International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Biomedical Waste Management in Three Hospitals in Khartoum State Sudan during COVID-19 Pandemic and Lessons Learned

Aseel Salaheldin Abdelhag[1], Hassan Ibrahim A. Mofadel[2]

[1]Department of Environmental and Ecology, Faculty of Geographical and Environmental sciences, University of Khartoum, Sudan

[2]Department of Environmental and Ecology, Faculty of Geographical and Environmental sciences, University of Khartoum, Sudan
[2]Department of Business Development, Kenana Sugar Company, Khartoum, Sudan

Abstract: ***Biomedical waste management is a basic rule to prevent environmental and health hazards. Subsequently, the emergence of COVID-19 as a pandemic creates great challenges in the health care sector and society in general, as well as in the strategies of biomedical waste management and disposal. This study was conducted to identify the procedures and methods used to manage COVID-19 pandemic waste. Also, identify the safety procedures to protect workers in the health sector and workers in COVID-19 pandemic waste management in isolation centers. Three hospitals were selected with isolation centers in the State of Khartoum, Sudan, namely, Al-Shaab Hospital, Royal Care Hospital, and Omdurman Maternity Hospital. Data and information were collected from these hospitals using interviews, questionnaires, and checklists. The results indicated a huge gap in the sorting and separation of medical waste in the three hospitals, as well a lack of adequate awareness and training of workers to protect themselves from exposure to COVID-19 pandemic medical waste. The results also showed a lack of personal protective equipment (PPE), sterilization, and workers receiving the COVID-19 vaccine, which increases the chances of infection among them. The study recommends increasing the training and awareness of workers while providing all PPEs and raising awareness among the medical staff about their role in waste management as a first step in waste management and educating the community about the dangers of medal waste and the infectious diseases and injuries among them, and others. Endorsement of the new regulations and procedures adopted by the World Health Organization (WHO) and Sudanese governmental medical entities is crucial. Although it is acknowledged that the COVID-19 pandemic differs from previous emergencies in terms of its nature and effects, it is now time to respond by using the lessons learned to pinpoint the shortcomings in the waste management system and implement the required changes.***

Keywords: Biomedical Waste; COVID-19 Pandemic; Khartoum State; Safety Procedures; Health Care sector; Workers; hospitals, waste system; PPE, lessons Learned

1. Introduction

Healthcare waste includes all wastes generated within health-care facilities, research centers and laboratories related to medical procedures additional to healthcare waste generated at homes.

COVID-19 waste is classified as infectious waste and must be deal within correct ways and should follow the directives and regulations issued by organizations such as the world health organization (WHO).

The safe management of health care waste involves three main principles such as; minimizing unnecessary waste, isolating general waste from hazardous ones, and treating waste in a way that reduces risks to health workers and the community. safe waste management is a complex issue, and although it is being addressed in the context of global activities related to water, sanitation and hygiene in health care facilities, there are a number of collaborations that continue to be implemented with teams working on infection prevention and control, injection safety and immunization campaigns chemicals, energy and emergency [1].

There are some elements established by the world health organization in 2014 are considered which should be included in healthcare waste management policies include: Identification of needs and gaps in the country, regulations specifying health care waste management such as waste segregation, collection, storage, handling, treatment, and disposal.

The first step in waste management is separation which is important component of efficient healthcare waste management. By separating hazardous waste from non-hazardous waste one that can significantly reduce the volume of waste that requires specialized treatment [2]. Other elements of healthcare waste management include waste classification, waste minimization, containers, color coding, labeling, signage, handling, transportation, storage, treatment and final disposal. Maintaining such a system requires continuous training, planning, budgeting, monitoring, evaluation, documentation and record keeping [2].

Poor medical waste management exposes healthcare workers, those involved in waste handling, the sick, their families, and the community to preventable infections, toxic effects and injuries. The problem of many developing countries is not only in the development of policies and plans, but in decision-making and how to implement these plans after their development and mobilization of resources and efforts to achieve sound management.

After the world the world health organization (WHO) declared the COVID-19 outbreak a public health emergency of international concern on 30 January 2020; and a pandemic on 11 March 2020 The problem of medical waste management arose, especially because it is considered a

major source of danger and infection for workers in the medical field and waste management workers from the stage of sorting and monitoring it until its final disposal [3].

During such an outbreak, many types of additional hazardous medical waste are generated, including contaminated masks, gloves and other protective equipment, along with a larger volume of uninfected items of the same nature [3].

The world health organization has developed considerations for managing waste from the COVID-19 pandemic, first mapping the sources of waste generation in order to determine changes in waste quantities and flows, identifying waste sources in hospitals, isolation centers and even home isolation, as well as identifying places where waste generation has decreased due to preventive closures such as schools and shops [3]. Second separation of waste, especially household waste, placing contaminated waste in sealed bags or in two-layer bags, and if necessary, governments distribute waste bags to homes and communities [3]. Thirdly, reduce and recycle so that families separate recyclable waste from non-recyclable waste [3].

As for hospital waste, it is separated into specific containers and color-coded and collected in certain periods and specific workers are trained and educated on the correct methods with wearing personal protective equipment and storing them for short periods according to available resources and sterilization after the process of disposal.

Improper management of this waste can have "unforeseen" impacts on human health and the environment. The safe handling and final disposal of this waste is a vital component of an effective emergency response [3].

Effective management of biomedical and healthcare waste requires its identification, collection, separation, storage, transportation, treatment and appropriate disposal, as well as important related aspects including disinfection, employee protection and training [3].

The Basel convention technical guidelines on the environmentally sound management of biomedical and health waste contain information and practical aspects of waste management beneficial to authorities seeking to reduce risks to human health and the environment [3].

The COVID-19 crisis resulted in tremendous increase in medical and hazardous waste generation and accumulation. To protect human health and the environment, it is vital to ensure the safe handling and final disposal of such waste is in place. Since the pandemic seem to be ended but still many variances are continually attaching old and sick people directly or by touching contaminated surfaces and requires health care and quarantine. This situation also continually generate huge amount of waste and needs disposal measurements in safe ways to preserve hospital workers.

The present study was launched with a view to understand and to identify the safety procedures and methods used to get rid of waste in the health isolation centers during COVID-19 pandemic period.

The research was raised a number of questions include the difference in medical waste management before and after the pandemic, the impacts of COVID-19 on biomedical waste management, the guidelines for handling of generated waste, waste sorted and method of sorting, waste workers education and training on the correct and safe ways to dispose, do workers wear personal protective equipment (PPE) and how long changed and the trend of amount and structure of waste due to the pandemic. Based on the ongoing discussion the objective of this study, therefore, is to identify the procedures and methods used to manage COVID-19 pandemic waste in three hospitals in Khartoum State Sudan with specific objectives of identifying the safety procedures to protect workers in the health care sector and workers in COVID-19 waste management in isolation centers as well as identifying all steps (collection, sorting, burning or burial) and lessons learned during COVID-19 pandemic for future prospects.

2. Methodology

A descriptive design based on cross-sectional study for three hospitals. The hospitals were selected with isolation centers in the State of Khartoum, Sudan, namely, Al-Shaab Hospital, Royal Care Hospital, and Omdurman Maternity Hospital. The study was carried out in the governmental and non-governmental health care sectors for patients with COVID-19 in Khartoum State between March 2021 and October 2021. The purpose of the study area and setting was aimed to evaluate the biomedical waste (BMW) management knowledge, practices, and attitudes of three mentioned hospitals in Khartoum State. The three specified hospitals and the study area were depicted in Figure 1.

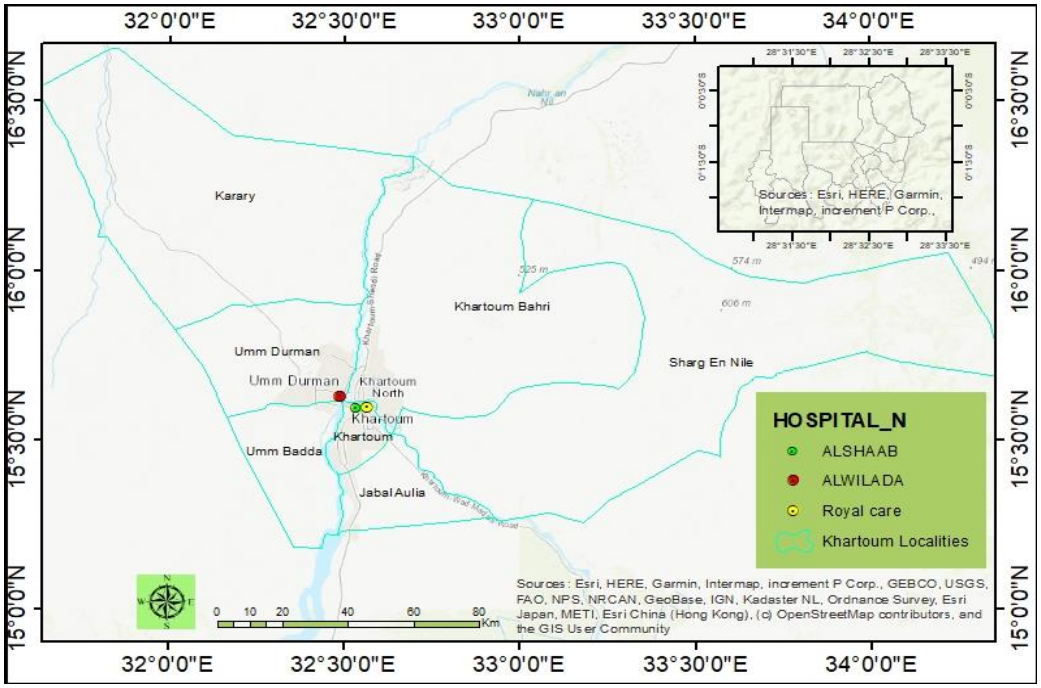

Figure 1: Map shows the study area and hospitals locations in Khartoum state

Inclusion criteria was used include all medical personnel in the selected hospitals are doctors, nurses, laboratory, pharmacists and trainees and all COVID-19 waste workers of both sexes, with their different educational stages and social status, as well as employees of the waste management and environmental Health departments in the selected hospitals were interviewed.

Data collection include primarily and secondary data. The primarily data obtained from three hospitals that are considered isolation centers were selected; namely Al-Shaab Hospital as a government hospital, Royal Care hospital as a private hospital and Omdurman Maternity hospital. The environmental health department and the waste management department of the selected hospitals were interviewed as well as the Higher Council of Environment, Urban and Rural Development Director and the Director of Waste Treatment Unit of the Company SEPCOSUDAN (Saudi Complex) responsible for transporting and treatment waste Al-Shaab hospital and Royal Care hospital. Sample size and sampling methods include three types of questionnaire were made for COVID-19 waste workers (9 questionnaires representing the study population), for medical staff (30 questionnaires) and for companions and those around the hospital (30 questionnaires). Those surrounding the hospitals are randomly selected. Statistical Package for Social Sciences (SPSS), IBM SPSS Statistics for windows, version 20 Armonk, NY, USA: IBM Corp. was used to analyze the study data, Pearson correlation scale calculation. The numbers and percentages were tabulated in the form of the frequency distribution, mean; and standard deviation calculated using descriptive analysis. Using Cross Tab Analysis, knowing the relationship between two variables.

Ethical approval was obtained from the research ethics committee Faculty of Geographical and Environmental Sciences at the University of Khartoum and from Research Department, Ministry of Health in Khartoum state, on 23/6/2021 and from the selected hospitals as well. The purpose and objectives of the research were also explained to the participants in simple and clear words and their right to withdraw from the research whenever they wanted, and to assure the participants the confidentiality of their information and data and their names and identities not been disclosed. The collected information will not be used for any purpose other than the objectives of this study.

For secondary data, existing documents related to medical waste management during the COVID-19 pandemic represented in eight previous studies, regulations and directives issued by various international organizations and agencies have been reviewed as well as the regulations and directives issued by WHO, UNEP, ADB.

3. Results and Discussion

3.1 Biomedical waste Management in three Hospitals in Khartoum State

Biomedical waste in Al-Shaab Hospital is managed by the department of waste management and environmental health under the directives of the Ministry of Health in Khartoum State, where the waste is separated in red bags for biomedical waste, or regular waste in black bags, whereas syringes and sharp elements in safety boxes. The biomedical waste inside the wards is collected by specialized workers whereas the other places inside the hospital the waste is collected by other different workers. The biomedical waste of COVID is placed in storage rooms for a period ranging between 48-72 hours and then transported and treated by the Saudi Complex. Three workers have been assigned to deal and to collect COVID-19 pandemic in a separate storage room. The rest of the medical waste rather than COIVD 19 is also transported and treated by the Saudi Complex. The amount of medical waste in the Al-Shaab Hospital is about 2, 436 tons per week, while the pandemic waste is about 150 kilograms per week, which represented only 6% from the total amount. Despite manuals and application steps issued by world health organization

(WHO) in 2020 regarding dealing with COVID-19 pandemic waste management the observation on this study showed no any singed of adoption of any applications steps by Al-shaab Hospital. This reflects poor awareness and country responses to world health organization (WHO) manuals.

In Royal Care Hospital biomedical waste is managed by the department of waste management and Infectious diseases. The waste in the hospital is divided into three levels, high, medium and low risk, each risk level with a specific color red and yellow for high risk, blue for medium risk whereas back color for the low risk level with restrict message showing no mix with normal waste as presented in Figure 2 and Figure3, respectively.

The waste inside the hospital is collected by trained workers, wearing personal protective equipment (PPE). The waste is always placed and stored in designated rooms for a period not exceeding 24 hours. Then transferred and treated by the Saudi Complex. DuringCOVID-19 pandemic, the same sorting system was followed, addition to that they considered all waste is a carrier of the virus, and three workers were identified to deal with the pandemic waste, in a separate sorting room where sterilization is done to the waste. The waste is also transported and treated by the Saudi Complex. The total amount of medical waste in the Royal Care Hospital is about one ton per week while COVID-19 pandemic waste is about 126 kilograms per week which represented 12.6% of the total generated waste in the hospital.

Figure 2: Shows classification waste in the hospital (color coding)

Figure 3: Guidance labels for waste separation.

The results showed that Royal Care Hospital established guidance and manuals dealing with COVID-19 pandemic waste management as the directives of world health organization (WHO) in 2020.

Omdurman Maternity Hospital biomedical waste is managed by the environmental health department in the hospital. The department is one out of other four departments namely operations department, the ward department, the obstetrics department and the laboratories department. Ordinary waste is placed in black bags and medical waste in red bags. Both wastes are collected and transported to the incinerator for treatment and disposal. The extracts, placenta and tissues are placed in red bags, then stored in refrigerators for 3-4 months, then burned using an old incinerator as shown in Figure 4. Syringes are placed in the safety box and incinerated as well. Liquid waste, cotton, gauze and ash left over from the incineration process are disposed of by the Khartoum State Cleaning Authority.

During COVID-19 pandemic, three workers were assigned to deal with the waste of the isolation center in the hospital. The waste is collected, sterilized, and stored until it is incinerated. For extracts, tissues, blood samples and COVID-19 test samples; they are sterilized by placing chlorine tablets containing 16 tablets per 20 liters. Such treatment is in line with Sangkham (2020) conclusion in the study conducted in Asia in 2020 where the COVID-19 pandemic waste is sterilized with chlorine 0.5% (5000 ppm).

The amount of Royal Care Hospital waste is 1, 750 tons per week, while COVID-19 pandemic waste is 350 kilograms per week which represented 20% from the total amount.

Figure 4: Shows Omdurman Maternity Hospital incinerator

Table 1 shows the steps for managing medical waste which consist of five elements segregation, collect, storage, transport and treatment and disposal according to the world health organization (WHO).

Table 1: Evaluation of disposal steps in the three hospitals**,** according to WHO **(**2020**)**

Hospital Name	segregation at source	collect	Storage	Transport	Treatment and disposal
Al-Shaab hospital	ˣ	ˣ	ˣ	ˣ	Saudi complex
Royal Care Hospital	✓	✓	✓	✓	Saudi complex
Omdurman Maternity Hospital	ˣ	✓	✓	ˣ	Khartoum State Cleaning Authority

✓ = WHO Criteria is followed

* = WHO Criteria is not followed

Table 2 shows amounts of waste per week for each individual hospital compared to COVID 19 pandemic waste and its percentage.

Table 2: Amounts of total biomedical waste per week for each individual hospital compared to COVID 19 pandemic waste and its percentage

Hospitals	Total Biomedical Waste tones	COVID-19 pandemic waste in tones	% of COVID 19 pandemic waste
Al-Shaab	2.436	0.15	6%
Royal Care	1	0.126	12.6%
Omdurman Maternity	1.750	0.35	20%

3.2 Third party Biomedical Waste (BMW) Management Contractor

The Saudi-Sudanese Complex for Sorting, Processing and Recycling of Medical Waste was inaugurated at its headquarters in Omdurman on February 24, 2015 [15]. It was implemented in a smart partnership between the Khartoum State Ministry of Health and Vipex Saudi Arabia, the goal of this partnership comes within the framework of recycling and treating medical waste, disposing of it and benefiting from it scientifically in order to preserve the health and safety of citizens from the damages caused by these wastes [15]. The biomedical waste in Khartoum State is equal to amount of 19 tons per day, and the partnership contributed to reduce medical waste to 30%, in addition to treat 16 tons of medical waste per day. The Saudi complex is considered the first complex or plant to recycle and treat medical waste in a scientific way in the history of Sudan [15].

The interview with the director of the processing unit for the Saudi complex indicated that the medical waste is treated before the COVID-19 pandemic and they continue doing so during pandemic. He explained that biomedical waste is collected from hospitals and centers according to work schedules and by qualified workers trained on the correct ways to deal with such waste, while wearing full personal protective equipment (PPE). When the waste arrives will be received by the engineers of the treatment unit and the waste is entered into the autoclaves system. If the quantity is large, the waste is placed in refrigerators until it is processed. It is determined whether the waste has been treated or not by giving each waste a specific color (color coding for the waste upon its exit). However, after treating the waste, it comes out as domestic waste and is disposed of in the Abu Walidat landfill in Omdurman with dedicated layers for medical waste dumping. The biomedical waste always transported with dedicated vehicles from the hospital to the treatment unit to transfer station to the landfill.

The study revealed that during COVID-19 pandemic, new policies were developed and followed. Moreover, the precautions represented in accommodating a separate team of workers for COVID-19 waste additional to specific transport vehicles where designated only for COVID-19 waste. Training department trains workers, provides full single-use protective suits with a nose mask, full face mask, protective glasses and boots, and provides spray pumps for sterilization of every car additional to set of personal protective equipment (PPE) to any worker as a backup.

The waste is sterilized again by the Saudi Complex team, then weighed, filled out the transportation form as shown in Figure 5, and then transferred to the treatment unit in the complex. The waste is treated by a team dedicated to COVID-19 waste and then transferred to the landfill after treatment.

Such treatment is in line with the regulations issued by the WHO in 2020 as shown in Figures 1 and 2.

Figure 5: Shows waste transfer form from hospitals to the Saudi Complex

3.3 Demographic Characteristics and Attitude of the workers towards BMW Management

Among BMW investigated workers 77.77 % are males and 22.23 % are females. The workers age is vary from 20-25 years, 26-30 years, 31-35 years, 36-40 years to older than 41 years. Four of workers are illiterate, two have basic education and two are secondary as shown in Table3. This variation is for sure will affect their attitude to worth dealing with BMW management.

Table 3: Demographic characteristics of the waste workers

		N	%
Gender	Male	7	77.7
	Female	2	22.3
Age	20-25 years	2	22.2
	26-30years	1	11.1
	31-35 years	3	33.3
	36-40 years	2	22.2
	More than 41	1	11.1
Educational level	Illiterate	4	44.4
	Basis	2	22.2
	middle	1	11.1
	secondary	2	22.2
	university	0	
Social status	single	3	33.3
	Married	6	66.7

3.4 Knowledge Level of the waste workers on BMW Management

The level of awareness and training of waste workers is shown in the figure 7. The results indicated 77.7% of the interviewers have sufficient awareness whereas, 22.2% have poor awareness on the correct way for dealing with waste. This is due to the high illiteracy rate among them and their young age, as shown in the demographic characteristics in Table 3, as well as the poor training in the hospital (Figure 7).

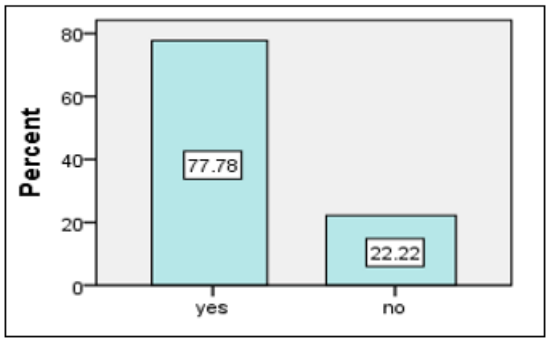

Figure 7: training of waste workers

All workers also stated that they wore personal protective equipment (PPE), and the percentage of trainees on the correct ways to wear the equipment was 77.7%, and the non-trained 22.2% as shown in Figure 8.

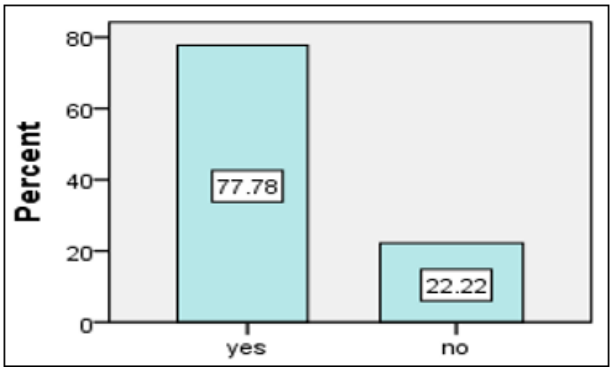

Figure 8: Correct ways to wear the equipment of awareness

The period of changing personal protective equipment (PPE) during work was done once by 55.5% of interviewed, twice by 22.2%, three and more by 22.2% as shown in Figure10. This is due to the lack of sufficient personal protective equipment and poor quality, as well as wearing the equipment at the time of the waste handling process only which resulted in prolonging the equipment life.

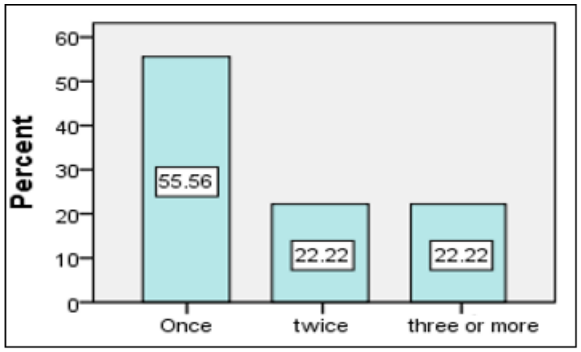

Figure 9: PPE changed during the disposal process

For those using personal protective equipment (PPE) more than a once they sterilized it after each collection process. Around 90% of the interviewers were satirized their PPE after each collection, whereas, 11.1% only did not sterilized as shown in Figure10. All of the interviewed workers (100%) sated that they had not being infected with COVID 19 during or before this study. This showed that the workers age might play a significant role in boosting immunity result in no noticed symptoms followed by poor or no regular COVID 19 test.

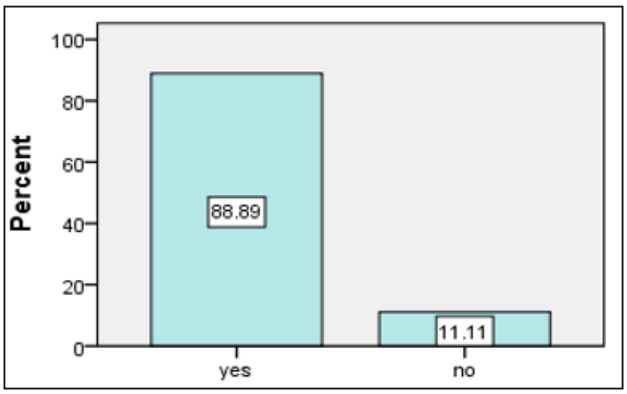

Figure 10: Sterilized after each collection process

Nevertheless, the number of workers who received the COVID-19 vaccine is only 44.4% compared to 55.5% not received the vaccine as shown in Figure 11.

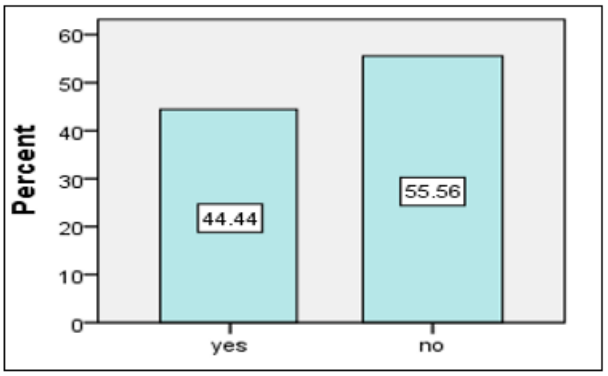

Figure 11: workers who received the COVID-19 vaccine

Statistical analysis to measure the Pearson correlation coefficient was used. The results indicted positive insignificant correlation coefficient in relation between hazards awareness and PPE importance (r =0.35). As well correlation coefficient between hazards awareness and the important of vaccine shows slightly positive significant (r = 0.47). However, a significant positive correlation (r =0.60) was obtained in three variables such as age, educational level and how often is PPE changed during the disposal process.

Using Cross Tab Analysis also been used to know the relationship between gender and wearing PPE during the working period. The results indicated that the relationship is highly significant with the male compared to female as presented in Table 4. This reflects that the percentage of PPE is higher among males than females.

Table 4: Relationship between gender and wearing PPE while working

Variables	Results

Gender	Male Female
Wearing PPE while working	77.8% 22.2%

3.5 Demographic Characteristics and Attitude of the Health Care (HC) workers towards BMW Management

Despite the high level of education and relatively young age of the interviewers as shown in Table 6, 80% of them follow the guidelines issued by the State Ministry of Health regarding infection control while treating COVID-19 patients. However, 10% of them do not apply it correctly, and 10% even they did not know the heard about such regulations as shown in Figure 12. This may be due to their young age and lack of experience as well as COVID 19 resistance's mind in many areas worldwide.

Table 5: Demographic characteristics of the HC Workers.

Item		N	%
Gender	Male	5	16.70%
	Female	25	83.30%
Age	20-25 years	7	22.3
	26-30years	7	22.3
	31-35 years	9	30
	36-40 years	5	16.6
	More than 41	2	6.6
Educational level	Illiterate	0	0
	Basis	0	0
	middle	0	0
	secondary	0	0
	university	30	100%

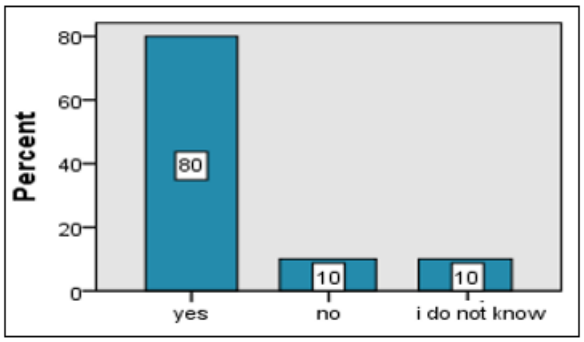

Figure 12: guidelines issued by the ministry of health regarding infection control

Most of interviewers (96.6%) in health care's (HCs) indicated that Medical waste is separated from COVID-19 waste using color coding for containers and bags as shown in Figure 13. The containers are sterilized after the waste collection process (Figure 14).

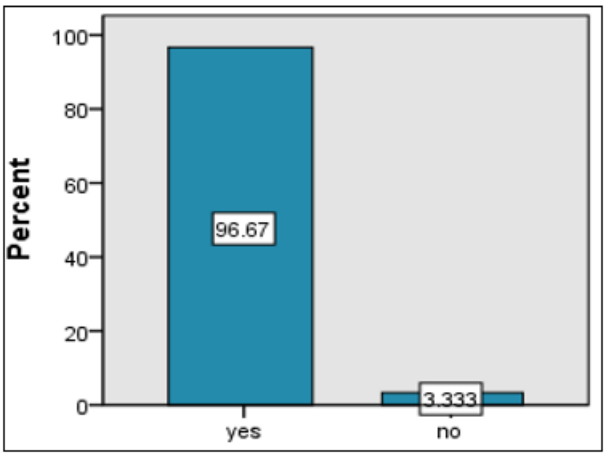

Figure 13: medical waste is separated from COVID-19 waste

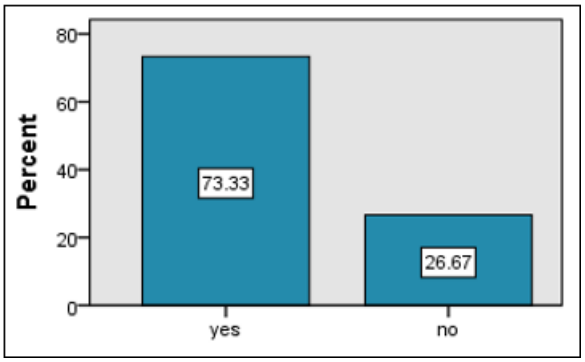

Figure 14: Containers are sterilized after the waste collection process

During COVID 19 pandemic all concerned in worldwide received support for the pandemic including Sudan[3]. However only 16.6% confirmed such support whereas 56.6% indicated that no support to help manage medical waste and 26.6% even they don't know about such support as shown in Figure 15.

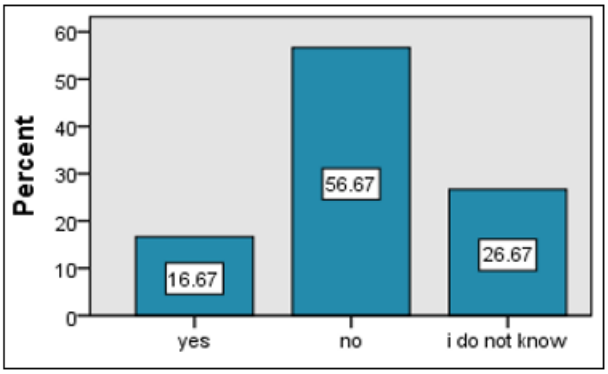

Figure 15: Support to help manage medical waste

3.6. Demographic Characteristics and Attitude for the Co-patients in the three hospitals towards BMW Management

Interview was conducted with a random sample of a total of 30 co-patients in the three hospitals for demographic characteristics as shown in Table 6.

Table 6: Demographic characteristics of for the Co-patients in the three hospitals

Item		N	%
Gender	Male	17	56.7
	Female	13	43.3
Age	20-25 years	3	9.9
	26-30years	5	16.7
	31-35 years	5	16.7
	36-40 years	11	36.7
	More than 41	6	20
Educational level	Illiterate	1	3.3
	Basis	2	6.7
	middle	2	6.7
	secondary	4	13.3
	university	20	66.7
	above university	1	3.3

Thus out of the total number of the interviewers only 16.6% of them have excellent awareness of the dangers of the COVID 19 pandemic and its remnants, while 50% of them have good awareness whereas 33.3% have poor awareness as shown in the figure 16.

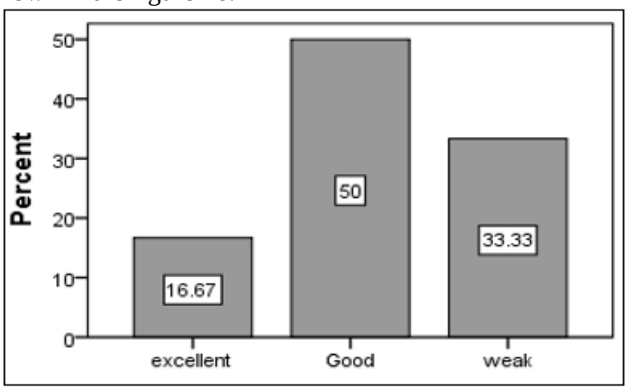

Figure 16: awareness of the dangers of the corona virus

The study results indicated that 70% of the interviewers wear personal protective equipment (PPE) such as masks and gloves, and 30% of them didn't wear any them as shown in the figure 17.

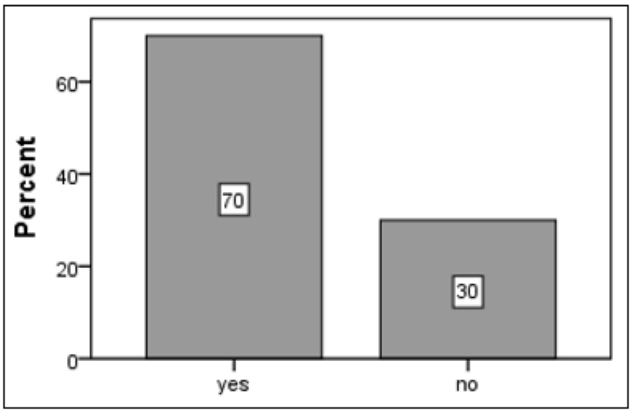

Figure 17: wear personal protective equipment

Among the interviewers 63.3% reported wearing one mask per day without changing it and 10% of them changed every 6 hours and 13.3% changed every 4 hours and 13.3% changes every two hours as shown in the Figure18.

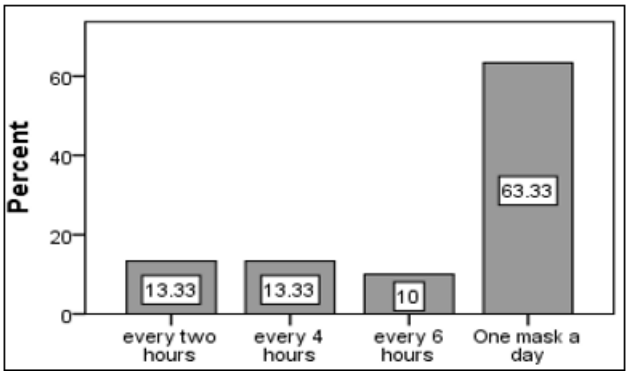

Figure 18: Periods of change mask

The survey results indicated that out of the interviewers only 16.6% infected by COVID 19 pandemic before this survey (Figure 19). However, 83.3% reported that none of them or their family member had infected with COVID 19 pandemic.

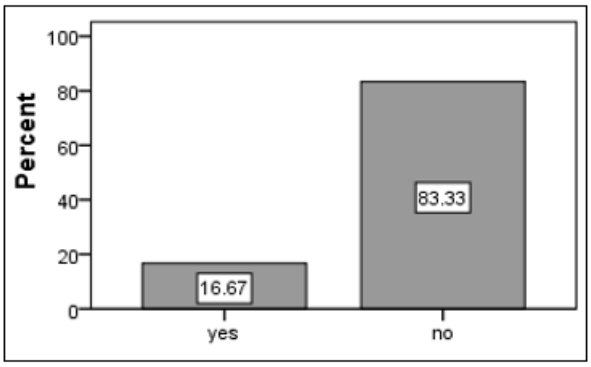

Figure 19: COVID 19 pandemic infection rate

Strong significant positive correlation coefficient (r= 0.93) was obtained between educational level and separation of household waste from medical waste and the use of PPE.

This study indicated that there is clear difference in the waste management processes before and after the pandemic. The issues of the regulations by the Ministry of Health and the process of sorting, collecting and intensifying sterilization are well noticed by most of the interviewers in this survey. Despite that there are huge differences and lack of strict adherence by medical personnel to the sorting process, which increases the burden and cost on the waste management department in the studied hospitals to reduce the risk among the workers and co-patients.

The government hospitals suffers from poor management and lack of available resources compared to private hospitals as private sector provides a section dedicated to examining and treating workers on how to deal.

4. Lessons Learned

One of the most important lessons learned that waste management system was not in a position to handle the volume of waste generated by healthcare facilities in the three hospitals and thus in Sudan during COVID 19 pandemic as the number of hospitalizations skyrocketed. Every locality or urban system's capacity to handle the growing amounts of medical waste is contingent upon a number of factors, including the formulation and implementation of policies; the

methods and facilities currently in place for collection, transportation, disposal, and treatment; the processes and capabilities currently in place for treating medical waste; and the funds allotted for medical waste management are limited. Therefore, effective medical waste management must include the proper identification, collection, separation, storage, transportation, disposal, and treatment. Thus, another area that requires special attention is productive medical waste administration, which includes knowing the required standards, following disinfection rules, safeguarding staff, and the related. Another matter of concern during the COVID-19 pandemic was the incapacity of treatment facilities in some regions, which led to the illegal dumping of waste in suburban areas and uncontrolled burning. Taking into account the long-term health and environmental implications, the improper waste disposal perpetuated by the pandemic could lead to environmental desolation in the post-pandemic world.

The COVID-19 pandemic was much more than just a worldwide health emergency; it also added both acute and chronic shocks and had an impact on every system of infrastructure, the economy, and society at large. It is difficult to get back to normal; therefore, a long-term, methodical, and comprehensive plan for the solid waste infrastructure must be developed.

Some of the major obstacles in addressing the COVID-19-related waste were identified as the limited resources and technology options, as well as the limited adaptability and capability of the current waste generation, collection, transportation, and disposal systems for managing the increased volume of healthcare waste [17, 18]. It takes more than one tactic or activity to successfully reduce the hazards related to waste. Combining a number of the several tasks included in the integrated solid waste management (ISWM) model could be the most effective strategy. Covering all the sources, actions, and facets related to waste management, the ISWM represents a systematic approach to the sustainable management of solid waste. The five R's of waste reduction at the source, product reuse, material recycling, energy recovery, and residual management are referred to as the ISWM hierarchy in this context, and it may be a useful tool [19]. In contrast to the more complex reactive approach, which treats waste after it has been produced, this strategy encourages a less complex proactive waste management strategy that involves anticipating problems and preventing them from occurring by producing less waste or zero waste. In addition, improved healthcare waste prediction models and tools—such as a non-linear, multi-level regression model—along with the related social and economic indicators would be helpful in the planning, designing, budgeting, and optimization processes, as well as in boosting sustainability in the healthcare waste management industry.

The COVID-19 pandemic led to a notable surge in the demand for single-use plastic due to the necessity of personal protective equipment (PPE), sanitary napkins, and other healthcare supplies, as well as packaging. Supply chain problems also arose in this scenario, particularly since these systems depended on disposables. Plastics were crucial to our survival during the pandemic, but the amount of unmanaged plastic waste that is piling up worldwide is causing ecological havoc because it could result in micro-plastic pollution, which could have long-and short-term effects on the environment and human health [20]. Managing plastic waste has never been easy. The majority of the plastic garbage generated during the COVID-19 epidemic was burned or landfilled, with very little of it being recycled due to therefore, even if it would be difficult, quick action is needed to move toward sustainable consumption and production as well as to investigate recycling and alternative treatment options for plastic waste management. In this environment, moving away from the conventional and unsustainable linear economy method and toward the circular economy approach has drawn a lot of attention recently In order to minimize the consumption of energy and natural resources, achieve zero waste goals, and lessen the associated environmental impacts, the circular economy encourages cyclical flows of resources in the production-consumption system within a closed loop. It also offers opportunities to identify best practices and, consequently, move towards sustainability.

Some researchers have drawn attention to the fact that the lack of adequate policies, protocols, and guidelines in the waste infrastructure prevented authorities from acting quickly to collect, classify, transport, and dispose of waste, especially in the early stages of the crisis [21, 22]. Among the problems noted are the following: unauthorized waste pickers posed a risk to the community; waste operators struggled to maintain manual collection and sorting procedures; and unlawful waste disposal in some locations created an extra risk to the neighborhood. It is consequently crucial to incorporate appropriate trash disposal procedures and give the populace protected logistics.

Similar to other measures discussed previously, it is appropriate to enforce global waste management and local authorities to critically revisit and improve the existing policies, protocols, guidelines, and best practices as needed to be able to improve the effectiveness of the post-pandemic waste infrastructure. Instead of approaching emergency management from a business-as-usual approach, there needs to be a thorough analysis of the short-term, long-term, and absolute worst-case scenarios when developing policies to improve waste management's resilience and efficiency. Examples include reviewing international and national guidelines for the management of biomedical waste; updating emergency preparedness measures in the waste infrastructure; assigning temporary, cost-effective facilities that can be used to continue waste management operations; reviewing local collection, handling protocols, and sanitation worker protection; prohibiting the sorting of waste by hand; improving funding for current waste management initiatives; giving consumers financial incentives to reduce waste generation; expanding public-private and national-international partnerships; and encouraging extended producer responsibility (EPR) and collaborations.

Because the COVID-19 pandemic altered the dynamics of trash generation beyond the capacity of the current waste management systems, it had a substantial influence on the waste infrastructure. The usage of required personal protective equipment (PPE) during the COVID-19 pandemic was a major factor in the significant increase in infectious medical waste produced by healthcare facilities worldwide.

The assessment carried out here indicates that there was an upward tendency in the residential waste streams, partially offset by downward trends in other waste streams, namely the ICI waste stream.

Although it is acknowledged that the COVID-19 pandemic differs from previous emergencies in terms of its nature and effects, it is now time to respond by using the lessons learned to pinpoint the shortcomings in the waste management system and implement the required changes. This study suggested five major long-term opportunities for building a resilient and sustainable waste management system: treating healthcare waste as a critical area of focus and managing it appropriately; promoting the integration and decentralization of waste management facilities; creating innovative and systematic methods and tools for waste quantification; moving toward a circular economy approach; and updating regulations to increase the efficiency of the post-pandemic waste management infrastructure. Long-term planning, designing, and implementation of integrated waste management strategies would benefit from these lessons learned, as we move toward more resilient and sustainable urban environments. On the other hand, creating such an integrated waste management system is extremely difficult. Policies, funding, social acceptance, multidisciplinary knowledge and experience, and behavioral adjustments are all necessary.

5. Conclusion and recommendations

Public health must be protected from environmental hazards by every healthcare sector through applying proper biomedical waste (BMW) management. During this COVID-19 pandemic, many government agencies published guidelines for the management of waste produced during the treatment, diagnosis; and isolation of COVID-19 patients. It must be managed properly to prevent the severe risk of contamination and disease transmission.

A survey study designed to investigate biomedical waste management during COVID-19 pandemic through investigating the knowledge, attitudes; and practices done by different stakeholders in three dedicated hospitals in Khartoum State namely; Al-shaab Hospital, Royal care Hospital and Omdurman Maternity Hospital.

It can concluded that, the ongoing pandemic and not expected to end soon, and thus the increase in medical waste infectious with the virus and personal protective equipment with poor resources and mismanagement leads to catastrophic results for the environment and society and to create a healthy and safe environment and a society aware of the danger of medical waste in general and waste of the COVID-19 in particular. The study recommends the following:

- Continuous support from the Ministry of Health for the safe disposal of medical waste.
- Continuous awareness and training for waste management workers and the community about the dangers of medical waste.
- Provide personal protective equipment for waste workers and be of good quality and according to the specifications recommended by the World Health Organization.
- Providing the COVID-19 vaccine and other vaccines for workers and their families inside hospitals.
- Providing resources for waste management departments in hospitals.
- Cooperation and solidarity of medical staff at all functional levels on waste separation.
- Providing fuel specifically for incinerators inside hospitals and waste transport vehicles with periodic maintenance.
- Contracting with BMW management specific contractors to manage medical waste.

6. References

[1] WHO, Healthcare waste report February 2017.
[2] United Nations Environment Programmer **(**UNEP) Report Waste management is an essential public service in the fight to beat COVID-19 in 24 Mar 2020.
[3] United Nations Environment Programmer **(**UNEP) Report Waste Management during the COVID-19, August 2020.
[4] Ahmed Ali Hassan, Terry Tudor, and Mentore Vaccari / HealthCare Waste Management: A Case Study from Sudan, 5 August 2018.
[5] Florin-Constantin Mihai / Assessment of COVID-19 Waste Flows During the Emergency State in Romania and Related Public Health and Environmental Concerns, 28 July 2020.
[6] Md. Sazzadul Haque, Shariar Uddin, Sayed Md. Sayem, Kazi Mushfique Mohib /
[7] COVID-19 virus disease 2019 (COVID-19) induced waste scenario: A short overview, 2020.
[8] Sarawut Sangkham / Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia, 2020.
[9] Jie Peng MM, Xunlian Wu, Rongli Wang MM, Cui Li MM, Qing Zhang BM, Daiqing Wei MD / Medical waste management practice during the 2019-2020 novel COVID-19 pandemic: Experience in a general hospital, 2020.
[10] Asian Development Bank (ADB) / managing infectious medical waste during COVID-19 Pandemic, 2020.
[11] Irin Hossain, Ashekur Rahman Mullick, Shazly Bari, Mohammad Tahsin Islam / Pandemic COVID-19 and Biomedical Waste Handling: A Review Study May 2020.
[12] Sadia Ilyas, Rajiv Ranjan Srivastava, Hyunjung Kim /Disinfection technology and strategies for COVID-19 hospital andbio-medical waste management, August 2020.
[13] Shobhana Ramteke, Bharat Lal Sahu / Novel COVID-19 virus disease 2019 (COVID-19) pandemic: considerations for the biomedical waste sector in India/ 25 July 2020.
[14] Long D. Nghiem, Branwen Morgan, Erica Donner, Michael D. Short / The COVID-19 pandemic: Considerations for the waste and wastewater services sector 2020.
[15] Khartoum State Government website http: //www.khartoum. gov. sd.
[16] Sudan News Agency website: Article dated 26/2/2015.
[17] Ramteke S., Sahu B. L. Novel coronavirus disease 2019 (COVID-19) pandemic: Considerations for the biomedical waste sector in India. Case Stud. Chem. Environ. Eng.2020; 2: 100029.

[18] Klemeš J. J., Van Fan Y., Tan R. R., Jiang P. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. *Renew. Sustain. Energy Rev.*2020; 127: 109883.
[19] Tchobanoglous G., Theisen H., Vigil S. *Integrated Solid Waste Management: Engineering Principles and Management Issues.* Irwin McGraw Hill; New York, NY, USA: 1993.
[20] Ilva A. L. P., Prata J. C., Walker T. R., Duarte A. C., Ouyang W., Barcelò D., Rocha-Santos T. Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. Chem. Eng. J.2020; 405: 126683.
[21] Sharma H. B., Vanapalli K. R., Cheela V. R. S., Ranjan V. P., Jaglan A. K., Dubey B., Goel S., Bhattacharya J. Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. Resour. Conserv. Recycl.2020; 162: 105052. doi: 10.1016/j. resconrec.2020.105052.
[22] Ragazzi M., Rada E. C., Schiavon M. Municipal solid waste management during the SARS-CoV-2 outbreak and lockdown ease: Lessons from Italy. Sci. Total Environ.2020; 745: 141159.