation of medical waste occurs during patient treatments, surgeries, and routine medical procedures. It is essential to handle this type of waste properly to prevent the spread of infections and protect the environment. The composition of medical waste can vary depending on the type of HCFs and the services they provide. Proper segregation and disposal methods must be followed to ensure compliance with regulations set forth by local environmental agencies. HCFs must have robust protocols in place for managing medical waste to safeguard public health and support sustainability efforts within the industry.

According to Abu Qdais et al. (2007), a prominent tertiary care hospital in Jordan conducted statistical analysis to assess the generation rates and composition of medical waste generated while managing the coronavirus pandemic. Over the course of 25 days, 95 patients with coronavirus infections were admitted to King Abdullah University Hospital. The average weight of medical waste generated by the coronavirus treatment was 14.16 kg per patient and 3.95 kg per bed daily. Therefore, this is more than ten times the usual generation rate during ordinary hospital operation hours. Therefore, to prevent the virus from spreading, medical staff members need to take extra precautions, such as donning protective clothing.

2.4 Literature Review of Medical Waste in Jordan

This review focused on the current state of medical waste management in Jordan. Significant gaps were found in the medical waste management system, including a need for adequate storage and disposal facilities and inadequate training for medical staff. These gaps must be addressed to ensure the safe management of medical waste. Additionally, more education and awareness around medical waste should be provided to ensure proper disposal practices.

Based on numerous studies looking at how to manage medical waste in Jordan, Table 2 shows the most significant results. In addition to various sources, such as the MOH, Alzboon et al. (2022) showed that an increase in COVID-19 cases affected the generation, types, and quantity of medical waste strongly in 2020 and compared to 2018. At the same time, it revealed a decrease in waste generation in governmental hospitals, health care centers, laboratories, and industries from 434,673 tons to 373,934 tons during the year 2020. The decrease in waste was due to a reduction in hospital visits, procedures, and surgeries and the implementation of waste management strategies such as reuse and recycling. The study concluded that there was a significant difference in medical waste generation between 2018 and 2020.

Using their knowledge of medical waste systems, components, and both conventional and cutting-edge methods for managing and controlling medical waste, Shareefdeen et al. (2022) covered waste management strategies like segregation, labeling, separation, and waste minimization procedures, as well as approaches for treating medical waste, such as plasma gasification, pyrolysis, landfilling, sterilization, chemical disinfection, and microwave disinfection. Additionally, the administration and control of medical waste during the COVID-19 epidemic have been closely examined. This is critical for ensuring medical waste's safe and sound disposal, which is especially important during a pandemic. By ensuring proper segregation and labeling, it is easier to track and manage medical waste so that it can be treated properly and safely. Furthermore, waste minimization procedures help to reduce the amount of medical waste that needs to be treated, thus reducing the strain on waste management infrastructure.

Al-Momani et al. (2013) used two methods to analyze the survey responses. Comparing the negative and positive responses was the first step. However, the results of the comparison showed that there were substantial differences between the study's participating hospitals. A sizable portion of affirmative responses to the poll were taken as a promising sign. A descriptive analysis of the responses was used as the second step, where the findings indicated that most participants had a positive opinion of the performance of their hospitals, and that the level of care they received was considered acceptable. However, the findings were not as positive in the southern region of Jordan, where it was found that there were inadequate administrative processes and medical waste collection protocols. This can be attributed to inadequate resources, such as personnel and facilities, necessary for proper medical waste collection and disposal in this region. Additionally, the inadequate infrastructure in the southern region can make it difficult to access medical waste disposal facilities, further contributing to the problem. Al-Soud et al. (2022) focused on Jordanian HCFs, medical waste generated as a result of drugs in the base year of 2018, and the impact of an increase in demand on overall quantities. To forecast the numbers for the horizon year of 2025, data were gathered from the MOH departments, particularly the environment department. The study concluded that, with the current rate of increase, the total weight of medical waste generated in Jordan was expected to double by 2025. The study also noted that the current infrastructure for medical waste management was inadequate and needed to be improved to handle the potential increase in waste.

Table 2. Published studies addressing medical waste issues in Jordan

Reference	Aim	Method	Result	Conclusion
Alzboon et al. (2022)	To discover the effect of COVID-19 on Jordan's medical waste management.	Literature review	There was a threefold increase in waste in hospitals during COVID-19 between 2020 and 2018.	Medical waste output increased during the COVID-19 pandemic in hospitals that treated COVID-19 patients; this issue needs to be assessed and handled.
Alzghoul et al. (2022)	To assess the degree of medical waste management knowledge possessed by healthcare personnel at the Jordanian coronavirus illness screening stations in 2019.	A cross-sectional survey	When it came to understanding and implementing COVID-19 medical waste management protocols, nurses showed the highest level of awareness. The inability of the private sector to successfully carry out national and international initiatives.	The pathogen may be eliminated thanks to Jordan's efficient solid waste collection and disposal practices.
Shareefdeen et al. (2022)	To evaluate the current management procedures and plans of health care workers (HCW) using a pilot study in a facility with its own plan in accordance with Jordanian and WHO standards.	Literature review	The trash generated in such a facility is categorized as liquids, solids, pharmaceuticals, or sharps.	Effective waste management in HCFs depends on improving healthcare personnel's education and standardizing the classification of medical waste streams.
Al-Soud et al. (2022)	To illustrate a thorough assessment of healthcare waste management procedures and the available technological solutions for improving their management.	Survey	The population growth rate utilized in the calculations was calculated to be 2%, and 100 grams of medical waste were generated for every drug administered in a HCF. The medical waste produced by HCFs increased to 1,030.9 tons in 2018 and will reach 1,240 tons in 2025.	While quality control and authorities should act quickly to enforce rules and regulations, additional work training is necessary.
Alrawi et al. (2021)	To assess the management of medical waste during COVID-19.	Literature review	Typically, medical waste consists of around 85% non-infectious waste, 10% hazardous and infectious waste, and 5% radioactive and chemical waste.	Successful management of the generated medical waste depends on everyone's participation in properly separating and collecting COVID-19 trash at the

				appropriate time and removing the waste quantity in order of priority.
Abu Qdais et al. (2007)	To conduct statistical analysis and evaluate the creation rates and the makeup of medical waste produced during the coronavirus pandemic treatment at a significant Jordanian tertiary care facility.	Survey	Medical waste generation has a correlation coefficient of 0.89 and is distributed according to a log-normal distribution, according to an analysis of the frequency patterns in the data. The distribution is distorted to the right and flatter than the standard distribution curve, which indicates that it is out of normalcy based on the skewness and kurtosis coefficients.	In some regions of Jordan, healthcare professionals' attitudes and behaviors were highly developed, while in others, they were more moderate.
Al-Momani et al. (2019)	To eradicate actual health and environmental risks using a medical waste management strategy that works for healthcare institutions.	Literature review	Hospitals in Jordan have several issues regarding disposing of medical waste.	Medical waste is typically handled and managed poorly, and this includes a lack of regulations pertaining to this process.
Al-Momani et al. (2013)	To evaluate the medical waste management strategy through the use of unique and unambiguous protocols that ensure the proper and accurate implementation of this plan.	Survey	Jordan's southern region has the least appropriate administrative practices and medical waste-collecting processes.	Jordan needs to improve a system for handling and processing medical waste. Despite the Jordanian government's intense focus on this issue, many involved in managing this type of garbage need to be made aware of the actual consequences of this waste.
Fraiwan et al. (2013)	To study medical waste practices in southern Jordan, including segregation, packaging, storage, and disposal.	Survey	Each hospital produced an average of 0.73 kg of refuse per bed for one day. It was discovered that medical waste management practices needed to be revised due to inadequate training and education.	The medical waste management infrastructure required oversight and monitoring by the MOH.

2.5 Literature Review of Medical Waste in Neighboring Countries

Recent studies have raised concerns regarding the administration of medical waste in Jordan and neighboring nations. Effective medical waste management in Jordanian hospitals can reduce health hazards and safeguard the environment (Al-Momani et al., 2019). A federal law in the United States, the Medical Refuse Tracking Act of 1988, prohibited the unlawful disposal of contaminated biological materials, blood refuse, and body tissues (Singh, 1989).

This section compares the medical waste management practices of various nations and any advancements that they have made. Table 3 provides data from many studies and summarizes their methodologies to make a comparison, namely, the global level, Australia, Nigeria, Bangladesh, Burundi, the Middle East and North Africa (MENA), developing countries, and the Gaza Strip. This comparison helps identify gaps in the current system and inform policy decisions on improving waste management in Jordan. Education and awareness campaigns can also be developed and targeted at the public to encourage responsible medical waste disposal. Comparing the medical waste management system in Jordan with that in other countries helps identify inefficiencies and areas for improvement. It also highlights successful policies or government initiatives that could be applied in Jordan. Additionally, it helps inform decisions about how to allocate resources best to improve the existing system. As stated in the study by Mol et al. (2022), advancements in medical waste separation and containment of the transmission of infections provide evidence that enhancements can guarantee more effective management and control of medical waste. Furthermore, improved medical waste treatment has decreased the release of hazardous substances into the environment. Additionally, it has contributed to the reduction of medical refuse disposal expenses. Enhanced management of medical waste consequently yields environmental and human health benefits. It can reduce disposal costs, hazardous material emissions, and the transmission of infectious diseases.

The comparison with Jordan shows that Jordan has some of the most stringent regulations for medical waste management. It requires complete segregation, storage, and disposal of medical waste and regular reporting and monitoring of the process (Shareefdeen et al., 2022). These regulations are stricter than those of most neighboring countries. However, according to Alzghoul et al. (2022), Jordan also has government-run programs that provide proper training to medical waste handlers and ensure that the waste is disposed of safely and responsibly. This rigorous approach to managing medical waste protects Jordan's citizens and those of other countries from

potentially hazardous materials. They also ensure that all medical waste is disposed of in an environmentally friendly way. Additionally, medical establishments are incentivized and encouraged to manage and dispose of waste correctly. Therefore, Jordan is setting a positive example for other countries by properly handling medical waste and promoting environmental sustainability.

Table 3. Comparison of case studies in different countries

Reference	Country	Aim	Method	Result	Conclusion
Singh et al. (2022)	Worldwide	To investigate the most recent developments and understanding of medical and healthcare waste management on a global scale and to examine the impact of diverse socioeconomic and environmental factors on medical waste generation in 78 countries.	Cross-sectional study	With an average segregation rate of 38.9%, only about 41% of personnel had undergone in-service training regarding appropriate medical waste management. Approximately 35% of medical waste consists of plastic materials, presenting an opportunity for sustainable resource recovery and recycling.	Environmental sustainability in the management of medical waste is a critical requirement for all nations in order to prevent the calamitous accumulation of infectious waste throughout and after pandemics.
Andeobu et al. (2022)	Australia	To review different management and disposal techniques used in Australia to deal with medical waste left over from the COVID-19 pandemic and their effects on environmental and public health.	Systematic review	The opening of new isolation/quarantine centers, homes, and hotels in different Australian states and territories has raised the hazards of transmission among residents of these locations as well as the probability that regular garbage may become contaminated with medical waste.	Lockdowns successfully stopped the spread of COVID-19.
Etim et al. (2022)	Nigeria	To perform a comprehensive evaluation of how COVID-19 affected the administration and disposal of medical waste in Nigeria throughout the pandemic.	Literature review	The daily average COVID-related medical waste in Nigeria increased by more than 143.01% in less than a year, from 131.24 tons per day in August 2020 to 318.92 tons per day in January 2021. Therefore, this has resulted in environmental contamination and posed a significant infection risk to healthcare personnel.	An efficient MWM plan should be put in place for HCFs to meet the majority of poor nations' needs.
Fadaei (2022)	Different countries	To examine and assess the current state of medical waste management across various nations.	Systematic review	A negative correlation between the rate of medical waste generation and the ranking of healthcare system performance was discovered. In various countries, the medical waste generation rate varied between 0.14 and 6.10 kg per bed for one day. Approximately 25% of nations implemented medical waste segregation, whereas 17% opted for standard storage for all medical refuse.	Guidelines and regulations for medical waste management, technologies, knowledge, and funding are critical requirements for the global improvement of medical waste management.
Thabit et al. (2022)	MENA	To assess the waste management system's	Literature review	Countries with a high GDP generate more waste	Several environmental

		current condition, composition, per capita waste generation, treatment alternatives, institutional frameworks, and a range of sectors and facets directly associated with waste generation.		(between 1.5 and 2.7 kg per person per day) with a reduced organic content (around 40%) due to their more affluent populations leading more active lifestyles. The per capita energy consumption sheds light on the critical function of refuse as an energy source.	stressors are already being encountered in the MENA region, including air pollution, water scarcity, the depletion of marine resources, the disappearance of arable land, biodiversity loss, and the degradation of coastal ecosystems.
Hossain et al. (2021)	Gopalganj Sadar, Bangladesh	To describe the current state of medical waste management and the procedures in place at several clinics and hospitals.	Survey	There was an absence of waste management and resource segregation infrastructure, along with a lack of pertinent healthcare practical training on appropriately handling such waste.	It is crucial to possess knowledge regarding hospital refuse management and control strategies. A minimal understanding of medical refuse and its management exists among senior staff and attendants.
Niyongabo et al. (2019)	Burundi	This study will access official government reports to investigate the storage and ultimate disposal practices of solid waste management (SWM) in 12 HCFs.	Survey	The findings revealed that for on-site and off-site SWM transportation, 75% and 92% of HCFs utilized uncovered wheelbarrows and vehicles, respectively. Furthermore, it was determined that unethical land disposal and incineration methods accounted for 92.8% (15,736.4 tons) of SWM from all 12 HCF.	Essential responsibilities for the sustainable and secure management of medical waste in Burundi include establishing efficient regulations and protocols for the transportation and treatment of SWM.
Ali et al. (2017)	Developing countries	To evaluate and summarize the primary challenges of hospital waste management in developing nations.	Literature review	The inadequate waste collection, storage, transportation, and disposal practices prevalent in hospitals in these countries pose risks to the environment and employees' health.	In general, hospital refuse management in developing countries is challenging. Although hospital waste can negatively affect the environment, this can be mitigated through sustainable waste management practices.
Caniato et al. (2016)	Gaza	To assess medical waste management during a crisis.	Literature review	Daily hospital production was 683 kilograms, whereas daily medical waste generation was 3,357 kilograms. A portion of hazardous and non-hazardous waste was segregated, medical waste treatment was infrequent, and 75% of dangerous waste remained untreated.	There was a proposition for a new approach that has the potential to enhance resource allocation in times of crisis.

3. Methodology

A survey of selected literature on medical waste management in Jordanian hospitals was conducted to accomplish the study's goal. The most critical research on Jordan's medical waste problems is displayed in Table 2. Additionally, Table 3 illustrates a review of some literature on medical waste management in surrounding nations and a comparison with Jordan. The sources of potential risks in the infectious medical waste disposal

process should be evaluated using the FMEA.

3.1 FMEA Method

The FMEA process is a systematic approach for evaluating and mitigating risks associated with healthcare delivery. It involves identifying potential failures and the associated risks, analyzing the causes and effects of those failures, and developing strategies to reduce the likelihood of their occurrence. Finally, strategies are implemented to monitor and control identified risks (Safety Culture, 2023). This method was a detailed quantitative and qualitative FMEA, a common technique in HCW management, used to execute risk management for enhancing healthcare quality.

Table 4. FMEA process using SOD evaluation criteria (Ho & Liao, 2011; Kumar et al., 2011)

Effect	Criteria: Severity of Effect	Detection	Criteria (%)	Probability of Failure	Likely Failure Rates	Rank
Hazardous without a warning	Entails disregard for governmental regulations. Unexpectedly, failure transpires.	Absolute uncertainty	0-5	Very high: persistent failures	≥100 per thousand cores	10
Hazardous with a warning	Violates governmental regulations in some way. Unforeseen failure ensues.	Very remote	6-15	Very high: persistent failures	50 per thousand cores	9
Very high	Inoperable core due to the absence of primary function. The client is unsatisfied.	Remote	16-25	High: frequent failures	20 per thousand cores	8
High	Although the core remains operational, it suffers from a decline in performance. The client is unsatisfied.	Very low	26-35	High: frequent failures	10 per thousand cores	7
Moderate	Significant impact on the system or individual upon complete recovery.	Low	36-45	Moderate: occasional failures	5 per thousand cores	6
Low	Core operable, but with a loss of performance for comfort items. The customer has some dissatisfaction.	Moderate	46-55	Moderate: occasional failures	2 per thousand cores	5
Very low	Defects observed by the majority of patients.	Moderately high	56-65	Low: relatively few failures	1 per thousand cores	4
Minor	A defect noticed by the average customer.	High	66-75	Low: relatively few failures	0.5 per thousand cores	3
Very minor	A defect noticed by discriminating customers.	Very high	76-85	Remote: failure unlikely	0.1 per thousand cores	2
Very minor none	No effect	Almost certain	86-100	Remote: failure unlikely	≤0.01 per thousand pieces	1

Table 4 shows the application of FMEA to a process entails taking a series of sequential steps, including an analysis of the process in all of its components, a list of potential failures, an assessment of their frequency, severity, and method of detection, a global evaluation of the issue, and the identification of corrective actions that could prevent or lessen potential failures. Carnero (2020) combined a weighted hybrid intuitive fuzzy Euclidean distance factor and a multi-criteria technique in the study to employ FMEA, which considers both subjective and objective weights of risk variables. The top three failure modes were improper trash management, erroneous container labeling, and improper waste storage, such as putting items in the wrong containers. In addition, there were improper collection periods and poor preparation. As a result, Carnero's study identified that these five failure modes had the highest risk value and thus needed to be addressed. Moreover, it proposed solutions to reduce the risk associated with each failure mode. The FMEA project and weights of end products of severity, occurrence and detection (SOD) were analyzed in this section for their significance, as shown in Table 4. Despite being a part of the hospital's operating operations, the procedures for disposing of infectious medical waste fall under administrative administration (Ho & Liao, 2011; Kumar et al., 2011).

- Severity of effect (S): Severity measures how serious a failure mode's effects are. A scale from 1 to 10 is used to measure the severity categories.
- Probability of occurrence (O): The likelihood that a failure occurs and its mode and cause are related.

• Detection (D): The evaluation of how well "design controls" can pinpoint a probable cause. Based on the possibility of detection by the pertinent company design.

• RPN: The rating of SOD results in the RPN. The RPN, which computes between "1" and "1000," is a measurement of design risk.

3.2 Measurements and Procedures

Table 5. Infectious waste process analysis weight

Process Step/Part Number	Failure Mode	Failure Effects	SEV	Potential Causes	OCC
Medical treatment	Inadequate disposal of infectious refuse by family members and patients.	Violate laws and regulations.	5	Lack of the ability to classify.	8
	Wrong disposal of infectious waste by the nursing staff.	Insufficient instruction and education.	7	Inadequate education and training.	6
	Improper disposal of infectious waste by medical personnel.	Not an exact classification.	9	Not an exact classification.	5
	Lack of posters indicating infectious waste.	Infractions of regulations and legislation.	7	Inadequate education and training.	5
Administration	Garbage that is improperly closed.	Environmental pollution in the hospital.	8	Cleaners don't have enough training.	4
	The storage duration for infectious refuse is excessive.	Infractions of regulations and legislation.	7	Cleaners forget to clean.	2
	Infectious waste is unattended.	The hospital generates infectious refuse.	9	Lack of cleaners.	3
	People are not responsible for infectious refuse management.	Waste cannot be traced.	8	Not enough manpower.	2
	Plans for responding to emergencies are not established.	An emergency cannot be handled.	7	Absence of preparation and emergency response plan development.	1
	Independent facilities are not established.	Can be easily infected.	5	Inadequately implemented refuse classification.	4
	Units of output are not specified.	Units of output cannot be tracked.	5	Cleaners forget.	6
Outsourcing	A designated location is used to store infectious waste.	A warning letter is issued by the Environment Bureau.	7	Infectious waste is wrongly disposed of.	3
	The cleaners are stabbed with sharp objects.	Cleaners are injured.	8	Medical people's wrong disposal.	6
	Lack of posters indicating infectious waste.	Violate laws and regulations.	7	Inadequate education and training.	5
	Specific transportation and collection vehicles have not been utilized.	Waste medical cannot be tracked and can be easily infected.	6	Inadequate education and training.	4
	Specific procedures are not followed.	Can be easily infected.	5	Inadequate personnel training.	3
	Inaccurate registration of weighted quantities happens.	Output and clean weight are different.	4	Incorrect weighing and registrar fault.	5
	Infectious waste collection containers are not positioned.	Infractions of regulations and legislation.	7	The cleaning staff is negligent and misuses personnel.	2
	Red bags that are not used.	Infectious waste cannot be identified.	8	Misuse of personnel.	7
	The date of infectious refuse removal is not documented.	The cleaning date is readily postponable.	5	Cleaners did not fill out.	5

	Current Controls	DET	RPN	Action Taken
Medical treatment	To check by personnel inside the unit.	8	320	Strengthen propagation, education, and marking.
	To control infectious waste flows out of the hospital.	7	294	Properly training the crew.
	To control infectious waste	6	270	Training for material

	flows out of the hospital.			handling.
	To directly print markings on sacks or buckets.	2	70	Post clearly marked according to laws and regulations.
	To ensure garbage is properly closed.	3	96	Verify that the trash is properly sealed.
	To check by personnel inside the unit.	3	42	Ensure that the date of placement is accurate.
Administration	To control infectious waste flows out of the hospital.	4	108	Bring cleaners to monitor infectious waste.
	To add waste management personnel.	3	48	Bring out specialized personnel to handle and manage waste.
	Regularly examining, adjusting, and exercising.	1	7	Develop emergency response strategies.
	To acquire independent facilities for use by the unit.	3	60	Add independent facilities.
	To immediately print the unit name on the buckets or bags.	4	120	Verify that the unit was indicated at the time the refuse was disposed of.
	Educate and train personnel involved in outsourcing.	4	84	Improve cleaning staff education and instruction regarding waste classification.
	To provide internal personnel with waste classification education and training.	5	240	Strengthen education and training for medical staff and marking.
	To directly print markings on sacks or buckets.	2	70	Post clearly marked according to laws and regulations.
Outsourcing	To conduct regular and irregular assessments.	2	48	Strengthen education and training for cleaning staff.
		6	90	
	Support training and education for personnel managing refuse.	6	120	To randomly determine whether or not the record is accurate.
	Establish collection containers without exception.	1	14	To provide an adequate bucket for collecting infectious refuse.
	Implement the mandatory use of red bags for refuse transport.	5	280	To ensure an adequate supply of crimson collection bags.
	Record the cleaning date promptly.	3	75	To use a computer for control.

	SEV	**OCC**	**DET**	**RPN**
Medical treatment	5	3	8	120
	5	4	7	140
	7	5	5	175
Administration	7	2	2	28
	8	2	3	48
	7	1	3	21
	9	2	4	72
	8	1	3	24
	7	1	1	7
	5	2	3	30
	5	2	4	40
	7	2	4	56
	8	2	5	80
	7	2	2	28
Outsourcing	5	2	2	20 0
	4	2	6	48
	7	1	1	7
	8	3	5	120
	4	2	3	24

By applying the FMEA method for evaluating infectious medical waste, RPNs in the study hospitals' infectious waste disposal processes were identified. Twenty items were categorized in FMEA format as system functions of the search results; these categories included medical treatment, administrative, and outsourced functions (Table 5). Due to medical treatment, three categories have been lowered below the other two. Ten are delegated, and seven are administrative.

The subsequent three issues about medical treatment items were patients and their families improperly disposing of infectious refuse and improper disposal by nursing and medical staff. Additionally, they were categorized as enhancement priorities. More specifically, the RPN value associated with patients and their families improperly disposing of infectious refuse was diminished from 320 to 120. Simultaneously, the RPN value associated with medical personnel improperly disposing of contagious waste decreased from 320 to 120 or 270 to 175. In addition, the nursing staff reduced the RPN value related to improper disposal of infectious refuse from 294 to 140.

Consequently, a reduction in the overall amount can be anticipated after the enhancements in these facets. In addition, improperly closed refuse reduced the RPN value for the administration item from 108 to 72, whereas unattended infectious waste reduced it from 96 to 48. Regarding the outsourcing item, the RPN value for the cleaners stabbed with sharp objects was decreased from 240 to 80, and the RPN value for red bags that are not used was reduced from 280 to 120.

4. Results

The findings of multiple studies examining medical waste management in Jordan are presented in Table 2, drawing from the most recent literature in the field. It can be demonstrated that most medical refuse is improperly disposed of, exposing the general public to potential health hazards. An inadequate regulatory framework for medical waste management is a significant factor contributing to this problem. In light of this, medical waste management procedures must be enhanced to safeguard the public's health. Medical waste generation conforms to a log-normal distribution with a correlation coefficient of 0.89, according to a study of data recurrence patterns conducted by Abu Qdais et al. (2007). The deviation from the standard distribution curve and right-skewed nature of the distribution, as indicated by the skewness and kurtosis coefficients, suggests that the knowledge and implementation of healthcare practices among providers employed in different Jordanian institutions varied from high to average in other regions. According to the study's findings, medical waste production in Jordanian institutions was substantial. Certain factors may influence the quantity of medical waste produced, as indicated by the log-normal distribution of the data. Due to the absence of effective waste management practices in Jordanian institutions, the skewness and kurtosis coefficients further suggest that the distribution of medical waste could be more representative. Hence, in light of the findings of this research, greater emphasis should be placed on the appropriate management and disposal of the various categories of medical waste being produced.

According to Al-Momani et al. (2019), many issues arise when medical waste is disposed of in Jordanian hospitals. First, show that medical waste is poorly managed and handled and that there are no regulations governing the management of medical waste. Both hospital staff and patients may be at risk for health problems due to this. If the waste is not adequately disposed of, it can also pose a risk to the environment, leading to the spread of infectious diseases, contamination of water sources, and air pollution; thus, it might result in higher hospital expenses. Therefore, lack of staff training, out-of-date waste management infrastructure, and a lack of resources allocated to medical waste management are all causes of these health risks, environmental hazards, and increased costs. As a result, ensuring proper staff training, implementing updated waste management infrastructure, and allocating resources to medical waste management are essential to minimizing health risks, environmental hazards, and costs associated with medical waste disposal. According to a study by Fraiwan et al. (2013), four out of every five hospitals burn medical waste in their own incinerators, and the remaining hospital sends all of their waste with household waste for municipal waste disposal. At the same time, the double-chamber incinerator that the MOH requires is only present in one of the four hospitals that use them. However, the three additional hospitals still use single-room, out-of-date incinerators where the incinerator has a daily capacity of 100 to 300 kg. In addition, the four hospitals used cremation temperatures between 600 and 700°C, which is a little lower than what the MOH requires, which is between 800 and 900°C in the main room and from 900°C outside to 1200°C in the secondary room. This lower temperature results in incomplete combustion and incomplete destruction of infectious agents, and the risk of air pollution due to improper incineration is high in these hospitals.

Table 3 shows that most countries have inadequate medical waste management systems. Furthermore, more awareness is needed among healthcare professionals about the proper disposal of medical waste. Finally, better legislation and enforcement of existing laws are needed to ensure proper disposal (Fadaei, 2022). All nations must handle medical waste in an environmentally sustainable manner, thereby avoiding catastrophic stockpiling of infectious waste during and after pandemics. This can be done through proper disposal, incineration, and recycling of medical waste (Singh et al., 2022). Effective management of medical waste also helps reduce the spread of infectious diseases. Additionally, it protects the environment by minimizing the release of hazardous substances (Ali et al., 2017). Healthcare professionals need education and training to ensure medical waste is disposed of

correctly, especially during the Corona crisis. Additionally, stricter laws and more effective enforcement of existing laws should be implemented (Carnero, 2020; Hossain et al., 2021). Based on these results, more research is needed to better understand how to improve medical waste management and dispose of it properly.

Recent research has brought attention to concerns regarding the administration of medical waste in Jordan and neighboring countries. According to an analysis of medical waste management in Jordanian hospitals, effective waste management can reduce environmental and health hazards. Nevertheless, the research also underscored the criticality for hospitals in Jordan to implement more effective waste management protocols (Al-Momani et al., 2019). An examination of healthcare waste management in the MENA region revealed that the waste management sectors of these countries are confronted with a multitude of obstacles and enduring problems that necessitate the development of inventive resolutions. Additionally, it was discovered that Jordan, Egypt, and Tunisia do not have effective solid refuse management oversight systems (Thabit et al., 2022). The Waste Sector Green Growth National Action Plan 2021-2025 of Jordan emphasises the importance of implementing enhanced waste management protocols on a national scale. The plan indicates that, relative to other upper-middle-income countries, Jordan has a higher daily municipal solid refuse production per capita. In contrast to the 10% average of Gulf Cooperation Council (GCC) states, Jordan exhibits a comparatively low rate of municipal refuse recycling. Furthermore, the plan acknowledges that Jordan produces substantial or rising volumes of hazardous, medical, construction, demolition, and electronic waste, which are inadequately treated and disposed of [Global Green Growth Institute (GGGI, 2020).

Overall, while there are some similarities in the medical waste management methods in Jordan and neighboring countries, there are also some significant differences. For example, Jordan has a centralized medical waste management system, while Saudi Arabia and Lebanon have decentralized systems. In contrast, the ongoing conflict in Syria has severely impacted the country's medical waste management system, leading to the widespread improper disposal of medical waste.

As a final point, Table 5 shows that RPN values are decreasing, meaning that the FMEA method successfully lowers the risks associated with hospital operations. This suggests that the safety precautions taken were successful. As a result, the risks of each item have been greatly diminished.

5. Discussion

Previous research conducted on hospitals in different categories and geographical regions in Jordan showed that birth rates differed between hospitals of different categories and within the same hospital with different units and departments. Thus, more management of medical waste in Jordanian hospitals is needed due to this discrepancy in the generation of medical waste and the expansion of medical services in Jordan (Al-Momani et al., 2019; Al-Soud et al., 2022). In addition, a large percentage of hospital deliveries occurred due to incorrect separation procedures. Therefore, nursing staff must be highly skilled and knowledgeable in this field due to the importance of medical waste and its risks to people and the environment (Alzghoul et al., 2022).

Furthermore, hospitals treating COVID-19 patients generate more medical waste that must be assessed and managed. More expert perspectives are needed to control the massive amount of medical waste generated by the pandemic (Abu Qdais et al., 2007; Alzboon et al., 2022). Government homes and offices are now sources of medical waste, and distinct advance plans for garbage collection, segregation, isolation, and treatment may be necessary. While protecting human health is important, the effects of COVID-19 on the environment must also be considered, particularly the handling and disposal of medical waste, because improper handling of medical waste can significantly negatively impact the environment, water supplies, and ultimately human health (Alrawi et al., 2021). In addition, for the study of the infectious waste score, the Risk Priority Index demonstrates that after screening multi-items, it is possible to determine the likelihood that essential components can manifest themselves (Table 5). The bottom-up risks for all groups can be decreased by employing the FMEA technique. Finally, although waste disposal is not a vital medical procedure, waste management is critical to hospital management. As a result, it is essential to properly treat hazardous infectious waste, as failure to do so can have a severe impact on the ecosystem. All medical facilities must operate to meet their management obligations and eliminate any risks to patients, the environment, or both, which is one of the basic societal duties of medical institutions.

6. Limitations

This review may have several limitations. Due to the speed of review and publication in this field, the literature retrieved may not include the most recent studies of medical waste management in Jordanian hospitals, the need for more detailed information about waste management processes in each hospital, and the inability to extrapolate the results to the entire country. It is also difficult to analyze data from a wide range of hospitals to identify gaps and areas for improvement. Moreover, the data collected may reflect something other than hospital practices due to self-reported data. In addition, the data may need to be updated to reflect the current hospital situation.

Moreover, the limitations of medical waste management are vast and multifaceted, posing significant challenges

for HCFs and organizations worldwide. One major limitation is the lack of resources and infrastructure in many developing countries, which hinders the proper segregation, collection, transportation, treatment, and disposal of medical waste. Additionally, inadequate training and awareness among healthcare personnel regarding safe handling practices further exacerbate the risks associated with medical waste. Furthermore, stringent regulations and compliance standards often create additional burdens for HCFs in terms of costs and operational logistics. The ever-evolving nature of medical waste compounds these challenges as new technologies and treatments produce different types of hazardous materials requiring specialized disposal methods. Ultimately, addressing these limitations requires a comprehensive approach that involves cooperation between healthcare professionals, policymakers, environmental agencies, and waste management experts to ensure the safe and effective management of medical waste.

7. Conclusion

Similar and dissimilar outcomes were observed in the articles examined in the study. Particularly within a single nation, medical waste standards vary considerably. Diverse factors, such as the location and scale of the HCF, as well as the political climate of the nation, manifestly impacted waste management practices, which needed to be more consistent across the country. The nation's medical waste management procedures are enhanced by implementing more effective medical waste treatment methods in HCFs. As a result, to prevent adverse health and environmental effects, medical refuse from hospitals and medical centres must be effectively managed. Collection, segregation, transportation, treatment, and disposal of medical refuse are all components of effective waste management. Proper infrastructure and healthcare personnel awareness are imperative for this to occur.

Moreover, all studies have identified the areas to be improved in the management of medical waste and the necessity for increased administrative dedication to the enforcement of regulations and protocols regarding its disposal. Nonetheless, it is agreed that it is possible to establish a medical waste management system that is both secure and durable. In conclusion, medical waste management deficiencies in Jordan and neighbouring nations have been identified in recent research. These studies emphasize the need for more effective waste management strategies to protect the environment and mitigate health hazards.

8. Recommendations

The main recommendations are proposed in this study as follows:

- Detailed training courses should be provided for medical and nursing cadres, thereby informing them of the dangers of medical waste, waste separation according to its severity, and the necessity of adhering to occupational safety requirements.
- The management of medical waste systems should be managed by special environmental units within the hospital, headed by a community health specialist and staff specializing in environmental protection.
- The bags used for storing medical and pathological waste should be thick and durable, and they cannot be torn easily or leak liquids. The thickness is not less than 200 microns if it is made of low-density plastic and not less than 100 microns if it is made of high-density plastic.
- Pathological waste and bacterial culture dishes should be destroyed using autoclaves before disposing of them with medical waste.
- Suitable and safe incinerators should be used for the environment and individuals, with a temperature of not less than 1000°C, to get rid of all pathogens. Also, some pharmaceutical waste needs an incinerator with a temperature of not less than 1200°C so that no toxic fumes are emitted.
- Chemical drug residues, which are used to treat cancer patients, should be carefully dealt with through sanitary landfilling or chemical analysis before burning.
- The coloring system should be used for containers and bags to collect solid waste from hospitals, as the WHO and environmental protection organizations recommend. A red color is suggested for the bags collecting medical waste. Additionally, the black color is for those collecting general waste, provided that they are resistant to rupture and exudation and are sufficient.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

References

Abu Qdais, H., Rabi, A., & Abdulla, F. (2007). Characteristics of the medical waste generated at the Jordanian hospitals. *Clean Technol. Environ. Policy.*, *9*, 147-152. https://doi.org/10.1007/s10098-006-0077-0.

Al-Ansi, A. M., Hazaimeh, M., Hendi, A., & Adwan, G. (2023a). How do social media influencers change adolescents' behavior? An evidence from middle east countries. *Heliyon*, *9*(5): e15983.

Al-Ansi, A. M., Hazaimeh, M., Hendi, A., AL-Hrinat, J., Adwan, G., & Garad, A. (2023b). Innovative responses to exogenous shocks in indonesian transportation firms: Mediating role of sustainable performance and outcomes. *Int. J. Sustain. Dev. Plann.*, *18*(9), 2663-2672. https://doi.org/10.18280/ijsdp.180905.

Ali, M., Wang, W., Chaudhry, N., & Geng, Y. (2017). Hospital waste management in developing countries: A mini review. *Waste Manag. Res.*, *35*(6), 581-592. https://doi.org/10.1177/0734242X17691344.

Al-Momani, H., Obaidat, M., Khazaleh, A., Muneizel, O., Afyouni, N. M., & Fayyad, S. M. (2019). Review of medical waste management in Jordanian health care organisations. *Br J Healthc Manag.*, *25*(8), 1-8. https://doi.org/10.12968/bjhc.2019.0041.

Al-Momani, T. D., Al-Zube, L. A., & Al-Bataineh, O. M. (2013). Assessment of medical wastes management protocols in Jordanian healthcare institutions. *Int. J. Environ. Waste Manag.*, *11*(3), 323-334. https://doi.org/10.1504/IJEWM.2013.053125.

Alrawi, A. S., Amin, S. A., & Al-Ani, R. R. (2021). Medical waste management during COVID-19 pandemic, a review study. *2021 IOP Conf. Ser.: Earth Environ. Sci.*, *779*(1): 012130. https://doi.org/10.1088/1755-1315/779/1/012130.

Al-Soud, S., Jamrah, A., & Al-Weshah, R. (2022). Medical waste management in Jordanian healthcare institutions and their effect on human and environment (Analytical Study). *Dirasat Hum. Soc. Sci.*, *49*(5), 571-580. https://doi.org/10.35516/hum.v49i5.2781.

Alzboon, K., Shawaqfeh, M., Shawaqfeh, M., Ammary, B., & Almomani, F. (2022). Impact of COVID-19 on medical waste management in Jordan. *Poll Res.*, 853-859. http://doi.org/10.53550/PR.2022.v41i03.013.

Alzghoul, S. E., Smadi, O. A., Almomani, T., Alzghoul, M. B., & Al-Bataineh, O. M. (2022). Solid medical waste management practices and awareness in COVID-19 screening stations. *Glob. J. Environ. Sci. Manage.*, *8*(3), 327-338. https://doi.org/10.22034/gjesm.2022.03.03.

Andeobu, L., Wibowo, S., & Grandhi, S. (2022). Medical waste from COVID-19 pandemic-A systematic review of management and environmental impacts in Australia. *Int. J. Environ. Res. Public Health.*, *19*(3), 1381. https://doi.org/10.3390/ijerph19031381.

Awodele, O., Adewoye, A. A., & Oparah, A. C. (2016). Assessment of medical waste management in seven hospitals in Lagos, Nigeria. *BMC Public Health.*, *16*, 1-11. https://doi.org/10.1186/s12889-016-2916-1.

Ba Awain, A. M. S., Al-Ansi, A. M., & Jaboob, M. (2023). Green supply chain management: A comprehensive review of research, applications and future directions. *Manag. Prod. Eng. Rev.*, *14*(3), 118-133. https://doi.org/10.24425/mper.2023.147194.

Cai, X. & Du, C. (2021). Thermal plasma treatment of medical waste. *Plasma Chem. Plasma Process.*, *41*, 1-46. https://doi.org/10.1007/s11090-020-10119-6.

Caniato, M., Tudor, T. L., & Vaccari, M. (2016). Assessment of health-care waste management in a humanitarian crisis: A case study of the Gaza Strip. *Waste Manag.*, *58*, 386-396. https://doi.org/10.1016/j.wasman.2016.09.017.

Carnero, M. C. (2020). Waste segregation FMEA model integrating intuitionistic fuzzy set and the PAPRIKA method. *Math.*, *8*(8), 1375. https://doi.org/10.3390/math8081375.

Darwazeh, D., Clarke, A., & Wilson, J. (2021). Framework for establishing a sustainable medical facility: A case study of medical tourism in Jordan. *World*, *2*(3), 351-373. https://doi.org/10.3390/world2030022.

Das, A. K., Islam, M. N., Billah, M. M., & Sarker, A. (2021). COVID-19 pandemic and healthcare solid waste management strategy-A mini-review. *Sci. Total Environ.*, *778*, 146220. https://doi.org/10.1016/j.scitotenv.2021.146220.

Etim, M. A., Omole, D. O., & Araoye, O. V. (2022). Impact of COVID-19 on medical waste management and disposal practices in Nigeria. *Cogent Eng.*, *9*(1), 2038345. https://doi.org/10.1080/23311916.2022.2038345.

Fadaei, A. (2022). Comparison of medical waste management methods in different countries: A systematic review. *Rev. Environ. Health.*, *38*(2), 339-348. https://doi.org/10.1515/reveh-2021-0170.

Fraiwan, L. A., Lweesy, K., Oweis, R., Qablan, H. A., & Hasanat, M. (2013). Medical waste management practices in southern Jordan. *Int. J. Environ. Waste Manag.*, *11*(3), 255-266. https://doi.org/10.1504/IJEWM.2013.053098.

GGGI. (2020). *Green Growth National Action Plan 2021 to 2025: Waste sector*. https://greengov.gov/pdfs/ggi-jordan-waste-sector.pdf

Goswami, M., Goswami, P. J., Nautiyal, S., & Prakash, S. (2021). Challenges and actions to the environmental management of Bio-Medical Waste during COVID-19 pandemic in India. *Heliyon*, *7*(3), e06313. https://doi.org/10.1016/j.heliyon.2021.e06313.

Ho, C. C., & Liao, C. J. (2011). The use of failure mode and effects analysis to construct an effective disposal and prevention mechanism for infectious hospital waste. *Waste Manag., 31*(12), 2631-2637. https://doi.org/10.1016/j.wasman.2011.07.011.

Hossain, M. R., Islam, M. A., & Hasan, M. (2021). Assessment of medical waste management practices: A case study in Gopalganj Sadar, Bangladesh. *Eur. J. Med. Health Sci.*, *3*(3), 62-71. https://doi.org/10.34104/ejmhs.021.062071.

Jaboob, M., Hazaimeh, M., & Al-Ansi, A. M. (2024). Integration of generative ai techniques and applications in student behavior and cognitive achievement in Arab higher education. *Int. J. Hum. Comput. Interact.*, 1-14. https://doi.org/10.1080/10447318.2023.2300016.

Kalantary, R. R., Jamshidi, A., Mofrad, M. M. G., Jafari, A. J., Heidari, N., Fallahizadeh, S., Arani, M. H., & Torkashvand, J. (2021). Effect of COVID-19 pandemic on medical waste management: A case study. *J. Environ. Health Sci. Eng.*, *19*, 831-836. https://doi.org/10.1007/s40201-021-00650-9.

Kargar, S., Pourmehdi, M., & Paydar, M. M. (2020). Reverse logistics network design for medical waste management in the epidemic outbreak of the novel coronavirus (COVID-19). *Sci. Total Environ., 746*, 141183. https://doi.org/10.1016/j.scitotenv.2020.141183.

Karnouk, C., Böge, K., Hahn, E., Schweininger, S., & Bajbouj, M. (2019). Psychotherapy in Jordan: An investigation of the host and Syrian Refugee Community's perspectives. *Front. Psychiatry*., *10*, 456817. https://doi.org/10.3389/fpsyt.2019.00556.

Kumar, A., Poonia, M. P., Pandel, U., & Jethoo, A. S. (2011). FMEA: Methodology, design and implementation in a foundry. *Int. J. Eng. Sci. Technol.*, *3*(6), 5288-5297.

Mol, M. P. G., Zolnikov, T. R., Neves, A. C., Dos Santos, G. R., Tolentino, J. L. L., de Vasconcelos Barros, R. T., & Heller, L. (2022). Healthcare waste generation in hospitals per continent: A systematic review. *Environ. Sci. Pollut. Res.*, *29*(28), 42466-42475. https://doi.org/10.1007/s11356-022-19995-1.

Niyongabo, E., Jang, Y. C., Kang, D., & Sung, K. (2019). Current treatment and disposal practices for medical wastes in Bujumbura, Burundi. *Environ. Eng. Res.*, *24*(2), 211-219. https://doi.org/10.4491/eer.2018.095.

Safety Culture. (2023). *FMEA: Definition, Steps, Types, & Tools*. SafetyCulture. https://safetyculture.com/topics/fmea/

Shareefdeen, Z., Ashoobi, N., & Ilyas, U. (2022). Medical waste management and treatment technologies. hazard. waste manag. *Adv. Chem. Ind. Waste Treat. Technol.*, pp. 113-133. https://doi.org/10.1007/978-3-030-95262-4_5.

Singh, K. N. (1989). *Appalachian states low-level radioactive waste compact consent act. House of Representatives*. One Hundredth Congress, First Session, United States.

Singh, N., Ogunseitan, O. A., & Tang, Y. (2022). Medical waste: Current challenges and future opportunities for sustainable management. *Crit. Rev. Environ. Sci. Technol.*, *52*(11), 2000-2022. https://doi.org/10.1080/10643389.2021.1885325.

Thabit, Q., Nassour, A., & Nelles, M. (2022). Facts and figures on aspects of waste management in middle east and North Africa region. *Waste*, *1*(1), 52-80. https://doi.org/10.3390/waste1010005.

Torkashvand, J., Pasalari, H., Jonidi-Jafari, A., Kermani, M., Nasri, O., & Farzadkia, M. (2022). Medical waste management in Iran and comparison with neighbouring countries. *Int. J. Environ. Anal. Chem.*, *102*(12), 2805-2818. https://doi.org/10.1080/03067319.2020.1759570.

United Nations Development Programme. (2020). *Surge in medical waste amidst COVID-19: GEF and UNDP leads the transformation of Medical Waste Management in Jordan: United Nations Development Programme*. https://www.undp.org/jordan/stories/surge-medical-waste-amidst-COVID-19-gef-and-undp-leads-transformation-medical-waste-management-jordan