

Evaluation of Medical Waste Generated from Government Hospitals and Healthcare Centers in the City of Hodeidah, Yemen

Mohammed Y. Talhi¹ and Hisham M. Nagi^{1*}

¹Department of Environmental Sciences, Faculty of Petroleum and Natural Sciences, University of Sana'a, Sana'a, Yemen

*Corresponding author: h.nagi@su.edu.ye

ABSTRACT

In the present study, the current status of medical waste management in the city of Hodeidah was presented in terms of its definition, components, sources, and threats that may result from improper handling. This investigation aims to study the potential environmental and health impacts of existing medical waste produced by the government hospitals and healthcare entities in Hodeidah City, in addition to comparing the applied methods and procedures with the methods and procedures that are applied in developed countries. The research study was carried out from January 2022 until January 2023, and targeted ten government hospitals and healthcare institutions in Hodeidah City. It relied on descriptive and analytical scientific methods, which aim to describe and analyze medical solid waste generated from the selected institutions. The result of the study showed that the total quantities of waste produced in all studied government health facilities amounted to approximately 599,038 kg/year. The percentage of non-hazardous waste was about 67% against hazardous waste which was 33%. Hospitals that receive more patients and have more beds as well as a multiplicity of their specialties generate larger medical wastes. The present research investigation revealed that government hospitals and healthcare centers in the city of Al-Hodeidah have low levels of health and safety conditions. They do not meet the local and international standards and requirements in the Medical Waste Management Guides and Recommendations. The poor management situation of medical waste could expose Yemeni citizens to danger. The healthcare institutions should be supervised and controlled and ensure management of medical waste following environmental regulations and laws.

ARTICLE INFO

Keywords:

Medical Waste, Healthcare, Management, Hodeidah, Yemen

Article History:

Received: 26-May-2024,

Revised: 2-August-2024,

Accepted: 13-August-2024,

Available online: 30 August 2024.

1. INTRODUCTION

Interest in human activities on the environment has increased significantly, especially in studies related to improving services and global trends toward resolving environmental issues and cleaning up polluted areas [1]. Regular pollution of our surrounding environment is one of the most common types of pollution faced by humanity [2]. Solid waste received the attention of human societies even before the problems resulting from water and air pollution were noticed [3]. As a result of industrial and technological development, industrial products have increased and their quality and quantity have changed sig-

nificantly over the past decades. The quality and amount of solid waste currently depend on the average income of the individual in different societies, in addition to his cultural, social, and economic levels [4]. The issue of solid waste and related environmental problems has occupied successive governments and national authorities, in addition to public opinion in urban and rural communities. According to Tchobanoglous et al. [5], solid waste may be classified based on the waste source and the type of human activities that produce it into domestic, commercial, industrial, institutional, municipal, and agricultural. It could also be classified into biodegradable organic waste or non-degradable, combustible or non-combustible, and

hazardous or non-hazardous wastes. There are several sources of solid waste, i.e., urban cities or rural areas. The waste of rural areas is mostly biodegradable organic waste, while the waste of Urban cities is mixed with large amounts of non-degradable materials [4]. On the other hand, according to Phelps et al. [6], solid waste could be classified according to its physical, chemical, and biological properties into garbage, ashes, and residues of burning, bulky waste, street waste, dead animals, abandoned vehicles, construction and demolition waste, farm waste, and sewage waste. Medical waste, sometimes called health care waste, is the waste produced by health institutions, whether governmental or private, such as hospitals, clinics, and laboratories. It could also be found in educational and research institutions concerned with medical specializations and research. This type of waste could pose a threat to human health and could pollute the environment in addition to spreading diseases and epidemics among communities. Healthcare waste could be defined as any solid, liquid, or gaseous waste produced from health services, whether these health services are provided in health institutions or homes. It may contain ordinary waste and hazardous waste and requires safe methods of disposal to avoid its health and dangerous effects on humans as well as the environment [7]. Medical waste could be classified into non-hazardous, or potentially hazardous waste, i.e. infectious, pathological, sharps, chemical, pharmaceutical, cytotoxic, and radioactive, in addition to compressed gas containers [8, 9]. Given the significant negative environmental impacts that result from the mismanagement of hazardous waste, including healthcare waste, this research study has been addressed due to its importance and urgent necessity in order to protect the communities surrounding the sources of these wastes as well as those surrounding the places of their disposal. In the Republic of Yemen, several studies on this issue have been conducted [10–12], which were limited to the Capital City of Sana'a. This investigation is the first to shed light on the issue of managing the disposal process of healthcare waste produced from government hospitals in Hodeidah City. This investigation mainly aims to study the potential environmental and health impacts of existing medical waste produced by the government hospitals and healthcare entities in Hodeidah City, in addition to comparing the applied methods and procedures with the methods and procedures that are applied in developed countries.

2. MATERIALS AND METHODS

2.1. THE STUDY AREA

Hodeidah Governorate is one of the coastal governorates that have a total area of approximately 117,145 km² and consists of 26 districts that vary in population and area (Figure 1). The coastline of the governorate is located

along the southern Red Sea approximately 519.7 km long, and extends from the coast of Al-Luhayyah District in the north to Al-Khawkhah District in the south [13]. It is the second in terms of population among Yemeni governorates, with an estimated total population of nearly 3 million with an annual growth rate of 3.25% [14]. Hodeidah City is the administrative capital of the governorate, which is located in the middle of its coastal line. It is one of the most important cities in Yemen, as it contains the main seaport of Yemen on the Red Sea. The city has a total area of about 181 km² and a total population of approximately 604,439 according to the projections based on the 2004 Census for the year 2017 by the Central Statistical Organization (CSO), Yemen [15]. The city is divided into three districts; i.e. Al-Mina, Al-Hali, and Al-Hawak districts.



Figure 1. Location of Al-Hodeidah Governorate.

According to the government's climatic records, the climate of Hodeidah Governorate is characterized by long hot summers and short warm winters. The average monthly maximum temperature varies between 37.5 °C and 19.6 °C in summer, while in winter it varies between 24 °C and 14 °C. Given that the city is located on coastal waters, the rate of evaporation leads to a significant increase in humidity, as the average relative humidity ranges between 70 and 85%. The rate of evaporation is greater than the rate of precipitation, as rain in Hodeidah Governorate is small, rare, and irregular. The amount of rain ranges between 60-150 mm annually.

2.2. METHODOLOGY

This study relied on descriptive and analytical scientific methods, which aim to describe and analyze medical solid waste generated from selected government medi-

cal institutions. In addition, the study also relied on the (quantitative) statistical analysis approach to analyze the data collected through field visits. The investigation does not include genotoxic (cytotoxic), and radioactive waste. Personal interviews have been conducted with members of the study samples in order to obtain available information that was not recorded nor studies earlier. Moreover, the research study also used the direct observation method as a tool for collecting information to determine the manner in which medical waste is managed in the targeted institutions. The research study was carried out from January 2022 until January 2023, and targeted ten government hospitals and healthcare institutions in Hodeidah City. Those institutions are Al-Thawra General Hospital Authority, September 21st Hospital, Dialysis Center, Al-Tahrir Health Complex, Health Centers of: Al-Yemen, Al-Mughtaribeen, Al-Za'afaran, Al-Hawak, and Al-Rabasah areas, and the National Center for Central Public Health Laboratories (Figure 2). Solid medical wastes generated by targeted health entities were sorted, classified, and weighed in order to determine the total daily rate, and characteristics of waste. Yellow polyethylene bags were used to collect hazardous medical waste and black polyethylene bags to collect regular medical waste according to the color guide approved by the World Health Organization (WHO) [16]. A 20-kg spring scale was used to weigh the generated medical solid waste and an adhesive patch was placed on each sample containing the name of the department from which the sample was collected, in addition to the collection date. Restricted safety procedures were followed in handling the hazardous materials. Medical waste produced in each hospital department was examined to determine its components through classification, separation, and weighing within 16 days according to WHO guidelines [16].

3. RESULTS

The rate of waste production from government medical institutions in the city of Hodeidah and its characteristics are investigated. Following are the findings of this research study.

3.1. GENERATED AMOUNTS OF MEDICAL WASTE

The total quantities of waste produced in all studied government health facilities amounted to approximately 1,641.2 kg/day (599,038 kg/year). The percentage of non-hazardous waste was about 67% (1,104.5 kg/day), while the percentage of hazardous waste was 33% (513.7 kg/day). The largest medical waste produced was from public hospitals, where the amount of waste generated constituted 81.3% of the total amount of waste in the health sectors studied. The least amount of medical waste produced was at the National Center for Cen-

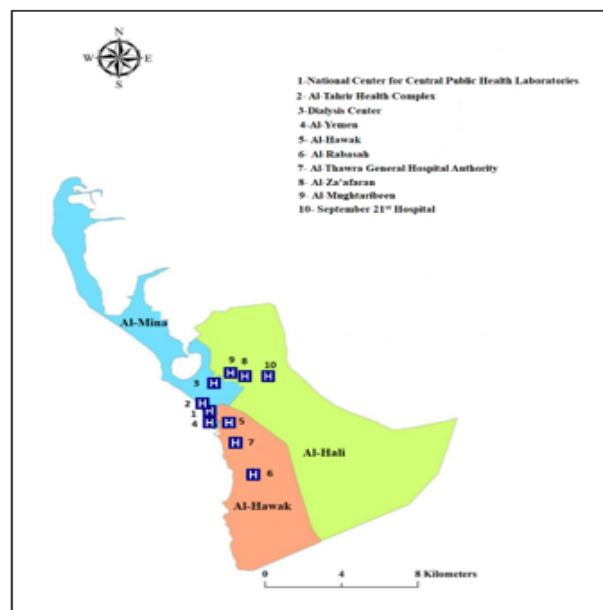


Figure 2. Distribution of health care institutions in the study area.

tral Public Health Laboratories (0.6%). The largest producer of hazardous medical waste is Al-Thawra Hospital (56.4%), the Dialysis Center (29%), and the September 21st Hospital (10.3%), while the smallest amount of hazardous waste produced was in the National Center for Central Public Health Laboratories (3.5%). The largest amount of regular waste produced was in Al-Thawra Hospital (76%) and the September 21st Hospital (12%), and the smallest amount of regular waste was produced in the National Center for Central Public Health Laboratories (0.6%). Figure 3 shows a comparison between the rate of production of hazardous and non-hazardous waste according to each health institution in the health sectors studied. From this figure, it is clear that the average production of non-hazardous waste ranges between 16% and 83% with an average daily production of approximately 64%, while the rate of hazardous waste ranges between about 17% and 84% with an average production of 36% per day. The overall average of medical waste produced per bed (in health institutions that contain beds) was 2.8 kg/bed/day, which are Al-Thawra Hospital, September 21st Hospital, Dialysis Center, and Tahrir Health Complex (2.3, 2.2, 6.0, and 0.7 kg/bed/day, respectively). The average of produced hazardous waste was 1.6 kg/bed/day, while the average of regular waste was approximately 1.2 kg/bed/day. On the other hand, the health institutions that do not have beds produce an average total medical waste of approximately 0.2 kg/patient/day in dispensaries, out of which 0.03 kg/patient/day of hazardous waste. Whereas the National Center for Central Public Health Laboratories produces an average medical waste of approximately 10.5 kg/day, and 0.37 kg/patient/day and the average production of hazardous waste per day was 3.5 kg/day, and

Table 1. The rate of medical waste generation in the studied government hospitals in the city of Hodeidah

Entity Name	Number of Patients	Number of Patients	Amount of Hazardous (Waste)			Amount of Hazardous (Waste)			Amount of Hazardous (Waste)		
Al-Thawra General Hospital	2,000	500	303 (56.4%)	0.6	0.15	841.5 (76.2%)	1.7	0.4	1,144.5 (69.7%)	2.3	0.57
September 21st Hospital	390	86	55.5 (10.3%)	0.6	0.1	136 (12.3%)	1.6	1.3	191.5 (11.6%)	2.2	0.49

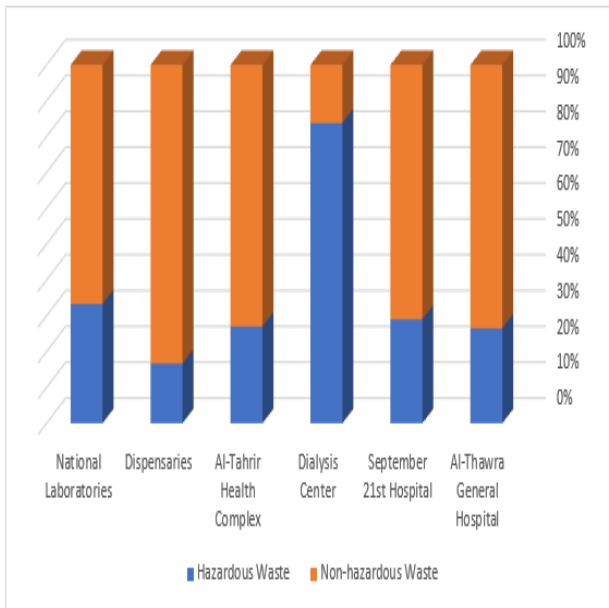


Figure 3. Average generation rate of hazardous and non-hazardous waste in the targeted health care institutions.

approximately 0.1 kg/patient/day. Table 1 below shows the total quantities of medical waste produced in all studied government health facilities, as well as the amount of medical waste produced per bed and per patient in each healthcare entity studied in the city of Hodeidah.

3.2. COMPOSITION OF NON-HAZARDOUS MEDICAL WASTE

The composition of medical waste varies from one hospital to another and also between different hospitals within the same category. The qualitative analysis of regular waste generated (non-hazardous) for all the hospitals studied shows that food constitutes 20%, plastic 26%, paper/cardboard 39%, glass 6%, metals 3%, and other waste constitutes 6% (Table 2).

3.3. CURRENT SITUATION OF MANAGING MEDICAL WASTE

Field visits, direct observations and meetings with hospitals' staff indicated that the segregation of medical waste into infectious and non-infectious classes takes place only in Al-Thawra Hospital, the September 21st Hospital, and the National Center for Central Public Health Laboratories. On the other hand, rest of the health institutions studied, only sharp waste is segregated. These hospitals are the dialysis center, primary care centers (dispensaries), and the Tahrir Health Complex, while the rest of the hazardous waste is mixed with regular waste. The process of transporting medical waste within the investigated health institutions is divided into two stages, one inside the health facility (internal transport), and the other outside it (external transport). Cleaners are used to move medical waste inside healthcare institutions using either special carts or manually. Most of them use drums with wheels and a lid to transport such waste. In healthcare entities that consist of several floors, it is difficult for cleaners to transport medical waste among floors via stairs, as in all the studied institutions, the absence of elevators is noticed. External transportation of medical waste from government hospitals in the studied area to the final dumping site was conducted once a day or once every two days. Trucks belonging to the Cleaning and Improvement Fund (CIF) are used. Primary treatment of hazardous medical waste is carried out only inside the National Center for Central Public Health Laboratories. Its process of treating medical waste is conducted by using an autoclave before final disposal. In addition, the Dialysis Center is treating discarded blood units by adding concentrated chlorine before discharging it into the sewage network. Interviews with workers and drivers of the trucks, as well as managers and supervisors of the CIF in Hodeidah Governorate, who work in transporting medical waste to the dumping site, indicated that they are constantly exposed to acupuncture while transporting this waste. They also reported that they had not received any vaccinations to prevent diseases that may be transmitted through medical waste. Several infections had previously occurred due to the sharp tools contained



Table 2. Percentages of non-hazardous waste composition in each health institution.

Entity Name	Food (%)	Food (%)	Paper/ Cardboard (%)	Glass (%)	Glass (%)	Other (%)
Al-Thawra General Hospital	32	25	22	8	4	10
September 21 st Hospital	29	24	23	10	3	11
Dialysis Center	23	40	21	8	4	4
Al-Tahrir Health Complex	13	17	60	6	1.5	2.5
Health Centers of: Al-Yemen, Al-Mughtaribeen, Al-Za'afaran, Al-Hawak, and Al-Rabasah areas	6	17	70	4	1	2
National Center for Central Public Health Laboratories	20	23	35	2	4	15
Overall percentage	20	26	39	6	3	6

in this waste, including one infection with acquired immunodeficiency syndrome (AIDS), five infections with hepatitis virus, in addition to several cases of injuries that led to tissue cutting. There are two methods followed for the final disposal of medical waste within the health entities studied. The first method involves the disposal of hazardous medical waste by using incinerators located inside the entity's premises. This method is followed by Al-Thawra Hospital, September 21st Hospital, Al-Tahrir Health Complex, the National Center for Public Health Laboratories, and Al-Mughtaribeen Health Center. All incinerators are the same of one-room ovens built of bricks. The ash resulting from burning is disposed of in the same location by placing it in special pits. The second method is sending medical waste along with garbage without any treatment to the main dumping site in the city of Hodeidah. This method is followed by the Dialysis Center and the rest of the primary health centers (dispensaries).

4. DISCUSSION

Dealing with medical and hazardous waste requires special methods that differ from those used to deal with general solid waste. Improper handling of hazardous waste during its collection, treatment, transportation, and disposal may cause substantial damage to those dealing with it, whether to their health or physical safety, in addition to significant environmental pollution. Therefore, medical wastes should be managed properly starting from their generation point till they are safely disposed of [17]. Hazardous wastes are classified according to their biological, physical, and chemical characteristics, and these characteristics may make them wastes of a toxic, reactive, flammable, corrosive, infectious, or radioactive nature, even if they are in very small quantities [12]. These wastes may have acute effects, dangerous diseases, chronic effects, or may cause damage that cannot be treated [18]. Some of these wastes are carcinogenic after years of exposure, and others may cause mutations and major biological changes in the offspring of humans

or wild animals exposed to them. According to the results of the present research study, there is a significant difference between general hospitals and other health institutions in the amounts of produced medical solid waste. Hospitals that receive more patients and have more beds as well as a multiplicity of their specialties generate larger medical wastes. The amount of medical waste produced by Al-Thawra Hospital was estimated to be the largest amount produced in the health sectors studied, which constitutes 70%. This is because this hospital is considered the largest hospital in Al-Hodeidah Governorate due to the multiplicity of its departments and specialties. The hospital includes 500 beds and serves approximately 3,700,000 people of Hodeidah Governorate, in addition to the five other neighboring governorates, as well as many patients' cases from all districts of Hodeidah Governorate are transferred to Al-Thawra Hospital. All other targeted healthcare institutions generate 19% of the total amount of medical waste produced in the governorate. The topmost healthcare institutions that generate the most hazardous waste among the studied entities are Al-Thawra Hospital and the Dialysis Centre with a total amount of approximately 303 and 155 kg/day, respectively (85.4% of the total hazardous waste generated by the targeted institutions). This could be attributed to the fact that Al-Thawra Hospital is the largest hospital studied, as mentioned above, and most childbirth operations in the city of Hodeidah are received in the hospital, and most citizens prefer the hospital due to the low treatment costs as it is a government hospital. As for the dialysis center, the type of service or specialty provided by the institution results in heavy solid medical waste consisting of plastic tubes and filters contaminated with blood. The economic conditions that Yemen is going through cause one bed in the dialysis center to perform approximately five sessions a day due to the great demand for the center, as it is the only one in the governorate. Dealing with this type of waste requires special procedures, whether during collecting and storing it temporarily or when transporting it to disposal sites, which must be completely

different from regular solid waste dumps. The present investigation showed that medical waste handling procedures from collection until disposal mostly do not comply with the standards and recommendations of the WHO [16]. Segregation of medical waste at the point of production is the cornerstone for their appropriate management [19]. Segregation of medical waste in the targeted entities into infectious and non-infectious classes varies from one governmental healthcare institution to another. The support of international organizations for some government medical institutions, particularly the larger ones, during the past period played a very important role in obligating these institutions to follow medical waste management methods and also provided them with the necessary equipment to do so. This result contradicts the study carried out by Al-Gheethi et al. [20] and Al-Wabr [10], which indicated that waste separation at the point of generation is not available, and all hospitals dispose of their waste without any segregation. With respect to other smaller medical institutions, only sharp waste is segregated. These results are consistent with some results of other studies conducted in Gaza, Palestine [21], and Sudan [22], which concluded that medical waste is not sorted in most hospitals except for sharp tools such as needles that are placed in special safety boxes, and neglecting segregation of other hazardous waste. The results of the current study showed that the process of transporting medical waste either inside the health facility (internal transport), or outside it (external transport) does not meet with the international standards in dealing with hazardous wastes. Manual carriage that are used in transportation of medical waste could expose workers to danger. These results are similar to the study conducted in Sudan by Andraws [23] and Al-Sheikh [22]. The reason for this consistency in results may be due to the weakness of the monitoring process, and similarity to the situation in both countries. Most government hospitals in Hodeidah City use drums with wheels and a lid to transport waste, which are easy to break or corrode and may cause fluid leakage of hazardous waste. Through the field study, it was found that government hospitals in Hodeidah do not carry out primary treatment of hazardous medical waste inside the facilities before transportation and final disposal. The only exception is the National Center for Central Public Health Laboratories and the Dialysis Center that adds concentrated chlorine before discharging it into the sewage network. The National Center for Central Public Health Laboratories processes medical waste using an autoclave before final disposal. Chitnes et al. [24] stated that "autoclaving of PVC blood bags is a safer and reliable method compared to chemical disinfection". Similar studies conducted on Yemen's medical waste produced from hospitals showed that no primary treatment of medical waste is executed before disposal [11, 20]. This could be attributed to that occupational health and safety (OHS) is weak in Yemen,

as well as the absence of laws that require health institutions to treat hazardous medical waste before disposal. Trucks belonging to the CIF are used in transporting medical waste from the studied government healthcare institutions to its final dumping site. The study showed that these trucks do not comply with WHO specifications, as they are intended for transporting household waste only and are not equipped to transport medical waste. Some of the trucks are open from the top, which allows this waste to fly into the air and fall on populated locations. This may cause major health harm and the spread of infection among the residents of the areas through which these trucks pass. Some of these trucks also contain a compactor, which causes the waste to be compressed and medical fluids to leak from it. These trucks do not meet the requirements mentioned in any proper medical waste management. This result is consistent with the results of previous studies conducted in Sana'a [10, 11], which concluded that the means of transporting waste from hospitals is the municipality trucks that transport household waste. The issue of health and safety was not paid much attention by the governmental authorities, as well as the economic situation did not allow the purchasing of special trucks for transporting medical waste. Such used vehicles do not meet the standards and requirements in the Medical Waste Management Guide [25]. The workers' lack of commitment to OHS procedures may cause potential disease transmission and may put public and cleaners' health at risk [26]. This is clearly indicated in the present investigation as several workers dealing with medical waste have exposed to different infections such as AIDS, hepatitis virus, and tissue cutting injuries. Failure to comply with the OHS procedures that aimed at protecting these workers by not adhering to wearing appropriate clothing and means of protection is what led to infection with the above-mentioned diseases. The present investigation showed that the process of final disposal of medical waste varies depending on the type of healthcare institution. Several government hospitals use incinerators that are located inside their premises, and the resulting ashes are disposed in the same location by placing it in special pits. The advantages of these types of incinerators are that they significantly reduce the volume and weight of medical waste, the resulting ash can be disposed of, easily and does not require power to operate, and the maintenance and operation cost is low. Its disadvantages are the inability to maintain performance or temperature constant, feeding and removing waste is done manually, releasing large amounts of black smoke, fly ash, toxic gases, and odors, causing air pollution well as. Most of the incinerators in the city of Hodeidah are equipped with special pits for accommodating the ash resulting from the burning process, other pits for pathological waste, and special pits for broken glass, where the glass ampoules are collected and ground using a hand tamper to reduce



their size, then the glass powder is placed in a special pit. The number of these pits varies from one incinerator to another. The disadvantages of the pits are that they are not suitable for areas subjected to heavy rain or flooding, nor suitable if the water level near the surface is less than 1.5 - 2m. Despite the unpleasant odors emanating from it, one of its advantages is that it provides good safety for disposing of anatomical waste, and it is also simple and inexpensive [27]. The second method is sending medical waste mixed with garbage without any segregation nor treatment to the main dumping site of the city. This method is not properly appropriate for hazardous waste management. The garbage dumping site was newly established in 2010 and receives about 250 tons of municipal waste per day. This dumping site is unattended, nor lined with protective means in order to prevent leachate seeps from reaching the groundwater. All the waste is thrown in open piles, and the waste could be easily accessed and tampered with by citizens and animals due to the lack of a protective fence. Medical waste is also randomly emptied and mixed with municipal waste, which is not buried or covered with a layer of dirt, which causes the spread of odors and the proliferation of harmful insects.

5. CONCLUSION

The present research investigation revealed that government hospitals and healthcare centers in the city of Al-Hodeidah have low levels of health and safety conditions. They do not meet the local and international standards and requirements in the Medical Waste Management Guides and Recommendations. The current critical condition and conflict that stormed the country ten years ago have worsened the economic situation of the country and deteriorated the governmental management of institutions in different sectors. Hospitals and healthcare institutions are no exception to this. This poor situation could expose Yemeni citizens to danger, the healthcare institutions should be supervised and controlled and ensure management of medical waste following environmental regulations and laws. Raising the level of cooperation between various institutions concerned with medical waste management to solve existing problems, improve the existing system, and make plans to develop medical waste management.

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