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Medical waste management at three hospitals in Jenin district, Palestine

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Abstract Medical wastes are considered hazardous because they may possess infectious agents and can cause unsafe effects on the environment and human health. This study is to analyze and evaluate the current status of medical waste management at Jenin's district in light of medical waste control regulations recommended by the World Health Organization. The results demonstrated that the average hazardous healthcare waste generation rate ranges from 0.54 to 1.82 kg/bed/day with a weighted average of 0.78 kg/bed/day. There was no established waste segregation of healthcare waste types in all hospitals, and these wastes were finally disposed of in a centralized municipal sanitary landfill, namely Zahrat Al-Finjan. The results suggest that there is a need for activation and enforcement of medical waste laws. This can be achieved through cooperation among key actors: Ministry of Health, Environmental Quality Authority, Ministry of Local Government, and Non-Governmental Organizations working in related fields. Additional remediation measures proposed to tackle the problematic areas of medical waste management in Jenin's district hospitals are addressed. Some recommendations to minimize potential health and environmental risks of medical waste are also introduced.

Keywords Healthcare waste · Hazardous waste · Waste management · Characterization · Medical waste · Jenin district

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Introduction

Medical waste (MW) management is of great importance due to the infectious and hazardous nature of MW that can cause undesirable effects on humans and the environment (Komilis et al. 2012). MWs are generated in healthcare facilities and include sharps, human tissues, body parts, and other infectious materials (Çalıs and Arkan 2014; Makajic-Nikolic et al. 2016; Korkut 2018; Su and Chen 2018). MWs pose serious threats not only to patients and health workers, but also to public health and the environment.

Additionally, MWs are of significant concern because they contain toxic pollutants such as mercury, chlorinated plastics and solvents, and a number of toxic

materials not found in municipal wastes (Rao et al. 2004; Conrardy et al. 2010). Handling, segregation, mutilation, disinfection, storage, transportation, and final disposal are vital steps for a safe and scientific management of biomedical wastes in any healthcare center. The most appropriate way to identify categories of biomedical wastes is by sorting the wastes into color-coded plastic bags or containers (Rao et al. 2004).

MWs contain pathogenic agents and therefore constitute a large portion of infectious wastes, which are hygienically dangerous (Abdulla et al. 2008). MWs, due to their toxic nature, can threaten natural resources that are necessary for human survival (Oweis et al. 2005; Rolewicz-Kalińska 2016). MWs consist of a wide range of hazardous, non-hazardous, and infectious wastes, sharps, chemical wastes, pharmaceutical wastes, pressurized containers, genotoxic wastes, radioactive wastes, and domestic wastes (Komilis et al. 2017; Hong et al. 2018). According to a 2009 World Health Organization (WHO) study, 80% of MWs are similar to domestic wastes, the remaining 20% is considered hazardous (infectious, toxic, and/or radioactive). Infectious wastes represent the majority of hazardous wastes from healthcare centers; the remaining minority of wastes includes sharps, genotoxic wastes, heavy metals, chemicals, and pharmaceuticals (WHO 2009; Sarsour et al. 2014; Le et al. 2018).

According to the WHO (2014) study, all individuals exposed to MWs are potentially at risk, and most especially healthcare workers (e.g., doctors, nurses, laboratory technicians, and waste handlers). Qusus (1988) and Bokhoree et al. (2014) reported that hospital staff contracts hepatitis B at a rate of three to six times higher than normal infection rates. There is strong epidemiological evidence that the danger of infectious wastes in hospitals is the transmission diseases through blood-contaminated sharps, particularly typhoid, cholera, human immunodeficiency virus, and—most commonly—hepatitis B and C viruses (Abdulla et al. 2008; Sarsour et al. 2014; WHO 2014).

In developing countries, management of MWs has not yet received enough attention (Al-Khatib et al. 2010; Sarsour et al. 2014; Ali et al. 2016). In these countries, hazardous MW is still handled and disposed of like domestic wastes, and thus, municipal workers, the public and the environment are all substantially endangered (Ali et al. 2017). Developing countries typically lack appropriate technical and financial resources (Guerrero et al. 2013; Minoglou and Komilis 2018) to establish their MW management systems and to provide training and awareness programs (Sarsour et al. 2014). Therefore, proper collection and disposal of MW are vital as it can directly and indirectly impact the public health and environment of the community (Baraka et al. 2006; Abdulla et al. 2008; Ali et al. 2016; He et al. 2016).

The Palestinian National Authority (2012) issued a MW management bylaw titled "Cabinet decision no. (10) of 2012, Medical waste management system and its uses." The bylaw regulates MW stream management and solicits external sponsors to fund a MW treatment plant for the Joint Services Council for Solid Waste Management in Hebron and Bethlehem districts (southern West Bank). Currently, all MW generated by public and private hospitals in the southern West Bank is treated at this plant before its final disposal at Al-Minya landfill. In the other districts of the West Bank, MW is still co-disposed with other municipal solid wastes.

For sustainable, long-term planning and design of a MW management system, it is crucial to quantify the MW generation rate and to understand the current management practices of the MW stream (Xin 2015). Therefore, the main objectives of this research are to quantify the MW produced by the three hospitals in Jenin's district and to evaluate the existing management practices of these hospitals.

Research methods

This study was carried out in two governmental hospitals and one private hospital in Jenin district, which lies in the northern West Bank of Palestine. The characteristics of the three hospitals are shown in Table 1. The study consists of two parts: (1) MW quantification and characterization and (2) current practices in MW management.

To understand current practices in MW management, data were collected through field visits, observations, and a questionnaire survey. The questionnaire aimed to collect information about MW generation, separation, collection, internal and external storage, transfer, treatment, and disposal. Safety of workers and general cleaning procedures at Jenin hospitals were also investigated. Interviews involved cleaners and sanitary workers in order to gather additional information about

the current practices in MW management. The analysis of data was carried out using the Statistical Package for Social Sciences software (SPSS Inc., Chicago, IL, USA), version 20.

Waste quantification and characterization were conducted through experimental fieldwork in which MWs were separated and segregated in the targeted hospitals. The waste samples were selected through a period of 5 weeks, seven consecutive days per week, 24 h per day. The composition of the MWs was determined in accordance with the study of Chul-Jang et al. (2006), and the waste categories were classified as tissue and pathological wastes, absorbent cotton items, discarded medical plastics, waste sharps, and wastes mixed with infectious wastes.

Two different sizes of waste collection baskets were distributed in each department of the three hospitals. In each basket, two different colors of bags were used: the yellow bags for MWs and the black bags for general wastes. The empty weight of each basket was recorded before collection. Also, sharp containers were distributed to each department of the hospitals. The weights were recorded using sheets designed for this purpose.

Table 1 Characteristics of the three hospitals in Jenin district

Characteristics of the hospital	Hospital		
	Dr. Khalil	Ar-Razi	Al-Amal
Size			
Number of beds	129	38	14
Number of employees	295	125	39
Departments			
Surgery	x	x	x
Pediatrics	x		
Male	x	x	
Female	x	x	
Emergency	x	x	
Neonates	x		
Intensive care unit	x	x	
Kidney dialysis	x		
Maternity	x	x	x
Orthopedic	x		
Supporting units			
Physiotherapy, radiography, laboratory, pharmacy, maintenance, laundry and kitchen	x	x	x

Results and discussion

For studying the current practices in waste management and safety measures, a sample of 30 workers was randomly surveyed, of which 60% were male and 40% were female. The socioeconomic conditions of the study sample are shown in Table 2.

Segregation of medical wastes

Table 3, related to segregation of MWs, shows that 72% of the respondents indicated that MWs are separated and classified prior to disposal. This highlights the important fact that most MWs are separated from ordinary wastes; yet, if separation is done, it is not done in a comprehensive way. The existing situation should be reevaluated so as to reach full segregation of MWs from ordinary wastes, thereby decreasing the probability of both infection and transfer of some diseases to the cleaning workers while dealing with MWs.

With respect to the body in charge of waste segregation, 32% of the respondents indicated that the medical staff carries out the segregation process, while only 14% of them indicated that they do not know who does so. In addition, 71% of the respondents indicated that the separation process takes place near the source of MWs, while 5% of them indicated that MW segregation occurs in the hospital's waste storage.

In the Palestinian territory, there is no mechanism for dealing with the screening, transportation and safe disposal of MWs. Furthermore, there are no written regulations by the Palestinian Ministry of Health, in particular, regarding MWs. Therefore, the process of waste collection within national healthcare institutions, whether public or private, takes place in an irregular manner. The MWs and ordinary wastes are collected together without considering the risks arising from hazardous MW residues. As MWs are mixed with ordinary wastes, all these wastes are contaminated with infectious agents.

There is no specific mechanism for the segregation of waste streams from one another, whether within wards or after collection in containers outside hospital premises. Also, there are no specially allocated MW containers, which should be particularly marked as a protection to workers and the public. It was also observed that workers in the private hospital transfer MWs and ordinary wastes manually due to the lack of special hazardous waste vehicles.

Table 2 Socioeconomic characteristics of hospital cleaning personnel surveyed

Independent group	Number of respondents (percentage in parentheses)				
Gender	Male 18 (60)	Female 12 (40)			30 (100)
Marital status	Single 9 (32)	Married 16 (57)	Divorced 3 (11)		28 (93)
Age	20–29 9 (30)	30–39 12 (40)	40–49 5 (17)	> 49 4 (13)	30 (100)
Level of education	Elementary 6 (22)	Preparatory 11 (41)	Secondary 10 (37)		27 (90)
Monthly income (USD[a])	135–270 9 (33)	271–405 10 (37)	406–540 7 (26)	> 540 1 (4)	27 (90)
Working period at hospitals (years)	< 1 4 (14)	1–3 14 (50)	4–7 5 (18)	> 7 5 (18)	28 (93)

[a] Figures are equivalent to monetary values in local currency

The process of separating and determining the quality of MWs is the solution to reducing wastes of healthcare centers and the key to effective management of these wastes. Appropriate handling, treatment, and disposal of wastes by type reduce costs and protect public health. Separation of waste must always be the responsibility of the producer of wastes (i.e., healthcare centers), and it must be in an area close to the source of these wastes. These wastes must be maintained in safe storage areas and monitored during transport (WHO 2005).

Containers and sacks to collect wastes

Figure 1 presents data of containers and sacks used to collect wastes in hospitals. Almost 63% of the respondents indicated that wastes are defined and distinguished. With regard to the possibility of rupture of waste sacks, 37% of the respondents indicated that this occurs sometimes, while 23% indicated that rupture takes place rarely. The rupture of sacks is considered dangerous to the safety of cleaning workers. This is an indication that sacks used were of low quality (thickness), and hence, it would be more probable for the sacks to be subjected to tear and rupture.

With regard to easy transfer of waste sacks from a place to another, the answers of 97% of the respondents were positive. This is a good indicator of decreased possibility of waste drop, alleviating pollution of surrounding places, and decreasing health problems to cleaning workers. With respect to the tightness of closure for MW sacks, 97% of the respondents answered yes always. Almost 97% of the respondents agreed that procedures implemented to prevent leakage of fluids from MW sacks are sufficient.

Table 3 Overall responses of hospital cleaning personnel to the survey questions regarding medical waste segregation

Question	Answers	Valid percent of respondents (%)
Are medical wastes segregated?	Yes	72
	No	28
Who segregates medical wastes?	Cleaning workers	27
	Medical staff	32
	Both	27
	Do not know	14
Where does segregation take place?	Near the source	71
	After waste is collected	24
	At the waste storage	5

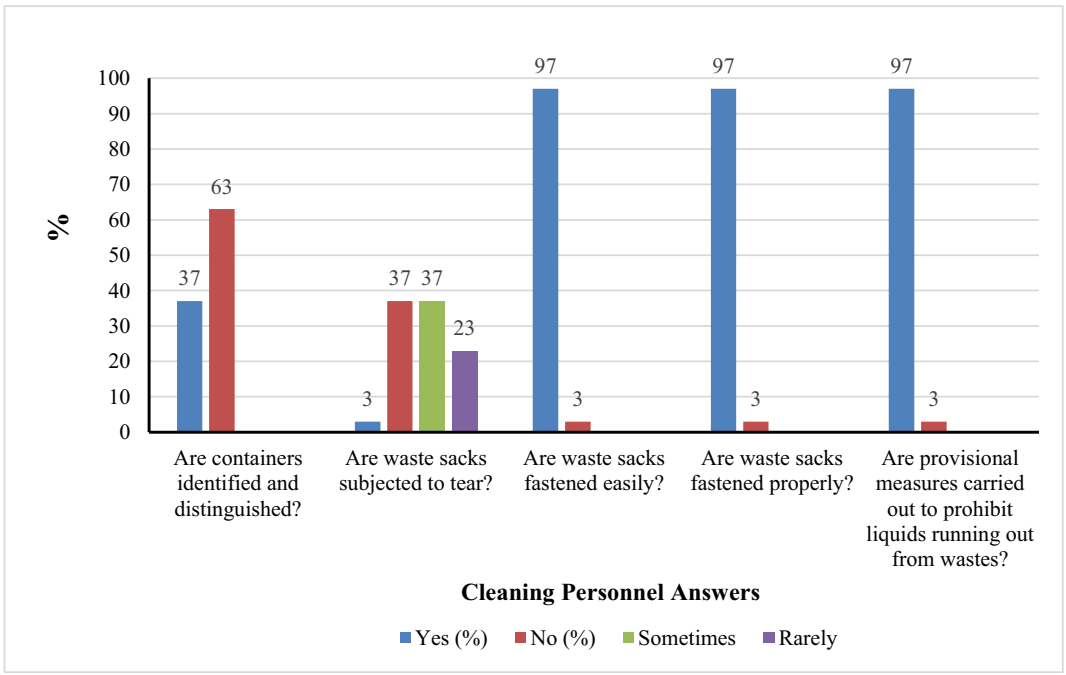

Fig. 1 Overall responses of hospital cleaning personnel to survey questions regarding waste containers and sacks

The nursing staff and other medical personnel ensure that waste sacks are tightly closed with these sacks filled up to three quarters of their full sizes. Lightweight sacks can be closed at the neck of the bag by linking, but heavyweight sacks must be closed by plastic tapes, not metal clamps. MWs were typically disposed of in ordinary waste containers. Sharp instruments, however, were collected and then transported via municipality vehicles for final disposal. In Jenin district, all these wastes were pressed and transferred to a landfill named "Zahrat Al-Finjan" that is about 17 km south of Jenin city.

The truncated human parts and embryos resulting from abortions are usually treated in accordance with legal religious practices. Such wastes are delivered back to their owners to be individually buried. Hazardous wastes and wastes resulting from high-risk laboratory dishes, such as incubation dishes or blood samples, are autoclaved for sterilization. These treated wastes are free of remaining bacteria and can be safely disposed of with MWs and ordinary wastes.

Liquid materials can be disposed of in the existing sewage system inside the hospital. Pathogenic microorganisms exist in blood, urine, or feces and can be disposed of through the waste water of the hospital.

Waste storage inside and outside hospitals

There were no specified places for the storage of wastes, medical or ordinary, within hospital premises. Yet, special vehicles were devoted to transfer wastes from hospital departments to containers in the vicinity of these hospitals. It is concerning that MWs were transferred using ordinary waste sacks, as denoted by 40% of the respondents. Another 40% of the respondents said that MWs are transferred using special vessels as shown in Table 4. The remaining 20% of the respondents indicated that only sharps are stored in special vessels.

It can be concluded that there was no special place for storing MWs in the hospitals. MWs were usually gathered into a corner until transfer to an outside container. This is also clear from the answers of the respondents regarding sufficient storage area inside the hospital. Although half of the respondents had no answer, another 33% declared that the storage area is insufficient.

Almost 20% of the respondents mentioned that the storage area is not closed properly, while another 40% of them did not know. When the respondents were asked whether the storage area inside the hospital is protected well, 29% of them disagreed while another 29% did not know. Additionally, 67% of the respondents declared that there are no specific marks distinguishing ordinary

Table 4 Overall responses of hospital cleaning personnel to the survey questions regarding waste storage

Question	Answers	Valid percentage of respondents (%)
Where are the medical wastes stored in the hospital?	Waste sacks	40
	Special vessels	40
	Sharps are stored in a closed place	20
Is there a specific mark showing the storage area of medical wastes?	Yes	22
	No	67
	Do not know	11
Is the storage area inside the hospital sufficient?	Yes	17
	No	33
	Do not know	50
Is the storage area properly closed?	Yes always	40
	No	20
	Do not know	40
Is the storage area well protected?	Yes	42
	No	29
	Do not know	29
Where are the medical wastes stored outside the hospital?	Container	100
Is there a specific mark showing the storage area of medical wastes outside the hospital?	Yes	11
	No	78
	Do not know	11
Is the storage area outside the hospital sufficient?	Yes	14
	No	79
	Do not know	7
What is the storage period in days?	1	100
Is the storage area outside the hospital properly closed?	Yes always	3
	No	80
	Do not know	17
Is the storage area outside the hospital well protected?	Yes	10
	No	79
	Do not know	11

wastes from hazardous wastes and both are collected and transferred together in the same vehicle. This is illicit and MWs and ordinary wastes should be transferred separately.

The location of waste storage within hospital premises must be properly determined and sized. In accordance with the WHO regulations regarding MW storage, the storage of waste within the hospital should not exceed (1) 72 h in winter and 48 h in summer (in cold areas) and (2) 48 h in winter and 24 h in summer (in hot areas such as Palestine). Toxic wastes should be stored separately from other healthcare wastes at a specific and safe site to control pollution caused by these wastes.

The recommendations for storage facilities of healthcare wastes as referred to WHO (2005) are (1) the ground area of the store shall be solid, non-porous with good drainage network, and easy for cleaning and disinfection; (2) a source of water for cleaning purposes must be provided; (3) an access to the storage area by the team responsible for handling the wastes must be facilitated; (4) the store must be normally closed to prevent entry of unauthorized persons; (5) waste collection vehicles can easily enter the store and this is an essential point; (6) there is a measure of protection from sunrays; (7) the store is secured to the entry of animals, insects, and birds; (8) the store is provided with a good illumination system (with at least negative ventilation); (9) the store should not be near the storage of fresh food or food processing areas; and (10) the cleaning equipment, protective clothing, and waste bags or containers must be provided in a convenient location close to the storage area.

Comparing the transfer and storing conditions of MWs in Jenin hospitals to the WHO regulations reveal large discrepancies. These discrepancies must be decreased to ensure the safety of workers, staff, patients, and visitors of hospitals. As mentioned above, MWs are collected in the containers of the municipality without any separation from ordinary wastes. As appears from the answers of 79% of the respondents, the storage areas of MWs outside hospitals were insufficient and had no specific marks. All respondents agreed that the storage period is only 1 day, and this means that the municipality truck picked the wastes up every day. The concern is that the storage area outside the hospital is not protected well. If this is valid, the risk of a person or animal contacting the wastes and contracting an infection will considerably increase.

Sharps boxes

From Fig. 2, it is clear that there was no MW burning inside hospitals as 94% of the respondents indicated. Most of the respondents (89%) said that vessels used to discard needles are not vulnerable to punching. This is a positive indicator for decreased risk on workers' safety. Yet, 29% of the respondents said that these vessels are not difficult to open. Thereby, the risk of being

unintentionally opened by someone may cause a serious threat. The most serious and dangerous point is that sharp boxes remained unmarked, according to 80% of the respondents. This is a real threat, and there must be a system to provide distinguishing marks for sharp boxes.

Transport of medical wastes inside the hospital

Table 5 depicts the condition of the transferring means used for MWs. Almost 43% of the respondents indicated that there is no such a means, while only 17% of them confirmed the presence of a special means devoted to transferring MWs. Most of the respondents (65%) felt that it is easy to control the waste transferring means. A similar percentage of respondents (62%) believed that the waste transferring means is frequently cleaned. The workers themselves were in charge of the waste transferring means as indicated by 93% of the respondents. About 80% of the respondents indicated that the surface of waste transferring means is smooth. The vast majority of the respondents (92%) ensured that the waste transferring means is impermeable to liquids. The waste transferring means was not devoted to a single ward as mentioned by 79% of the respondents.

The transfer of MW within hospital premises has to be conducted by wheeled vehicles or other vehicles fitted with hand wheels. The vehicles used as a waste transferring means are not to be used for any other purposes. The standards for a safe waste transferring means should include (WHO 2005) (1) easy loading and unloading mechanisms, (2) absence of sharp edges that can cause severe damages to both workers and waste containers or sacks during loading and unloading, (3) easy cleaning, (4) sterilized using an appropriate purificator on a daily basis, and (5) all waste sacks must be closed tightly and properly.

Transport and treatment of medical wastes outside the hospital

The process of transferring wastes collected in containers was regular, in which wastes retransferred through a specified itinerary by municipal trucks. The municipality of Jenin has four waste transport trucks; as each truck is responsible for the transfer of wastes from a certain area of the city. Then, the waste is directly deported to Zahrat Al-Finjan landfill without storing the wastes in a transition station.

As for municipal workers, they were supervised by the "Director of Health and Environment Directorate" in the municipality of Jenin. The director's responsibility is to enforce safe work procedures (wearing gloves, precaution towel to the legs, and helmets) and health regulations, such as blood tests. Blood tests included examination for hepatitis B, to avoid the infection of workers from MW sharps injuries.

The MWs from hospitals were mixed with regular wastes in the same compactor truck, without any classification or treatment. There was no special treatment to get rid of sharp boxes, hazardous wastes, or infectious wastes due to the absence of sanitizing incinerators. At Zahrat Al-Finjan sanitary landfill, MWs were disposed of with other municipal solid waste without any treatment.

Worthy of note: the transfer of wastes off-site is the responsibility of the municipality of Jenin after ensuring that instructions and regulations are followed. The producer of MWs is responsible for safe packaging and labeling, thereby indicating the particular wastes transported off-site and identifying their contents. Packaging and labeling must be dictated according to national regulations governing the transport of hazardous wastes, and consistent with international conventions in case of shipment abroad for treatment.

In the absence of such national regulations, responsible authorities can be guided by the recommendations of the transport of dangerous goods by the United Nations (WHO 2005). Because of the hazardous nature of MWs, special precautions in handling, separating, collecting, and storing this type of wastes shall be taken. In addition, cost-effective, easily implemented, and low-maintenance sterilization methods are required to prevent contamination of landfill sites.

Hygiene and sanitation

Table 6 depicts the status of water and sanitation in the hospitals. The cutoff of water supply during the past 2 years was uncertain as the percentage of the respondents who agreed (41%) was identical to that of those who did not agree. This indicates the possibility of interruption in the water supply as well as the spread of dirt, wastes, and diseases.

With regard to cleanliness of the toilets in hospitals, 50% of respondents agreed that toilets are clean; yet, a similar percentage (47%) of them disagreed and found them unclean most of the time. This will not increase the

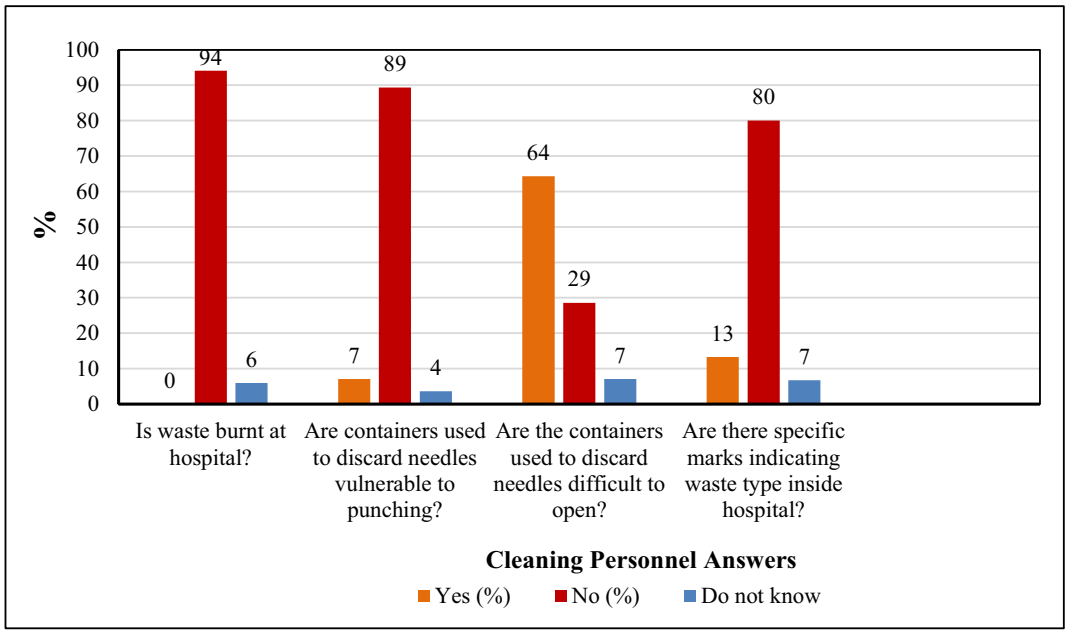

Fig. 2 Overall responses of hospital cleaning personnel to the survey questions regarding sharp boxes

risk of infection for cleaning workers only, but also for other staff, patients, and visitors.

As for the causes of dirtiness of hospital toilets, 38% of the respondents indicated that the patients are the main reason of dirty toilets, while 31% of the respondents indicated it is due to visitors. All other possible causes of dirtiness such as companions and workers had minor effects. There must be a stringent monitoring system in the hospital to ensure toilets are clean all the time. In addition, notice boards to keep all hospital facilities including toilets clean have to be installed to draw attention of staff, patients, and visitors.

Waste management is a complementary part of cleanliness and infection control in healthcare facilities. Healthcare wastes must be viewed as a repository of pathogenic microorganisms, which can cause infections. The inappropriate management of such wastes can allow microbial organisms to be transmitted through direct contact, surrounding air, or various insect vectors. Thereby, the infectious wastes contribute to the risk of infection for workers as well as patients in healthcare facilities and make them more vulnerable to health threats.

Therefore, cleaning is one of the key actions to maintain sanitation in the hospital environment. The principle of cleaning is thus: its objective is to remove direct (clear) dirt and this is basically a mechanical process. Then, the dirt is dissolved and reduced until the dirt becomes invisible and then the surfaces are rinsed with water. Soap and other cleaning substances work as melting agents. The microbiological effect of cleaning is basically considered as a mechanical process. The reduction and removal of dirt will eliminate the ground for any bacterial growth (WHO 2005).

Training

Table 7 clarifies whether cleaning workers receive proper training. Table 7 shows that 68% of the respondents answered they have received training. As for the period of training, 33% of the respondents received training for the duration of 1–3 days; while only 7% of them received training for 1 year. Almost 70% of the respondents said that any new staff is trained. The above figures and percentages are terrifying. It shows that training of workers is not a priority and it is not given the right importance. However, it can be concluded that the time spent in training will contribute to reducing the possibility of infection for the trainees.

Training should focus on health and safety of workers, to improve their understanding of both the potential risks associated with MWs generated by healthcare facilities and the benefits of vaccination and immunization against communicable diseases. Furthermore, training should include the provision of suitable equipment and protective clothing as well as the

Table 5 Overall responses of hospital cleaning personnel to the survey questions regarding transport method of medical wastes

Question	Answers	Valid percentage of respondents (%)
Is there a special means for transferring medical wastes?	Yes, a special means	17
	A common means	40
	No means	43
Do you feel it is easy to control the waste transferring means?	Yes	65
	No	5
	Not applicable	30
Does anyone clean the waste transferring means?	Yes	62
	No	19
	Do not know	19
Who is in charge of the waste transferring means?	A special worker	7
	Workers	93
Is the surface of waste transferring means smooth?	Yes	80
	No	7
	Do not know	13
Is the waste transferring means permeable to liquids?	Yes	8
	No	92
Is the waste transferring means devoted to a specific ward or to multiple wards?	A specific ward	14
	Multiple wards	79
	Do not know	7

development of safety measures for an effective occupational health. Training must also include the provision of preventive treatment after exposure to medical threats.

In addition, the health system has to maintain public safety for patients and staff. This goal can be attained by washing hands with soap and water and providing sacks with two colors (e.g., yellow and black) so that wastes are classified according to health risk. Transport vehicles of MWs must be closed tightly and provided with special impermeable surfaces. Allocating a specified and secured place in the hospital for the storage of MWs and regular wastes is highly essential. The storage area must include all necessary features for a warehouse as well as substantial materials such as pesticide sprayings and containers to reduce the risk of disease transmission by insects or animals. It is important to spraying pesticides to manholes and stores (i.e.,

Table 6 Overall responses of hospital cleaning personnel to the survey questions regarding water and sanitation in hospitals

Question	Answers	Valid percentage of respondents (%)
Has the water been cut off during the last 2 years?	Yes	41
	No	41
	Do not know	18
Do you think that toilets inside the hospital are clean?	Yes always	47
	Sometimes	3
	No	50
What are the reasons for the dirtiness of toilets?	Visitors	44
	Patients	38
	Companions	6
	Workers	12

Table 7 Overall responses of hospital cleaning personnel to the survey questions regarding training

Question	Answers	Percentage of respondents (%)
Have you been trained?	Yes	68
	No	32
What was the training period?	1–3 days	33
	5–7 days	33
	1 month	20
	3 months	7
	1 year	7
Did new workers get proper training?	Yes	70
	No	30

warehouses and kitchens) regularly (e.g., every month), providing gloves to workers, and conducting vaccination for cleaning workers and medical staff who deal directly with these residues.

Management policies and plans of MWs must consider the activities of healthcare facilities and provide proper precautionary measures to control for the safety for all workers. This is to ensure that proper procedures are followed during handling, treatment, and disposal of healthcare wastes. Processes from generation, sorting, transport, treatment, and disposal of healthcare wastes represent a circulation operation of hazardous materials. The protection of all workers in these areas of hazardous substances against personal injury is elementary. Hospitals are fully responsible for the protection of persons through proper management of wastes in healthcare enterprises.

It is important to identify and define all potential risks in processing equipment so that adequate protection against these risks may be maintained. A comprehensive risk assessment of all activities associated with the management of MW will allow the identification of necessary protection measures. Procedures should be established to prevent the exposure to hazardous substances or to keep exposure within safe limits.

Generation and classification of hospital wastes

The MWs generated by each hospital were carefully recorded, and the average quantity of wastes was calculated. A summary of MW generation rates is presented in Figs. 3, 4, and 5. The generation rates represented in kg/bed/day, kg/patient/day, and in % from total mass of each waste type. Overall, the average generation rate of

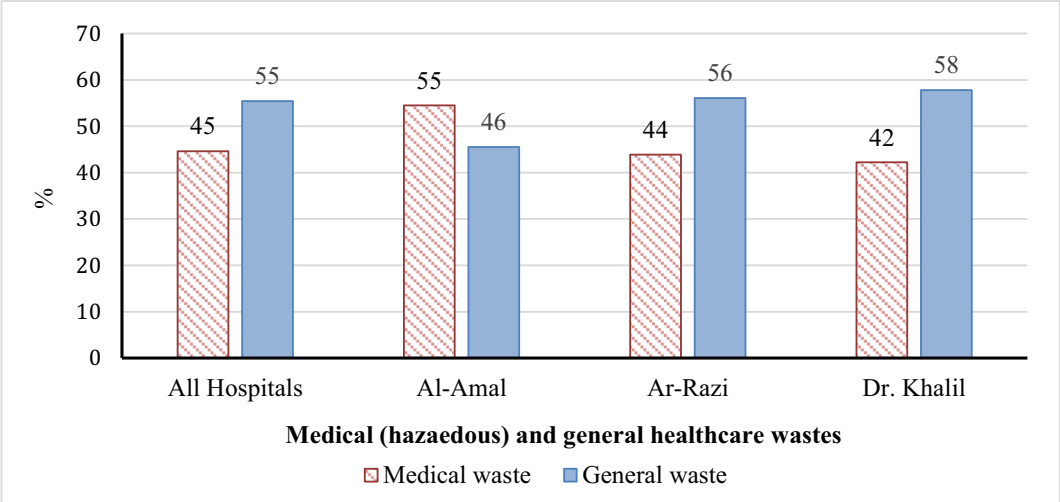

Fig. 3 Percentage distribution of medical (hazardous) and general healthcare wastes in all surveyed hospitals (% mass)

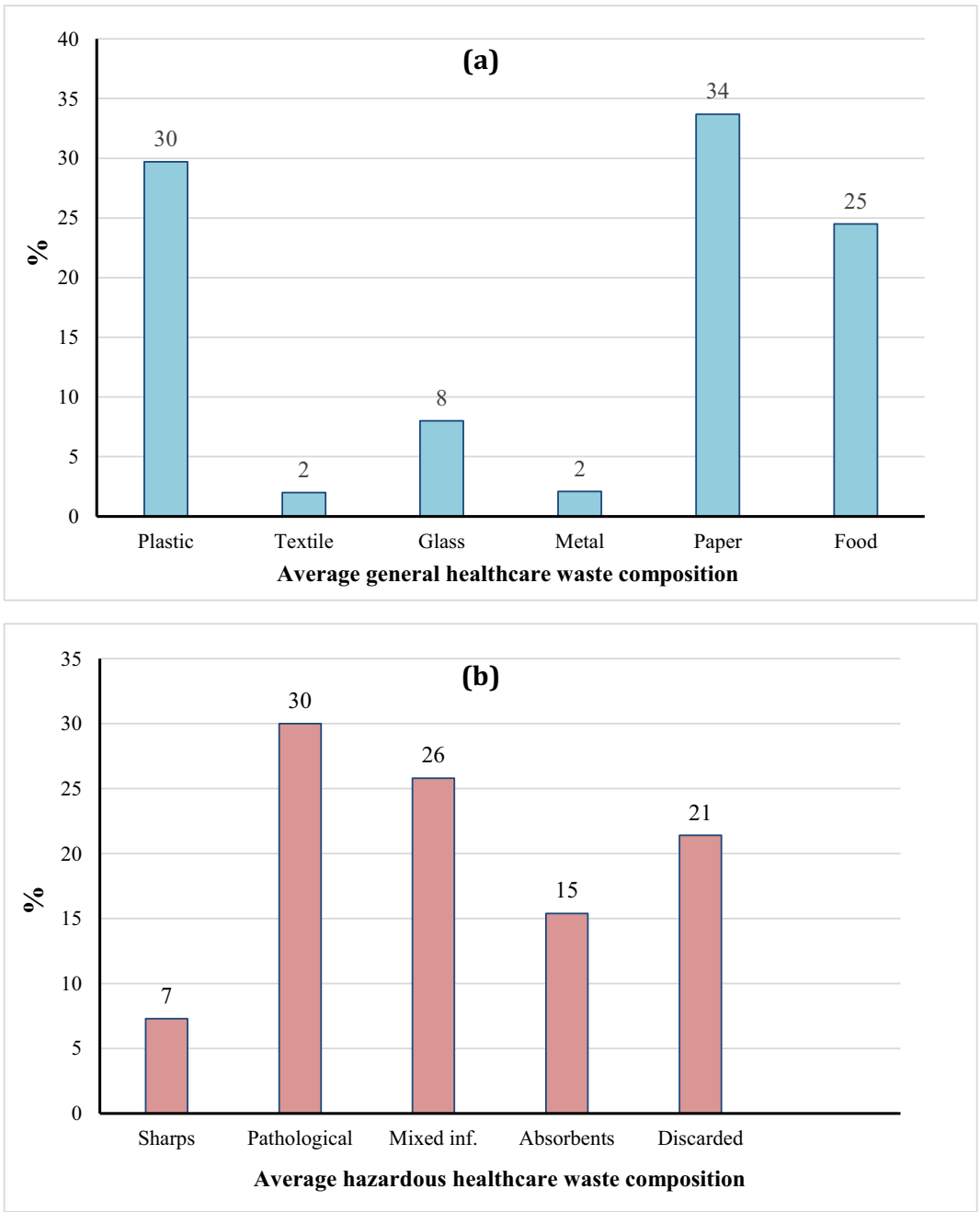

Fig. 4 The average composition of **a** general healthcare wastes and **b** hazardous healthcare wastes in all surveyed hospitals (% mass)

healthcare wastes was 0.97 kg/bed/day (1.95 kg/patient/day) of which 0.78 kg/bed/day (1.57 kg/patient/day) were hazardous. These MW generation rates were higher than those found in poor developing countries (e.g., Ali et al. 2016), and lower than those found in developing countries with higher quality of life (see UNEP 2012; Windfeld and Brooks 2015).

The highest generation rate of 1.82 kg/bed/day MWs was found in Al-Amal hospital, followed by 1.18 kg/bed/day in Ar-Razi hospital (see Fig. 3). The lowest rate of 0.54 kg/bed/day was found in Dr. Khalil hospital. The average generation rate of hospital MWs in Jenin district was 0.78 kg/bed/day. Compared to other developing countries, the total MW generation rate was found to

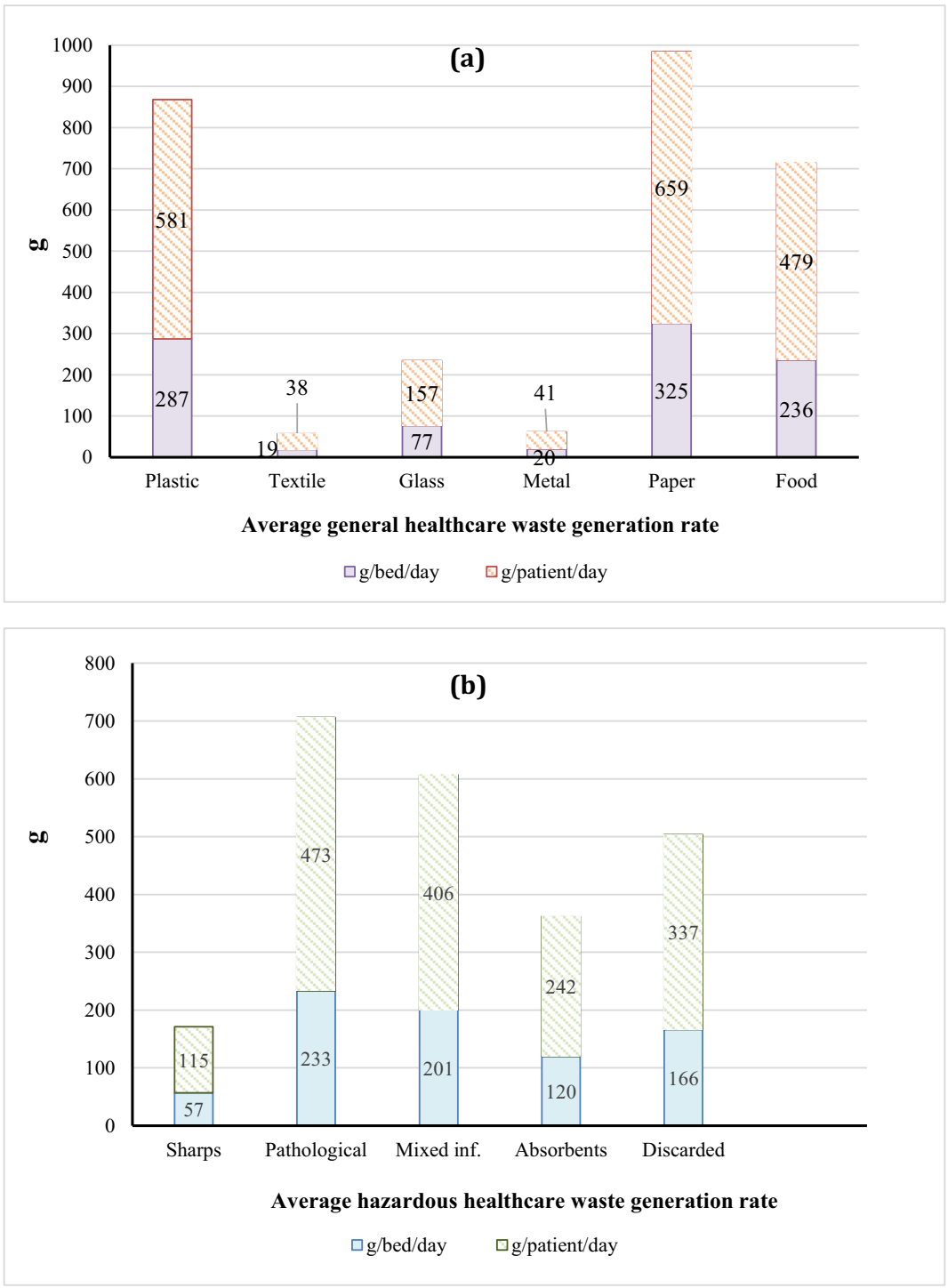

Fig. 5 The average generation rates of **a** general healthcare wastes and **b** hazardous healthcare wastes in all surveyed hospitals

be 6.1, 2.07, and 0.14 kg/bed/day in Jordan, Pakistan, and Tanzania, respectively (UNEP 2012). In Taiwan, MW generation rate was found to be 3.26 kg/bed/day (The World Bank Group 2015; Windfeld and Brooks 2015). In Turkey, MW production rate is 1.39 kg/bed/day (Akbolat et al. 2011; Windfeld and Brooks 2015). In

Brazil, it was found that the production rate of MWs was 3.25 kg/bed/day (Windfeld and Brooks 2015).

Waste generation rates depend on many factors, including, but not limited to, the type of healthcare facility and the level of instrumentation. The higher generation rates at Al-Amal hospital were due to the fact that it is a private hospital with modern facilities, and thus serving patients of higher income levels in comparison with the other hospitals, namely Dr. Khalil hospital.

The average waste generation rate obtained by this study is 1.57 kg/patient/day which is within the range estimated by the WHO of 1.3–3 kg/patient/day for countries in North Africa and Middle East (Sawalem et al. 2009). It is also below the reported range of 1.5–3.9 kg/bed/day in other developing countries (Mato and Kassenga 1997; Idowu et al. 2013). However, the generation rate of MWs in developed countries was found 3.9 kg/bed/day in Norway, 3.3 kg/bed/day in the United Kingdom and France, and 4.4 kg/bed/day in Spain (Bdour et al. 2007; Windfeld and Brooks 2015).

The analyzed hospital waste comprised 45% hazardous wastes and 55% general wastes for all surveyed hospital as shown in Fig. 3. The range of hazardous wastes was between 42 and 55%, while the range of general wastes was from 46 to 58%. Stanković et al. (2008) found that general wastes represented 98.7% of the waste stream while sharps, including needles, scalpels, lancets, syringes, etc., represented only 1.3%. Chih-Shan and Fu-Tien (1993) found that sharp waste was in the range of 0.5–9% of the total MW stream. Ali et al. (2016), however, found that general, hazardous, and sharp wastes comprised about 73.9, 25.8, and 0.9% of the total hospital wastes.

As shown in Fig. 4a, the qualitative analysis of general wastes determined papers as the primary component (34%), followed by plastics (30%). The high plastic content is due to the widespread use of disposables rather than reusable materials for various purposes (e.g., bottles, packaging materials, and food bags). Food wastes (or organic materials) had the third highest percentage (25%). Bdour et al. (2007) found that the sequence of MW fractions generated in departments of health facilities in north Jordan was papers (11.7–52.7%), plastics (1.5–38.4%), garbage similar to household wastes (0.0–26.9%), textiles (1.6–44.4%), metals (1.2–8.5%), and glasses (6.2–21.0%). In hospitals of Pakistan, the wastes consisted of 16% papers, 13% plastics, 22% textiles, 6% glasses, 2% rubbers, and other wastes (Ali et al. 2016).

Classification of hazardous wastes indicated that the summation of pathological and mixed infectious wastes represented about 56% of all hazardous wastes as shown in Fig. 4b. Sharps represented 7% while sharps and pathological wastes represented 37%. Bdour et al. (2007) found that sharps and pathological wastes represented 26% of the total infectious wastes in Jordan. They also found that sharps have the lowest fraction of wastes in the range of 0.8 to 4.8% (Bdour et al. 2007). Blackman Jr. (1996) reported that 60% of MWs is infectious while 40% of them are non-infectious, but this depends on the classification used.

In all surveyed hospitals, the average general healthcare waste generation is shown in Fig. 5a. Papers had the highest generation rate per patient per day (659 g/patient/day), followed by plastics (581 g/patient/day) and then food wastes (479 g/patient/day). The generation rate per bed per day showed the same sequence of generation rate per patient per day but less in quantities as presented in Fig. 5a. These recyclable materials can be sold out in nearby markets to the benefit of local residents and corresponding authorities (see Ali et al. 2016). The income generated from waste reuse and recycling will be a good motive to adopt environmentally sound practices and programs in Palestine.

The average generation rate of hazardous healthcare wastes for all surveyed hospitals is shown in Fig. 5b. The data showed that the generation rate per patient per day is the highest for pathological wastes (473 g/patient/day), followed by mixed infectious wastes (406 g/patient/day), discarded wastes (337 g/patient/day), and finally absorbent wastes (242 g/patient/day). However, the generation rate per bed per day showed the same sequence of the generation rate per patient per day but in lower quantities as shown in Fig. 5b.

Conclusions and recommendations

The study demonstrates that medical waste (MW) management at Jenin hospitals in the north of Palestine faces many challenges. This sector received little attention in terms of waste management options including segregation, collection, transport, treatment, and final disposal. In this study, waste characterization is performed for all three hospitals that exist in Jenin district, as there is a deficit of data on quantities and nature of wastes generated. Such

basic data are of high importance for the proper planning and setting of comprehensive procedures necessary for MW management. A medical waste management bylaw had been issued in 2012, but most of relevant healthcare institutions lack the financial resources to establish a MW management system. Currently, the management of infectious waste is conducted by unskilled and uneducated workers from poor backgrounds. The handling of hazardous or general wastes is below acceptable MW standards. Collectively, this study indicates important implications for the health of handlers. The average healthcare waste generation rates in all surveyed hospitals are 0.97 and 0.78 kg/bed/day for the total general and hazardous wastes, respectively. However, based on the results of this study, the following recommendations are hereby made:

- There is a dire need for reinforcement of MW bylaw through the activation of this regulation and the establishment of treatment and disposal facilities. This can be achieved by cooperation among all key actors including the Ministry of Health, the Environmental Quality Authority, the Ministry of Local Government, and the other Non-Governmental Organizations working in this field.
- Healthcare facilities should be obligated to ensure a safe and hygienic MW management system with a minimal risk to handlers, public health, and the environment.
- Occupational health and safety training is a cornerstone to safeguarding medical staff and waste handlers in healthcare facilities. Training of workers and waste handlers can reduce many health risks.

MW treatment facility at the national level shall be established. The planning at national level for MW management is more effective economically and environmentally and more sustainable administratively. This issue is to be addressed to the small stream of wastes generated by healthcare facilities in comparison with municipal wastes in Palestine.

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References

Abdulla, F., Abu Qdais, H., & Rabi, A. (2008). Site investigation on medical waste management practices in northern Jordan. *Waste Management, 28*, 450–458.

Akbolat, M., Dede, C., Isik, O., & Saglam, H. (2011). Medical waste management practices in Turkey: A case study in Sakarya. *Pakistan Journal of the Medical Sciences, 27*(4), 892–895.

Ali, M., Wang, W., & Chaudhry, N. (2016). Management of wastes from hospitals: A case study in Pakistan. *Waste Management & Research, 34*(1), 87–90.

Ali, M., Wang, W., Chaudhry, N., & Geng, Y. (2017). Hospital waste management in developing countries: A mini review. *Waste Management & Research, 35*(6), 581–592.

Al-Khatib, I. A., Monou, M., Abu Zahra, A. F., Shaheen, H. Q., & Kassinos, D. (2010). Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district - Palestine. *Journal of Environmental Management, 91*, 1131–1138.

Baraka, F., Nanyunja, M., Makumbi, I., Mbabazi, W., Kasasa, S., & Lewis, R. F. (2006). Hepatitis B infection among health workers in Uganda: Evidence of the need for health worker protection. *Vaccine, 24*(47–48), 6930–6937.

Bdour, A., Altrabsheh, B., Hadadin, N., & Al-Shareif, M. (2007). Assessment of medical wastes management practice: A case study of the northern part of Jordan. *Waste Management, 27*(6), 746–759.

Blackman Jr., W. C. (1996). *Basic hazardous waste management* (2nd ed.). New York: Lewis Publishers/CRC Press.

Bokhoree, C., Beeharry, Y., Makoondlall-Chadee, T., Doobah, T., & Soomary, N. (2014). Assessment of environmental and health risks associated with the management of medical waste in Mauritius. *APCBEE Proscenia, 9*, 36–41.

Çalıs, S., & Arkan, B. (2014). The views of the nursing students about the medical wastes and their effects on the environmental and human health. *Procedia - Social and Behavioral Sciences, 116*, 1472–1476.

Chih-Shan, L., & Fu-Tien, J. (1993). Physical and chemical composition of hospital waste. *Infection Control and Hospital Epidemiology, 14*, 145–150.

Chul-Jang, Y., Lee, C., Yoon, O., & Kim, H. (2006). Medical waste management in Korea. *Journal of Environmental Management, 80*(2), 107–115.

Conrardy, J., Hillanbrand, M., Myers, S., & Nussbaum, G. F. (2010). Reducing medical waste. *AORN Journal, 91*(6), 711–721.

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management, 33*, 220–232.

He, Z., Li, Q., & Fang, J. (2016). The solutions and recommendations for logistics problems in the collection of medical waste in China. *Procedia Environmental Sciences, 31*, 447–456.

Hong, J., Zhan, S., Yu, Z., Hong, J., & Qi, C. (2018). Life-cycle environmental and economic assessment of medical waste treatment. *Journal of Cleaner Production, 174*, 65–73.

Idowu, I., Alo, B., Atherton, W., & Al Khaddar, R. (2013). Profile of medical waste management in two healthcare facilities in

Lagos, Nigeria: A case study. *Waste Management and Research, 31*(5), 494–501.

Komilis, D., Fouki, A., & Papadopoulos, D. (2012). Hazardous medical waste generation rates of different categories of health-care facilities. *Waste Management, 32*(7), 1434–1441.

Komilis, D., Makroleivaditis, N., & Nikolakopoulou, E. (2017). Generation and composition of medical wastes from private medical microbiology laboratories. *Waste Management, 61*, 539–546.

Korkut, E. N. (2018). Estimations and analysis of medical waste amounts in the city of Istanbul and proposing a new approach for the estimation of future medical waste amounts. *Waste Management, 81*, 168–176.

Le, A. B., Hoboy, S., Germain, A., Miller, H., & Lowe, J. J. (2018). A pilot survey of the U.S. medical waste industry to determine training needs for safely handling highly infectious waste. *American Journal of Infection Control, 46*(2), 133–138.

Makajic-Nikolic, D., Petrovic, N., Belic, A., Rokvic, M., & Tubic, V. (2016). The fault tree analysis of infectious medical waste management. *Journal of Cleaner Production, 113*, 365–373.

Mato, R. R., & Kassenga, G. R. (1997). A study on problems of management of medical solid wastes in Dar Es Salaam and their remedial measures. *Resources, Conservation and Recycling, 21*, 1–16.

Minoglou, M., & Komilis, D. (2018). Describing health care waste generation rates using regression modeling and principal component analysis. *Waste Management, 78*, 811–818.

Oweis, R., Al-Widyan, M., & Al-Limoon, O. (2005). Medical waste management in Jordan: A study at the king Hussein medical center. *Waste Management, 25*, 622–625.

Palestinian National Authority (2012). *Medical waste management system and its uses*. Cabinet decision no. (10) of 2012. Ramallah, Palestine: Palestinian National Authority.

Qusus, S. K. (1988). *Composition and generation rates of the solid waste of hospitals and medical laboratories in Amman-Jordan*. M.Sc. Thesis, Jordan University, Amman, Jordan.

Rao, L., Ranyal, W., Bhatia, L., & Sharma, L. (2004). Biomedical waste management: An infrastructural survey of hospitals. *MJAFI, 60*, 379–382.

Rolewicz-Kalińska, A. (2016). Logistic constraints as a part of a sustainable medical waste management system. *Transportation Research Procedia, 16*, 473–482.

Sarsour, A., Ayoub, A., Lubbad, I., Omran, A., & Shahrour, I. (2014). Assessment of medical waste management within selected hospitals in Gaza strip Palestine: A pilot study. *International Journal of Scientific Research in Environmental Sciences, 2*(5), 164–173.

Sawalem, M., Selic, E., & Herbell, J. D. (2009). Hospital waste management in Libya: A case study. *Waste Management, 29*, 1370–1375.

Stanković, A., Nikić, D., & Nikolić, M. (2008). Report: Treatment of medical waste in Nišavaand Toplica districts, Serbia. *Waste Management & Research, 26*, 309–313.

Su, E. C., & Chen, Y. (2018). Policy or income to affect the generation of medical wastes: An application of environmental Kuznets curve by using Taiwan as an example. *Journal of Cleaner Production, 188*, 489–496.

The World Bank Group (2015). *GDP per capita - World Bank open data*.The World Bank. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD. Accessed16 August 2018.

United Nations Environment Programme (UNEP). (2012). *Compendium of technologies for the treatment/destruction of healthcare waste*. Osaka: United Nations Environment Programme.

Windfeld, E. S., & Brooks, M. S. (2015). Bottom of form review. *Journal of Environmental Management, 163*, 98–108.

World Health Organization (WHO). (2005). *Management of solid health–care waste at primary health–care centers, a decision-making guide*. Geneva: World Health Organization.

World Health Organization (WHO). (2009). *Wastes from health-care activities*. Fact sheet no. 253. Geneva: World Health Organization.

World Health Organization (WHO). (2014). *Safe management of wastes from health-care activities*. Geneva: World Health Organization.

Xin, Y. (2015). Comparison of hospital medical waste generation rate based on diagnosis-related groups. *Journal of Cleaner Production, 100*, 202–207.