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Medical Waste Management and Treatment Techniques: Insights from Sulaymaniyah Governorate, Kurdistan Region- Iraq

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ABSTRACT

Inadequate medical waste management (MWM) has serious consequences for the environment and human health. Therefore, developing an optimal MWM system in healthcare facilities is of great importance. Unlike previous research, this study aimed to evaluate the MWM techniques practiced at private hospitals in Sulaymaniyah City. Qualitative and quantitative data collection and analytical methodologies were employed. Direct observation was conducted according to the guidelines established by the World Health Organization (WHO), along with semi-structured interviews for qualitative data collection. The quantitative data on waste generation rates for the present study were derived from the pre-existing records maintained by the General Directorate of Health in Sulaymaniyah. The statistical and graphing software GraphPad Prism version 9.5.1 was used to analyze the data. The analysis revealed that the quantity of the hospitals' monthly medical waste generation ranged between 274.0 ± 167.5 kg and 1212 ± 391.6 kg. Moreover, monthly medical waste generation per bed per hospital ranged between 20.20 ± 6.527 kg and 3.177 ± 0.8819 kg. It was also found that the daily generation rate ranges between 0.0576 and 0.827 kg/bed. Concerning management practice, all the studied hospitals have a separation system, a collection system, on-site temporary storage, and personal protective equipment. Meanwhile, 83% of the studied hospitals deliver training courses for their waste management staff. In addition, the three treatment techniques practiced are autoclave shredder systems, incineration, and deep burial.

Index Terms: Healthcare Waste, Private Hospitals, Public Health, Environmental Impact, Waste Management

1. INTRODUCTION

The term medical waste refers to waste produced by healthcare facilities, including public and private hospitals, clinical laboratories, healthcare sectors, and research centers. Several key factors influence waste generation, such as waste management strategies, the percentage of patients treated on a day-care basis, the classification of healthcare facilities, the medical specializations of hospitals, and the proportion of reusable materials used in healthcare. There are two main types of medical waste: Hazardous and non-hazardous, along with general medical waste. In developing countries, waste generation is categorized as follows: 80% is general waste, 15% is infectious waste, 3% is pharmaceutical and chemical waste, and 1% is sharp waste. The remaining <1% includes special wastes, such as used batteries and damaged thermometers. [1], [2]. The composition of medical waste encompasses municipal, chemical, metal, plastic, pharmaceutical, pathological, and laboratory wastes [3]. Anatomical waste includes animal and human waste as defined within the parameters of "biomedical

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material," except for bodily fluids and blood, nail clippings, hair, and removed teeth. Non-anatomical infectious waste refers to any waste that is recognized or clinically evaluated to pose a risk of contamination by microorganisms. Sharps and similar waste include any clinical item capable of causing a laceration or puncture, such as needles, blades, clinical glass, syringes, and similar objects. [4]. Pharmaceutical waste encompasses products and medicinal compounds that are no longer viable for patient treatment. Chemical waste pertains to refuse generated from diagnostic or experimental procedures or any other applications that possess genotoxic properties [5]–[7]**.** Radioactive waste comprises all materials that have been tainted with radioisotopes [8]. The most perilous dimension of medical waste arises from the management of such refuse, as waste handlers are susceptible to needle stick injuries from contaminated needles and sharp instruments, which may result in infections with the human immunodeficiency virus, as well as hepatitis B and C viruses, and this risk is most pronounced in healthcare institutions among medical personnel [9]. Internationally, regulatory agreements have been concluded in the planning of medical waste management (MWM). Some of those agreements are the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal [10], [11]. Moreover, within any country, national legislation constitutes the foundational framework for the enhancement of MWM practices. According to an investigation on medical waste by the World Health Organization (WHO) [12], in 22 developing countries, the percentage of healthcare institutions that failed to employ appropriate waste disposal techniques varied between 18% and 64%. A research investigation conducted at King Abdullah Hospital in Jordan elucidated that the present standards still fail to adequately safeguard the health and safety of healthcare practitioners both within public hospital settings and in external environments [13]. Moreover, a study conducted in Morocco indicated that the operational practices in the majority of surveyed hospitals did not adhere to the principles stipulated in Moroccan legislation [14]. In Iran, an examination performed at Tehran Hospital disclosed that the management of medical waste within healthcare institutions is grossly inadequate, with a conspicuous absence of appropriate health and environmental safety protocols [15]. In Turkey, the management of medical waste has been improved. According to a study by Arikan *et al.*, since 2010, medical waste has been sterilized and rarely incinerated [16]. Moreover, in healthcare centers, there is a manager and a management plan for MWM [17]. In Kurdistan of Iraq, Sulaymaniyah City, an investigation has been conducted that indicates a deficient understanding of MWM, accompanied by widespread hazardous practices among healthcare professionals (HCPs) concerning waste management and occupational health safety [18]. Inadequate management practices exert both direct and indirect effects on healthcare Staff, patients, waste pickers, and the overall hospital environment [19], [20]. The resistance to treatment and the pathogenicity of medical waste make it more dangerous and infectious. Water, air, and land can also be contaminated by medical waste. Through the incineration process of the improper treatment of medical waste, some harmful gases are emitted into the environment, which cause serious problems, such as skin diseases and cancer [21]. In addition, poor MWM leads to many other health and environmental issues, such as unpleasant smell, insect growth, and transmission of diseases through contaminated sharps [22], [23]. There is a huge desire for disposable medical products, which has increased the amount of waste generated and, then, more environmental and health problems [24]. The management of medical waste in an appropriate manner is of paramount significance to mitigate risks associated with both human health and environmental integrity. This study aimed to evaluate the MWM practices of selected private hospitals in Sulaymaniyah City by:

1. Quantifying the daily and monthly medical waste generation rates (in kg/bed/day).
2. Presenting the current MWM practices and techniques implemented by private hospitals.

In addition, the study offers recommendations for improvement based on the findings.

2. METHODOLOGY

2.1. Study Area Description

The present study was conducted in Sulaymaniyah, one of the four major urban cities of the Kurdistan Region of Iraq. The location of this city is approximately 370 km northeast of Baghdad, Iraq's capital, between latitudes from 35° 0' 0" N to 35° 45' 0" N and longitudes from 44° 50' 0" E to 45° 45' 0" E [25]. The city is located in a valley at the foot of Goizha Mountain in the north, stretching southward to the lower lands around the Tanjaro River, covering about 2400 km^2 with a population of approximately 963,390 residents in 2016 [25], [26].

2.2. Study Design and Data Collection Methods

A Mixed-method research approach that integrates both qualitative and quantitative data collection and analytical

methodologies has been utilized to achieve the goals of the present study. The study was limited to private hospitals that provided informed consent and agreed to participate in qualitative interviews.

Data were collected from six private hospitals located in Sulaymaniyah City (five general hospitals and one specialized hospital). In accordance with the principles of confidentiality, the names of the hospitals were designated as H1–H6 for the collection and utilization of information gathered from each hospital. Direct observation following the guidelines provided by the WHO for the safe management of wastes from health-care activities, along with semi-structured interviews, were used in this study. One interview has been conducted at each hospital. Respondents included the infection control officer, nursing superintendent, and the hospital's scientific research officer. Notes were taken during the interviews and after observing waste segregation, collection, treatment, and disposal practices. Quantitative data on the waste generation rate for the present study were based on the existing records from the General Directorate of Health in Sulaymaniyah.

2.3. Data Analysis Techniques

The results are presented as Mean ± standard deviation; an independent samples t-test was used to identify significant differences between the two groups. The data were analyzed using the statistical and graphing software GraphPad Prism version 9.5.1. Normality was assessed using the Kolmogorov-Smirnov test. Mann-Whitney analysis was used to investigate differences between non-parametric values. A $P < 0.05$ was considered statistically significant [27].

3. RESULTS AND DISCUSSION

3.1. Medical Waste Generation

The recorded data from January to June 2024 were analyzed to estimate the Monthly average of medical waste generation across the hospitals. The data indicated that the lowest quantity of medical waste generation among the included hospitals in this study for one month was 274.0 ± 167.5 kg, and the highest amount was 1212 ± 391.6 kg, as shown in Fig. 1 and Table 1.

The data also revealed that the maximum monthly medical waste generation for one bed was 20.20 ± 6.527 kg/hospital, while the minimum amount was 3.177 ± 0.8819 kg, as displayed in Fig. 2 and Table 2.

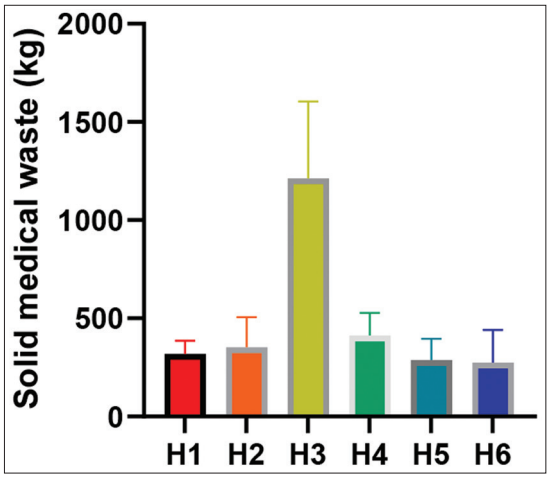

Fig. 1. Solid medical waste generation for hospitals/month.

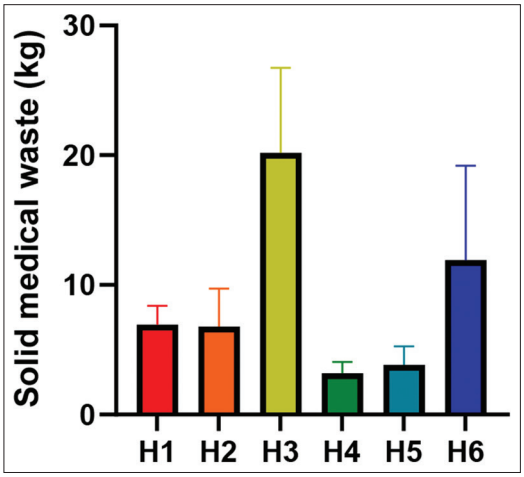

Fig. 2. Medical waste generation for a bed/hospital/month.

TABLE 1: Solid medical waste generation for hospitals/month

Hospital	Amount of solid medical waste (Mean±standard deviation)
H1	319.0±66.75
H2	353.0±152.4
H3	1212±391.6
H4	413.0±114.7
H5	288.0±107.1
H6	274.0±167.5

This indicates that the rate of medical waste generation in hospitals in this study was between 0.0576 and 0.827 kg/bed/Day. However, factors, such as hospital type, size, patient volume, and services offered may affect the variation in waste generation [28].

TABLE 2: Medical waste generation for a bed/ hospital/month

Hospital	Amount of solid medical waste (Mean±SD)
H1	6.935±1.451
H2	6.788±2.930
H3	20.20±6.527
H4	3.177±0.8819
H5	3.840±1.428
H6	11.91±7.284

According to studies, in some hospitals in Baghdad, Ramadi, and Tikrit, the rates of medical waste generation range from 0.43 kg/bed/day to 1.11 kg/bed/day, and they differ among areas and healthcare institutions in Iraq [29], [30]. Upon comparing the findings of this study with those of other cities in Iraq, it is apparent that the medical waste generation in the hospitals studied in Sulaymaniyah City was lower than the typical levels reported in hospitals from the middle and southern parts of Iraq. In other developing nations, such as Iran, Turkey, India, Thailand, and Bangladesh, hospital waste generation ranges from 0.11 to 3.9 kg/bed/day [31].

The findings further confirm that the medical waste generation in the present study is lower than what has been reported by the WHO (2014), which estimated the range of medical waste generation at 0.5–3.0 kg/bed/day in countries worldwide [32].

3.2. Waste Management Practices

Qualitative data on the recommended steps of MWM were collected and analyzed to assess MWM in the studied hospitals. All studied hospitals provide Personal Protective Equipment PPE for their waste management staff, as shown in Fig. 3 and Table 3.

3.2.1. Source Segregation and Collection

The results presented in Fig. 3 and Table 3 demonstrate a high proportion of waste separation in hospitals, as all 6 hospitals were doing source separation for waste, with a percentage of 100%.

Hospitals systematically separate different waste categories at the source, such as sharp, infectious, and general waste. Doctors, head nurses, pharmacists, and laboratorians working in the clinics and various hospital units carry out this process. This segregation is necessary to lower the risk of contamination and ensure that hazardous items are managed correctly. It also diminishes environmental and health risks associated with hospital waste and lowers waste management costs in private hospitals [28].

TABLE 3: Waste management practice in the studied hospitals

Waste management practices	Number of hospitals/practices	Occurrence %
Separation	6	100
Collection		
Four-bin system	4	66
Three-bin system	2	34
On-site temporary storage	6	100
Personal protective equipment	6	100
Training course	5	83
On-site waste treatment	0	0

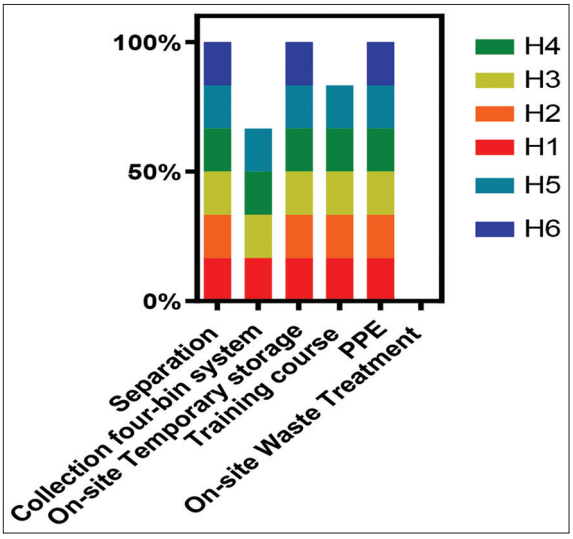

Fig. 3. Waste management practices in the studied hospitals.

The Color-coded bin system, following the WHO (2017) approach, was used for various waste categories to help with appropriate segregation in the studied hospitals (Fig. 4). The data revealed that four out of the six hospitals under study used the 4-bin collecting system, with a percentage of 66%according to the data in Table 3 and Fig. 3.

- Yellow bin with a yellow plastic bag in the bin for infectious, chemical, and pharmaceutical wastes.
- Disposable plastic or cardboard medical biohazard sharp containers for sharps (Fig. 5).
- Red bin with red plastic bag in the bin for anatomical waste. Particularly used in hospitals with a Maternity unit.
- Black bin with black plastic bag for general/non-hazardous waste.

By filling three-quarters of the bins' capacity, all kinds of waste are collected following WHO guidelines. This is to prevent spillage and kept covered to avoid casual access by individuals or disease vectors [33].

Fig. 4. Color-coded bins for collecting waste at the studied hospitals.

Fig. 5. Disposable medical biohazard sharp bins utilized in the studied hospitals.

Presented data from Table 3 and Fig. 3 also reveal that 83% of the studied hospitals conduct training courses on MWM for their medical and janitorial staff. The goal of training is to improve skills and increase awareness among healthcare workers. WHO (2017) has emphasized the necessity of intensive training courses, suitable personal protective equipment PPE, and more efficient resource use to improve the efficiency of MWM in healthcare facilities [33].

3.2.2. Storage and Transportation

On-site storage serves as a transitional phase before waste is processed or sent to other facilities. Efficient storage practices are essential for minimizing the risks associated with hazardous waste. Storage sites were located in the backyards and covered with plastic roofs to shield the waste from rain and direct sunlight. The areas were secured with concrete walls and metallic chain-link fences to minimize exposure to people and animals, as captured in Fig. 6. However, the storage areas in the studied hospitals were partially secured in terms of access to vectors that may cause the spread of diseases. According to WHO (2017) and UNEP (2021), the on-site storage space should be situated away from areas used for patient care, places where food is prepared, and areas where the public can enter. Only authorized staff and

Fig. 6. On-site storage area for temporarily storing medical waste.

waste collection vehicles should have access to these areas. To prevent leaks or mitigate contamination, storage facilities must include drainage systems, adequate ventilation, and impermeable, easy-to-clean flooring [33], [34].

Medical wastes are collected from the on-site storage areas 2–3 times/week. As stated in WHO guidelines (2017), the length of time medical waste can be kept on-site is determined by the waste type and the local climate. Without refrigeration, infectious waste should not be kept for longer than 48 h in a tropical climate or 72 h in a temperate climate. To avoid deterioration and odor release, extended storage times require cooling below 8°C [33].

Medical waste is typically kept in yellow-colored containers separate from regular waste in hospitals. Data in Table 3 and Fig. 3 reveal that none of the studied hospitals implement on-site treatment practice. This is due to the cost-effectiveness of treatment technologies and space limitations in certain hospital areas. To ensure the safe transportation, treatment, and final disposal of medical waste, the studied hospitals made a (Pay as you generate) contract with the Ministry of Health/ General Directorate of Health in Sulaymaniyah. Accordingly, private hospitals incur costs to the government based on the weight of the medical waste they generate. The hospital is billed depending on the measured waste, with different charges for different types of waste (hazardous, infectious, or anatomical). Penalties for underreporting or incorrect segregation could apply. This encourages hospitals to source-segregate wastes, which reduces the cost of waste disposal as well as the environmental footprint of hospital garbage [33], [35]. Waste is eventually transferred by the specialized Box Trucks for off-site treatment processes and final disposal.

3.2.3. Treatment Techniques

The effective treatment of medical waste is crucial for safeguarding public health, ensuring environmental safety,

and averting the transmission of infectious illnesses. Autoclave-shredder systems, incineration, and deep burial are the most popular techniques for medical waste handling in the studied area.

3.2.3.1. Autoclaving

Collected medical wastes are then treated using autoclave-shredder systems, which combine mechanical shredding and steam sterilizing [36]. By subjecting the waste to high-pressure steam at temperatures between 121°C and 134°C, autoclaving effectively destroys germs. This is followed by a shredding process, which increases the surface area and reduces the volume of the waste, ensuring thorough sterilization. According to M. A. Asad (Head of infection control, General Directorate of Health in Sulaymaniyah, personal Communication. Aug. 7, 2024), the General Directorate of Health in Sulaymaniyah placed two autoclave shredders in the Sulaymaniyah City Center, each capable of processing around 1000 kg of medical waste/day (Fig. 7).

The autoclave-shredding system is environmentally sustainable, as it produces no harmful emissions and is appropriate for processing sharps, contaminated plastics, textiles, and other biohazardous items. Although it has high operating costs due to high energy demand, and is not suitable for chemical and pharmaceutical waste [37].

3.2.3.2. Incineration

Medical waste is burned at high temperatures during incineration. It converts the waste's combustible components into gaseous byproducts, such as CO_2, H_2O, CO, and other gases (some of which are poisonous), while non-combustible components remain as a solid byproduct (ash) [36]. Incineration is carried out at temperatures ranging from 800 to 1200°C in the presence of sufficient air to destroy infections and organic wastes [38].

In the present study area, six incinerators are installed (Fig. 8). Two incinerators, which are located in a secure room with more advanced smoke treatment, are used for prohibited drug eradication as discussed by (N. M. Ahmed, incineration plant supervisor, General Directorate of Health in Sulaymaniyah, Personal Communication, Jan 16, 2025).

Incineration can release toxic emissions, such as furans and dioxins; therefore, sophisticated air pollution control systems are necessary to mitigate their environmental impact [38].

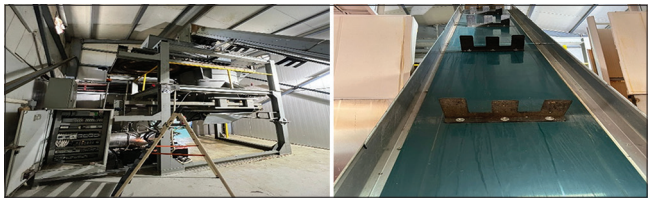

Fig. 7. Autoclave-shredder at the Sulaymaniyah teaching hospital in Sulaymaniyah city.

Fig. 8. Incinerators in the Tanjaro area.

In the present study area, the incinerators are located outside the city, precisely in the Tanjaro area near the dumping site. The leftover ashes are then buried in the specially designed concrete pits and covered to minimize the risk of exposure and contamination.

3.2.3.3. Deep burial

Deep burial is the disposal of garbage in defined sites, often several meters below the surface. This strategy can be especially beneficial in developing nations where resources and facilities for more advanced waste treatment are restricted [35]. Certain forms of waste are appropriate for deep burial. This comprises anatomical waste, microbiological trash, and other garbage that has been treated to lower its hazard level.

In the present research area, waste is deposited in an approximately 7–8-m pit in strata, with each stratum being encapsulated by a layer of soil. Upon filling the pit, it is enclosed with a substantial layer of soil, which aids in reducing odors and deterring scavengers, as discussed by Asad (2024). Although the deep burial method can serve as an effective waste disposal technique, inadequately managed burial sites may result in the leaching of hazardous compounds into groundwater and soil, along with the possible emission of greenhouse gases [39].

Despite the mentioned methods, other advanced approaches are practiced for hospital waste treatment in developed nations, including Microwave Disinfection, UV Disinfection, and Chemical disinfection using various chemical agents [40].

4. CONCLUSION

MWM begins at the point of generation and continues through the entire treatment process. In the present study, only private hospitals that provided informed consent and agreed to participate in qualitative interviews were included. The findings revealed that the maximum medical waste generation, 0.827 kg/bed/day, is lower than the WHO standard for medical waste and some other cities in the middle and southern parts of Iraq. The diversity in waste creation may be affected by hospital size, type, patient volume, and services offered.

The management procedure in Sulaymaniyah City's private hospitals starts with an infection control unit. The insights gathered from interviews at the participant hospitals underscore the critical importance of effective MWM in safeguarding both healthcare workers and patients. The data reveals that most hospitals conduct training courses on MWM for their medical and janitorial staff. Color-coded bins were applied to separate waste into various categories, and 66% of the studied hospitals used a 4-bin system. Each hospital has a designated area with specified features for collecting garbage, and none of them has a treatment unit. The General Directorate of Health in Sulaymaniyah handles the transportation, treatment, and final disposal phase. Medical waste is transported to various treatment facilities, such as autoclave-shredder units, incineration, and deep burial, depending on the type of waste, using specialized box trucks.

RECOMMENDATIONS

In light of the findings of this study, the following recommendations are suggested:

- Increase capacity and raise awareness: Public awareness campaigns and extensive training programs for HCPs can aid in enhancing MWM -related knowledge, attitudes, and behaviors.
- Invest in sustainable treatment and disposal technologies: The governorate ought to investigate and finance eco-friendly treatment and disposal techniques, such as microwave disinfection, autoclaving, or other technologies that have minimal negative effects on the environment.
- Continuous monitoring and control systems: Continuous supervision and control systems are essential to guarantee adherence to MWM laws and enhance procedures in all healthcare facilities.

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