

# Evaluation of hospital wastes management with emphasis on genotoxic wastes in Semnan University of Medical Science's hospitals

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## Abstract

**Aims:** This study aimed to evaluate the management of hospital wastes with an emphasis on genotoxic waste. In this regard, wastes production rate, separation method, temporary storage, collection, and disposal were investigated. **Materials and Methods:** A comprehensive survey was conducted at six public hospitals by designing a questionnaire regarding medical waste management. Furthermore, face-to-face interviews were arranged. **Results:** The results demonstrated that the generation rate of total medical waste, hazardous-infectious waste, genotoxic waste, and the generation rates of general waste in Semnan city were 2.904, 0.9 (31%), 0.09 (3%), and 1.914 (66%) kg/bed-day, respectively. Approximately 50% of the hospitals used unsuitable containers to collect genotoxic wastes from hospital wards. It was found that all the hospitals have temporary storage rooms. However, there is not a specific and separate temporary storage place for genotoxic wastes in the hospitals. Four hospitals (83.3%) are equipped with steam sterilization and shredding equipment. One hospital (16.7%) has steam sterilization without shredding for treating infectious and sharp wastes. In this study, chemical neutralization was considered the principal method for treating genotoxic waste in hospitals. Moreover, lack of staff training (46% of hospitals) and shortage of personal-protective equipment (85% of hospitals) were considered significant problems in these hospitals. **Conclusions:** This study revealed that the healthcare waste management index is acceptable for all types of hospital wastes except for genotoxic waste. Therefore, it is essential to pay more attention to the on-site collection and safe storage of genotoxic wastes. Furthermore, in terms of treatment, transfer, and disposal stages, general hospital waste was managed properly compare to genotoxic waste.

**Keywords:** Genotoxic waste, hospital waste, waste management index

## INTRODUCTION

Over the past decades, medical waste production has been dramatically increased due to the increase in the number and size of healthcare facilities, medical services, and the use of disposable medical products.<sup>[1,2]</sup> Medical waste can be divided into two major categories, including general and hazardous wastes. The World Health Organization (WHO) and US Environmental Protection Agencies reported that about 10%-25% of hospital wastes are classified as hazardous.<sup>[2,3]</sup>

The hazardous wastes are comprised of cytotoxic, pathological, genotoxic, pharmaceutical, chemical, heavy metals, pressurized containers, and radioactive waste, which are mutagenic,

teratogenic, and carcinogenic.<sup>[3-5]</sup> For instance, occupational exposure to antineoplastic drugs occurs through mucous membranes, skin contact, inhalation, and unintentional eating.

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**How to cite this article:** Forumadi M, Vanaei F, Mostafaii G, Ghafari Y, Ghobakhloo Z, Ghobakhloo S. Evaluation of hospital wastes management with emphasis on genotoxic wastes in Semnan University of Medical Science's hospitals. *Int J Env Health Eng* 2023;12:13.

**Received:** 27-07-2021, **Revised:** 25-04-2022,  
**Accepted:** 28-05-2022, **Published:** 17-07-2023

### Access this article online

#### Quick Response Code:



**Website:**  
www.ijehe.org

**DOI:**  
10.4103/ijehe.ijehe\_21\_21

Furthermore, the work environment can be contaminated in various ways and affect personnel's health. For example, exposure to the leakage from defective syringes and excretion of chemotherapy patients has been considered the potential high-risk factor. Finally, these wastes will enter the municipal solid waste stream and cause harm to the environment and everybody who comes in contact with the environmental waste.<sup>[6]</sup>

In some countries, rigorous methods exist for manufacturing and handling cytostatic drugs.<sup>[7,8]</sup> For example, in Mauritius, the unsafe portion of healthcare waste has traditionally been burnt on-site in incinerators. The noninfectious part is mixed with the domestic waste stream at the sole sanitary landfill on the island. Therefore, unsafe healthcare waste is completely be ascertained, quantified, taken apart, handled, treated, and disposed of.<sup>[9,10]</sup>

Researches have been shown that waste segregation and the lack of personnel training were the main problems in hospital waste management in Iran.<sup>[1,12]</sup>

Despite the infrastructure, Industry, and Environment Commission of Iran adopted a regulation entitled "Criteria and Procedures for the executive management of medical waste and waste dependent" in 2007, there are still some deficiencies in managing hospital waste in Iran.

To the best of our knowledge, there is no clear perspective for hospital waste management conditions, especially genotoxic waste in Semnan hospitals. Therefore, considering all these drawbacks, the purpose of this study is to provide an accurate description of actual hospital waste management, especially genotoxic waste, which can be considered as the basis for an appropriate waste management strategy. The specific objectives of this study are comprised of conducting a survey for the current practices and determining the amount of the produced medical and genotoxic wastes, the condition of segregation of waste, the type of the used storage containers, temporary storage area, collection and disposal of hospital waste, as well as assessing the kind of training provided for the hospital personnel, and suggestions for the improvement of the existing conditions and get away with the identified problems.

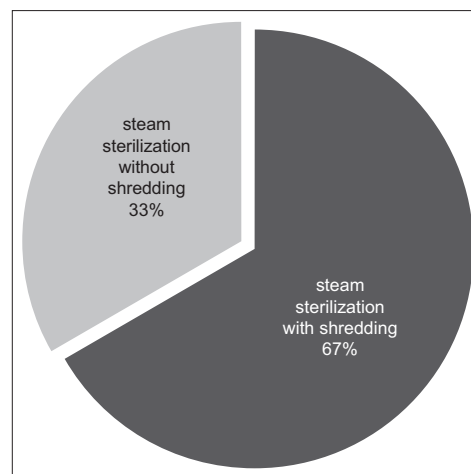
## MATERIALS AND METHODS

### Study area

Semnan is a city located in the northeast of Iran, with 200,673 people (2017) and 22,120. Semnan province on the southern slopes of Alborz Mountains with its height reduced gradually from North to South and led to the salt desert, at an altitude of 2065 meters above sea level, a latitude of 34.15° N longitude of 52.46° E [Figure 1]. The region has undergone heavy urbanization and development in recent decades.

### Preparation of questionnaires and data collection

There are 12 hospitals in Semnan city with more than 623 active beds. The hospitals and health centers in the city can be divided into three groups, including governmental,



**Figure 1:** Pie charts showing the methods of treating medical waste in 2016 in Semnan

educational, and private hospitals. This study investigates the Semnan Medical Waste Control Regulation application for the healthcare services in the hospitals affiliated to Semnan University of Medical Sciences. Face-to-face interviews were conducted in this study in six hospitals of Semnan. The results are evaluated according to the regulation. Furthermore, the current state of medical waste management is specified. A survey was conducted by developing a questionnaire. After completing the questionnaires for each hospital, each question was rated based on either compliance or noncompliance with the hospital waste management law. Then, the genotoxic index and other hospital waste management indexes were calculated for each hospital. After collecting the points in each stage, the score of each stage was calculated from 100. Then, each step was given weight to convert each hospital score into a hospital management index and a genotoxic waste management index. The weighting of different steps was done according to Table 2. According to the percentage obtained in each stage of waste management, the results are 0-25 as deplorable condition, 26-50 as weak condition, 51-70 as moderate condition, 71-90 as good condition, and 91-100 was considered excellent status.<sup>[11]</sup> In this study, the names of hospitals were refused, and hospitals were named with codes A to F.

### Statistical analysis

The rearrangement method was used to evaluate the reliability and validity of the questionnaire. So that after filling out the questionnaires in the first stage and after spending a short time under the conditions above, the questionnaires were filled in again, and finally, the reliability coefficient (Cronbach's alpha) was calculated. Cronbach's  $\alpha$  is a function of the number of items in the test, the mean of the covariance between the item pairs, and the total score variance. The results showed that in this case, 113 questions in the retest had the same answer among all questions (total questions = 124), and Cronbach's alpha coefficient in the rest of the questions (11 questions) was calculated between 0.7 and 1, which indicates the validity of our questionnaires. After filling out the questionnaires,

each ward was scored from 0 to 10 according to compliance with the standards. The sum of the scores in each stage of the management process is divided by the number of questions in that section and multiplied by 100 to convert the initial scores into relevant management process scores [Table 1]. Finally, to convert the final score of each hospital to Hospital Waste Management Index (HWMI), the weighting factor related to each health care waste management process was used according to Table 2.<sup>[11]</sup> In each hospital, the first step was to interview the hospital directors, waste management employees, and other personnel. Then, the processes of collection and disposal of wastes were observed for obtaining actual data. The data were analyzed using Excel and SPSS software (version 19) (Chicago, IL, USA).

Ethical approval for this study (No: IR.SEMUMS.REC.1395.46) was provided by the Ethical Committee Semnan University of Medical Sciences (SEMUMS), Semnan, on 20 April 2016.

## RESULTS

### Generation rates

The survey results indicate that the average generation rates are 0.9, 0.09, and 1.914 kg/bed-day for infectious waste, genotoxic waste, and general waste in all the hospitals affiliated to Semnan University of Medical Sciences, respectively [Table 2]. Another study was conducted in several hospitals in Iran (Shiraz city). The results demonstrated that the amount of infectious waste, sharp waste, and general waste were 27.85%, 0.76%, and 71.11%, respectively.<sup>[11]</sup> Among the studied hospitals, the lowest generation rates of infectious and genotoxic wastes were related to the hospitals with the F code of 0.35 (kg/bed-day)

and B code of 0.07 (Kg/bed-day). According to Table 3, the generation rate of medical waste differs not only from country to country but also within a country. According to Table 2, the amount of waste is significantly different from hospital to hospital, and it is also different for the hospitals within the same category. This variation may be due to the difference in the patient hospital specializations, hospital sizes, economic, social, and cultural traits, the proportion of patients treated on a day-care basis, waste management practices, and the application of disposable items. Therefore, we recommend that a separate study be performed to design healthcare waste management. Based on the results of Table 2, the generation rates of infectious waste were 1.32, 0.97, 1.27, 1.06, 0.44, and 0.35 kg/bed-day in hospitals with the codes of A, B, C, D, E, and F. Furthermore, the genotoxic waste generation rates were 0.18, 0.07, 0.14, and 0.182 kg/bed-day in hospitals with the codes of A, B, C, and D. The WHO has estimated that 75%–90% of the produced wastes by healthcare providers and hospitals are concerned with general healthcare waste, and the rest of wastes (i. e., 10%–25%) are hazardous-infectious wastes.<sup>[3,4]</sup> Another study was performed for a hospital in Libya. The results revealed that the amount of general and infectious wastes were 72% and

Range	Rank
91-100	Excellent
71-90	Good
51-70	Medium
26-50	Poor
0-25	Very poor

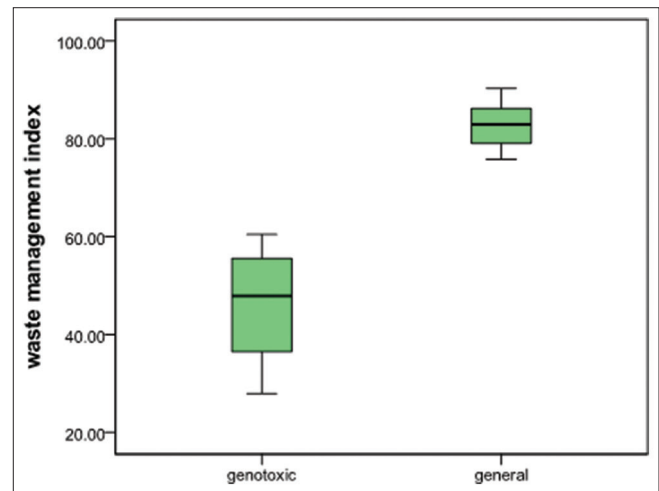


Figure 2: Comparison of the genotoxic waste management index with other general hospital wastes

Hospital code	Active beds	Average of medical waste generation rate (kg/bed-day)							
		Total waste		infectious		genotoxic		General	
		kg/y.b	kg/y	kg/y.b	kg/y	kg/y.b	kg/y	kg/y.b	kg/y
A	100	1511.3	151,130	484	48,400	67.3	6730	940	94,000
B	224	1052.58	235,780	357.14	80,000	25.80	5780	669.64	150,000
C	89	1347.78	119,952.6	465.16	41,400	51.15	4552.55	831.46	74,000
D	150	1321.92	198,288	387.64	58,146	66.53	9980	867.74	130,162
E	18	688.61	12,395	162.22	2920	0	0	526.38	9475
F	42	485.71	20,400	128.57	5400	0	0	357.14	15,000
Total	623	6407.9	737,945.6	1984.74	236,266	43.406	27,042.55	4192.38	472,637
Mean±SD		2.91±1.09		0.9±0.41		0.09±0.08		1.91±0.61	

SD: Standard deviation

28%, respectively.<sup>[12]</sup> According to Figure 1, the total medical wastes generated in Semnan hospitals are composed of general waste (66%), hazardous–infectious waste (31%), and genotoxic waste (3%) (total genotoxic–infectious waste is 34%). The different proportions of general and hazardous-infectious wastes can be analyzed by implementing the various medical waste management systems in the hospitals and their specializations. Regardless of the specific proportions, the levels of infectious, general, and genotoxic wastes in the total medical waste stream reveal the importance of designing a particular segregation program. This program utilizes color-coded plastic bags or containers and adds general waste to the stream of domestic refuse. The demands for treating medical wastes can be reduced by designing and implementing an exact segregation program in Semnan city. Besides, the monetary costs, public health risks, and environmental pollution will be decreased at the same value. In the absence of a proper segregation program in the hospitals, all generated medical wastes (100%) are categorized as hazardous-infectious waste, which requires a considerable

cost for the treatment and disposal of medical waste in each society. It is concluded that more attention should be paid to the education of management, staff, and employees to reduce and minimize the generation rates of general, genotoxic, and infectious wastes since millions of staff members and employees in various parts of the hospitals in Iran can be exposed to hazardous substances, such as genotoxic waste. Exposure to hazardous healthcare waste can have various consequences such as infection, genotoxicity and cytotoxicity, chemical toxicity, radioactivity hazards, physical injuries, and public sensitivity. The liquid was the third most crucial contributor to genotoxic and infectious wastes. Although there is a limitation for discharging genotoxic and toxic liquids into sewers, the waste liquids are primarily suitable for disposal in the sewerage system.<sup>[3,4]</sup>

### Separated collection of waste

There are five questions about healthcare waste collection and eight questions about temporary storage depots in the questionnaire [Table 4].

The following segregation preparations were applied at the hospital where the research was conducted (color codes were used to identify containers for different types of waste): Red bags for infectious waste, yellow for sharp wastes, and cytotoxic/cytostatic drugs were collected in their original packaging.

According to this study, the following practices were identified as problematic: In 50% of the hospitals, insufficient segregation of genotoxic waste was observed, and some hospitals throw out their genotoxic waste separated in a brown or sometimes in a white bag. Moreover, even though 100% of containers had their logo but there was no appropriate label.

### On-site transport and temporary waste storage area

At the end of each shift, the hospital workers collect and transport the hospital wastes to a temporary storage location. In two hospitals (50% of the hospitals), trolleys and other manual methods are used to collect, disinfection, and daily cleaning of genotoxic waste. By generating waste, the staff usually collect and transfer the waste to a temporary waste storage area. The temporary waste storage area keeps the hospital waste before transporting to the final disposal site. This area must be well-sanitized and secured. Furthermore, it should only be accessible to authorized people.<sup>[11]</sup> About 16% of the temporary waste storage area does not have the required facilities (e.g., sewer systems, covered, and ventilation). According to the national regulations, most facilities (83.33%) collected and transported waste within 24 h.

However, 16% of these storage areas were not favorable. The results of site inspections revealed that some storage areas were dealt with a lack of ventilation and inadequate storage temperature. Besides, these areas were located around sensitive zones such as treatment rooms and kitchens. It was observed that personnel used personal protective equipment for handling healthcare waste in most of the extensive public facilities. However, it was a challenge in some of the private facilities.

**Table 3: Comparison of medical waste generation rate in Semnan city with other studies**

Country - Region	Generation rate (kg/bed-day)	Reference
Iran - Semnan	2.9	Present study
Iran - Tehran	4.095	Ghasemi <i>et al.</i> <sup>[11]</sup>
Iran - Mazandaran	3.51	Gorgani <i>et al.</i> <sup>[12]</sup>
Iran - Hormozgan	1.83	Dehghani and Vafadar (2017) <sup>[14]</sup>
Nepal - Lamjung	0.860	Aryal <i>et al.</i> <sup>[15]</sup>
Brazil - Bauru	4.375	Delmonico <i>et al.</i> <sup>[16]</sup>
India - Uttarakhand	0.24	Thakur and Anbanandam <sup>[17]</sup>
Pakistan - Gujranwala	0.667	Ali <i>et al.</i> <sup>[18]</sup>
Ethiopia - Amhara	2.45	Tesfahun <i>et al.</i> <sup>[19]</sup>
Palestine - GazaStrip	1.3	Caniato <i>et al.</i> <sup>[20]</sup>
Nigeria - Lagos	0.181	Awodele <i>et al.</i> <sup>[21]</sup>

**Table 4: Content of hospital waste collection and storage questions**

Question	Response	n (%)
Does healthcare waste segregation take place in the hospital wards?	Complete segregation of all hospital wastes	2 (50)
	Segregation of all hospital wastes except genotoxic waste	2 (50)
Are colored containers used to separate all kinds of healthcare wastes?	Yes	2 (33.3)
	No	4 (66.7)
Is there a list of genotoxic materials in the hospital?	Yes	3 (75)
	No	1 (25)
What color is the segregation container of the genotoxic waste?	Brown	1 (50)
	White	1 (50)
Are the waste bags or containers labeled?	Yes	2 (100)
	No	-

The collected data were analyzed by considering the storage issue, and the results showed that all the surveyed facilities had a centralized temporary waste storage area. All the studied hospitals did not have a temporary storage place for genotoxic waste. Only 16.7% of the hospitals use a temporary storage place before transporting waste out of the hospital. Genotypic

waste is kept for a week in a temporary place before starting the next operation [Table 5].

### Hospitalwaste treatment

Propper waste treatment can decrease volume, weight, and risk of infectivity and organic compounds of the waste.<sup>[12]</sup>

**Table 5: Content of hospital waste the on-site transport and the temporary storage depots questions**

Question	Response	n (%)
Type of the vehicle to collect/transport all kinds of wastes except genotoxic	Trolleys	5 (83.3)
	Carts	1 (16.7)
Is the waste transport container washed daily?	Yes	5 (83.3)
	No	1 (16.7)
Is the waste transport container disinfected?	Yes	5 (83.3)
	No	1 (16.7)
The frequency of waste transportof the hospital ward per day	Once a day	1 (16.7)
	Twice a day	1 (16.7)
	Three a day	4 (66.7)
The waste collection time of hospital wards	Morning, afternoon, night	3 (50)
	Morning, afternoon, evening	1 (16.7)
	Morning, evening	1 (16.7)
	Last night	1 (16.7)
What kind of vehicle is used to transport genotoxic waste from the ward?	Trolleys	2 (50)
	Carts	2 (50)
Is thegenotoxic waste transport container washed daily?	Yes	2 (50)
	No	2 (50)
Is thegenotoxic waste transport container disinfected?	Yes	1 (25)
	No	3 (75)
The frequency of genotoxicwastetransportation of hospital ward per day	Once a day	2 (50)
	Twice a day	2 (50)
	Three a day	-
The genotoxic waste collection time of hospital wards	Morning	-
	Afternoon	-
	Late night	4 (50)
Is there a temporary storage place in the hospital?	Yes	6 (100)
	No	0
What is the purpose of using temporary storage areas for hospital waste?	Storage of waste for disinfecting and in order to be taken out of the hospital	5 (83.3)
	In order to be taken out of the hospital	1 (16.7)
How much is the approximate distance of the temporary place to the nearest ward? (m)	100	2 (33.3)
	100-200	2 (33.3)
	200-1000	2 (33.3)
Which of the following facilities are used to equip the temporary waste storage areas?	Faucet	6 (100)
	Sewer systems	5 (83.3)
	Covered	5 (83.3)
	Ventilation	5 (83.3)
How is the quality of temporary storage of cleaning and disinfection?	Very favorable	1 (16.7)
	Favorable	4 (66.6)
	Average	1 (16.7)
The duration of waste stopping in a temporary place until the next operation (h)	1-12	3 (50)
	12-24	2 (33.33)
	24-48	1 (16.66)
Is there a temporary storage place separately in the hospital for genotoxic waste?	Yes	0
	No	4 (100)
How long is the duration of stopping genotoxic waste in a temporary place until the next operation?	A week	4 (100)
	1 month	0
	2 months	0
	3 months	0

Medical waste treatment methods include incineration, steam sterilization, microwave sanitation, chemical disinfection, dry heat disinfection, and disinfection with superheated steam.<sup>[13-15]</sup> In this study, steam sterilization has only been employed as a treatment system for infectious and sharp wastes in hospitals. Moreover, steam sterilization has commonly been utilized for treating medical waste in Iran. According to the Waste Management Act, before sterilization, appropriate shredding equipment is utilized for shredding the medical waste to a size of 4 cm × 4 cm.<sup>[15]</sup> This waste was collected in a plastic bag or steel container. The purpose of shredding is to convert healthcare wastes into a more homogenous form that can easily be controlled and sterilized. After shredding, the sterilization process is performed by loading waste into an autoclave. A biological indicator (e.g., *Bacillus stearothermophilus*) should be placed at the center of the load processed under standard operating conditions. This process is repeated at least once a month to confirm the attainment of adequate sterilization conditions. These biological indicators may either be ampules or strips (i.e., Kilit, Spordex). These indicators also contain spores, which are incubated after the sterilization process. A color change occurs to indicate whether growth happens after the sterilization process or not. Standard written operating procedures should be established for biological indicators, including time, temperature, pressure, type of waste, type of container, closure on the container, the pattern of loading, water content, and maximum load quantity. According to the Iranian guidelines, sterilization conditions can be fulfilled by processing from 10 to 30 min in contact with steam (138°C) and pressure above 4 bar. After steam sterilization, the final products are often incinerated at the medical waste treatment facilities. However, many communities are reluctant to accept the sterilized products in their MSW landfills. Only one hospital has treated the on-site hospital waste among the six hospitals by employing steam sterilization without shredding.

In comparison, three hospitals have employed steam sterilization with shredding the medical wastes. Then, the hospital wastes were transferred to another hospital for treatment. Chemical neutralization was the principal process for genotoxic waste in the studied hospitals. Details of other treatments in different questions are given in Table 6 and Figure 1.

**Off-site transportation of healthcare waste**

Medical waste must be transferred from the treated place to the off-site installations for the disposal of wastes. In five hospitals (83.3% of the hospitals), the municipality is responsible for the off-site transportation of the waste, and in another hospital (16.7% of the hospitals), the private contractors are in charge of transporting the wastes to the final disposal site. In this case, the wastes contained all infectious waste, sharps, and other domestic wastes. The whole of the hospitals had a daily waste transportation program. In two hospitals (50% of the hospitals), the municipality is responsible for off-site transportation of the genotoxic waste. In one hospital (25% of the hospitals), the private contractors accomplished the off-site

**Table 6: Content of hospital waste on-site and off-site treatment questions**

Question	Response	n (%)
Does the hospital have a waste treatment facility?	Yes	5 (83.33)
	No	1 (16.7)
What kind of waste treatment facilities are available in the hospital?	Steam sterilization without shredding	1 (16.3)
	Steam sterilization with shredding	4 (83.33)
	Incinerator	-
Is the device at the moment usable?	Yes	5 (100)
	No	-
Does the machine have a skilled technician?	Yes	4 (66.6)
	No	2 (33.3)
The primary method of treatment and disposal of genotoxic waste	Chemical neutralization	2 (50)
	Incinerator	-

transportation of the wastes and transferred the wastes to the final disposal site. The off-site transportations of the wastes have been implemented by a pickup truck, special trucks, and general trucks in one (16.7%), two (50%), and three (33.3%) hospitals, respectively [Table 7].

**Final disposal of hospital waste**

In this study, all hospitals disposed of healthcare wastes in a landfill site outside the city, except for a hospital that used the land around the center for this purpose. All hospitals have transported the wastes to an off-site area. This area has been located about 30 km away from the city. In two hospitals (50%), several unique methods are used for destroying genotoxic waste. Then, these are buried apart from domestic waste. In two other hospitals, after elimination, the waste is buried with other wastes. Besides, regular monitoring is performed during genotoxic waste disposal and other hospital wastes. Also, facility auditing contributes to maintaining a practical situation. The results of this study revealed that there are three organizations for transferring the genotoxic waste, including private contractors (25%), the municipality (25%), and hospitals (50%) [Table 8].

**Personnel training**

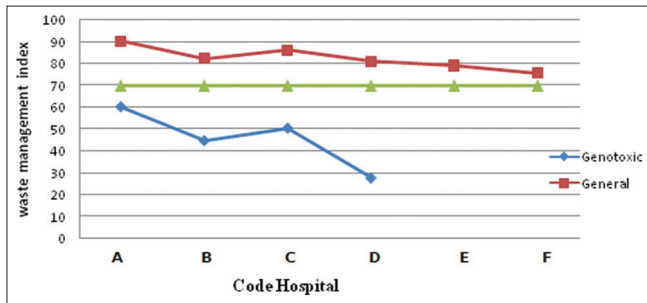
According to the investigations, all personnel (i.e., managers, employees, and cleaning staff) were trained for hospital waste management and had detailed information about their duties. The results of this study demonstrated that 66.7% of hospitals were responsible for waste management. In all hospitals, the environmental health expert is one of the infection control committee members and laundry members, and he/she attends the meetings. In four hospitals, there were standards and control strategies for genotoxic waste. The analysis results showed that 50% of the workers of hospitals responsible for collecting and transporting genotoxic waste from hospital to final disposal sites received the required training against the hazards associated with hospital waste. However, complete protective equipment was used in two hospitals (33.3%)[Table 9].

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**Index management of hospital wastes**

In this study, the HWMI was introduced as a mathematical tool to convert the scores of different stages of hospital waste management into a specific unit that displays the status of waste management. In this research, the highest and lowest waste management indexes depend on the waste type. Hence, there is a significant difference between general and genotoxic wastes. For example, the genotoxic waste group received much lower scores than general waste [Figures 2 and 3]. It was observed that hospital A had the best status of hospital waste management.

Furthermore, according to this investigation, the management of all hospital wastes is desired except for genotoxic waste. The

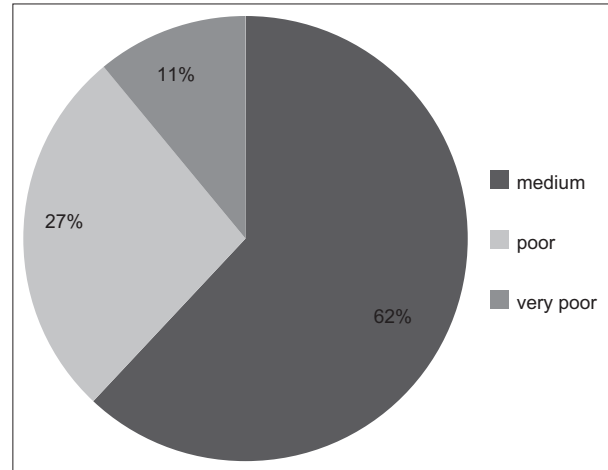


**Figure 3:** Comparison of the status of genotoxic and hospital waste management index with respect to good conditions

management of these wastes was average in every hospital. As shown in Figure 4, the states of the genotoxic waste indexes were undesirable in 11% of hospitals.

**DISCUSSION**

The total medical wastes generated in Semnan hospitals are comprised of general waste, hazardous-infectious



**Figure 4:** The status of Genotoxic Waste Management Index in selected hospitals

**Table 7: Content of hospital waste the off-site transport questions**

Question	Response	n (%)
Method of transportation healthcare waste	Transfer whole waste directly to final disposal	6 (100)
	Transfer the waste to Temporary storage of waste and then to the final disposal	0
	Transfer of special waste separately to final disposal	0
Who is responsible for waste transport to final disposal sites?	Municipality	5 (83.8)
	Private contractor	1 (16.7)
	Hospital	0
Time to transfer waste from a temporary storage area	Once-daily	6 (100)
	Twice daily	0
	At the end of each work shift	0
Waste transfer vehicle into the waste truck	Special mechanized machine	5 (83.3)
	Hand	1 (16.7)
	Manual shovel	0
What kind of trucks are used to transport waste from the hospital?	Roofed trucks special	2 (33.3)
	Roofed trucks ordinary	3 (50)
	Pickup truck	0
Which methods are used to transport and transfer genotoxic waste in a hospital?	Genotoxic waste transfer along with other hospital wastes to the temporary place and then to the final disposal site.	2 (50)
	Transfer waste to the temporary place separately and then to the final disposal site.	2 (50)
Who is responsible for genotoxic waste transport to final disposal sites?	Hospital	3 (75)
	Municipality	1 (25)
	Private contractor	0
Is there any supervision by the hospital in the transport process and final disposal of waste after the exodus of the genotoxic waste from the hospital?	Yes	1 (25)
	No	3 (75)
Is there any supervision by the hospital in the transport process and disposal of waste after the exodus of the hospital waste from the hospital? (regardless of genotoxic waste)	Yes	5 (83.3)
	No	1 (16.7)

**Table 8: Content of hospital waste final disposal questions**

Question	Response	n (%)
How is the output of the sterilization device disposed of?	Along with municipal wastes are disposed	5 (83.3)
	They are disposed of around the hospital grounds	1 (16.7)
How is the genotoxic waste disposed of in the hospital?	Transport and disposal of separate	0
	Disinfection and disposal with other wastes	4 (100)
How is the method of disposal of genotoxic waste outside the hospital?	Landfill	4 (100)
	Incineration	0
Does the hospital have documentation concerning genotoxic waste disposal?	Yes	1 (25)
	No	3 (75)
Is there monitoring for the disposal of genotoxic waste?	Yes	1 (25)
	No	3 (75)
Is there any supervision in the disposal of other hospital waste?	Yes	5 (83.3)
	No	1 (16.7)

**Table 9: Content of Personal Protective Equipment questions**

Question	Response	n (%)
Does the hospital personnel been trained about hospital waste?	Yes	6 (100)
	No	0
Does the hospital have a waste management expert?	Yes	4 (66.7)
	No	2 (33.7)
Does the hospital have an environmental health expert?	Yes	6 (100)
	No	0
Does the environmental health expert have a membership in the Health and Infection Control Committee and is continuously present at the meetings?	Yes	6 (100)
	No	0
Are there standards and strategies for controlling genotoxic waste in the hospital?	Yes	3 (75)
	No	1 (25)
Are there trained people in hospital wards to collect and transport wastes genotoxic?	Yes	2 (50)
	No	2 (50)
Does the genotoxic waste service personnel are equipped with personal-protective equipment?	Yes	2 (50)
	No	2 (50)

waste, and genotoxic waste with the percentages of 66%, 31%, and 3%, respectively. In this study, the average waste generation is 2.91 Kg/bed-day. These results are matched with the results of a study in hospitals affiliated with Kashan Medical University (2014), which reported an average waste generation rate of 2.9 Kg/Bed-Day.<sup>[22]</sup> Furthermore, in the study conducted by Farzadkia *et al.* in eight educational hospitals in Tehran (2009), waste generation rates were between 2.5 and 3.1 Kg/Bed-Year.<sup>[25]</sup>

However, Askarian and his colleagues reported an average waste generation rate of 8.025 Kg/Bed-Day,<sup>[23]</sup> and the waste generation rate in Libya was shown to be 1.3Kg/Bed-Day.<sup>[24]</sup>

According to the research in seven hospitals in Mazandaran province, the average generation of genotoxic waste was 5 kg/Day. Additionally, two studies were performed in Tehran (Tehran University of Medical Sciences) and Croatia. These studies revealed that the amounts of genotoxic waste generation rates were 3.5 and 9 kg/day, respectively.<sup>[11,25]</sup> It should be noted that the major causes of these differences in the rates of daily generated waste in hospitals are related to the hospital capacity, the variety of hospital segments (e.g., surgical and general), as well as the cultural, economic, and social location of the hospital, and waste management practices in hospitals. In the current study, all hospitals had colorful containers for various types of healthcare waste. Whereas the segregation of genotoxic waste was not appropriately managed in some hospitals. Alagoz *et al.* reported that the segregation of wastes in Turkish hospitals was not correctly performed due to the lack of education, information, and insufficient fund.<sup>[26]</sup> In collecting waste from the wards, almost more than half of the hospitals were in good condition. The wastes were being collected from the wards in specific timetables when three-quarters of the bags were full of waste. Therefore, the collection stage was desirable in the majority of hospitals. On the other hand, the study of Gorgani *et al.* revealed that there are still problems in the studied hospitals about collecting, washing, and disinfecting garbage bins together with collection equipment. The waste collection frequencies from the hospital wards were twice and three times a day in 20% and 71% of hospitals, respectively.<sup>[12]</sup> Yong *et al.* stated that the waste collection process is managed appropriately in 73% of hospitals in China.<sup>[27]</sup> According to hospital regulations, the location and container of the genotoxic waste storage should be separated from other wastes. This study showed that none of the hospitals had a separate process to maintain genotoxic waste. The findings of this study are consistent with the Gorgani *et al.* research.

In Semnan city, there is no temporary storage site for genotoxic waste. In comparison, genotoxic wastes were stored within a specific storage location in 17% of hospitals in Mazandaran province. However, in other hospitals, genotoxic wastes were stored along with other wastes.<sup>[12]</sup>

The study revealed that hospital waste management needs immediate attention to fulfill the environmental regulations in Semnan.

Furthermore, it is necessary to develop a practical management strategy to reduce waste production. According to the research in 12 Asian countries, healthcare waste management has been addressed as one of the most challenging environmental issues caused by a lack of knowledge, strategies, regulations, and funding.<sup>[16]</sup>

Among the studied hospitals, three hospitals performed the disposal of genotoxic waste by themselves. Consequently, the process was not monitored or documented. Only one of the hospitals allocated the genotoxic waste transportation to a private contractor that would eventually be burned in a waste incinerator outside the urban areas. Moreover, all the hospitals

applied nonburning techniques for the sterilization of infectious waste. On the other hand, genotoxic waste disposal was implemented by the burning method in 80% of the hospitals belong to Tehran University of Medical Science. All infectious wastes were sterilized by autoclave and hydroclave.<sup>[11]</sup> The burning method was utilized as a disposal technique in all hospitals in Mazandaran province.<sup>[12]</sup>

In developing countries, the hospital wastes are transported to landfills to incinerate them. A study in South Africa found that the used incinerators have improper design and have many operational problems.<sup>[28]</sup> Despite the environmental issues of the burning method, it is considered the most common method for the disposal of hospital waste in Spain.

It is suggested that the management of cytostatic waste should be conducted under the supervision of a specialist. For instance, the ashes generated by burning cytostatic waste contain a high concentration of hazardous substances, which must be neutralized before disposal of waste in the landfill. The incineration process is cheap and environmentally desirable.<sup>[29]</sup> Only 25% of hospitals documented genotoxic waste incineration, and 25% had no monitoring for waste incineration. The availabilities of qualified waste management procedures and staff training play an essential role in efficient waste management.<sup>[18]</sup> Indeed, lack of proper training causes as much risk as hospital waste. The exposure to hazardous wastes can be due to the lack of suitable protective equipment and the shortage of knowledge about the benefits of using protective equipment.<sup>[12]</sup>

Ghasemi *et al.* conducted a study in the hospitals belonging to the Tehran University of Medical Science. They found that 87% of hospitals provided personal protective equipment for the personnel of genotoxic waste service, and 67% of hospitals have trained personnel regarding genotoxic substances.<sup>[11]</sup>

Another study performed in Mazandaran province showed that only 14% of hospitals had a standard waste control strategy, and 20% of hospitals employed trained personnel who use proper clothing and personal protective equipment for carrying genotoxic waste.<sup>[12]</sup> A study reported that nurses did not use personal protective equipment for dangerous drugs, and even they did not have information about the proper disposal of waste. As a result, drug interventions can increase the potential risk of exposure.<sup>[29]</sup>

Ferdowsi *et al.* (2012-2013) investigated infectious waste in Gachsaran. This study demonstrated that infectious waste increased due to the improper separation of infectious wastes from noninfectious ones caused by the lack of awareness in personnel.<sup>[30]</sup> In this study, the proposed HWMI is a powerful tool for describing the status of hospital waste management to compare with other hospitals. This study revealed that the management of on-site genotoxic waste does not provide a desirable condition. It is required to find appropriate solutions by improving the management strategies or technological interventions to solve this problem and provide a safer environment.

## CONCLUSIONS

In general, a practical approach is recommended to develop healthcare waste management systems, especially genotoxic waste, including:

1. Fulfilling the current national standards and regulations by all the healthcare centers
2. Improving and correcting the existing deficiencies in the regulations by the authorities of the Ministry of Health
3. Offering educational courses regarding infectious and genotoxic wastes management can decrease the risk of exposure to hospital employees.
4. Providing facilities and standard protective equipment for collecting, segregating, transporting waste inside the hospital,
5. Allocating temporary rooms for genotoxic waste storage.

## Acknowledgments

Ethics Code: 1056.

## Financial support and sponsorship

This project was financially supported by Semnan University of Medical Sciences.

## Conflicts of interest

There are no conflicts of interest.

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