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Case Report

Comprehensive analysis of hospital solid waste levels and HSE risks using FMEA technique: A case study in northwest Iran

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ABSTRACT

This study tackled the global challenge of managing specialized hospital waste, emphasizing its sensitivity due to toxic and pathogenic agents. Focused on Imam Khomeini Hospital (RA), the research employed both quantitative and qualitative approaches to assess waste production, evaluating health, safety, and environmental risks. Over a 3-month period, sampling at the hospital waste station covered household, infectious, medicinal, and sharps waste. Results disclosed an average per capita healthcare waste production of 3.52 kg per bed per day, with specific breakdowns for various waste types. The study evaluated waste management quality, establishing acceptable conditions. Utilizing the Failure Mode and Effects Analysis (FMEA) technique, health, safety, and environment risk assessments identified potential risks in different waste management sectors. Comparisons with global studies and national average levels highlight elevated per capita hospital waste production in Urmia city, necessitating increased attention to align facilities with World Health Organization (WHO) standards. The study emphasizes the importance of allocating funds, providing training, raising awareness, and implementing effective waste management methods to address identified challenges, underscoring the need for clear organizational structures and decision-making authorities in hospital waste control aligned with international standards.

1. Introduction

In the realm of modern waste management, the safe and efficient handling of medical waste remains a paramount concern, necessitating a comprehensive understanding of potential hazards and associated risks within the Waste Management Organization medical waste unit [1]. The rapid progress in medical technologies has led to an increase in hazardous materials and biohazardous substances in medical waste. This underscores the critical necessity for a systematic and proactive approach to hazard assessment and risk management in medical waste units. The complexity of modern medical waste requires careful evaluation and mitigation of potential risks, especially with the emergence of novel biohazardous materials. A proactive stance ensures adaptability to evolving technologies, prioritizing the safety of healthcare workers and the broader community [2,3]. Against this backdrop, the application of the Failure Mode and Effects Analysis (FMEA) technique has gained prominence as a robust methodology for identifying, evaluating, and mitigating potential failure modes and associated risks within complex operational frameworks. This approach has proven efficacy in assessing the positive outcomes both prior to and following the correction of failures and risks in each process [4].

In recent research, a series of studies has scrutinized hospital waste management practices, drawing attention to key operational aspects requiring focus and improvement. Zamparas et al., in 2019 examined waste management procedures at Rio Hospital, Greece, and revealed shortcomings in staff training and procurement awareness, utilizing the Romero-Carnero (F-AHP) method to gauge effectiveness [5]. The study by Naghla et al. (2019) in Kuwait emphasized the challenges linked to hazardous chemical and pharmaceutical waste, stressing the need for enhanced handling strategies [6]. Meanwhile, studies by Junadi et al. in Tehran, Noormohammadi et al. in Sabzevar, and Keshavarz et al. in Tehran underscored the significance of proper waste segregation, adherence to health regulations, and risk reduction strategies within waste management systems [7–9]. These studies collectively advocate for comprehensive waste management frameworks to ensure both environmental sustainability and public health safety within healthcare settings [10].

The studies highlighted shortcomings in staff training, procurement awareness, challenges with hazardous waste, and the importance of proper waste segregation, health regulation adherence, and risk

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reduction strategies. These findings highlight the need for comprehensive waste management frameworks to ensure environmental sustainability and public health safety in healthcare settings.

However, the worldwide issue of accumulating municipal solid waste (MSW) in the face of urbanization and industrialization poses a significant challenge. A thorough analysis of recent technological progress in MSW valorization underscores the possibility of transforming waste into valuable resources, addressing economic, environmental, and health aspects. The insights provided present valuable perspectives for scientific and industrial communities seeking to improve large-scale MSW management through sustainable and cost-effective methods [11].

This study presents a comprehensive exploration of the hazards assessment within the medical waste unit of the Waste Management Organization, employing the FMEA technique as a strategic tool to proactively identify critical failure modes and potential risks. By leveraging the systematic and analytical capabilities of the FMEA methodology, this research seeks to illuminate the intricate network of potential hazards, failure points, and associated consequences inherent within the medical waste management process. The intricate interplay of diverse operational components, ranging from waste collection and segregation to treatment and disposal, underscores the complexity of the medical waste management system, emphasizing the critical need for a rigorous and systematic approach to risk assessment and mitigation [12].

The integration of the FMEA technique within the context of the medical waste unit not only facilitates the comprehensive identification of potential failure modes and associated risks, but also enables the prioritization of critical issues for targeted intervention and strategic management. By fostering a deeper understanding of the potential failure modes and their corresponding effects, this study endeavors to provide valuable insights into the formulation of robust risk management strategies and proactive mitigation measures [10,13]. Moreover, the findings of this study hold significant implications for the development of enhanced operational protocols, the implementation of advanced safety measures, and the establishment of comprehensive contingency plans aimed at ensuring the safe, efficient, and environmentally responsible management of medical waste within the Waste Management Organization operational framework.

This study represents a pioneering effort in assessing the management, quantity, and physical quality of production wastes in Imam Khomeini Hospital of Urmia city, considering the critical impact of effective waste management on the health of employees, patients, and the environment. By employing the FMEA technique, the research aims to comprehensively evaluate and prioritize potential health, safety, and environmental risks within the waste management department, addressing a significant gap in existing literature and contributing to the development of robust risk management strategies in the northwest region of Iran.

In the present study, the integration of the FMEA technique enabled the identification and prioritization of potential failure modes and risks, offering insights crucial for the development of enhanced operational protocols, advanced safety measures, and comprehensive contingency plans. This pioneering effort in waste management at Imam Khomeini Hospital had significant implications for ensuring safe, efficient, and environmentally responsible medical waste management within the operational framework of the Waste Management Organization.

2. Materials and methods

2.1. Study area

Imam Khomeini hospital as Medical Training Center in Urmia City, established in 1995, is a prominent healthcare facility in the northwest region of Iran in west Azerbaijani province. With a nominal capacity of 298 beds initially, it has expanded significantly, currently operating with 552 active beds and 689 approved beds across 29 inpatient units. The center serves as a key hub for medical education and research, specializing in fields such as surgery, internal medicine, neurosurgery, pathology, orthopedics, urology, and radiology. Managed by a board of trustees, it plays a pivotal role in providing high-quality medical services, including trauma care, to the province and neighboring areas.

Table 1
Ranking the likelihood (O - Occurrence) index of failure.

Order (O)	Criterion: the proportion of potential failure/total number of working days.	Likelihood of failure
10	$O \leq 1{:}\ 2$	Extremely high
9	$O \leq 1{:}\ 10$	Extremely high
8	$O \leq 1 : 20$	High
7	$O \leq 1{:}\ 100$	High
6	$O \leq 1{:}200$	Moderate
5	$O \leq 1{:}\ 1000$	Moderate
4	$O \leq 1{:}\ 2000$	Somewhat minimal
3	$O \leq 1{:}\ 10000$	Low Extremely
2	$O \leq 1{:}\ 20000$	low
1	$O \leq 1{:}\ 50000$	Infrequent

2.2. Quantitative and physical properties of hospital waste

The quantitative and physical properties waste involved determining the weight and composition of various types of hospital waste across different departments. Prior to the commencement of the operational phase, workers were instructed to adhere to these measures during the collection, transportation, weighing, and analysis of waste samples.

The weighing and segregation of wastes were done in collaboration with health center managers and the assistance of service personnel, all under the direct supervision of the project's executive. The detailed plan included the following steps.

- Determination of the total number of patients visiting the hospital during active work shifts.
- Identification of the number of active occupied beds to calculate per capita waste production.
- Three months from March to Jun 2023 of weighing hospital waste, conducted monthly for one week.

2.3. Health, safety and environment (HSE) effects evaluation

Simultaneous evaluation of HSE effects was conducted using the FMEA method, as outlined by Keshavarz et al. [9]. The executive steps for HSE risk assessment included.

- Preliminary investigation
- Recognition of hospital waste management departments
- Identification of HSE risk
- Using observation, interviews, and checklists
- Risk assessment using FMEA

2.4. Determination of HSE risk levels

The FMEA technique was employed to determine the severity, occurrence, and detection levels of HSE risks. The final disposal of rendered wastes involved specific methods based on waste categories, ensuring compliance with recommended procedures and transportation regulations. Risks were identified through departmental activities, historical accidents, and near-accidents within the last five years. The FMEA technique, a powerful risk assessment tool, employed a risk priority number based on occurrence, severity, and detection parameters (according to previous studies recommendations [3,13]) for data analysis, which was calculated by Equation (1):

Table 2
Assigning a rank to the S (severity) index of failure.

Order (S)	Criterion severity	Impact
$9 \le S \le 10$	Causing fatalities or complete system breakdown	Lethal
$8 \le S \le 7$	Inflicts severe harm to individuals or has a substantial impact on the system.	More detrimental
$6 \le S \le 5$	Results in lesser harm or a reduced impact on the system. Less	Less detrimental
$4 \le S \le 3$	Signifies a significant impact on individuals or the system with complete recovery.	Moderate
$S = 2$	Causes minimal disruption to the system or individuals	Low
$S = 1$	no effect on people or the system	No effects

Table 3
Rating for the capability to detect failures (Detection).

Order (D)	Identifiable percentage	ID
10	Completely unknown	$0 \le D \le 5$
9	Very detailed	$6 \le D \le 15$
8	Partial	$16 \le D \le 25$
7	Very little	$26 \le D \le 35$
6	Low	$36 \le D \le 45$
5	Moderate	$46 \le D \le 55$
4	Moderately high	$56 \le D \le 65$
3	high	$66 \le D \le 75$
2	too high	$76 \le D \le 85$
1	Almost known	$86 \le D \le 100$

$$RPN = O \times S \times D \quad \text{Equation (1)}$$

RPN: risk priority number, O: probability of occurrence, S: severity of effect, D: detectability.

The occurrence, severity, and detection parameters were determined based on data extracted from Tables 1–3. In fact, each parameter "occurrence, severity, and detection" was allocated an associated quality factor determined by the activity nature, as outlined in Tables 1–3 The numeric result derived from Equation (1) indicates the RPN level. The RPN number is categorized into four classes as follows: RPN <70 is considered low risk, $70 \le$ RPN <200 is categorized as moderate risk, $200 \le$ RPN <400 indicates high risk, and RPN >400 signifies extremely high risk.

2.4.1. *Quality assurance/quality control*

Thorough training sessions were provided for all staff engaged in waste-related tasks. Quality assurance (QA) checks were implemented to verify the consistent adherence of the entire team to standardized procedures. A regular calibration schedule was established for all weighing and analytical equipment to maintain accuracy. Standardized data collection protocols were employed to minimize errors and ensure uniformity. Quality control (QC) measures were introduced to independently verify the accuracy of RPN calculations. Regular QC audits were conducted to ensure the proper application of the RPN formula.

By categorizing QA and QC into separate sections, the study ensures a comprehensive approach to both ensuring quality and controlling it throughout the materials and methods utilized in the evaluation of hospital waste management.

3. Results and discussion

3.1. *Solid waste composition and distribution*

In this research, the mean daily solid waste per capita generation of household, infectious, medicinal, sharps waste, and leachate per operational bed were obtained 2.15, 1.13, 0.12, and 0.13 kg, respectively. Fig. 1 illustrates the percentage distribution of waste components at Imam Khomeini Hospital in Urmia, compared with several other hospitals in Iran. The World Health Organization (WHO) categorizes the quantity of infectious waste generated in hospitals within developing nations ranging 10–25 % of the total hospital solid waste [14,15]. The variation in the percentage of infectious waste is affected by various factors such as economic status, culture, season, geographical location, nutrition, and environmental conditions. Additional determinants include management style, target community, and facilities [16]. In this study, the proportion of infectious waste was notably higher at 38.93 %, attributed to the mixing of semi-domestic and infectious waste. The component percentage of hospital solid waste in the other studies was documented 22.99 % in Ahvaz city, 34.65 % in Bandar Abbas, and 18.4 % in Kerman [17–19]. In a Greek hospital, Tsakona et al. noted that 75–90 % of solid waste from healthcare centers is non-infectious, with 10–25 % categorized as infectious residues [20]. Therefore, infectious solid waste in Urmia exceeded that of the other locations. In Fig. 2, the per capita daily generation of hospital waste per active bed is depicted for Imam Khomeini Hospital in Urmia alongside several other hospitals in Iran. Fig. 3 illustrates the per capita daily generation of hospital waste

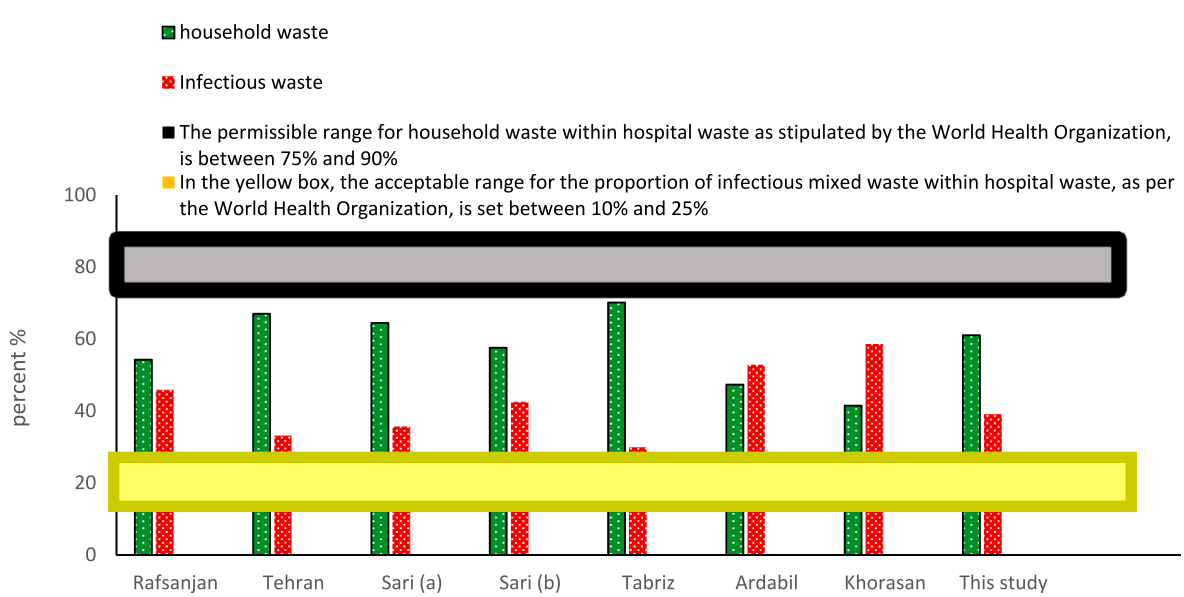

Fig. 1. The percentage of hospital waste components for both this study and other hospitals in Iran [15–17].

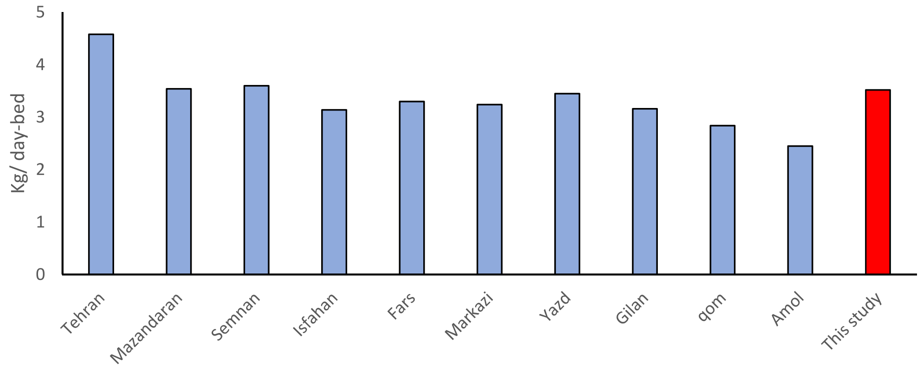

Fig. 2. A per capita comparison of the daily production of hospital waste per active bed (Kg/d) in the examined hospital, juxtaposed with other hospitals in Iran [15–17].

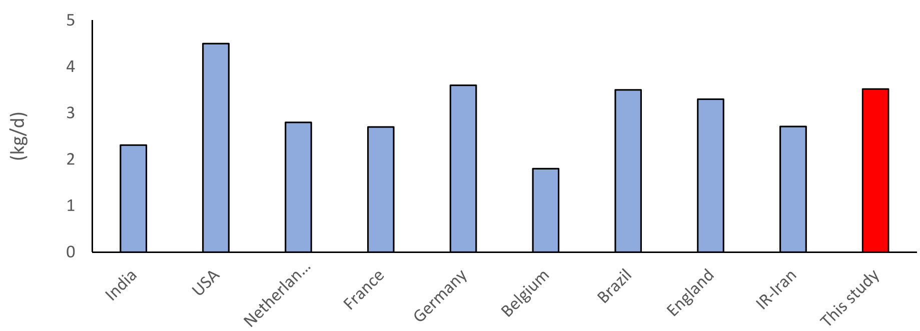

Fig. 3. The daily generation of hospital waste per capita for each active bed (kg/d) in the studied hospital, compared with other hospitals worldwide [21].

for each active bed in Imam Khomeini Hospital in Urmia and in hospitals from various other countries.

In this investigation, concerning waste quantity, the mean per-person generation of healthcare waste in the examined facility was 3.52 kg per bed per day. This comprised 2.15 kg of semi-household waste, 1.13 kg of infectious waste, 0.12 kg of medicinal waste, and 0.13 kg of sharps waste. These quantities represent approximately 61.07 %, 32.1 %, 3.23 %, and 3.6 % of the total hospital waste in this facility, respectively.

The observed higher percentage of infectious waste in Imam Khomeini Hospital in Urmia compared to other locations raises questions about the specific factors contributing to this discrepancy. Possible factors could include the hospital scope of services, patient demographics, or variations in waste management practices. A deeper exploration of these factors could provide valuable insights.

In this study, the increase in waste production appears to stem from employee unawareness and improper segregation practices. The study by Shirzad et al. (2010) on public and private hospitals in Mazandaran province revealed that despite a separation process being in place, correct separation occurred in only 15 % of cases, leading to the presence of infectious waste in non-infectious waste bins [21]. Another study by Alagoz et al. (2017) in health and treatment centers in Istanbul, Turkey, introduced an effective method for reducing waste production and enhancing segregation and recycling. This approach, targeting three main categories of waste (semi-household, infectious, and recyclable), was particularly emphasized in developing countries due to its economic benefits [22].

3.2. Challenges in waste management practices

Contrasting the waste management practices observed in Urmia with findings from studies conducted in various cities of Iran underscores notable regional differences. An exploration into the potential drivers behind these variations, encompassing aspects such as socio-economic conditions, regulatory structures, and cultural influences, is crucial for obtaining a more thorough and comprehensive comprehension of the overall waste management scenario. Understanding these multifaceted factors can shed light on the unique challenges and opportunities faced by different regions in their efforts to manage and mitigate the impact of solid waste.

However, the study by Patil GV et al. (2014) on healthcare waste management in India reported compliance with current regulations, emphasizing proper segregation, collection, transfer, and final disposal of infectious waste [23]. Discrepancies in waste production percentages across different hospitals can be linked to factors such as patient volume, staff awareness, the range of services offered, and management practices. Studies have indicated that insufficient awareness, inadequate training, and a lack of programs and continuous educational conferences pose significant barriers to the implementation and adherence to waste management laws. Notably, some officials in these centers were unaware of certain laws, highlighting the need for superior officials to facilitate access to health laws and guidelines [9].

In another study conducted by Mamoori et al. (2023) in Jordan, examining medical waste practices in private medical clinics, it was discovered that a well-designed training program and increased staff awareness significantly enhanced separation, transfer, and monitoring techniques, emphasizing their effectiveness [24].

Comparing the per capita waste production in this study with other referenced research and the national average levels reveals a higher rate of hospital waste generation per capita in Urmia city. This current situation demands focused attention from authorities, planners, and waste management professionals to drive educational and medical institutions towards achieving the standard hospital waste composition, as outlined by the WHO (10–25 % for infectious waste). The significance lies in preventing mismanagement within this sector, which could pose health risks to employees, staff, and their families, as well as negatively impacting the environment. The decontamination of infectious waste also incurs substantial costs on the healthcare system, underscoring the

Table 4
Assessment of key risks in hospital waste generation and segregation using the FMEA approach.

NOM	Key risks in waste generation and segregation	O	S	D	RPN	Risk level
1	Disposal of sharp and cutting waste in bags designated for infectious, pharmaceutical, or semi-domestic waste by ward staff	4	8	5	160	Moderate
2	Disposal of infectious waste in bags intended for semi-domestic and chemical-pharmaceutical waste by ward personnel	3	7	5	105	Moderate
3	Disposal of chemical-pharmaceutical waste in bags intended for semi-domestic by ward personnel	2	7	5	70	Moderate
4	Disposal of semi-domestic waste in bags designated for infectious, pharmaceutical, or semi-domestic waste by ward staff	2	6	5	60	Low
5	Incorrect positioning of bags within the appropriately color-coded surface bin	3	7	2	42	Low
6	Incorrect sorting of waste by the patient's companion, including items like bed sheets and contaminated sheets	3	7	6	126	Moderate
7	Lack of yellow, blue, and white bins, and safety boxes for waste disposal in hospital wards	2	7	3	42	Low
8	Failure to possess a suitable bag or using an unsuitable one to segregate waste into designated bins as per the hospital's coding system	3	8	4	96	Moderate
9	Insufficient focus from the treatment staff on the efficient utilization of medical consumables	2	7	5	70	Moderate
10	The use of an incorrect or undersized waste bin at the temporary waste location	2	7	3	42	Low

need for timely intervention [25].

The recognition of improper waste segregation arising from employee unawareness signals a crucial need for targeted interventions to address this issue. Examining challenges associated with the implementation of effective waste segregation practices and exploring potential solutions can enhance the comprehensiveness of this section. One significant challenge is the lack of awareness among employees, leading to the incorrect disposal of different waste types. Implementing comprehensive training programs could be a strategic solution to enhance employee knowledge regarding proper waste segregation practices. These programs could focus on educating staff about the distinct categories of waste and the significance of correctly sorting waste at the source. Furthermore, emphasizing the role of improved waste disposal infrastructure, such as clearly labeled bins and designated areas for different types of waste, can facilitate and reinforce correct waste segregation. By thoroughly examining challenges and proposing feasible solutions, such as targeted training initiatives and infrastructure improvements, the discussion can provide a more nuanced understanding of the identified issue and offer practical recommendations for mitigating improper waste segregation in the healthcare setting.

A study conducted by the regional office of the WHO in Europe emphasized that effective medical center waste management necessitates a comprehensive program. This program should include heightened personnel awareness, the segregation of quasi-household and infectious waste in designated black and yellow bags, minimizing sources of waste production, separate collection of all waste types especially infectious and radioactive waste faithful implementation of comprehensive waste disposal plans, and meticulous collection of information related to all types of waste generated in healthcare centers

Table 5
Assessment of key risks in the collection of hospital waste using the FMEA approach.

NOM	Key risks in waste collection	O	S	D	RPN	Risk level
1	Overfilling waste bins in departments beyond three-quarters of their capacity.	4	5	5	100	Moderate
2	Neglecting to position color-coded bins appropriately within the hospital wards	4	7	5	140	Moderate
3	Absence of yellow, blue, and white bins for waste disposal in the department.	3	7	4	84	Moderate
4	Neglecting to properly label waste bags.	3	8	5	120	Moderate
5	Failure to utilize personal protective equipment during the collection process	4	7	4	112	Moderate
6	Overfilling the safety box beyond three-quarters of its capacity	3	8	4	96	Moderate
7	Failure to timely wash and disinfect waste bins as per instructions (twice a week)	5	2	3	30	Low
8	Delayed collection of waste (retaining waste for more than 8 hours)	4	4	5	80	Moderate
9	Utilizing individual trailers for waste collection in each section.	5	4	5	100	Moderate
10	Dispersal of waste during the collection process	3	3	4	36	Low

Table 6
Assessment of key risks in hospital waste transfer using the FMEA approach.

NOM	Key risks in hospital waste transfer	O	S	D	RPN	Risk level
1	Ripping of waste bags during transport	5	5	1	25	Low
2	Bag openings occurring during the transfer process	5	7	1	35	Low
3	Opening the doors of waste bins during transportation	5	7	1	35	Low
4	Lack of larger trailers for transporting waste from the departments	5	6	1	30	Low
5	Incidents of needle sticks for service personnel during waste transfer.	5	8	4	160	Moderate
6	Neglecting to utilize waste-carrying bins when transferring waste to a temporary location	4	6	2	48	Low
7	Failure to use gloves, masks, etc., during the handling of waste	5	7	4	140	Moderate
8	Not washing waste trolleys after unloading at the disposal site	8	6	5	240	High
9	Individual sorting of recyclable materials during waste transfer to the disposal site by service personnel	4	4	1	16	Low
10	Contamination of water, soil, and hospital surfaces due to faucet leakage from transport trolleys	5	7	3	105	Moderate

[26]. Attending to these aspects is undoubtedly pivotal for enhancing and elevating the waste management standards of educational and medical institutions.

3.3. HSE risk assessments with FMEA technique

The overall outcomes of the HSE risk assessment across four stages including generation and segregation, collection, transfer, storage, and decontamination utilizing the FMEA technique are presented in Tables 4–7. These tables reveal that each one 10 health and safety risk items have been identified in association with 7, 10, 9, and 9 activities within these respective sections.

The highest risk scores in the four sectors of generation and segregation, collection, transfer, storage, and decontamination were obtained

Table 7
Assessment of key risks in the hospital waste storage and decontamination sector using the FMEA approach.

NOM	Key risks in waste storage and decontamination	O	S	D	RPN	Risk level
1	Inaccurate weighing of various waste types, leading to recording errors	4	1	5	20	Low
2	Mixing infectious and non-infectious waste in shared storage	3	7	4	84	Moderate
3	Allowing waste to remain in temporary storage for over 24 hours	2	7	3	42	Low
4	Occurrence of needle sticks for the safety device operator	2	8	3	48	Low
5	Failure to adhere to the use of specific personal protective equipment, such as secure gloves, filter masks, and boots, by the operator	3	8	2	48	Low
6	Neglecting to clean the decontamination site with prescribed detergents and disinfectants according to the established protocol	2	7	5	70	Moderate
7	Omission of daily washing and disinfection of both infectious and non-infectious waste storage areas	2	7	4	56	Low
8	Failure to incorporate required indicators in each operational cycle of the device by the operator	2	8	1	16	Acceptable
9	Excessive workplace noise	2	4	1	8	Acceptable
10	Air pollution and release of microbial pollutants into the atmosphere during the decontamination process by the device	3	4	7	84	Moderate

160 (moderate), 140 (moderate), 240 (high), and 84 (moderate), and the lowest scores included 42 (low), 30 (low), 25 (low), and 8 (acceptable), respectively.

No activity within the four sectors of the hospital solid waste management was classified as very high risk. However, the activities recognized in these sectors led to high-risk levels, with corresponding numbers of 0, 0, 1, and 0 risks, respectively.

The moderate risk level was found inactivity with 6, 8, 3, and 3 risks, respectively. The low-risk level was attributed to activities in these sectors, resulting in numbers of 4, 2, 6, and 5 risks, respectively. Furthermore, an acceptable risk level was associated with activities identified, yielding 0, 0, 0, and 2 risks, respectively.

Fig. 4 displays the outcomes of health and safety risk assessment for various waste stages using the FMEA method. Accordingly, the transfer stage was the only phase identified with a high risk, while the other stages exhibit acceptable, low, and medium risks.

Analyzing the FMEA worksheets in the present investigation revealed that a significant portion of identified issues stems from inadequate personnel training, a low level of awareness, insufficient allocation of credit, a shortage of staff, and lack of diligence in their duties.

Robinson et al. (2016) demonstrated that applying the FMEA model to identify treatment errors in chemotherapy patients resulted in a 9 % reduction in incorrect drug prescriptions and a 54 % improvement in adherence to standard guidelines. They emphasized that computerized registration of drug prescriptions stands out as a crucial measure contributing to enhanced system performance [27].

The relevance of these findings extends to healthcare waste management, providing an opportunity to apply lessons learned and potentially initiate innovative solutions. Key shared challenges identified in both contexts include inadequate personnel training, low awareness, insufficient allocation of credit, and staff shortages. The systematic approach employed in hospital, particularly the emphasis on identifying and mitigating risks, can be adapted to enhance healthcare waste management practices.

By applying a methodical approach to identify and address potential failure modes, FMEA can contribute to the development of targeted interventions in healthcare waste management. This may involve improved training programs and infrastructure enhancements, fostering a culture of diligence and awareness among healthcare staff.

Hence, the provision of adequate funds and the implementation of training programs focused on waste classification for medical staff, patients, their families, as well as emergency services and support personnel, along with the incorporation of warning signs during error assessments, contribute significantly to the mitigation of adverse effects. Strengthening these measures proves to be effective in minimizing negative consequences.

4. Conclusion

Finally, this research focused on solid waste generation in Imam Khomeini Hospital in Urmia, highlighting a notably high proportion of infectious waste at 38.93 %. This exceeds percentages observed in other cities and emphasizes the need for adherence to the WHO standards. The study identifies challenges such as insufficient awareness and improper waste management practices, emphasizing the importance of targeted training programs.

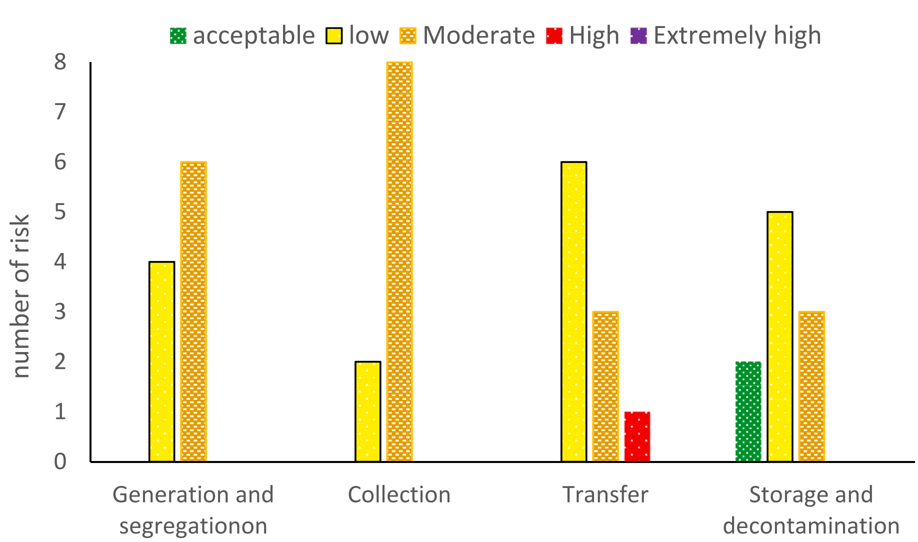

Fig. 4. The outcomes of the health and safety risk assessment in different waste wards using the FMEA method.

The research underscores disparities in waste production across hospitals, linking factors like patient volume and staff awareness to management practices. Additionally, the health and safety risk assessment using FMEA identifies different risk levels, calling for a comprehensive program to enhance waste management standards.

In conclusion, urgent attention is needed for waste management practices, including funding, training, and awareness campaigns. Strengthening these measures is vital for aligning with international standards, ensuring the health and safety of healthcare personnel, and minimizing negative consequences associated with waste mismanagement.

The recognition of improper waste segregation due to employee unawareness highlights a critical need for targeted interventions. Addressing challenges through comprehensive training programs and improved waste disposal infrastructure is crucial for enhancing employee awareness and mitigating improper waste segregation in healthcare settings. A nuanced understanding of the issue and practical recommendations make these interventions essential for effective waste management.

CRediT authorship contribution statement

Saeed Hosseinpoor: Formal analysis. **Towhid Dadashi:** Writing – original draft. **Amir Mohammadi:** Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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