



Medical waste management and the UN Sustainable Development Goals in Ukraine: An assessment of solutions to support post-war recovery efforts

Walter Leal Filho^{a,b,c}, Tetiana Lisovska^{c,1,*}, Mariia Fedoruk^c, Derya Taser^c

^a European School of Sustainability Science and Research (ESSSR), Hamburg University of Applied Sciences, Federal Republic of Germany

^b Department of Natural Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK

^c Faculty of Life Sciences, Research and Transfer Centre Sustainability & Climate Change Management (FTZ-NK), Hamburg University of Applied Sciences, Ulmenliet 20, Hamburg 21033, Federal Republic of Germany

ARTICLE INFO

Keywords:

Medical waste
SDGs
Management medical waste
Hazardous waste
Sustainable management
Survey

ABSTRACT

The active hostilities in Ukraine have not only changed the lives of the pre-war population of nearly 44 million people, but have also had a global environmental impact that negatively impacts the achievement of the United Nations Sustainable Development Goals (UN SDGs). This study examines the impact of compliance and safety processes related to medical waste management and final disposal strategies on the achievement of the UN SDGs in Ukraine during the period of the conflict. To conduct this research, the relationship between climate change and the production, proper disposal and environmental pollution of medical products was studied using bibliometric analysis. The interdependence between effective medical waste management and the SDGs is identified, and the importance of this issue for achieving a sustainable future is shown. Based on data analysis, the paper shows ways to reduce the negative impact of improper medical waste disposal on the environment. The study also recommends the creation of a strategy that prioritises international partnerships and exchange of experience, investment in medical waste disposal capacity, recycling and recovery, information dissemination, and international cooperation to achieve the UN SDGs.

Introduction

The purpose of the SDGs was, among other things, to create a framework for ending poverty, eradicating hunger, protecting the planet and improving the quality of life in the world, while achieving a balance between all key areas: social, economic and environmental sustainability. The challenges raised and described in the 17 SDGs are interconnected and require comprehensive solutions. In order to successfully achieve the UN SDGs, it is also important to share and implement the experience of other countries that have already gone part of the way and achieved some success.

Medical waste management is a key practice in healthcare management, as improper disposal of waste generated by healthcare facilities can have a direct impact on human health and the environment. As a member of the international community, Ukraine must take into account the 17 SDGs in all its decisions, including medical waste management, and the proper disposal and management of medical waste is of particular importance (The EU-Ukraine Association Agreement).

Ukraine is facing a critical situation with the generation, accumulation, storage, processing, and disposal or burial of waste, and due to active military operations, the situation is only getting worse with the further rapid development of environmental threats.

Medical waste is waste generated in healthcare facilities and other healthcare institutions that carry out medical procedures, regardless of ownership, in institutions and healthcare facilities for sanatorium treatment, pharmacies, research institutes, and medical educational institutions (<https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80#Text> Accessed 06 March 2023) (ABC, 2023b).

Uncollected or improperly collected medical waste has a negative impact on public health and the environment, and the cost of eliminating the consequences of such waste management exceeds the cost of developing and implementing simple waste management practices that do not require significant investment (Kaza et al., 2018).

As stated in the National Waste Management Plan for Ukraine until 2030 (<https://zakon.rada.gov.ua/laws/show/117-2019-%D1%80#Text>) (ABC, 2023c) and the National Waste Management Strategy for

* Corresponding author.

E-mail address: wct224@haw-hamburg.de (T. Lisovska).

¹ Present address: Ulmenliet 20, 21033 Hamburg.

Ukraine until 2030 [<https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80#Text> Accessed 06 March 2023], the main problems in the field of medical waste management in Ukraine are:

- Inadequate medical waste management carried out in healthcare facilities;
- Lack of necessary facilities and premises for the accumulation, transportation on the territory of healthcare facilities, and safe temporary storage of infectious waste;
- Lack of refrigeration equipment for waste storage;
- Lack of appropriate containers and packaging;
- Limited opportunities to purchase high-quality equipment for medical waste treatment.

A significant portion of medical waste is disposed of at landfills and unauthorised dumpsites due to the irresponsibility of healthcare workers in healthcare facilities and the insufficient and inaccessible waste treatment and disposal facilities, including waste generated in healthcare facilities.

Severely limited financial resources are an important constraint to the development and improvement of the medical waste management system. The financial support of the healthcare sector is closely linked to the state of the national economy, and it is clear that the allocation of the financial resources required to implement a proper medical waste management system has not been a priority [<https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80#Text>. Accessed 06 March 2023.] (ABC, 2023b).

Also, this document states that the situation has become a vicious circle, when due to the accumulation of waste in Ukraine and the lack of effective measures aimed at preventing its generation, utilisation, neutralisation and disposal, the environmental crisis is deepening; this, in turn, is an inhibiting factor in the development of the national economy. In order to break the vicious circle described above, meet today's needs

and preserve the rights of future generations, there is the need for a comprehensive solution to medical waste management, integrated into the concept of sustainable development, to achieve the goal of protecting nature and obtaining environmental and social benefits (Wan et al., 2019). This situation necessitates the analysis of the European experience and the development of a rational management plan, including for medical waste.

The main drivers for achieving the UN SDGs remain public health, solutions to environmental problems, and the conservation of valuable resources, with the relatively recent additions of climate change mitigation and inclusiveness (Wilson, 2007). Public health is often the key point that motivates people to think about and implement radical changes. At the same time, the healthcare system generates many different types of waste, so the development of sustainable medical waste management is relevant.

It should be noted that not all medical waste is potentially hazardous. 75–80% of the waste generated by healthcare facilities that does not come into contact with patients' biological fluids or infectious patients is similar in composition to household waste. This includes, for example, glass waste (bottles, vials, jars, etc.), paper, stationery, packaging residues, furniture, decommissioned soft goods (gowns, bed linen) and diagnostic equipment that has lost its consumer properties. [<https://zakon.rada.gov.ua/laws/show/z0959-15#Text> Accessed 16 March 2023].

A portion of medical waste, 10–25 %, is classified as hazardous and can be a risk factor for the environment and human health. The list of hazardous medical waste is shown in Fig. 1.

The healthcare crisis caused by the COVID-19 pandemic has led to a rapid increase in the amount of contaminated medical waste worldwide. There has been an increase in the relevance and necessity of using personal protective equipment for the face, gauze wipes, masks, oxygen masks, swab tubes, cotton swabs, saline sachets, disposable syringes and needles to treat patients with COVID-19, which have become hazardous

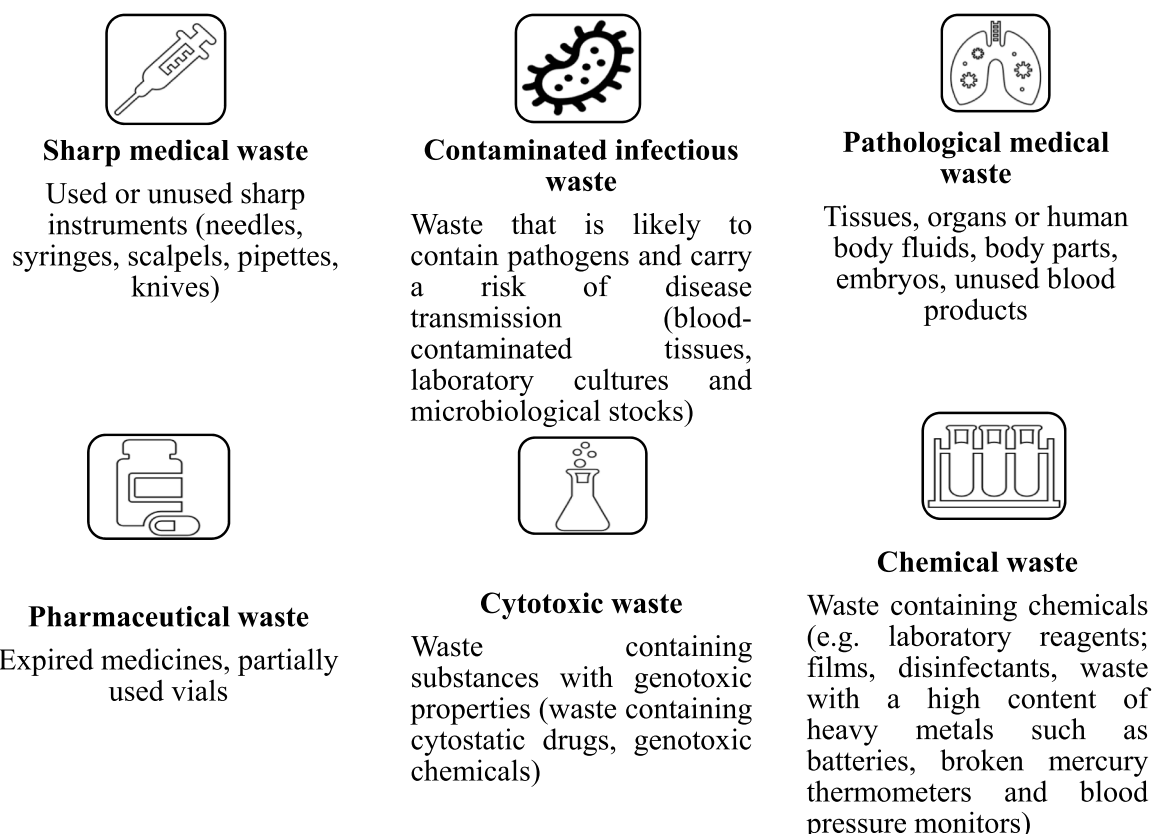


Fig. 1. List of hazardous medical waste, defined in accordance with Ukrainian legislation (Source: authors).

medical waste. Used personal protective equipment is a source of dangerous infectious diseases that require a special protocol for their handling. The inadequacy of existing means, such as incineration, to manage the growing generation of contaminated medical waste also increases the risk of hazardous waste being disposed of in the open (BIR, 2020; Vanapalli, et al., 2021; Lee and Lee, 2022).

Methods

In this study, a bibliometric analysis of scientific publications related to the UN SDGs and medical waste management was conducted to identify interdisciplinary research in this area.

Also, this publication provides an overview of Ukrainian legislation on medical waste management, shows the connection between medical waste management processes and the achievement of the SDGs, and describes the results obtained through bibliometric analysis.

To conduct the bibliometric analysis, we chose the Scopus scientific literature database to search for relevant literature. Scopus is the largest multidisciplinary database in science, engineering, technology, and medicine. In addition, Scopus has a keyword search function and provides various document data formats, which allows the search results to be used and processed in bibliometric software (Beuckels et al., 2021).

For the first part of the bibliometric analysis, keywords were identified on the selected topic and entered into the search bar in the following form: TITLE-ABS-KEY ((medical AND waste OR medical AND wastes OR town* OR municipal*) AND (basic AND service OR {basic services} OR {medical waste governance} OR {medical waste management} OR {medical waste management model} OR {natural heritage} OR {UNESCO} OR {disaster} OR {ecological footprint} OR {environmental footprint} OR {waste} OR {pollution} OR {pollutant*} OR {medical waste water} OR {recycling medical waste} OR {circular economy} OR {air quality} OR {green space} OR {green spaces} OR {nature inclusive}))

To conduct the next part of the bibliometric analysis on the selected topic, keywords were selected to identify other relationships on this

topic and entered into the search bar in the following form: TITLE-ABS-KEY (medical AND waste, AND sustainable AND disposal AND med-waste, AND risks AND problems of improper handling of medical waste).

The bibliometric mapping method was used to analyse the publications of 2019–2023 ($N = 874, 327$). The results indicate the existence of several relatively independent research areas with three and four major clusters. As a result of the bibliometric analysis, several clusters were obtained for the appraisal of the current research situation regarding the identification of methods for researching the impact of medical waste on nature.

Here is an analysis of the received scientific articles in the Scopus database according to the subject area, that is, the point of view from which scientists study medical waste.

The study was conducted using the VOSviewer software (VOSviewer, 2021), and the frequency of term recurrence illustrates the areas of research that researchers discuss on the topic of medical waste in the context of achieving Sustainable Development Goals. The results of this analysis are presented in the form of network graphs (Figs. 2 and 3), and the diameter of the sphere indicates the frequency of use of the term. The terms are grouped by colour, which indicates the frequency of their common use, thus forming clusters. The figures show three and four thematic clusters, respectively. The case studies were conducted while taking into account the limitations of bibliometric analysis, analysing publications that are directly related to the purpose of this study.

The study also adopted a questionnaire survey to collect quantitative and qualitative data about medical waste management in Ukraine during the war. A three-stage process was extensively used to collect data about the actual situation in Ukrainian hospitals.

In the first stage of our research, the development of the questionnaire was supported by the comprehensive literature review described above, which entailed some of the most recent literature publications and relevant works on the topic in the world. This was followed by a second stage, which was the design of a survey instrument, namely a questionnaire. This consisted of a set of closed questions, where respondents were asked to choose their answers from a fixed set of options.

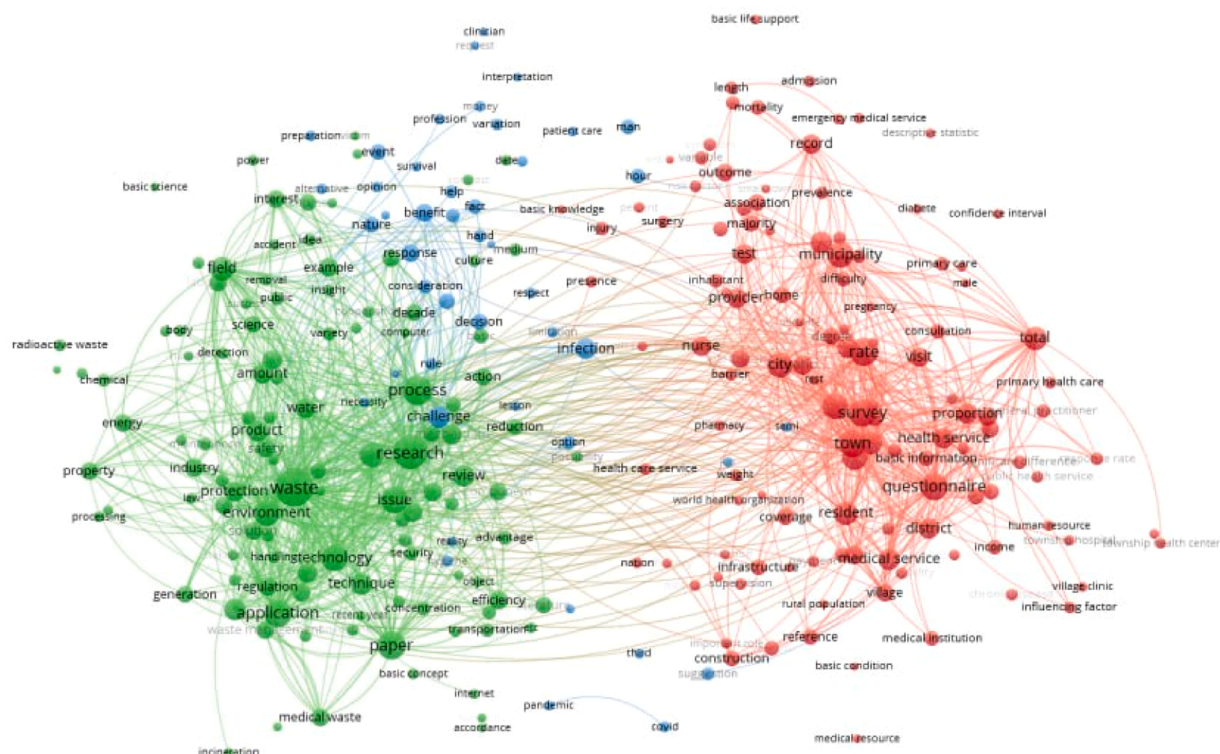


Fig. 2. Results obtained from the bibliometric analysis and clustering of Part I.

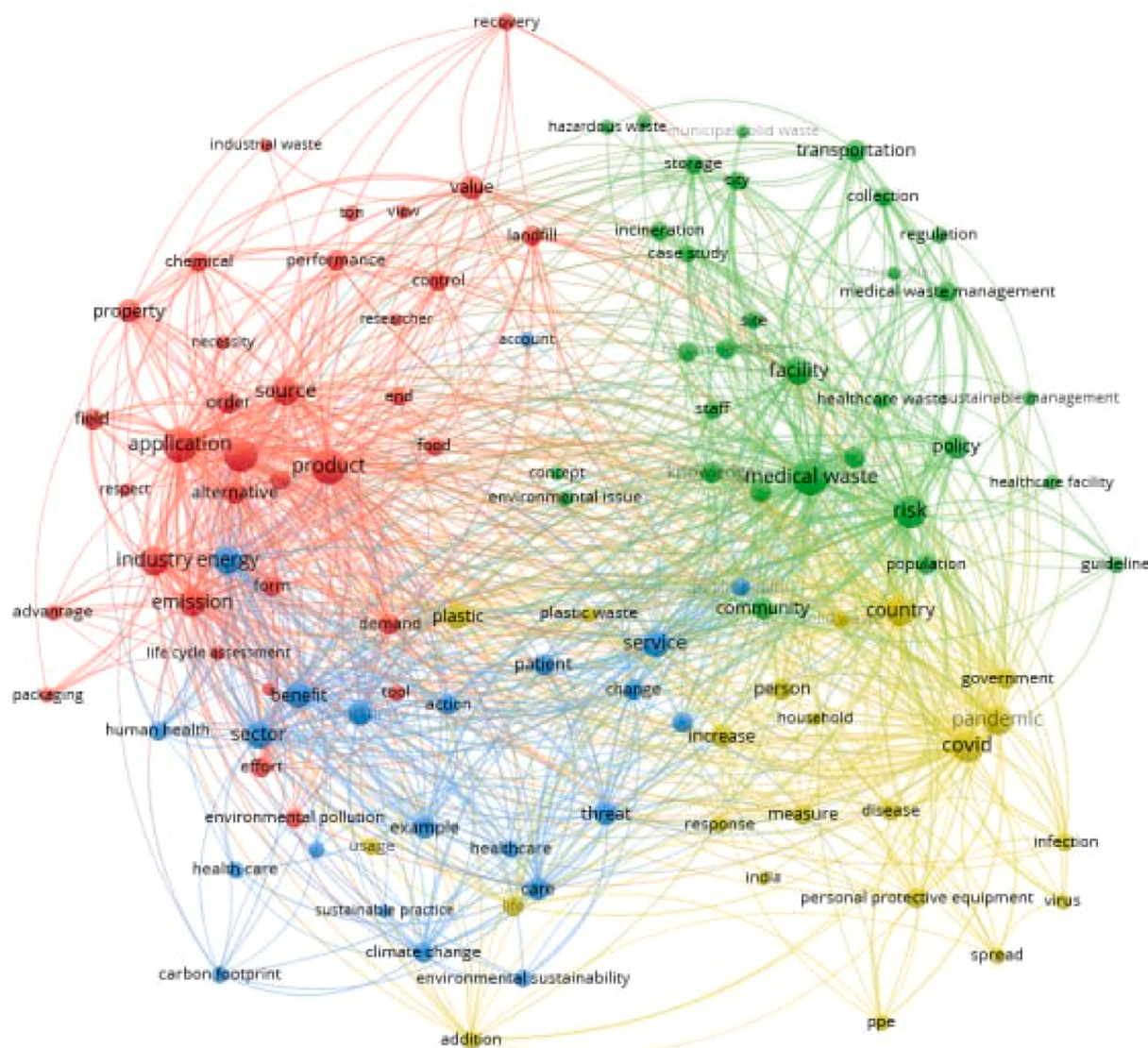


Fig. 3. Results obtained from the bibliometric analysis of Part II.

These types of questions were deployed because the obtained data cater to a reliable collection and analysis (reference). General open questions were also used at the end of the structured questionnaire in order to allow respondents to identify new issues not captured in the closed questions (reference). This type of question provided an increase in response rates (reference).

In the second stage of our research, an online survey was performed, with 25 questions divided into 5 groups based on the developed questionnaire. The invitation to participate in the study was sent to the hospital's head of management. The data were collected through the Lime Survey online survey tool (<https://www.limesurvey.org/>, accessed on 20 April 2023). This web tool is widely used for survey studies because it offers a wide variety of question types, and at the same time, it has a convenient interface (Leal Filho, and Walter, 2017; LimeSurvey — Free Online Survey Tool, 2023). The online questionnaire was used to collect the actual data about the waste management situation with clear instructions.

The sample was composed of managers in the hospitals who work on the subject and are knowledgeable, thus providing well-informed answers. The authors did not engage in the analysis of errors or tests of the sample, such as correlation, regression, and structural equations, among others, as the work would have had to obtain a large number of

responses and thus reach other groups of respondents.

In the third stage of our empirical study, the collected data were analysed using simple descriptive statistics and presented in the form of diagrams and tables.

Results and discussion

The problem of medical waste

Based on the results obtained during the first part of the bibliometric analysis, 3 different clusters were identified. The results clearly demonstrate that the process of researching the problem of medical waste and its impact on the environment touches upon many issues and is in fact an interdisciplinary study. As a result, it is noticeable that research is carried out in terms of the dependence on urban or rural areas and the availability of medical waste, as well as in terms of the availability of appropriate infrastructure.

C1 Green cluster - identifies a group of studies in which the issue of waste is most often studied in the context of environmental impact, water quality and development of new technologies, and the actual

study of medical waste is somewhat distant and with a limited number of connections.

C2 Red cluster - refers to research on issues such as healthcare facilities, healthcare services, nursing, pharmacy, health services, surveys, urban and rural clinics, etc.

C3 Blue cluster - forms a small group of studies on infections, challenges, including Covid 19, benefits and care, and patient management and care.

The aim of the analysis was to identify the interrelationships of scientific research on medical waste in the context of achieving SDGs, environmental protection, and the development of effective medical waste management strategies. Therefore, we conducted another stage of searching for scientific publications in the Scopus database, but only keywords to determine the relationship between medical waste and the corresponding risks and sustainable development were selected. The results of this analysis are shown in Fig. 3.

As a result of reducing the number of keywords and terms, a new graph was obtained (Fig. 2), which contains 4 thematic clusters, used to assess the current research situation in determining methods for studying the impact of medical waste on the environment and identifying successful strategies for medical waste management in the context of

achieving sustainable development goals.

C 1 Green cluster - relates to the issue under study; key terms such as medical waste, medical waste management, hazardous waste, sustainable management, risks, incineration, storage, regulation, transport, population, environmental problem and healthcare facilities are highlighted.

C 2 Yellow cluster - the following keywords are highlighted: Covid, disease, virus, plastic, plastic waste, increase, disease and personal protective equipment, and community, and there are a lot of connections with the previous cluster, i.e., medical waste.

C 3 Red cluster - contains interrelated research with the following keywords: application, alternative, product, emission, preference, chemical, industrial waste, recovery, plastic demand and packaging.

C 4 Blue cluster - contains research related to the key terms of: healthcare sector, healthcare, care, benefit, patient, service, sustainable practices, benefit, environmental impact, climate change, carbon footprint, environmental pollution, and environmental sustainability.

Fig. 4 illustrates the clear link between research on medical waste and cleaner production and environmentalism, climate change and

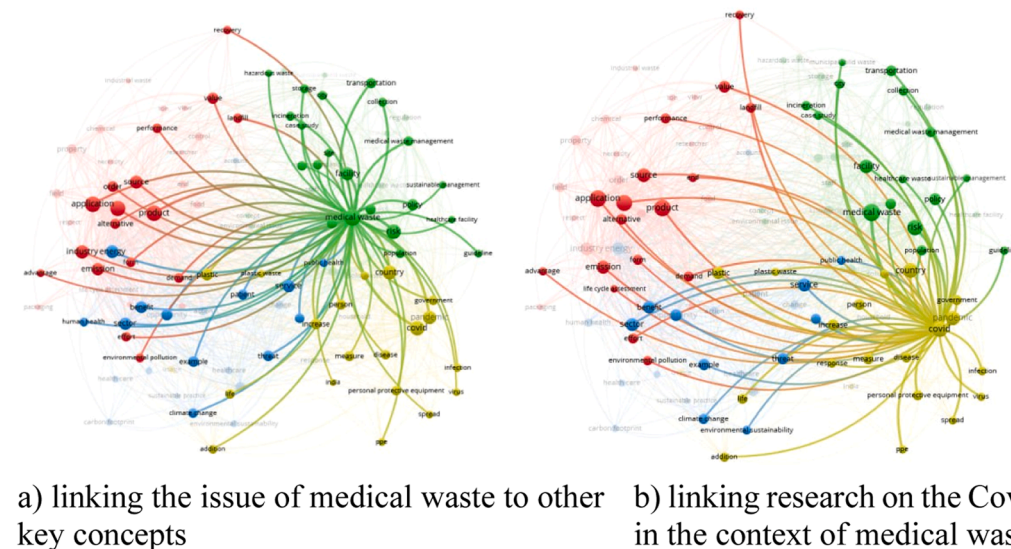


Fig. 4. Selecting clusters to visualise relationships.

pollution. In addition, during the Covid 19 pandemic, due to the use of large numbers of disposable personal protective equipment, many studies were conducted to contribute to preventing the generation of medical waste, in particular plastic medical waste. It has been established that, during the pandemic, 0.5 kg/capita of hazardous waste was generated daily in developed countries, and 0.2 kg/capita of contaminated waste in developing countries. In addition to health-related risks, improper medical waste management can lead to adverse environmental impacts, not only soil and water contamination, but also the destruction of beneficial microorganisms in septic systems and physical injury due to sharp instruments (Sharma et al., 2020).

Thus, as a result of the Covid 19 pandemic, it has become clear that the availability of a system for the safe disposal of medical waste is a key factor in controlling the risks to public health and the environment associated with medical waste. The field of good medical waste management practices has great potential for the development and implementation of advanced solutions. Developing an effective medical waste management strategy and implementing it will accelerate progress toward achieving many of the UN SDGs.

Medical waste and the UN SDGs

Solving the problem of rational medical waste disposal is an interdisciplinary issue that affects various aspects of sustainable development and directly relates to UN SDGs 3, 12 and 17 and indirectly to 1, 2, 5, 6, 9, 11, 13, 14, 15. When assessing the impact of medical waste on sustainable development, all three dimensions of sustainable development should be taken into account: nature, economic factors, and the situation in society (Rodić and Wilson, 2017; SDG Indicators, 2023).

According to the results obtained, as shown in Table 1, effective medical waste management is linked to 13 of the 17 UN SDGs in one way or another.

The absence of a clear medical waste management strategy and infrastructure for recycling often leads to unregulated disposal and the formation of unauthorised open dumpsites that pollute soil, air and water (SDGs 11, 12, 13, 14).

It should also be noted that the development and implementation of an effective medical waste management strategy is only possible if the principles of the circular economy are applied, and this requires integrated solutions for managing all types of waste.

As noted in one study, the main obstacles to the implementation of the circular economy are political barriers, technological barriers and public participation (Sharma et al., 2021).

It goes on to state that a necessary step towards achieving the concept and principles of the circular economy is to build on the experience of smaller, carefully planned, monitored pilot studies in key areas, which will be key to the creation of national regulations and standards. Therefore, better communication between all stakeholders and innovative public participation programmes can help to increase the effectiveness of the implementation of circular economy principles (Sharma et al., 2021).

According to some estimates, cities around the world will produce 2.2 billion tonnes of waste annually by 2025, more than triple the amount in 2009. The study also found that due to improper waste management, about 2.8 % of global anthropogenic greenhouse gas (GHG) emissions are released into the atmosphere through waste and wastewater. Yet achieving good waste management remains a significant challenge for countries and cities around the world. Another challenge is the gender division of labour in the waste management sector. It has been found that women in the waste management sector mostly work at lower levels, collecting and sorting waste at landfills, without proper working conditions. And men dominate higher-income and decision-making positions: truck drivers, scrap metal sellers, repair shop workers, and recyclable materials resellers. Often in developing countries, there are no clear regulations on waste management, so wages are extremely low and health protection for these workers is

Table 1

Relationship between the Sustainable Development Goals and the need for a sustainable medical waste management strategy.

Sustainable development UN SDGs Smaller goals that are directly linked to the UN SDG indicators*.	Background
SDG 1 1.3 Establish appropriate social protection systems and measures for all at the national level, with significant coverage of the poorest and most vulnerable. 1.4 Ensure equal rights to economic resources and financial services, including microfinance, for all, regardless of gender, or social status. 1.5 By 2030, increase the resilience of the poor and vulnerable and reduce their vulnerability to climate extremes and other economic, social, and environmental shocks and climate-related disasters.	Good health is the key to overcoming poverty. Healthcare and the production of medical products contribute significantly to national economies and job creation. But poor medical waste management puts the poorest communities at the highest risk due to their occupation, living conditions, and limited access to clean food and water.
SDG 2 2.4 By 2030, sustainable food production systems are in place through sustainable agricultural practices that vary by area but contribute to improved productivity, ecosystem conservation, climate change adaptation, and gradually improve land and soil quality.	This SDG aims to achieve food security and promote sustainable agriculture. Illegal dumping poses a significant threat to human health and causes pollution and land degradation, which has a direct impact on agriculture, food quality and safety.
SDG 3 3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria, and tropical diseases, and eliminate hepatitis, waterborne diseases, and other infectious diseases. 3.4 Reduce premature mortality from non-communicable diseases through prevention and treatment and promote mental health. 3.9: The number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution is planned to be seriously reduced.	Ensuring a healthy lifestyle is directly linked to the efficient functioning of the healthcare system. The production of medical products and medicine in general help prevent millions of deaths every year. At the same time, we must ensure that reliable mechanisms are in place to dispose of medical waste in a manner that does not cause environmental pollution or contaminate water, soil, and air, and instead protects human health and prevents death and disease.
SDG 5 5.1 Cease all forms of discrimination against all women and girls everywhere. 5.5 Guarantee women's full and effective access to leadership and equal opportunities for participation at all levels of decision-making in political, economic, and public life.	Achieving gender equality and empowerment for all women and girls requires a clear legislative framework, monitoring, and regulation of the ratio of women's to men's wages, especially in hazardous working conditions associated with medical waste management.
SDG 6 6.3 Enhance water quality by reducing pollution, eliminating the discharge and minimizing the release of hazardous chemicals and materials, halving the proportion of wastewater that is untreated, and significantly increasing the recycling and safe reuse of water globally. 6.4 Improve water efficiency in all sectors and ensure sustainable freshwater abstraction and supply to address water scarcity and significantly reduce the number of people suffering from water insecurity. 6.6 Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes.	Medical waste is dangerous because of its infectiousness, toxicity, and ecotoxicity. The chemicals contained in medical waste can cause pollution that can seriously affect water quality. Developing an effective medical waste management strategy will help prevent the contamination of water sources and contribute to the protection and restoration of water resources and their biodiversity.
SDG 8 8.3 Support the implementation of development-oriented policies that	Decent work and sustainable economic growth are directly related to medical waste management.

(continued on next page)

Table 1 (continued)

Sustainable development UN SDGs Smaller goals that are directly linked to the UN SDG indicators*.	Background
support productive activities, the creation of decent jobs, and entrepreneurship. 8.4 Gradually improve global resource efficiency in consumption and production and seek to decouple economic growth from ecological degradation. 8.8 Safeguard labor rights and promote safe and secure working conditions for all workers, including migrant workers, migrant women, and those in precarious employment.	Proper training and the provision of quality personal protective equipment for medical waste management personnel help to ensure their rights to decent work and occupational safety. Decoupling economic growth from environmental degradation requires an effective medical waste management strategy.
SDG 9 9.4 Modernize infrastructure and retrofit industry to make it sustainable, increase resource efficiency and increase the adoption of clean and eco-friendly technologies and industrial processes, with all countries taking action within their means. 9 a. Promote sustainable and resilient infrastructure development in developing countries through enhanced financial, technological, and technical support.	Sound waste management, including medical waste, is an integral part of sustainable industrialisation. Sustainable industrialisation and medical waste management can stimulate innovation and create new job opportunities. An effective waste management strategy should include the introduction of clean and environmentally friendly technologies and industrial processes as early as the production of medical products.
SDG 11 11.6 Decrease the negative per capita ecological impact of cities, including by paying special attention to air quality and household and other waste management.	Only 3 % of the world's surface is covered by cities, but due to their dense population, they are home to half of the world's population and use 75 % of the Earth's resources. At the same time, cities are the largest sources of pollution. Implementation of a medical waste management strategy is essential for cities to become more sustainable through improved medical waste management practices and services. Sustainable management and efficient use of natural resources cannot be achieved without proper medical waste management practices. The principles of reuse and minimisation of waste generation and the optimisation of resources through recycling should be the basis of a sustainable medical waste management strategy.
SDG 12 12.2 Ensure sustainable management and efficient use of natural resources. 12.4 Ensure ecologically sound management of chemicals and all wastes throughout their life cycle by agreed international frameworks and significantly reduce their emissions to air, water, and soil. 12.5 Significantly reduce waste generation through prevention, reduction, recycling, and reuse.	Rational management of medical waste, in particular, is key to strengthening sustainability and combating climate change through resource recovery and recycling, waste-to-energy processes, optimising waste transport, using the latest techniques, etc. Wastewater and industrial effluent discharges pollute waterways, seas and oceans. Improving the management and disposal of medical waste is an important measure to protect the world's oceans and marine resources. The production, use, and disposal of medical waste can lead to serious environmental degradation, water and soil pollution, and disruption of ecosystems if not managed properly. Improving medical waste management and disposal systems by preventing and minimising waste discharges into the environment helps protect biodiversity and reduces the need for difficult and costly remediation.
SDG 13 13.1 Increase resilience and adaptive capacity to climate threats and natural disasters in all countries.	
SDG 14 14.1 Prevent and significantly minimize all forms of marine pollution, including from land-based activities, including marine litter and nutrient pollution.	
SDG 15 15.1 Ensure the conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems and their services, including forests, wetlands, mountains, and arid areas, in accordance with obligations under international agreements.	

Table 1 (continued)

Sustainable development UN SDGs Smaller goals that are directly linked to the UN SDG indicators*.	Background
SDG 17 17.7 Support the creation, transfer, dissemination, and diffusion of ecologically sound technologies to developing countries on favorable terms, including preferential and concessional terms, as mutually agreed.	Proper medical waste management starts with environmentally friendly technologies, and the introduction of such existing technologies is possible through international cooperation. International partnership and dissemination of European experience is the key to developing rational management and disposal of medical waste for the sustainable development of society.

* - <https://unstats.un.org/sdgs/metadata/>.

lacking. This situation is especially dangerous in cases where there is no proper disposal of medical waste that can carry viruses, bacteria, etc. (<https://www.unep.org/news-and-stories/story/why-gender-dynamics-matter-waste-management>) (ABC, 2022). Developing and implementing an effective medical waste management strategy has a direct impact on reducing plastic pollution in the world's oceans, improving public health and restoring ecosystems. An effective medical waste management strategy will contribute to sustainable urban development, decent working conditions, and gender equality in environmentally friendly production facilities in developing countries with international cooperation. The first step towards implementing an effective waste management strategy is to establish control over disposal and move away from open dumping and incineration to clearly defined operations (Wilson, D.C.; Rodic, L. et. al. ; Wilson et al., 2015).

Overall, medical waste management practices should be improved at every stage of the process, from waste generation to final disposal outside the healthcare facility. Responsibility for final disposal should be clearly defined between waste generators and waste disposers (UKR-Waste-management-report.pdf) (Shortage of Personal Protective Equipment Endangering Health Workers Worldwide, 2023).

The development of an effective waste management strategy, including medical waste, is only a part of all the necessary measures that should be taken to develop specific green jobs within the waste management system, investments in recycling infrastructure, research and development of new product designs and business models, and smart manufacturing, all of which can lead to the initial creation of a niche that can help in the gradual transition to a circular economy.

Medical waste management in Ukraine

A questionnaire survey was undertaken among head managers of hospitals in the west of Ukraine, in Ivano-Frankivsk. This involved the collection of quantitative and qualitative data from 9 medical institutions of different types and sizes. Data was collected from medical institutions of therapy, dentistry, highly specialized medicine of the tertiary level, cardiology, obstetrics-gynaecology, and palliative care. In addition to asking the survey participants specific questions on the selected topics, other aspects were raised in several open questions.

According to our survey results, 6 out of 9 hospitals have clearly defined guidelines for the disposal, reuse, or recycling of medical waste. Only one institution has agreements with manufacturers of medical products that bear financial and organisational responsibility for the stage of waste management of their products. With the beginning of Russia's full-scale invasion of Ukraine, the specialisation of 2 out of 9 hospitals changed, and the number of patients increased for 6 of them (between 10 % and 40 %).

This led to an increase of the amount of waste to be disposed as well as the amount of plastic waste; at the same time, the amount of waste that was reused after special treatment was also higher.

The survey results showed that the amount of plastic medical waste generated in the surveyed medical facilities on average per month is 50 % (of the total amount of medical waste), but in some facilities it can reach even 72 %.

Many of these plastic materials might be recycled or re-used with proper separation procedures, such as syringes, systems, elastomers, and pumps for infusions.

According to our survey results, the most popular method of sterilising instruments to re-use them is by autoclaves (Fig. 5). Among the other methods are chemical cleansing and ultraviolet and plasma sterilisation.

Challenges that hospitals currently experience with medical waste are mostly due to the lack of finance. This leads to a permanent need for containers and packages of different sizes for medical waste separation as well as autoclaves. There is a lack of money even to pay for outside companies and for storage facilities reconstruction. There is no centralised disposal of medical waste in the west of Ukraine. There are only two certified companies that are able to utilise medical waste, and both are located more than 700 km away. Moreover, both facilities are endangered now due to constant shelling in Kyiv and Odesa.

Conclusions

As this paper has shown, the current problems associated with medical waste pose not only a threat to the environment and well-being of the population in Ukraine, but also negatively influence the implementation of the UN SDGs in the country. In particular, the increase in the amount of plastic used is a worrying trend, since most of these materials are not recycled or re-used. Moreover, the survey showed that the use of autoclaves is the most common method use for sterilising instruments.

A conclusion which can be drawn from this paper is that the lack of modern and properly equipped medical waste treatment facilities hinders effective waste disposal. Also, the fact that many healthcare workers and waste management personnel may not have received adequate training on proper medical waste handling and disposal methods, means that good opportunities for addressing the problems are being missed. Moreover, it is clear from the study that limited funding and resources dedicated to medical waste management, negatively affect the overall effectiveness of the system.

This paper has some limitations. The first is the fact that the bibliometric analysis focused on a set terms associated with medical waste and the UN SDGs, and did not take other variables into account. Secondly, the survey involved hospitals in Ivano-Frankivsk, and did not investigate hospitals in other parts of the country. The paper provides nonetheless a welcome contribution to the literature, since it investigated the subject matter of medical waste in Ukraine, an issue not so much emphasised due to other competing priorities seen in a country at war.

As to the future, improving medical waste management in Ukraine requires concerted efforts from the government, healthcare institutions, waste management companies, and the public. Raising awareness, strengthening regulatory enforcement, and investing in modern waste treatment facilities are among the necessary steps to ensure safe and environmentally friendly medical waste management in the country.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Tetiana Lisovska reports financial support was provided by Deutsche Bundesstiftung Umwelt. Tetiana Lisovska reports a relationship with German Federal Environmental Foundation that includes: funding grants.

How are reusable materials being sterilized for re-use?

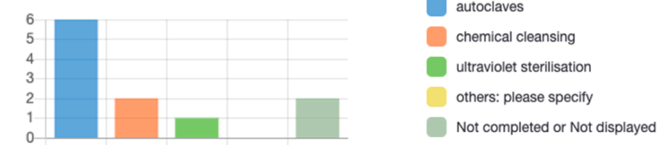


Fig. 5. Methods of sterilising used by the researched medical institutions.

Data availability

No data was used for the research described in the article.

Acknowledgments

We gratefully acknowledge the support from the German Federal Environment Foundation (Deutsche Bundesstiftung Umwelt DBU) to this work, and to the project «Sustainable Medical Waste Ukraine».

The article was prepared with the support and funding of the Deutsche Bundesstiftung Umwelt (DBU) Foundation within the framework of the project «Sustainable Medical Waste Ukraine».

References

- Beuckels, E., et al., 2021. Media multitasking: a bibliometric approach and literature review. *Front Psychol.* 12, 623643 <https://doi.org/10.3389/fpsyg.2021.623643>.
- BIR. Covid-19 update: fragmented picture for under-pressure recycling industry. <https://www.bir.org/news-press/news/item/covid-19-update-fragmented-picture-for-under-pressure-recycling-industry>.
- Kaza, S., et al., 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. World Bank, Washington, DC. <https://doi.org/10.1596/978-1-4648-1329-0>.
- Leal Filho, and Walter. Identifying and Overcoming Obstacles to the Implementation of Sustainable Development at Universities. *Journal of Integrative Environmental Sciences*, 14 (1) 2017, 93–108 [10.1080/1943815X.2017.1362007](https://doi.org/10.1080/1943815X.2017.1362007).
- Lee, S.M., Lee, D.H., 2022. Effective medical waste management for sustainable green healthcare. *Int. J. Environ. Res. Public Health* 19 (22). <https://doi.org/10.3390/ijerph192214820>.
- LimeSurvey — Free Online Survey Tool. <https://www.limesurvey.org/>, Accessed on 20 April 2023.
- “On approval of the national waste management strategy in Ukraine until 2030”. Official web portal of the Parliament of Ukraine, <https://zakon.rada.gov.ua/go/820-2017-%D1%80>. Accessed 06 March 2023b.
- “On approval of the national waste management plan until 2030”. Official website of the Parliament of Ukraine, <https://zakon.rada.gov.ua/go/117-2019-%D1%80>. Accessed 10 March 2023c.
- Rodić, L., Wilson, D.C., 2017. Resolving Governance Issues to Achieve Priority Sustainable Development Goals Related to Solid Waste Management in Developing Countries. *Sustainability* 9, 404. <https://doi.org/10.3390/su9030404>.
- SDG Indicators — SDG Indicators. <https://unstats.un.org/sdgs/metadata/> Accessed 16 March 2023.
- Sharma, H.B., et al., 2020. Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. *Resour. Conserv. Recycl.* 162, 105052 <https://doi.org/10.1016/j.resconrec.2020.105052>.
- Sharma, H.B., et al., 2021. Circular economy approach in solid waste management system to achieve UN-SDGs: solutions for post-COVID recovery. *Sci. Total Environ.* 800, 149605 <https://doi.org/10.1016/j.scitotenv.2021.149605>.
- Shortage of Personal Protective Equipment Endangering Health Workers Worldwide. <https://www.who.int/news/item/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide>. Accessed 26 March 2023.
- UNEP Why gender dynamics matter in waste management. 13, October 2022, <http://www.unep.org/news-and-stories/story/why-gender-dynamics-matter-waste-management>.
- Vanapalli, K.R., et al., 2021. Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic. *Sci. Total Environ.* 750, 141514 <https://doi.org/10.1016/j.scitotenv.2020.141514>.
- VOSviewer, 2021, Visualizing Scientific Landscapes. <https://www.vosviewer.com/>. Accessed 6 March 2023.
- Wan, C., et al., 2019. Waste management strategies for sustainable development. In: Filho, W.L. (Ed.), *Encyclopedia of Sustainability in Higher Education*. Springer

- International Publishing, pp. 1–9. https://doi.org/10.1007/978-3-319-63951-2_194-1.
- Wilson, D.C., et al. Global Waste Management Outlook. 08, September 2015, <http://web.unep.org/ourplanet/september-2015/unep-publications/global-waste-management-outlook>.
- Wilson, D.C., 2007. Development drivers for waste management. Waste Manag. Res. J. Sustain. Circ. Econ. 25 (3), 198–207. <https://doi.org/10.1177/0734242X07079149>.