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Statistical analysis and characteristics of hospital medical waste under novel Coronavirus outbreak

H.A. Abu-Qdais[1,*], M.A. Al-Ghazo[2], E.M. Al-Ghazo[3]

[1]*Department of Civil Engineering, Jordan University of Science and Technology, Irbid, Jordan*

[2]*King Abdullah University Hospital, Jordan University of Science and Technology, Irbid, Jordan*

[3]*University of Tennessee Health Science Center, Memphis, Tennessee, USA*

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ABSTRACT

One of the sources of infection as a result of coronavirus disease treatment is the medical waste generated during the health care activities. Since the registration of the first infected case of coronavirus in Jordan the daily number of patients fluctuated from as low as zero to as high as 40 with a recovery ratio and case fatality risk of 39% and 1.7%, respectively. The main objective of the present study is to carry out statistical analysis and assess the generation rates and the composition of the medical waste generated during the treatment of coronavirus pandemic with reference to a major tertiary care hospital in Jordan. Data on the daily generated waste, number of the admitted patients and on the amounts of consumables like various personal protective equipment, testing kits, and disinfectant used during the treatment of coronavirus disease was obtained. Data was subjected to descriptive statistical analysis to find the average generation rates, 3 days moving average, as well as the frequency distribution of the generated amounts. During 25 days' period, King Abdullah University Hospital has admitted 95 infected patients by coronavirus. The amount of the average rate of the medical waste generated as a result of coronavirus treatment was found to be 14.16 kg/patient/day and 3.95 kg/bed/day, which are more than tenfold higher than the average generation rate during the regular operational days of the hospital. Frequency analysis of the data revealed that the medical waste generation follows log normal distribution with correlation coefficient of 0.89. The distribution is distorted to the right and flatter than the normal distribution curve as judged by the skewness and kurtosis coefficients, respectively, which indicates deviation from normality.

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*Corresponding Author:
Email: *hqdais@just.edu.jo*
Phone: + 962 795885235
Fax: +962 2 7095123

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INTRODUCTION

The novel coronavirus outbreak has become a global problem that poses a serious risk for the whole population of the world (Khan *et al.,* 2020, Al-Ganees *et al.,* 2020). Because of the unusual spread rate of the disease, World Health Organization (WHO) declared it as a pandemic (Isaifan, 2020). According to John Hopkins University Coronavirus Resource Center, as of 9th of April, 2020, the novel virus has infected 1 485981 people in 177 countries and has caused a total death of 88 538 people, while 329876 patients were recovered (JHU, 2020). This gives a global case fatality risk (CFR) of 5.9% and recovery ratio of 22.1%. The fear from such pandemic has led to a global panic that put all countries around the world in an emergency case (Khan *et al*., 2020). To mitigate the spread of the disease most of the countries around the world have put restrictions on the mobility of goods and passengers as they announced either partial of full lockdown their boarders, which has adversely affected the world trade, banking and tourism, and consequently the world economy. In cases of pandemic outbreak, the sharp increase of infection within a short time frame puts a huge pressure on the health care services by increasing the demand of various resources including medical staff, medical supplies and health care facilities. For example, the hospitals and medical centers in China and Italy during the spread of pandemic are overwhelmed by the flood of daily patients that are getting admitted to those facilities. Consequently, the health care providers are faced with the challenge of providing a timely and sufficient medical services, where it is of great importance to deal with such drastic increase in demand in a safe and effective manner with minimal risk of infection (WHO, 2020a). On the other hand, the supply chains and logistics under pandemic conditions have to meet the increasing demand on the resources like throat and nasopharyngeal swap testing kits to conduct the corona PCR test, personal protective equipment (PPE) and disinfectants. Most of these items are disposable and eventually find their way to medical waste stream that should be dealt with as a medical waste which should be managed properly to mitigate the infection risks (Hau *et al*., 2020). By reviewing the literature on Coronavirus outbreak, it can be noticed that tremendous amount of research articles has been published during the last four months on how to adopt preventive and control measures to minimize the spread of the disease and how to mitigate the risks of its infection and transmission. Although proper management of the healthcare waste produced during the treatment of coronavirus patients is one of the means of minimizing the risks associated with such pandemic disease, little attention in the published literature has been directed to this type of waste that is generated during the quarantine and treatment of the infected patients by coronavirus. For example, the search in the WHO database of publications on coronavirus disease (COVID-19) (WHO, 2020b) revealed that only two articles dealt with coronavirus medical waste management. One article dealt with the optimization of the medical waste management during the corona pandemic in Wuhan (Hau *et al*., 2020), while the other article covered the issue of mitigating the transmission of COVID 19 via the wastewater plumbing systems (Gormley *et al., 2020*). The main objective of the present paper is to provide information on the spread of the novel coronavirus disease in Jordan and to analyze the medical waste generation rates as well as its composition during the treatment of coronavirus patients with reference to a major tertiary care hospital assigned for treatment of the disease in northern Jordan. The study was carried out during March, 2020 at the King Abdullah University Hospital (KAUH), which is a main health care facility in northern Jordan.

MATERIALS AND METHODS

For the purpose of this study, data on the spread of the coronavirus disease and the amount of medical waste generated was collected on two levels. The first one was on the country level, where data on the development and spread of the pandemic was obtained from the website of John Hopkins University Coronavirus Resource Center (JHU, 2020). The second one was specific information on the level of KAUH, which is the main subject of the study. To estimate the impact of the Coronavirus pandemic on the amounts of the medical waste generated at KAUH, the records on medical waste generation from the wards and sections of the hospital that are dealing with the reception and treatment of the infected patients, including the emergency section, laboratory, and isolation wards were obtained from the Environmental Health Section of the hospital. Furthermore, the number of beds in the emergency

ward that is devoted for the treatment of the infected patients was obtained. As for the composition of the waste, the data from the hospital supply department was obtained on the PPE and consumable during the same period. Based on the collected information, it was possible to have insight on the spread and development of the number of the cases infected by the novel coronavirus pandemic in Jordan after which the recovery and case fatality risk (CFR) ratios of the country were calculated. On the other hand, the data collected from KAUH, enabled us to estimate the average generation rate of the medical waste in terms of kilogram per patient per day and in kilogram per bed per day. The data collected were subjected to descriptive statistical analysis to determine parameters like mean, median, standard deviation and coefficient of variance. To find the frequency distribution curve of the daily medical waste generated at KAUH, the coefficients of skewness and kurtosis were calculated using Excel.

RESULTS AND DISCUSSION

Spread of Coronavirus pandemic in Jordan

Jordan as a country is divided into three regions namely: Northern, Middle and Southern region. Each region comprises 4 governorates. The total population of Jordan as of 2020 is 10.2 million (WorldoMeter, 2020). As part of the coronavirus disease control and prevention plan, the Government of Jordan assigned one main health facility in each region to deal with the pandemic. In the northern region King Abdullah University Hospital, while in the Middle Region Prince Hamzah Hospital and Al-Karak Government hospital is the assigned hospital in the southern region. As the case with all countries around the world, Jordan has been affected by the spread of Coronavirus outbreak. Assessing the severity and transmissibility of the infection in the early stages can help in quantifying the coronavirus pandemic potential and the expected number of mortalities. One important measure to assess the pandemic severity is the case fatality risk (CFR) (Jung *et al.*, 2020), which can be measured by the proportion of the cumulative number of deaths out of the cumulative number of reported infected cases at a certain time. In Jordan the first confirmed infection by coronavirus in the country was reported on March 3rd, 2020 which is a case of a Jordanian patient who arrived from Italy. After that and for a period of 12 days, no cases were reported in the country. As shown in Fig. 1, starting from March 15th, the confirmed infection cases started to increase gradually, where the total reported confirmed infected cases as of April 6th was 353 cases. Out of that, there were 138 recovery and 6 mortality cases. This yields a recovery and CFR ratios of 39% and 1.7%, respectively. Considering the global average

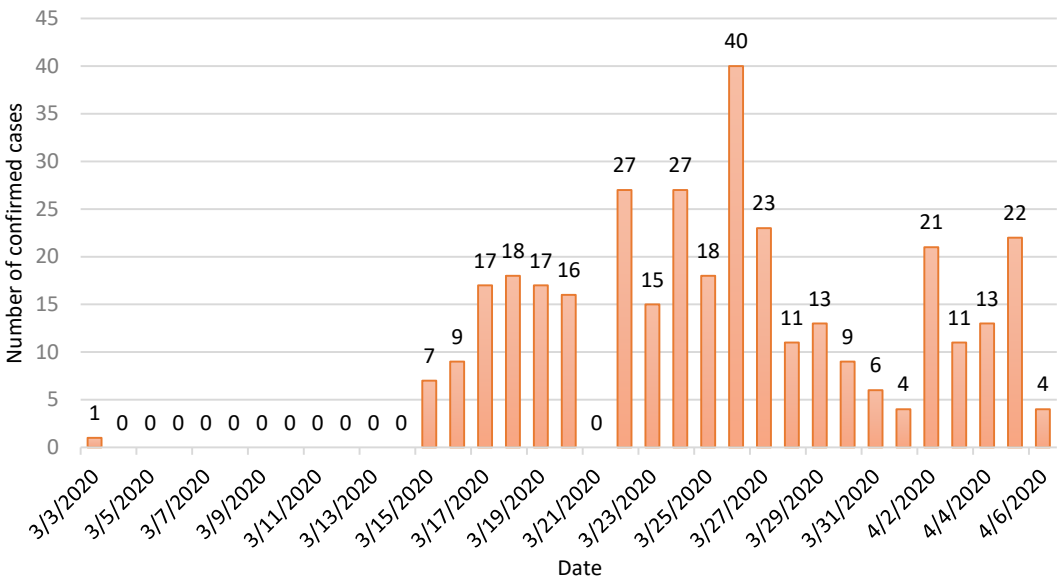

Fig. 1: Number of the confirmed infected cases by coronavirus in Jordan until April 6th, 2020

recovery ratio and the CFR values of 22% and 5.9%, respectively, it can be concluded that the recovery ratio in Jordan is higher than the global average ratio by 1.7 folds, while the fatality risk ratio is less than the global average by almost 3 folds.

Out of the total 353 reported infected cases, 258 were reported in the central region, 95 cases in the northern region, while no cases reported in the southern region. The number of the infected patients per one million of the population in Jordan was found to be 35 persons.

King Abdullah University Hospital

Located within the campus of Jordan University of Science and Technology, King Abdullah University Hospital started its operations in the year 2002 with a vision to be a distinguished state of the art health center and comprehensive referral medical facility in the Middle East in terms of health services and scientific research. Beside other goals, KAUH has two prime goals, namely offering advanced health care services to both Jordanians and non-Jordanians, and giving education and training to students in various medical specialization. The hospital comprises 15 story building with total 687 beds operational capacity which is expandable to 820 beds in case of emergency (Abdulla *et al.,* 2008). According to Abu Qdais *et al.* (2007) and Al Shraideh and Abu Qdais (2017), the average generation rate of the medical waste from KAUH hospital ranged from 0.36 to 0.5 kg per patient per day. The first case of corona infection has been reported in Jordan on March 3rd, 2020 in Amman, while the first case admitted to KAUH was in March 15th, 2020. Since that date, KAUH has been assigned by the health authorities to be the only health care center in Northern Jordan to deal with testing the suspected patients and treating the confirmed ones. At the beginning, one ward with a capacity of 100 beds has been converted to an emergency ward to deal with the coronavirus patients. With the increase in the number of patients and to meet the demand on treatment the capacity has been increased to 200 beds. Table 1 presents the number of confirmed infected cases by coronavirus that admitted to KAUH, along with number of recovered and mortality cases as of 2nd of April, 2020. It can be seen that out of 95 cases infected, 39 cases has been discharged from the hospital as they recovered (41% recovery) and only 1 case of death (CFR 1.05%).

Table 2 shows the daily generated amount of medical waste from the first day when the hospital started to admit the infected patients until 2nd of April, (the time of writing up this article) along with the number of patients that were admitted to treatment each day.

As it can be observed, due to the current spread out of Coronavirus, the healthcare medical waste is being generated at higher rates than normal**.** The average generation rate found to be 14.16 kg per patient per day which is pretty high. This is may be attributed to the fact that when the KAUH hospital selected to be as a center for treatment of coronavirus disease, the hospital administration converted one of the regular wards for this purpose. To get it ready for receiving the infected patients, full disinfection process was carried out in the ward which was reflected on the amount of the generated medical waste in the first two days though small number of patients were admitted at those days as shown in Table 2. In terms of the number of beds that were put into operation (100 beds) the average generation rates was found to be 3.95 kg/bed/day. The generated medical waste from KAUH is daily collected and sent to the nearby incinerator that is located within the campus of Jordan University of Science and Technology, where it is get incinerated. Comparing the current rate of the medical waste generation as a result of coronavirus treatment (3.95 kg/bed/day) with the rate recorded by the incinerator before the coronavirus disease of 0.41 kg/bed/day (JUST, 2014) and with that reported by Abu Qdais *et al.,* 2007 of 0.3 kg/bed/day, it can be noticed that the current generation rate as a result of coronavirus is almost tenfold higher than the average amounts that is generated from other wards that deal with regular patients. Similar findings were reported by Yu *et al.* (2020), who indicated that the generation

Table 1: Number of admitted patients to KAUH, recovered cases and deaths as of 2nd April, 2020.

Number of confirmed infected cases	Number of recovered cases	Number of death	Recovery Ratio (%)	CFR (%)
95	39	1	41	1.05

Table 2: Amount of medical waste generated from KAUH as a result of Coronavirus treatment

Day	Medical waste generated	Admitted Patients	Daily generation rate of medical waste	
	(kg/d)	No.	kg/patient/d*	kg/bed/d**
1	106	2	53	
2	206	6	34	1.06
3	210	12	17.5	2.06
4	220	15	15	2.1
5	386	15	26	2.2
6	284	16	17.75	3.86
7	220	19	11.5	2.84
8	320	19	16.8	2.2
9	302	31	9.7	3.2
10	300	41	7	3.02
11	340	46	7.4	3.4
12	500	73	6.8	5
13	300	76	3.9	3
14	500	83	6	5
15	550	86	6.4	5.5.
16	600	87	6.9	6
17	720	91	7.9	7.2
18	800	92	8.7	8
19	650	95	6.8	6.5
Average			14.16	3.95

* During the period covered by the study no patients were recovered and discharged from KAUH

**Based on operational capacity of 100 beds.

rate of medical waste as a result of the Coronavirus disease in Wuhan city which is the epicenter of the pandemic has been increased from 0.6 kg per bed per day up to 2.5 kg per bed per day. Such an increase is expected, as during the treatment of infectious diseases like the novel coronavirus there is an increase use in the personal protective equipment (PPE) like masks, protective glasses and protective coating that are disposable items and should be dealt with as an infectious medical waste, which leads to higher generation rate of the medical waste (ECDC, 2020). To understand the mechanism of waste generation in a better way and to develop a waste management system, it is important to determine the statistical characteristics of the observed waste generation rates which will be useful for assessing the sizes of the required storage and collection equipment. Furthermore, such information is needed by solid waste collection and treatment private contractors to base their contracts on the trends and distribution of the waste generation data (Tchobanoglous *et al.,* 1993; Ricky *et al.,* 2019). Figure 2 shows the daily generation rate as well as the three day moving average of the medical waste generated at KAUH as a result of the activities associated with coronavirus treatment. It can be seen that the minimum amount (160 kg/d) was in the first day of admitting the first batch of patients. The amount continues to increase with time as more patients were admitted which reached to 800 kg/d at the end of the study period when the total number of the admitted infected patients reached 95. The 3 day moving average shows a mild increasing trend in the first two weeks after which a sharp increase can be observed in its values as can be observed from Fig. 2. This may be attributed to the increase in the medical staff number who joined the emergency coronavirus treatment team at the hospital to meet the increase demand on health care services. More staff, implies more personal protective equipment and consequently increased generation of medical waste. With more data on the generation rates, the three days moving average plot is expected to get milder (Ricky *et al.,* 2019). Optimizing the medical procedures may reduce the frequency of medical personnel's contact with patients (Zhi-Min Chen *et al.,* 2020) and consequently decrease in the amounts of medical waste generated.

To assess the impact of the number of the patients infected by corona virus on the amount of the medical waste that is generated at KAUH, a best fit correlation

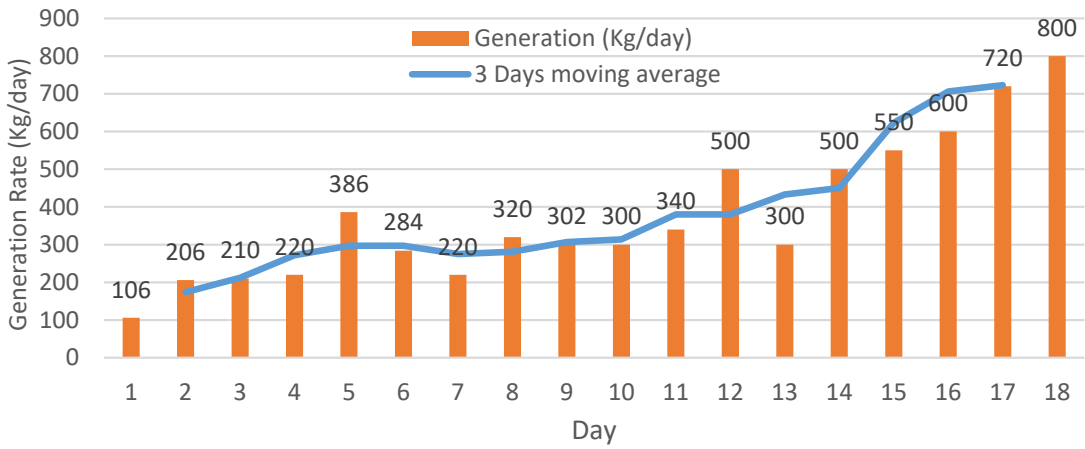

Fig. 2: Generation rate and three days moving average of medical waste from Coronavirus Healthcare Units at KAUH

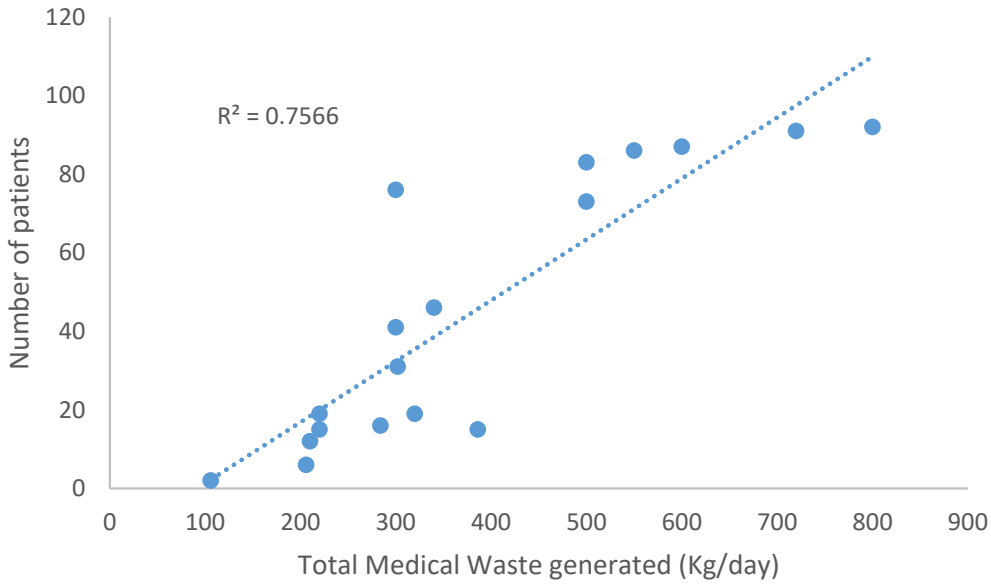

Fig. 3: Correlation between the number of admitted patients and the amount of medical waste generated

was carried out as shown on Fig. 3. It can be observed that there is a positive relation between the patients' number and the generated amount of the medical waste with a correlation coefficient value of 0.87.

Finding a distribution model that adequately fits the waste generation data is a vital step that enables planners in solid waste management sector making proper decisions (Abu Qdais *et al.*, 2007; Araisa *et al.*, 2020). The generated amounts of the medical waste from the KAUH units and wards that were assigned to the treatment of the infected patients by Coronavirus have been subjected to frequency distribution analysis. The analysis revealed that the daily generated amounts of the medical waste can be described by log normal distribution with a correlation coefficient of 0.89 as shown on Fig. 4.

To give insights into the shape of the distribution of the medical waste generated amounts and to estimate its deviation from normality, both skewness and kurtosis coefficients were calculated. Skewness is

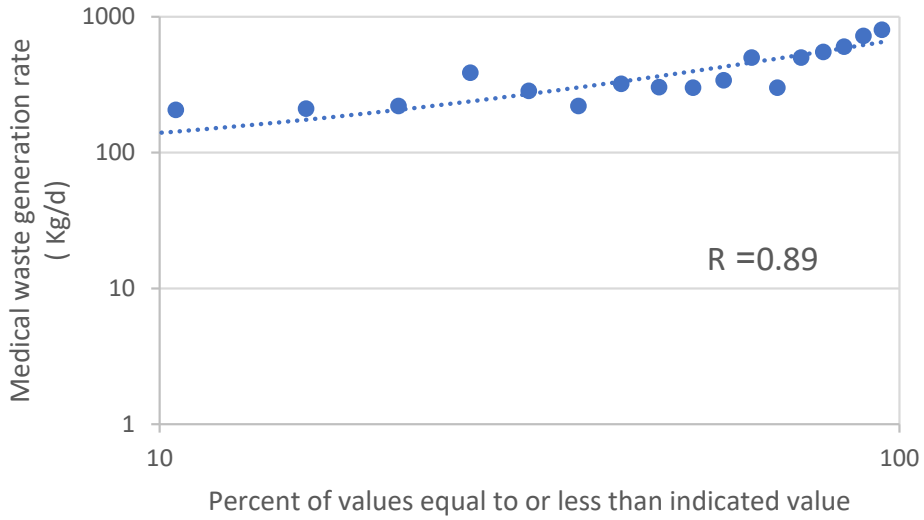

Fig. 4: Log normal distribution of the medical waste generated at KAUH from Coronavirus Treatment Units

a measure of the symmetry in a distribution, where normal distribution has a skewness coefficient equal to zero, while the positive value of the skewness coefficient indicates a normal bell-shaped curve that is distorted to the right, while negative value indicates that the curve is distorted to the left side. Skewness coefficient can be calculated by Eq. 1 (Tchobanoglous *et al.,* 1993).

$$\alpha_3 = 2\,(X' - \text{Mod})/\,S \qquad (1)$$

Where, α3 is coefficient of skewness

X' - Mean value of the medical waste generation

Mod- is the statistical mode of the data which most frequently data set among the random variables

S- is the standard deviation value of the random variables in the sample.

On the other hand, kurtosis coefficient measures the flatness or the narrowness of the distribution curve with respect to normal distribution which can be calculated by Eq. 2 (Tchobanoglous *et al.,* 1993)

$$\alpha_4 = \sum (X_i - X')\,/nS^4 \qquad (2)$$

Where: α4 is coefficient of kurtosis,

X_i – Medical waste generation amount at day i,

X' - Mean value of the medical waste generation

n - Size of the sample (number of days during which the medical waste generated).

A normally distributed dataset will have a kurtosis coefficient value of 3, flatter distribution will have kurtosis coefficient less than 3, and more peak distribution curve having kurtosis coefficient greater than 3 (Abu Qdais *et al.,* 2007; Araiza *et al.,* 2020). Statistical parameters such as mean, median, standard deviation, coefficient of variance along with skewness and kurtosis coefficients of the generated amounts of medical waste are presented in Table 3. The value of the skewness coefficient is 1.69 which implies the distribution curve is a bell-shaped one that is highly skewed to the right, while it is moderately flatter than the normal distribution curve as judged by the coefficient of kurtosis which has a value of 2.38 (Abu Qdais *et al.,* 2007).

Table 4 shows the type of PPE and consumables and their amounts that were used in testing, analysis, disinfection and treatment of the patients during the

Table 3: Statistical parameters of the medical waste generated at KAUH during the treatment of Coronavirus disease in northern Jordan

Parameter	Mean	Median	Mode	Standard deviation	Coefficient of skewness	Coefficient of Kurtosis
Value	381.3	311	220	190.5	1.69	2.38

Table 4: Number of personal protective equipment items, disinfectants amounts and test kits used during March month in KAUH

No.	Item	Unit	Quantity
1	Gloves	pairs	250 000
2	Goggles	No	695
3	Face shield	No	128
4	Suits	No	1 850
5	Gowns	No	22 000
6	Shoes cover	No	14 000
7	Mask N95	No	5000
8	Face mask	No	60 000
9	Head caps	No	500 000
10	Corona virus PCR test kits	No	2 500
11	Throat and nasopharyngeal swap	No	1700
12	Floor disinfectant	Liter	495
13	Solid surface disinfectant	Liter	1 140
14	Hand disinfectant	Liter	2 950
15	Hand kerchief tissue	Packet	1 495
16	Toilet papers rolls	Roll	1 435
17	Hand wash liquid soap 500 ml	No	1 150

study period (March 5th until April 2nd, 2020). Since 90% of the consumables are disposables, this leads to increased amounts of medical waste generation. Rational use of PPE and disinfectants by the health care staff will lead to the decrease in the amounts of medical waste generated (ECDC, 2020). However, it is important to achieve such rationalization without jeopardizing the preventive and mitigation measures of the infection transmission. Due to their direct contacts with the patients, health care workers are at an increased risk of infection by coronavirus (Colaneri *et al.,* 2020). One way to minimize the risk of infection during the treatment of patients is to provide the health care staff with adequate training and knowledge on appropriate PPE (Marroufi *et al.*, 2020, Morioka *et al.*, 2020). Furthermore, the implementation of several interventions and medical procedures by the medical staff during one contact with the patient will result in the reduction of the need for disposable masks and other PPE, which will lead to the minimization of the generated medical waste quantities.

CONCLUSION

Since the emergence of the first cases in Wuhan, China, the novel coronavirus infection has been spreading out in high rates to all countries around the world. One pathway of the disease transmission is the medical waste generated during the treatment of the infected patients. Unless properly managed, this waste will pose a health risk for the public, as well as to the medical staff involved in the treatment of the disease. The present study deals with the spread of coronavirus in Jordan and the medical waste generated as a result of treatment of such pandemic with reference to one of the major Hospitals which is responsible for the treatment of coronavirus patients in northern Jordan. As of 6th of April, 2020, the total confirmed number of coronavirus patients in Jordan were 353 with CFR of 1.7% and recovery ratio of 39%. The amounts of the medical waste generated at KAUH were subjected to descriptive statistical analysis. The average generation rate was found to be 3.95 kg/bed/day which is 10 folds greater than the generation rate from the hospital during regular daily operation. The high generation rate is attributed to the fact that most of the health care personnel at the hospital are using the PPE that are disposable. Furthermore, the frequent disinfection and cleaning of the equipment, floors and hard surfaces are also leading to such increase in the amounts of the generated medical wastes. This suggests the need for rationalizing the use of the PPE and the disinfectants without jeopardizing the safety of the health care employees and the patients. The frequency analysis of the generated medical waste showed that it follows log normal distribution with correlation coefficient of 0.89. Capacity building of the health care staff is needed on how to minimize

the risks associated with the treatment of such novel coronavirus pandemic, especially how to manage the medical waste generated during the treatment. In addition, more attention should be directed by the researchers and investigators to the issue of medical waste management generated as a result of dealing with coronavirus pandemic.

AUTHOR CONTRIBUTIONS

H.A. Abu Qdais performed the literature review, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. M.A. Al-Ghazo compiled the data and participated in the manuscript preparation. E.M. Al-Ghazo helped in the literature review, and in the statistical analysis of the collected data.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

%	Percentage
CFR	Case fatality risk
Covid-19	Coronavirus disease 2019
d	Day
Eq.	Equation
Fig.	Figure
JHU	John Hopkins University
KAUH	King Abdullah University Hospital
kg/day	Kilogram per day
kg	Kilogram
PCR	Polymerase chain reaction
PPE	Personal protective equipment

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AUTHOR (S) BIOSKETCHES

Abu-Qdais, H.A., Ph.D., Professor, Department of Civil Engineering, Jordan University of Science and Technology, Irbid Jordan.
Email: *hqdais@just.edu.jo*

Al-Ghazo, M.A., Ph.D., Professor, King Abdullah University Hospital, Jordan University of Science and Technology, Irbid, Jordan.
Email: *alghazo@just.edu.jo*

Al-Ghazo, E.M., M.D., Neurology Resident, University of Tennessee Health Science Center, Memphis, Tennessee, USA.
Email: *ealghazo@uthsc.edu*

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