STUDIA UBB AMBIENTUM, LXVIII, 2023, 1-2, pp. 105-127
(RECOMMENDED CITATION)
DOI:10.24193/subbambientum.2023.06

MEDICAL WASTE MANAGEMENT BEFORE AND DURING THE COVID-19 PANDEMIC IN ROMANIAN HOSPITALS

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ABSTRACT. The proper management of medical waste is very important, throughout its life cycle, from correct collection to final recovery or disposal. The hazardous potential of this waste needs to be known by all those who handle it to protect their health, the health of the general public, and the environment. Studying them with a view to their correct management also aims to reduce the potential risks that may arise from their improper handling. The objective of the paper was to present the influence that the COVID-19 pandemic has had through the increased amounts of waste generated by health facilities to limit the spread of the virus and to treat patients infected with SARS-CoV-2. The work of the health units mainly focused on measures to limit the spread of the virus through the use of personal protective equipment, testing of the population, treatment of patients infected with SARS-CoV 2 and other patients who needed other types of medical services. To highlight how the pandemic influenced the amount of medical waste produced, three health facilities of various types were analyzed: an Infectious Diseases Hospital, a Municipal Hospital, and a hospital for a small-medium city. Data from the months when the pandemic waves started were used and compared with similar months in previous years. Hazardous medical waste disposal costs were estimated and graphs were plotted to show the unprecedented increase in the amount of medical waste generated during the SARS-CoV 2 - Covid-19 pandemic.

Key words: *pandemic, SARS-CoV 2 (COVID-19), hazardous waste, protective equipment, medical waste management.*

INTRODUCTION

Services that provide care and health to the population, whose main objective is to reduce health problems through the activities carried out in medical practices, generate significant quantities of waste, which, based on their properties, can be classified as non-hazardous or hazardous waste for human health and the environment.

The waste resulting from healthcare activities, as hazardous waste, presents a multitude of risks with a high potential for infection and injury to medical staff and other people who come into contact with it, as well as to the economic agents involved in its management. For hazardous waste, these risks may be higher than for other types of waste classified as non-hazardous and generated from the same type of activities.

A poor management system for the management of medical waste poses a risk to healthcare staff, both patient care staff (as doctors and nurses) and ancillary healthcare staff (as carers and cleaning staff), waste disposal staff, patients, and their relatives. Improper disposal of medical waste can also lead to environmental contamination.

A poor system can increase the costs of managing medical waste by increasing disposal costs due to large quantities of waste that, if not properly sorted, will be disposed of as hazardous waste, in addition to costs related to the payment of damages to employees, sick leave, or possible penalties for non-compliance with legislation. Costs of medical waste management can be reduced, and hazards caused by the presence of hazardous medical waste by implementing appropriate waste management measures, starting with proper collection of the waste, depending on its type and hazardousness.

The SARS-CoV-2 pandemic has also changed people's behaviours, from rigorous hygiene to the use of disposable items, which has also led to an increase in the amount of waste produced, with a significant impact on ecosystems (Silva et.al., 2021).

In addition to controlling the spread of COVID-19, managing large quantities of plastic and medical waste has been a major challenge for the current waste management and disposal system (figure 1).

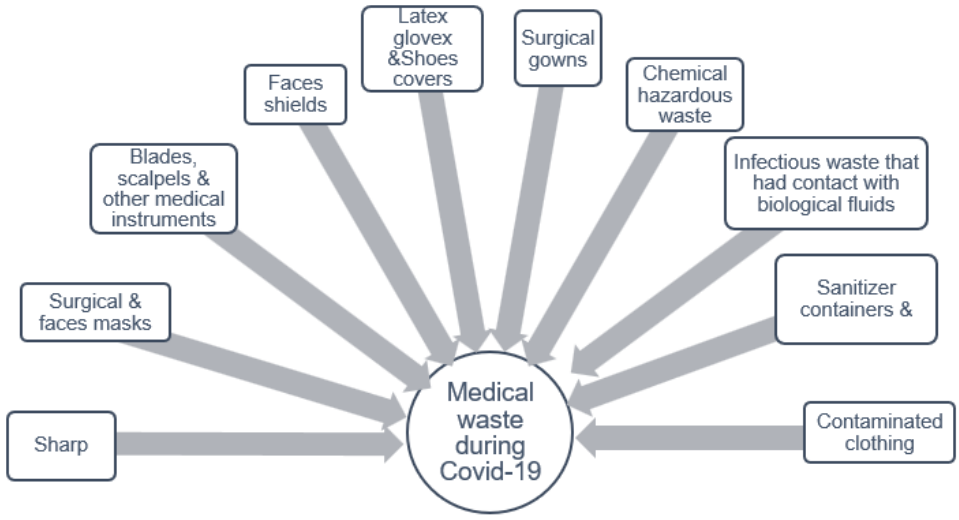

Fig.1. *Biomedical waste generation during COVID-19 (after Dehal et.al., 2022)*

Increasing amounts of medical waste can become a problem for health and the environment as it is a source of infection. The increase is largely due to the use of disposable personal protective equipment.

Globally, an estimated 129 billion masks and 65 billion gloves were used each month (Prata et al., 2020).

MEDICAL WASTE MANAGEMENT IN ROMANIA

In Romania, the management of hazardous medical waste began during the Second World War, and in the 1950s, the first disposal facilities, crematoria, were built to deal with the risks generated by medical waste. The term ‘medical waste’ began to be used after 1970. A significant change in medical waste management occurred after 1989. To align with European standards, the Order of the Minister of Health No 219/2002 was issued, containing for the first time the “Methodology for Data Collection for the National Database”. After 10 years, another order on the management of medical waste was issued, the Order of the Minister of Health No. 1226/2012, which approved the technical norms on the management of waste from medical activities and the methodology of data collection for the national database on waste resulting from medical activities (Curea et.al, 2021).

From an environmental point of view, the management of medical waste in Romania is carried out according to the European List of Waste (LoW), transposed into Romanian legislation by the Government Decision, GD 856/ 2002, updated several times in recent years. According to the LoW and the order of the Ministry of Health, hazardous medical waste codes are found in category 18 and depending on the subcategories they belong to, they can be collected and packaged only in containers accepted by the rules in force (Table 1, after Curea et.al., 2021; Order 1226/2012, GD856/2002).

Table 1. *Types of packaging and containers used for medical waste and their characteristics (after Curea et.al., 2021; Order of the Minister of Health No. 1226/2012; GD856/2002)*

Waste code	Packaging	Example of packaging
18 01 01 & (18 01 03*) sharps	Sharps waste identified by 18 01 01 and 18 01 03* shall be collected separately in the same rigid plastic container resistant to mechanical action.	
18 01 02 (18 01 03*) Body parts and organs including blood bags and blood preserves	Pathological waste falling under code 18 01 02 (18 01 03*), destined for incineration, must be collected in rigid cardboard boxes with a polyethene bag inside, which must be securely closed, or in rigid plastic boxes with a tight-fitting lid, bearing a yellow marking, specifically designed for this category of waste and disposed of by incineration.	
18 01 03* wastes whose collection and disposal is subject to special to prevent infection	For infectious wastes which are not sharps identified with 18 01 03*, cardboard boxes containing yellow polyethene bags or polyethene bags marked yellow or yellow shall be used.	

Waste code	Packaging	Example of packaging
18 01 04 wastes whose collection and disposal are not subject to special requirements to prevent infection (for example dressings, plaster casts, linen, disposable clothing, diapers)	To be collected in black bags marked Non-hazardous waste	
18 01 06* chemicals consisting of or containing hazardous substances	Chemical hazardous wastes from sanitary facilities identified by code 18 01 06* are collected in special containers, marked according to the hazard (“Flammable”, “Corrosive”, “Toxic”, etc.).	
18 01 07 chemicals other than those mentioned in 18 01 06	Non-hazardous chemical waste identified by 18 01 07 from sanitary facilities shall be collected separately in the original packaging. In the case of waste from diagnostic equipment containing dangerous chemicals in negligible concentrations, the instructions specific to the equipment shall be followed. This waste shall be recovered or disposed of as non-hazardous waste.	
18 01 08* cytotoxic and cytostatic medicines	Waste resulting from the administration of cytotoxic and cytostatic treatments represented by used syringe bodies with or without needles, bottles and infusion systems, contaminated soft materials, contaminated personal protective equipment, etc. must be collected separately, packed in safe disposable containers with lids and disposed of separately.	

Waste code	Packaging	Example of packaging
18 01 09 medicines other than those mentioned in 18 01 08	This waste is collected in cardboard boxes with bags inside.	
18 01 10* amalgam waste from dental care	Dental waste identified by code 18 01 10* represented by dental amalgam shall be collected separately in sealable containers and taken back by authorized firms for recovery.	

The stages of the medical waste management system in Romania

Step I: After identifying the types of waste generated in the health facility, they will be classified in one of the categories presented in GD no. 856 / 2002, on waste management records and for the approval of the list of waste, including hazardous waste and the assignment of a waste code, respectively in Order no. 1226 / 2012 for the approval of the Technical Standards on the management of waste resulting from medical activities and the Methodology for data collection for the national database on waste resulting from medical activities (figure 2).

The stages of the medical waste management system in Romania are the following:

- Step I. Identification of sources of medical waste generation and types of waste generated
- Step II: Collection of medical waste
- Step III Packaging of medical waste
- Step IV. Temporary storage of medical waste
- Stage V. Transport of healthcare waste
- Step VI: Treatment and disposal of waste arising from healthcare activities
- Step VII. Recording the quantities of waste generated by healthcare establishments
- Step VIII. Staff training and education
- Step IX. Drawing up the plan for the management of healthcare waste
- Step X. Implementation of a hazardous waste management system for healthcare waste

Fig. 2. *The stages of the medical waste management system in Romania*

Step II: Collection is a very important step because if hazardous waste is mixed with non-hazardous waste, it can contaminate them. Disposal costs will also increase, as hazardous waste requires different, more careful management and the possibility of environmental contamination, which will pose a risk to the personnel handling it and ultimately to the population. These are the reasons why producers of medical waste are obliged to collect medical waste separately at the place of production to facilitate the specific treatment/ disposal of each type of waste, an obligation imposed by legislation.

An additional responsibility for medical waste generators is to avoid mixing different types of hazardous waste or combining hazardous waste with non-hazardous waste. If the collected waste is not segregated by each hazardous type or is mixed with non-hazardous waste types, the entire quantity of waste is treated as hazardous waste, with increased costs for waste management.

Step III: The packaging/container in which the collection is made and comes into direct contact with hazardous waste from medical activities is disposable and is disposed of with the contents.

The codes used for the packaging/containers in which medical waste is collected are: (i) yellow for hazardous medical waste (according to art. 7 and 8 of Order no. 1226 / 2012); (ii) black for non-hazardous waste (according to art. 7 Order no. 1226 / 2012).

Step IV: Temporary waste storage should be carried out according to the categories of waste collected at the place of production. In each hospital or health care facility, there must be a space for the temporary storage of medical waste, consisting of two appropriately sized compartments, one for hazardous waste and the other for non-hazardous waste.

Step V: The transport of hazardous medical waste within the premises of the medical facility where it was produced is done on a separate route from that of patients and visitors. Hazardous medical waste is transported using special trolleys or mobile containers. Both the vehicles and the mobile containers used for the transport of medical waste are cleaned and disinfected after each use at the place of unloading, using authorized biocidal products, as demonstrated by a written document. The transport of hazardous medical waste outside the healthcare establishment where it was produced is carried out by an authorized economic operator for the management of such waste.

Step VI: The processes and methods used for the treatment and disposal of waste resulting from medical activities must not endanger the health of the

population and the environment, and it is necessary to ensure the rapid and complete destruction of factors with the potential to harm the environment and the health of the population.

The methods used for the disposal of waste resulting from medical activities in Romania, according to the legislation, are incineration, thermal decontamination at low temperatures, and finally, landfilling for those wastes that have become non-hazardous through the previously applied treatments.

***Step VII**:* Each establishment that is a producer of waste is obliged to keep separate records for each category of waste. For this purpose, a person designated by the coordinator of the environmental health protection activity keeps records of waste by type and is responsible for filling in the forms provided for in the legislation drawn up by the Romanian Ministry of the Environment. Medical units submit an annual report on their waste management activity following the methodology laid down in the legislation drawn up by the Romanian Ministry of Health.

The forms for the transport and disposal of hazardous medical waste leaving the health facility for disposal purposes shall be drawn up and completed in compliance with the provisions of Government Decision No. 1.061/2008 on the transport of hazardous and non-hazardous waste on the territory of Romania.

***Step VIII**:* Each healthcare facility is required to provide training and continuing education for employees on medical waste management in any of the following: (a) upon hiring; (b) upon taking on a new job assignment or moving to another job; (c) upon introduction of new equipment or modification of existing equipment or introduction of new technology; (d) upon recommendation of the person designated to coordinate the waste management activity resulting from the existing health care facility, who has found irregularities in the application of the code of procedure or upon recommendation of the environmental health protection activity coordinator; (e) periodically, whether or not changes in the medical waste management system have occurred.

Staff involved in the management system of hazardous medical waste should be familiar with: the types of waste produced in the health care facility; the risks to the environment and human health at each stage of the medical waste disposal cycle; the medical waste management plan, with internal regulations and codes of procedure for the segregated collection by category, temporary storage, transport and disposal of hazardous medical waste, and the procedures/protocols applicable in the event of accidents or incidents occurring in the waste management activity.

Studies carried out by various researchers have concluded that successful management of medical waste requires additional thinking and planning by all actors involved in the waste cycle. Workers and managers need to receive information, materials, support, and appropriate training to ensure the safe management of medical waste. At the same time, proper management of infectious disease materials needs to be developed to close identified gaps so that rapid and correct action can be taken to ensure public safety. In general, staff involved in medical waste management have information on how to manage this waste, but there is also a need to improve the education of workers on the management of this type of waste, the risks to which they, the population (directly or indirectly), and environmental factors are exposed. This improvement could be achieved through information and education courses, seminars, brochures, and guides as explicit as possible and with clear examples (Le et.al., 2018, Bhagawati et.al., 2015, Çalıs et.al., 2014).

***Step IX**:* All healthcare facilities or other medical waste generators are required to draw up a medical waste management plan. The medical waste management plan must include information about the healthcare facility, the current situation regarding medical waste management, and measures to reduce the quantity of waste generated.

***Step X**:* For efficient management of the waste resulting from the medical activity, solutions are proposed, such as: educating the staff involved, followed by the implementation of a plan to reduce the quantity of waste.

The measure of particular importance is source separation by waste type because they have different properties (Dehghani et al., 2019). To minimize medical waste, one can (i) choose products that generate less waste (e.g., packaging); (ii) choose suppliers that will take containers in which certain substances have been delivered to be reused as packaging; (iii) prevent waste, choose the waste treatment administration procedure, and correct the dosage of substances used in cleaning and disinfection (Padmanabhan & Barik, 2019).

Hsu et al. (2021) presented the results of an audit, conducted in an emergency unit in a community hospital in the U.S. in January 2020, which clarified the composition of medical waste produced in the emergency unit, and improved the disposal of this waste to reduce carbon emissions and disposal costs. The waste, the quantities generated, and their hazardousness were determined and classified. The conclusion, which is also valid in other countries, was that the implementation of audits in wards and medical units can improve the medical waste management system by reducing medical waste, with a direct contribution to reducing environmental impact and greenhouse gas emissions.

Methods used for the disposal of hazardous waste from medical activities in Romania

The main method of disposal of hazardous medical waste is incineration. Through incineration, medical waste is burned in incinerators at high temperatures (generally above 1000^0C) (Order 756/2004, approving the technical regulation on waste incineration) and the flue gases are purified before reaching the atmosphere. The result of the incineration process is ash, which will have a substantially reduced volume compared to the initial volume of the medical waste. Following incineration, the initially hazardous medical waste becomes biologically inert, and the various pathogens contained in it are destroyed.

Modern incinerators also have systems for recovering the thermal energy produced by burning waste. Some waste has calorific power that helps the process. This energy can be partly reused in the incineration system, but the remaining energy must be recovered as either thermal or electrical energy. The main incinerators used for the destruction of medical waste are (i) pyrolytic, (ii) fixed or mobile grate incinerators with post-combustion chambers, and (iii) rotary kilns.

For less hazardous medical waste, such as sharps, protective clothing, and others, thermal decontamination can also be used, at much lower temperatures than those used for incineration and therefore less expensive (Ilyas et al., 2020).

Thermal decontamination at low temperatures can be done by exposing for 30-120 minutes the shredded waste to (i) hot air disinfection; (ii) moist heat (steam) disinfection; or (iii) microwave disinfection. (Order 1226/2012). Decontamination of medical waste is carried out after the waste has been crushed into small pieces and also an initial decontamination step to make the operation more efficient. The temperatures used for decontamination are most often between 100 – 300^0C (Order 1226/2012) the aim being to destroy the biological agent.

Waste landfilling is the last acceptable waste management solution in Europe. Medical waste cannot end up in landfills in the form it comes from health facilities because it produces a biological and chemical hazard to the environment and human health. Medical waste can only be disposed of in landfills after pre-treatment to ensure its biological neutralisation (see fig.3).

It can be seen that of the technologies presented by Thind et al. (2021), autoclaving is the technology with the lowest construction and operational costs and also the lowest environmental impact. The treatment technology is accepted in Romania by Order 1226/2012 and can be chosen for the part of the medical waste, as it involves much lower costs than incineration.

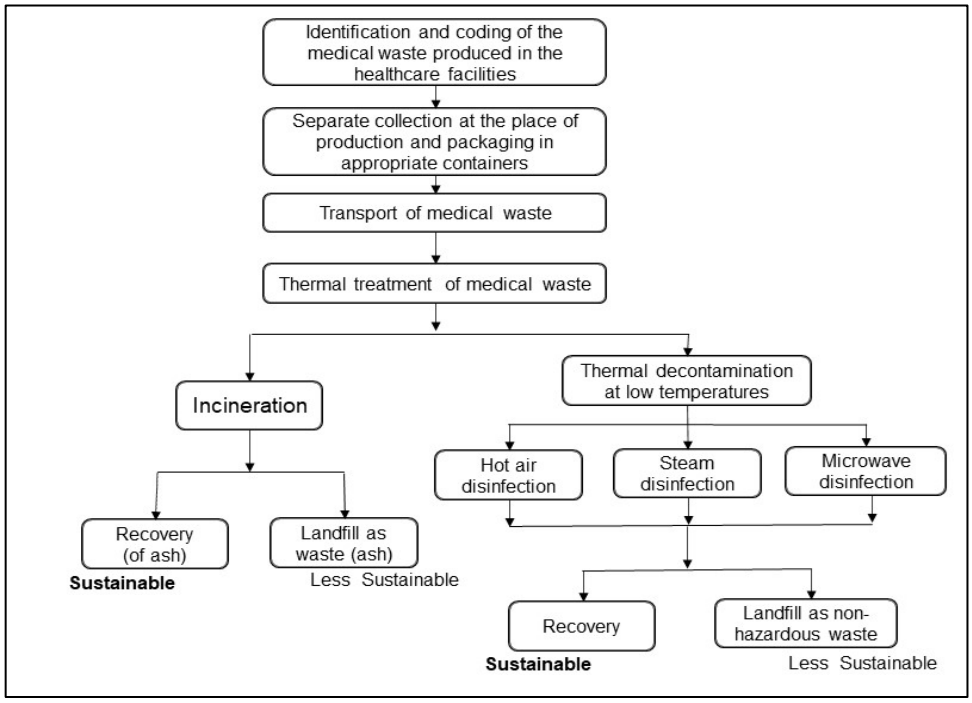

Fig.3. *Methods used for the disposal of hazardous waste from medical activities in Romania*

Thind et al. (2021) made a comparison between different methods of acceptable thermal treatment of medical waste, which they summarized in Table 2.

Table 2. *Comparison between thermal treatment methods of medical waste (Source: Thind et.al., 2021)*

Tip of technology	Capacity	Installation costs	Operation cost	Pollution (air & water)	Volume reduction
Autoclave	●●●●	●●	●●●	●	●●
Microwave	●●	●●	●●	●	●●
Incineration	●●●●●	●●●●	●●●●	●●●●●	●●●●●
Pyrolysis	●●●	●●●●●	●●●●●	●●	●●●
Plasma	●●●	●●●●●	●●●●●	●●	●●●
Chemical disinfection	●●●	●●●	●●●	●●●	●●●

Estimated costs of medical waste management in Romania

The costs vary, depending on different factors that influence the waste management calculation values (table 3): (i) the amount of waste generated by the health facility; (ii) the costs of packaging, transport, and infrastructure; (iii) the operating conditions of the disposal equipment.

An example of a calculation of the costs generated by the treatment/ disposal of medical waste is presented below, choosing the technique of treatment by decontamination at low temperatures, data provided by AKSD Romania, a company specialized in hazardous waste disposal, which has implemented environmental management systems (ISO 14001), quality management (ISO 9001) and occupational health and safety management (OHSAS 188001).

Table 3. *Cost of disposal of 1 kg of hazardous waste by thermal treatment at low temperatures (Source AKSD Romania)*

Month / year 2021	Amount of waste treated		Water consumption [m^3]	Cost/m^3 drinking & waste water	Natural gases consumption [m^3]	Cost/m^3 natural gases	Electricity consumption [kWh]	Cost/ 1kWh	Cost/1kg municipal waste treatment	Cost/1 kg hazardous waste treatment
	entry [t]	exit [t]								
August	122	126	8370	8.09	6241	2.43	6689	0.26	0.89	1.44
July	130	146	11044	8.09	7565	2.43	7625	0.26	0.89	1.18
*The waste coming out of the steriliser is heavier, by 5-10 %, depending on the type of waste (whether it retains water or not).										

Medical waste management during the new SARS-CoV-2 pandemic

The COVID-19 pandemic has put countries' healthcare systems to the test, including because of the huge amount of medical waste generated. Treatment systems, especially incinerators, were stretched to the limit, and the average daily amount of medical waste from infected patients was well above the average daily amount of medical waste from before the COVID-19 pandemic. Thind et al. (2021) studied the effects of the generation of medical waste during the pandemic period on the environment, showing the variation of medical waste generation according to the number of cases (figure 4). Because of the large amounts of waste generated, the emissions to the environment from waste incineration and other infectious waste treatment processes have been substantial, and the massive releases of heavy metals and other pollutants resulting from these types of activities have begun to become hazardous to human health (Thind et al., 2021).

The city of Wuhan in China generated nearly 247 tonnes of medical waste per day at the peak of the pandemic, almost six times more than before the pandemic. The frequent use of personal protective equipment and its mostly

plastic composition led to the overuse of waste management systems and sometimes their failure.

In order to dispose of this amount of waste safely and as quickly as possible, the Chinese authorities installed 11 mobile incinerators and took strict measures to dispose of this amount safely. Improper management of medical waste not only impacts the environment through pollution but also impacts the health of the population through the spread of infectious diseases (Singh et al., 2020). Peng et al. (2020) also presented some medical waste management practices during the COVID-19 pandemic.

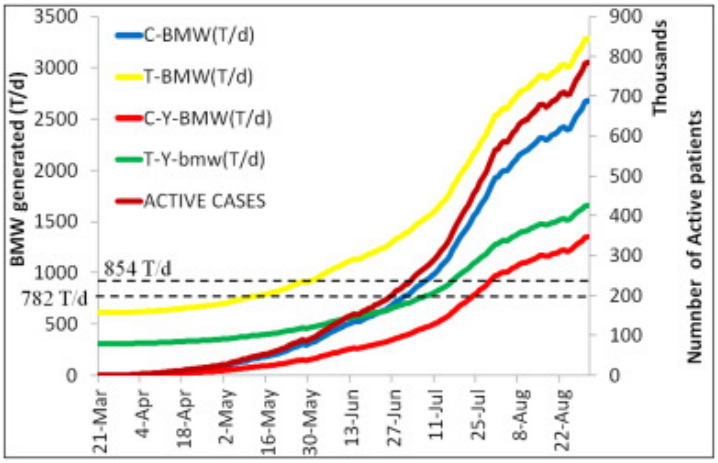

Fig. 4. *Daily generation of different types of biomedical waste in India during the pandemic (Thind et al., 2021)*

They consider that standardisation and strict implementation of medical waste management related to COVID-19 should be carefully considered to reduce the risk of the epidemic in hospitals (Peng et al., 2020).

The first case of a patient infected with Sars CoV-2 was reported in Romania on 26 February 2020, a Romanian citizen confirmed in Gorj County, that a patient appeared after contact with an Italian citizen who visited Romania at that time (Dascalu, 2020; Mihai, 2020).

Already on 14 March, more than 100 cases of infected persons were reported in Romania, and because the increase in the number of cases became worrying, a state of emergency was declared (Dascalu, 2020, Mihai, 2020). The evolution of the number of cases in Romania in spring 2020 (27 February - 5 June 2020) is shown in figure 5.

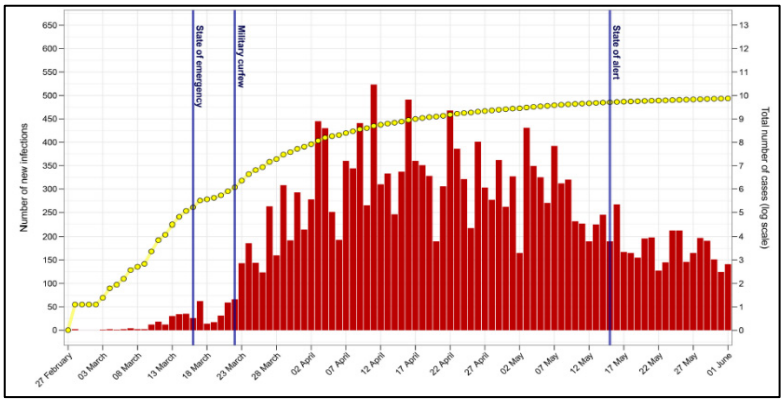

Fig. 5. *The Romanian COVID-19 epidemic from 27th February to 1st June 2020 (Souce: Dascalu, S., 2020)*

Figure 5 shows the daily number of confirmed cases, and the total number of cases (logarithmic scale), according to the graph made by Dascalu, based on data published by the Romanian Ministry of Internal Affairs.

CASE STUDY

The case study starts by comparing the total amounts of hospital waste produced in ten healthcare facilities situated in the NW part of Romania over 5 years from 2017 to 2022, a time that included the COVID-19 pandemic. The three health units analysed were the following (table 4).

The COVID-19 pandemic had a significant impact on the amounts of waste generated by health facilities, as shown in the graph presented (Fig. 6). The amounts of waste from the different health facilities assessed were variable in the pre-pandemic years, depending on the type of health facility, its size, and the number of patients assessed. However, it can be seen that the quantities of medical waste generated in the pre-pandemic years were in most cases well below the quantities of waste generated during the two pandemic years evaluated.

Table 4. *Medical units surveyed on quantities of waste generated in the period 2017-2022*

	Type of hospital	**Number of beds**
Hospital 1.	Infectious diseases hospital	191
Hospital 2.	Municipal hospital	527
Hospital 3	City hospital	226

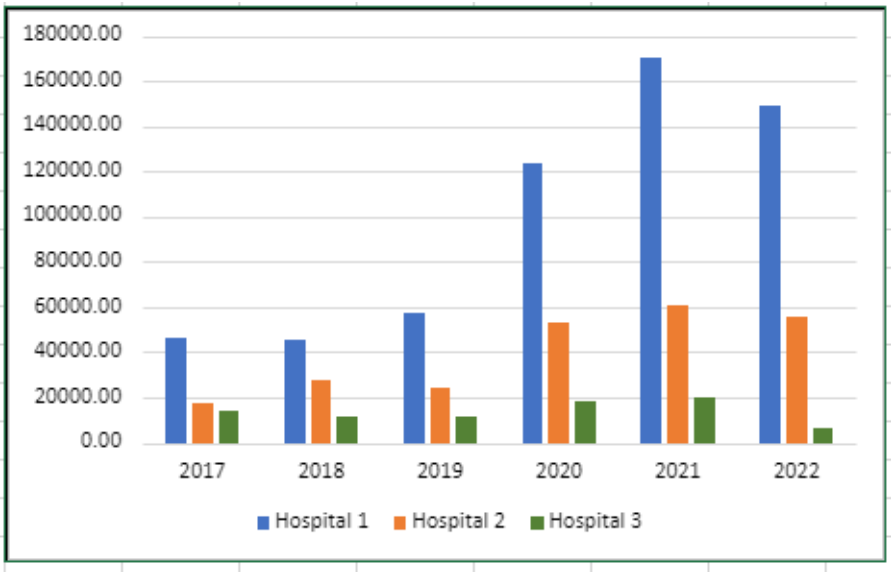

Fig. 6. *Total quantities of medical waste from the 3 sanitary units in the period 2017–2022 [kg/year]*

Because some health facilities, such as some dental practices or other specialised surgeries that sometimes only offered online consultations, were temporarily closed or restricted in their activity, the amount of waste during the pandemic decreased.

In the post-pandemic year, 2022, the amount of medical waste generated has decreased compared to the pandemic years. However, they are still above the values recorded in the pre-pandemic years. The explanation may lie both in the continued use of more protective equipment than previously employed and in the registration of more patients in hospitals, as individuals with less serious health conditions avoided, during the pandemic, routine check-ups in health units, unless absolutely necessary.

The following presents the evolution of the quantities of medical waste in the pandemic compared to previous years. During the SARS-CoV-2 pandemic, the amount of medical waste increased significantly. Table 5 lists the amounts of the principal waste streams produced at three hospitals in the northwest of Romania that treat SARS CoV-2 virus patients: sharps waste (code 18 01 01); and infectious hazardous waste in contact with blood or other biological fluids (code 18 01 03*). For comparison, the quantities of medical waste from the same hospitals in the years before the pandemic, i.e. from 2017 onwards, are shown.

Table 5 lists the amounts of the principal waste streams produced at three hospitals in the northwest of Romania that treat SARS CoV-2 virus patients: sharps waste (code 18 01 01); and infectious hazardous waste in contact with blood or other biological fluids (code 18 01 03*). For comparison, the quantities of medical waste from the same hospitals in the years before the pandemic, i.e. from 2017 onwards, are shown.

The first SARS-CoV-2 infected patient registered in Romania was on 26 February 2020, and the first pandemic peak registered was in November 2020. The next pandemic peaks in Romania were in March 2021, in October 2021 and in February 2022. The pandemic peaks in Romania were determined using data from the dedicated online platform for COVID-19, supported by Amazon Web Service (AWS), Sage Group and the University of West Timisoara, which was last updated on 14 November 2022 (https://covid19.geo-spatial.org).

The months in which pandemic peaks were recorded in Romania were those used as reference months for comparing the resulting medical waste quantities, namely February, March, October and November for a 5-year interval. All three hospitals analysed received patients infected with SARS CoV 2, starting in 2020.

As can be seen from the data presented in Table 5, there was a significant increase in the amount of waste generated in the months when the pandemic waves started, compared to similar months in previous years. In Table 5. the values indicating the maximum amounts of waste are highlighted, by colouring the respective table cells. These quantities are due to the use of a very large number of personal protective clothing items such as: disposable masks, both surgical and FFP2/FFP3/N95, face shields, goggles, protective suits, booties, and disposable waterproof aprons.

Individual protective equipment had a well-defined use regime, the most frequently exchanged being protective masks. Personal protective equipment was changed at certain intervals or as needed. A complete set of equipment contained booties, overalls, two pairs of disposable hand gloves, a protective mask, a visor and/or goggles.

Before the pandemic, the hospital ward profile and the number of patients admitted were the only factors affecting medical waste amounts.

Table 5. *Comparison between the quantities of medical waste resulting from 3 Romanian hospitals, from 2017 to 2022, using as reference periods the months in which pandemic peaks were recorded*

Reference month	Categories of waste (by waste code) considered [kg]					
	Infectious diseases hospital [191 beds]		**Municipal Hospital** [527 beds]		**City Hospital** [226 beds]	
	Waste produced 18.01.01 [kg]	Waste produced 18.01.03* [kg]	Waste produced 18.01.01 [kg]	Waste produced 18.01.03* [kg]	Waste produced 18.01.01 [kg]	Waste produced 18.01.03* [kg]
Feb-2017	154.00	3053.00	0.00	509.00	89.00	777.00
Feb-2018	164.00	3240.00	168.46	2323.51	94.00	892.00
Feb-2019	132.00	4166.00	49.47	885.07	83.00	646.00
First patient 26.02.2020	158.00	4143.00	192.34	2309.83	76.00	673.00
Feb-2021	177.20	12807.00	116.70	3290.36	33.50	994.00
The 4th peak 01.02.2022	263.00	14890.00	276.75	4747.97	51.00	448.00
Mar-2017	188.00	3497.00	43.40	851.70	149.00	1060.00
Mar-2018	157.00	3597.00	171.07	2368.27	88.00	1003.00
Mar-2019	159.00	4471.00	29.03	893.32	66.00	678.00
Mar-2020	123.20	5529.10	19.92	637.49	81.00	795.00
The 2nd peak 25.03.2021	254.00	18173.00	171.18	5290.27	48.50	1901.00
Mar-2022	263.40	11991.00	251.59	3219.25	44.00	389.00
Oct-2017	150.50	3950.50	158.40	2445.45	53.00	789.00
Oct-2018	123.00	4078.00	82.04	1495.81	64.00	648.00
Oct-2019	148.00	4391.00	0.00	465.65	138.00	767.00
Oct-2020	133.80	14218.00	208.78	6491.81	20.00	1214.00
The 3rd peak 21.10.2021	368.00	19778.00	57.13	6029.93	83.50	4290.00
Oct-2022	311.80	11321.00	274.26	3450.96	44.00	418.00
Nov-2017	146.00	3336.00	155.92	2409.34	90.00	1101.00
Nov-2018	106.00	3080.00	52.72	1310.93	57.00	653.00
Nov-2019	136.00	4366.00	121.60	1635.03	70.50	546.00
The first peak 06.11.2020	148.80	13328.20	215.59	7649.43	21.50	3200.00
Nov-2021	385.00	19664.00	176.69	5855.03	65.00	999.00
Nov-2022	304.90	12280.00	251.92	3224.16	28.00	338.00

Table 6. *The effects of the COVID-19 pandemic on the costs incurred by health facilities for the disposal of hazardous medical waste*

Reference month	**Waste disposal cost** [lei]					
	Infectious diseases hospital [191 beds]		**Municipal Hospital** [527 beds]		**City Hospital** [226 beds]	
	Waste disposal cost for 18.01.01	Waste disposal cost for 18.01.03*	Waste disposal cost for 18.01.01	Waste disposal cost for 18.01.03*	Waste disposal cost for 18.01.01	Waste disposal cost for 18.01.03*
Feb-2017	221.97	4396.32	0	732.96	128.16	1118.88
Feb-2018	236.39	4665.60	242.58	3345.85	135.36	1284.48
Feb-2019	190.26	5999.04	71.24	1274.50	119.52	930.24
First patient 26.02.2020	227.74	5965.92	276.97	3326.16	109.44	969.12
Feb-2021	255.41	18442.08	168.05	4738.12	48.24	1431.36
The 4th peak 01.02.2022	378.72	21441.6	398.52	6837.10	73.44	645.12
Mar-2017	270.72	5035.68	62.50	1226.45	**214.56**	1526.40
Mar-2018	226.08	5179.68	246.34	3410.31	126.72	1444.32
Mar-2019	228.96	6438.24	41.80	1286.38	95.04	976.32
Mar-2020	177.41	7961.90	28.68	917.99	116.64	1144.80
The 2nd peak 25.03.2021	365.76	26169.12	246.50	7617.99	69.84	2737.44
Mar-2022	379.30	17267.04	362.29	4635.72	63.36	560.16
Oct-2017	216.72	5688.72	228.10	3521.45	76.32	1136.16
Oct-2018	177.12	5872.32	118.14	2153.97	92.16	933.12
Oct-2019	213.12	6323.04	0	670.54	**198.72**	1104.48
Oct-2020	192.67	20473.92	300.64	**9348.21**	28.80	**1748.16**
The 3rd peak 21.10.2021	**529.92**	**28480.32**	82.27	**8683.10**	120.24	6177.60
Oct-2022	448.99	16302.24	**394.93**	4969.38	63.36	601.92
Nov-2017	210.24	4803.84	224.52	3469.45	129.60	**1585.44**
Nov-2018	152.64	4435.20	75.92	1887.74	82.08	940.32
Nov-2019	195.84	6287.04	175.10	2354.44	101.52	786.24
The first peak 06.11.2020	214.27	19192.61	310.45	11015.18	30.96	4608.00
Nov-2021	**554.40**	**28316.16**	254.43	8431.24	93.60	1438.56
Nov-2022	439.06	17683.20	**362.76**	4642.79	40.32	486.72

After the onset of the pandemic, this calculation was no longer valid, as the existing medical waste management infrastructure faced challenges related to the collection, transportation, and treatment of 4-5 times higher quantities of medical waste than before.

In general, the highest quantities of medical waste were recorded in October and November 2020 and 2021, possibly also due to the overlap of pandemic waves on top of the seasonal autumn flu.

Similarly to the increase in the amount of waste in pandemic years, the costs incurred for the disposal of hazardous waste from the site of health facilities were, in most cases much higher in the months and years of the pandemic. The only exception is the high cost at the city hospital assessed, and that was likely due to an increased number of patients during the pre-pandemic seasonal flu periods.

As is shown in Table 6, in general, significant increases in the amount of hazardous medical waste have resulted in significant disposal costs for this waste, severely impacting health facility budgets.

DISCUSSIONS

The COVID-19 pandemic has been a challenge to humanity as a whole, as it has been handling every issue that has emerged since the pandemic began. The SARS-CoV-2 virus posed a serious threat to Romania's and the world's medical hazardous waste management systems at the time. In certain instances, the amount of medical waste rose by 400% during peak times. Due to the identical storage facilities, businesses that specialize in the disposal of hazardous medical waste faced pressure, and economic agents were forced to reconsider when to implement new technical advancements.

Current governments have not been able to tackle this issue because numerous high-risk diseases have been eradicated in many nations in recent decades. Because of the medical waste, among other reasons, the pandemic has had a devastating impact on the infrastructure and economies of several countries.

In countries where the hazardous medical waste management system was poor and had untrained staff and insufficient infrastructure, the waste stream was not well defined, and this also put pressure on the environment. In some cases, large quantities of hazardous medical waste were collected and had to be disposed of as soon as possible. Non-hazardous waste and plastic waste also resulted in large quantities overloading the waste streams. Poorly enforced legislation, infrastructure, unfamiliarity, and the novelty of the virus

were other factors that created unmanageable challenges for hospitals, waste management companies, and authorities, in addition to problems common to the whole population.

Since at the onset of the Covid-19 pandemic, the knowledge about the mode and extent of transmission of the infection were not fully known, excessive protection of staff and the population was achieved through the overuse of personal protective equipment, leading to an overload of waste management systems due to large quantities of medically hazardous waste.

These increases in the quantities of hazardous medical waste have had a significant impact on hospital budgets, which, in addition to the costs of disposing of hazardous medical waste, have also accumulated expenses for the purchase of medical equipment used to treat infected patients, the large quantities of disinfectants used, and personal protective equipment. Before the outbreak of the pandemic, in many hospital wards, in addition to the classic personal protective equipment, only disposable gloves, caps, and in some cases, protective masks were used to treat patients. During the pandemic, treating a patient infected with SARS-CoV-2, in addition to personal protective equipment, was much more complex in all hospital wards. This led to significant increases in medical hazardous waste, as could be seen in the previous sections.

Based on the data provided, which only included the months when the pandemic waves began and was compared to similar months in prior years, the amount of hazardous medical waste produced by health facilities in NW Romania increased by 260% following the onset of the pandemic (February 2020) in comparison to the same period in 2019. The costs of treating them also increased, which put a big strain on the budgets of hospitals that also had to provide protective equipment or medicines needed to treat patients. It should also be stressed that this cannot be extrapolated to all health units in Romania, but only to those health units that were nominated as COVID support hospitals, where only COVID cases or suspected patients were treated. These were the hospitals with the maximum load. Probably a better distribution of patients to more hospitals would have benefited the staff employed in these hospitals, the comfort of patients, and the overloading of some hospital collection points with waste.

CONCLUSION

Healthcare facilities, medical diagnostic laboratories, treatment centres, and other economic operators providing healthcare services generate waste, some of which, depending on their composition, are classified as non-hazardous and others as hazardous to the environment and public health.

The increase in hazardous waste in Romanian hospitals treating Covid-19 infected patients was largely due to the large volume of personal protective equipment used, sanitary materials used in screening and treating patients or preventing the spread of the virus (Covid tests, waste from antibody vaccination of the population), and the shift of household waste produced by infected patients from the non-hazardous to the hazardous waste category. The fact that hospitals designated to treat patients with COVID-19 worked continuously at full capacity throughout the pandemic was another reason for the increase in waste.

The problems of managing hazardous waste and plastic waste have not been exclusive to hospitals, neither in Romania nor in other countries in the world. Thus, the correct management of hazardous medical waste must be regulated at the level of the localities and the population. Also, large quantities of plastic, including plastic masks, are causing problems in many places around the world and are becoming sources of environmental pollution. More efficient treatment methods for hazardous medical waste to increase its recovery potential and decrease the percentage of hazardous medical waste going to landfills would also be welcome.

Further research would be useful to highlight some of the lessons learned throughout the pandemic. The provision of flexible “toolkits” with hazardous waste management procedures and programs designed to meet the challenges that arise at different times, even when the situation has many unpredictable aspects, such as the COVID-19 pandemic, would be useful for all stakeholders involved in waste management and beyond.

Acknowledgement

Many thanks to AKSD ROMANIA SRL for their help in providing information on hazardous medical waste collected from various hospitals during the COVID-19 pandemic and the average cost of treating it.

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