Ecological Questions 33 (2022) 3: 79–88 http://dx.doi.org/10.12775/EQ.2022.026

Medical waste generation, handling and crime statistics' analysis in this activity field: a case study of the Poltava region (Ukraine)

Olena Hanoshenko[1], Viola Vambol[1,*], Sergij Vambol[2], Sergiy Yeremenko[3], Mykhailo Fialka[4], Ihor Bodnar[5], Oksana Inozemtseva[6]

[1]National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine
[2]State Biotechnological University, Kharkiv, Ukraine
[3]Institute of Public Administration and Research in Civil Protection, Kyiv, Ukraine
[4]Kharkiv National University of Internal Affairs, Kharkiv, Ukraine
[5]Academy of the State Penitentiary Service, Kharkiv, Ukraine
[6]State emergency service of Ukraine, Kyiv, Ukraine
*corresponding author's e-mail: violavambol@gmail.com

Received: 16 March 2022 / Accepted: 4 April 2022

Abstract. The medical waste problem has swept the whole world. Medical waste accounting and management is urgently needed to reduce the threat of the infections spread and sustainably manage environmental hazards. It is the solution of these issues on the Poltava region example that is this study purpose. Source data have been provided by the Main Department of Statistics in the Poltava region. This data is not available on the open Internet. The predictive dynamics of medical waste generation for 2010–2019 indicates a high probability of an increase in the amount of medical waste to 2030 to the volume of about 71 tons per year. The main sources are Poltava region medical institutions of which 52.3% of the total waste amount is generated in Poltava. To assess the possibility of influencing the situation with medical waste, the crime statistics in this field in the period from 2017 to 2021 was analyzed, which demonstrates an increase in offenses by more than 2.35 times. Ukrainian legislation in the field of offenses for improper handling of medical waste should be revised and articles should be developed and implemented criminal liability for offenses in this activity field.

Keywords: medical waste, forecasting, management, environmental hazards, crime statistics, Poltava region.

1. Introduction

The medical waste problem has swept the whole world and is the most pressing problem in every country (Khan A.H. et al., 2020; Ma et al., 2020; Bucătaru et al., 2021; Chisholm et al., 2021).

Medical waste refers to waste generated in medical institutions and other health care institutions conducting medical procedures, regardless of the form of ownership, in institutions and medical institutions of sanatorium treatment, pharmacies, research institutes and educational medical establishments.

The sustainable development of mankind depends to a large extent on the rational management of natural resources. The accumulation of waste and improper handling of it provides a negative impact on natural components, which, in turn, contributes to the rapid depletion of natural resources and the formation of weak immunity in new generations.

Medical waste is a special group of waste, as it is often not only toxic, but also biologically hazardous, such as during

the COVID-19 pandemic or the active spread of other infections. This is evidenced by numerous scientific studies in this area (Ilyas et al., 2020; Bucătaru et al., 2021; Tirkolaee & Aydın, 2021; Tirkolaee et al., 2021).

Infected medical waste is a major global health and environmental sustainability issue if handled incorrectly that is documented in detail using the example of COVID-waste in the papers (Ilyas et al., 2020; Tirkolaee & Aydın, 2021). Disposal of infectious waste into the environment can contribute to an exponential spread of deadly diseases as the waste acts as an infectious carrier. For example, SARS-CoV-2 can survive on waste (such as face masks) for up to 7 days (Ilyas et al., 2020). In recent years, outbreaks of infectious diseases have also been observed in Ukraine (Illyash & Yurchenko, 2020; Shulha & Karnaukh-Holodnyak, 2020; Husyeva & Kopytsya, 2021), and in recent days a significant part of the population needs medical treatment due hostilities in the country. These situations provide a constant increase in the amount of waste. Among the scientific problems raised by Ukrainian and foreign scientists in their research:

- Formation and implementation of a regional plan for the municipal solid waste management, including medical waste (Aung et al., 2019; Barua & Hossain, 2021; Safranov et al., 2021);
- Features of administrative and legal regulation of medical waste management (Parida et al., 2019; Mao et al., 2020; Khan N.A. et al., 2021; Strelchenko & Bukhtiyarova, 2021);
- Energy, environmental and economic aspects of waste disposal technologies (Zamparas et al., 2019), etc.

Therefore, given the above, it can be argued that proper accounting and management of medical waste is urgently needed to reduce the threat of the infections spread and sustainably manage environmental hazards. It is the solution of these issues on the example of the Poltava region that is the purpose of this study.

2. Materials and Methods

All source data that are sorted, processed and analyzed have been provided by the Main Department of Statistics in the Poltava region upon official request. This data is not available on the open Internet.

The following methods were used for the obtained statistics:

- Classification in accordance with the Order of the Ministry of Health of Ukraine No. 325 of August 6, 2015 "On approval of the State sanitary and anti-epidemic rules and norms for handling medical waste";
- Mathematical methods of forecasting;
- An analytical approach to the choice of methods for handling a certain category of medical waste, based on our own knowledge and the study of modern scientific sources in open publications.

According to the data of the Main Department of Statistics in the Poltava region (letter No. 13395/0/01–27 dated November 26, 2020); an analysis was made of the generation and volumes of medical waste according to 3 classifications in accordance with:

- Order of the State Statistics Service of Ukraine No. 24 dated January 23, 2015 "On Approval of Lists of Categories, Waste Groups and Waste Management Operations";
- State waste classifier DK 005–96, approved by the State Committee of Ukraine for Standardization, Metrology and Certification dated February 26, 1996 N 89;
- Waste hazard classes.

3. Results and Discussion

3.1. Waste generation sources and their volumes

An analysis of the volumes of medical waste generation for 2010–2019 showed a fairly stable nature of the dynamics of their generation (Table 1).

The predictive dynamics of medical waste generation for 2010–2019 (Fig. 1) indicates a high probability of an increase in the amount of medical waste in the period up to 2030. And given the difficult situation that has developed in 2020–2021 associated with the pandemic, we should expect a significant increase in the amount of such waste in the future to a projected volume of about 71 tons per year.

The analysis of the volumes of medical waste generation was carried out taking into account the classification according to the Order of the State Statistics Service of Ukraine No. 24 dated January 23, 2015 "On approval of the lists of categories, groups of waste and waste management operations."

Medical waste includes the following groups:

1001 – Medical devices that do not meet the established requirements, are not properly marked, damaged or used (including syringes, thermometers, diagnostic test kits, medical instruments, etc.);
1002 – Waste of production and preparation of pharmaceutical products;
1003 – Waste containing pharmaceutical or veterinary compounds and intermediate products of their production;
1004 – Wastes from the production, preparation and use of biocides and phytopharmaceuticals;

1006 – Waste generated during disinfection, disinfestation, deratization;
1007 – Waste containing disinfecting and antiseptic substances, spoiled, used or unidentified;
1008 – Waste containing infectious substances;
1801 – Other wastes with hazardous properties.

The volumes of medical waste generation for these groups are shown in Table 2.

The largest groups of medical waste are:
1001 – Medical devices that do not meet the established requirements, are not properly marked, damaged or used (including syringes, thermometers, diagnostic test kits, medical instruments, etc.);
1801 – Other hazardous wastes.

Table 1. Dynamics of changes in the total generation of medical waste for 2010–2019

Name of waste	Formation of medical waste by years, tone									
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Medical waste	46.921	55.618	57.207	56.697	56.056	50.022	51.481	49.653	46.919	54.460

Table 2. Dynamics of medical waste generation by groups for 2017–2019 (by hazardous component)

Group code	Name of the group	Waste generation tons/ year		
		2017	**2018**	**2019**
1001	Medical devices that do not meet the established requirements, are not properly labelled, damaged or used (including syringes, thermometers, diagnostic test kits, medical instruments, etc.)	25.414	24.229	26.329
1002	Waste production and preparation of pharmaceutical products	0.039	-	-
1003	Wastes containing pharmaceutical or veterinary compounds and their intermediates	0.024	0.031	0.19
1005	Wastes from the production, preparation and use of biocides and phytopharmaceuticals	0.199	-	-
1006	Waste generated during disinfection, disinfestation, deratization	1.815	0.592	0.204
1007	Waste containing disinfecting and antiseptic substances, spoiled, used or unidentified	2.748	2.152	2.395
1008	Waste containing infectious substances	0.822	1.055	1.828
1801	Other wastes with hazardous properties	18.592	18.86	23.514
	Total:	**49.653**	**46.919**	**54.460**

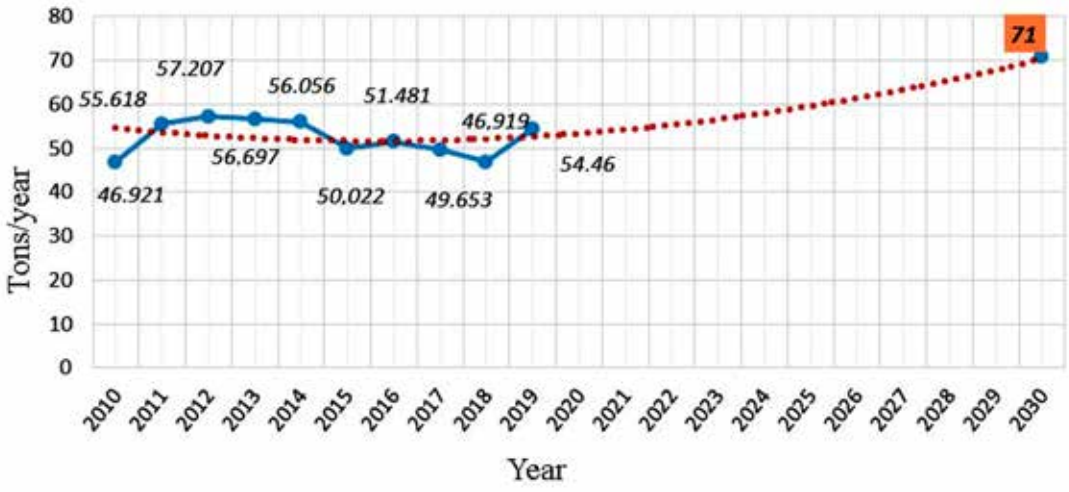

Figure 1. Dynamics of total medical waste generation for 2010–2019 and projected dynamics for the period up to 2030

Data on the amount of medical waste generation according to the classification according to DK 005–96, approved by the State Committee of Ukraine for Standardization, Metrology and Certification of February 26, 1996 N 89 are shown in Table 3.

According to Table 3, it was found that the largest volumes of education have:

8510.2.9.04 – Body parts and organs, including blood bladders and preserved blood;

8510.2.9.03 – Other medical devices (including syringes, thermometers, diagnostic test kits, medical instruments, etc.) that do not meet the established requirements, are not properly marked, damaged or used;

8530.2.9.04 – Pharmaceutical packaging is damaged or worn out.

An analysis of the medical waste generation by hazard class shows that the largest volumes of generation are characteristic of medical waste of classes 4 and 3 (Table 4).

Separately, the dynamics of the medical waste generation of the group 9999.9.9.99 – Other hazardous waste classified by DK 005–96 as other types of waste due to the presence of several hazardous components in them was analyzed (Table 5). A general trend has been established to reduce these wastes from 4630.69 tons in 2010 to 483.098 tons in

Table 3. Dynamics of medical waste generation by groups for 2017–2019 (according to the state classifier)

Group code	Name of the group	Volume of waste generation by years, tone/year		
		2017	2018	2019
8510.2.9.01	Medical needles are damaged or used	1.736	1.974	2.016
8510.2.9.02	Disposable medical equipment and instruments are damaged or used	2.869	3.142	5.888
8510.2.9.03	Other medical devices (including syringes, thermometers, diagnostic test kits, medical instruments, etc.) that do not meet the established requirements, are not properly marked, damaged or used	11.839	12.903	12.184
8510.2.9.04	Body parts and organs, including blood bladders and stored blood	14.960	14.252	16.819
8510.2.9.05	Waste generated during disinfection, disinfestation, deratization	0.352	0.116	0.044
8510.2.9.06	Other waste, the collection and destruction of which is subject to special requirements to prevent the occurrence of infection	1.152	1.598	2.892
8510.2.9.07	Other waste, the collection and destruction of which is not subject to special requirements to prevent the occurrence of infection	5.544	3.040	3.765
8520.2.9.01	Needles are damaged or used	0.038	0.033	0.003
8520.2.9.02	Equipment and tools for veterinary services other damaged or used	-	-	-
8520.2.9.03	Other waste from the provision of veterinary services, the collection and destruction of which is subject to special requirements to prevent the occurrence of infection	0.885	0.870	0.890
8520.2.9.04	Waste from the provision of veterinary services, the collection and destruction of which is not subject to special requirements to prevent the occurrence of infection.	0.012	0.013	0.591
8530.2.9.01	Preparations and pharmaceutical substances (including veterinary ones), medicinal products and products (including aerosols), their remains are spoiled, expired or unidentified	0.012	0.003	0.012
8530.2.9.02	Decontaminating and antiseptic substances, spoiled, spent or unidentified	0.300	0.300	0.300
8530.2.9.04	Pharmaceutical packaging is damaged or worn out	9.954	8.675	9.056
	Total:	**49.653**	**46.919**	**54.460**

Table 4. Dynamics of medical waste generation by classes for 2017–2019

Waste hazard class	Volume of waste generation by years, tone		
	2017	2018	2019
1st class	0.023	0.018	0.236
2nd class	0.094	0.091	0.172
3rd class	5.254	4.914	8.594
4th class	44.282	41.896	45.458
Total:	**49.653**	**46.919**	**54.460**

Table 5. Dynamics of changes in the volume of waste group 9999.9.9.99 for 2010–2019

Waste group name	Volume of waste generation by years, tone									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
9999.9.9.99 – Other hazardous wastes not specified by the waste classifier	4630.690	2514.780	3668.937	1116.232	21068.918	977.927	706.378	697.129	718.817	483.098

2019, with the exception of sharp increase in their amount in 2014 to 21068.9 tons.

The main sources of medical waste are medical institutions of the Poltava region. The contribution of institutions to medical waste generation on the territorial basis in 2019 is shown in Figure 2.

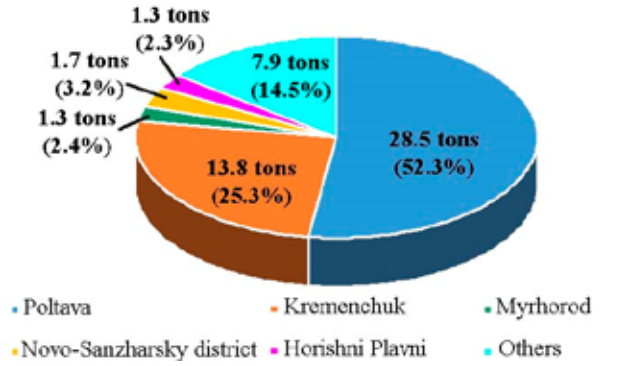

Figure 2. The contribution of medical institutions in the medical waste generation on the territorial basis in 2019

3.2. Waste management system

For the last 2017–2019, the main areas of medical waste management are:

- R4 – recycling/utilization of metals and their compounds;
- R5 – recycling/utilization of other inorganic materials;
- D10 – incineration on land;
- Transfer of these wastes to a third party for recycling or disposal (Table 6).

Table 6. Basic methods used for medical waste

Year	Waste generated during the year, tons	Waste handling methods, tons			Transferred to third parties, including	
		R4	R5	D10	for disposal, tons	to remove, tons
2017	49.653	-	-	0.139	46.591	3.24
2018	46.919	-	-	0.097	43.644	3.251
2019	54.460	0.195	0.009	0.115	51.443	3.293

Separately analyzed group of wastes 9999.9.9.99 – Other hazardous wastes, which include wastes classified according to a hazardous component 1801 – Other wastes with hazardous properties. The main areas of dealing with them are:

- R3 – recycling/utilization of organic substances not used as solvents (this includes gasification and pyrolysis when the components are used as chemicals);
- R5 – recycling/utilization of other inorganic materials;
- D4 – discharge into surface (usually artificial) water bodies (placement of liquid or sludge-like waste in pits, storage ponds, settling basins, etc.);
- Transfer of waste to specialized enterprises, including for recycling, disposal and to individuals for use (Table 7).

3.3. Waste treatment infrastructure

Collection and temporary storage of medical waste is carried out directly by medical institutions, where the relevant waste is generated.

According to the requirements of the State Sanitary and Anti-epidemic Rules and Norms for the Treatment of Medical Waste, category B wastes are subject to mandatory decontamination (disinfection) by physical methods (thermal, microwave, radiation, etc.). The use of chemical methods of disinfection is allowed only for the disinfection of food waste from the infectious departments of patients, as well as in the organization of primary anti-epidemic measures in the foci of infection. Chemical disinfection of category B waste at the place of their generation is used as a mandatory temporary measure in the absence of a waste management facility or in the absence of a centralized disinfection system.

Category B wastes after decontamination must be transferred to enterprises licensed to carry out operations in the field of hazardous waste management and appropriate certified equipment. Such a license is issued by the Ministry of Environmental Protection and Natural Resources of Ukraine.

On the territory of the Poltava region, there are four entities that have the appropriate license to collect, store, process, recycle, and neutralize certain category B wastes

Table 7. Basic methods used for the waste group 9999.9.9.99 – Other hazardous wastes

Year	Waste generated during the year, tons	R3		R5		D4		Transferred to third parties, including					
								for disposal		to remove		individuals for use	
		tons	%	tons	%	tons	%	tons	%	tons	%	tons	%
2017	697.129	92.256	13.23	0.107	0.02	348.64	50.01	55.33	7.94	120.34	17.26	-	-
2018	718.817	534.39	74.34	-	-	-	-	96.60	13.44	87.536	12.18	0.002	0.0003
2019	483.098	381.45	78.96	-	-	-	-	41.02	8.49	60.91	12.61	0.002	0.0004

(Table 8). In addition, individual medical institutions of the Poltava region transfer their own waste to licensed organizations registered and operating in other regions of Ukraine. Category C medical waste management requirements are similar to those for hazardous waste

3.4. Problems, threats and crime statistics' analysis in the medical waste management field

The main problem that requires special attention when organizing a medical waste management system is the increase in the volume of their generation and the risk that associated primarily with the epidemiological situation, which may result from the spread of infection. For example, at the end of 2019, the problem became most acute due to:

- Accumulation of volumes of waste that are generated as a result of the treatment of patients with acute respiratory disease COVID-19 caused by SARS-Co-2 virus (waste category B);
- An increase in the production of personal protective equipment (PPE), while a significant amount of medical waste, in particular PPE, remains in everyday

Table 8. Business entities operating in the field of hazardous waste management in the region (According to the web portal of the Ministry of Environmental Protection and Natural Resources of Ukraine https://menr.gov.ua/ in the section "Business" – "Permits and licenses" – "License register (handling hazardous waste)")

No.	Name	Specialization (operations and types of hazardous waste)
1	UKRMITBEST LTD*	– clinical and similar waste, namely waste arising from medical care, veterinary or similar practices and waste generated in hospitals or other institutions during research, patient care or research activities (collection, storage, disposal, neutralization); – waste of chemicals obtained during the research or educational process, which are not yet infected, which are new, and their impact on humans and/or the environment is unknown (collection, storage, disposal, neutralization)
2	ECO NEW LTD*	– clinical and similar waste, namely waste arising from medical care, veterinary or similar practices and waste generated in hospitals or other institutions during research, patient care or research activities (collection, storage, disposal, neutralization); – wastes from the production, receipt and use of pharmaceuticals, with the exception of wastes specified in the Green List of wastes (collection, storage, disposal, neutralization)
3	INDUSTRIAL COMPANY ECOSPHERE LTD*	– clinical and similar waste, namely waste arising from medical care, veterinary or similar practices and waste generated in hospitals or other institutions during research, patient care or research activities (collection, storage, disposal, neutralization);
4	ENVIRONMENTAL PROCESSING TECHNOLOGIES LTD*	– wastes from the production, receipt and use of pharmaceuticals, with the exception of wastes specified in the Green List of wastes (collection, storage, disposal, neutralization); – clinical and similar waste, namely waste arising from medical care, veterinary or similar practices and waste generated in hospitals or other institutions during research, patient care or research activities (collection, storage, disposal, neutralization);
5	EQUIVALENT LTD*	
6	SVITKOM-TORG LTD**	– wastes from the production, receipt and use of pharmaceuticals, with the exception of wastes specified in the Green List of wastes (collection, storage, disposal, neutralization); – clinical and similar waste, namely waste arising from medical care, veterinary or similar practices and waste generated in hospitals or other institutions during research, patient care or research activities (collection, storage, disposal, neutralization);
7	GREEN ART LTD**	– wastes from the production, receipt and use of pharmaceuticals, with the exception of wastes specified in the Green List of wastes (collection, storage, disposal, neutralization)
8	POLEKOZASHCHITA LTD**	– clinical and similar waste, namely waste arising from medical care, veterinary or similar practices and waste generated in hospitals or other institutions during research, patient care or research activities (collection, storage, disposal, neutralization); – waste of chemicals obtained during the research or educational process, which are not yet infected, which are new, and their impact on humans and/or the environment is unknown (collection, storage, disposal, neutralization); – wastes from the production, receipt and use of pharmaceuticals, with the exception of wastes specified in the Green List of wastes (collection, storage, disposal, neutralization)
9	EKO-FORS LTD**	– wastes from the production, receipt and use of pharmaceuticals, with the exception of wastes specified in the Green List of wastes (collection, storage, disposal, neutralization)

Note:

* Enterprises licensed to carry out operations in the field of hazardous waste management, information provided by the Health Department of the Poltava Regional State Administration dated October 29, 2020.

** Enterprises licensed to conduct operations in the field of hazardous waste management, information according to the Ecological passport of the Poltava region (2019).

life (as a result of self-treatment of people at home) and is removed together with mixed household waste to landfills without undergoing preliminary disinfection.

According to the medical waste management statistics, most of the waste generated in medical institutions is sent for recycling, only about 6.5% is sent for disposal. However, the statistics of criminal liability for offenses indicates an increase in crimes in this activity field.

Unfortunately, there is no direct responsibility for the improper handling of medical waste in the existing legislation of Ukraine. It should be pointed out that administrative punishment is not an effective lever for solving this problem. Most enterprises and institutions were given material penalties for the improper handling of household waste, which are not critical from the point of view of the economic activity of these entities. Another matter concerns more severe liability, namely that which is criminal. But even in this case, there are no direct articles of the Criminal Code of Ukraine (CCU) that would clearly formulate the responsibility of both the heads of institutions and enterprises, and individuals for careless and criminal handling of medical waste.

The current Criminal Code of Ukraine, namely Article 325 "Violations of sanitary rules and norms for the prevention of infectious diseases and mass poisoning" and Article 326 "Violations of the rules for handling microbiological or other biological agents or toxins" can partially be applied in case of careless and criminal handling of medical, and only in the case when the guilt of the subject will be fully proven. It is rather difficult to single out guilt in this process, which directly indicates that improper handling of medical waste is the cause of the crime.

To assess and understand the possibility of influencing the situation with medical waste, the dynamics of criminal offenses under Article 325 of CCU and Article 326 of CCU in the period from 2017 to 2021 was analyzed. The report of the Office of the Prosecutor General of Ukraine [https://www.gp.gov.ua/] on criminal offenses against public health has statistical data for this period. Conventionally, two characteristic periods of time can be distinguished, before the start of the spread of the COVID-19 viral infection and during the pandemic (since 2020), when the use of medications and personal protective equipment (PPE) began actively.

An analysis of the diagram (Fig. 3) shows a sharp jump in criminal offenses precisely with the intensive use of medical supplies, drugs, PPE, etc. The number of such offenses was increased by more than 2.35 times. That is, implicitly, we have a connection between the treatment of medical waste and the statistics of the growth of criminal cases under Article 325. It should be noted that official statistics are, so to speak, "the tip of the iceberg".

One of the important elements of this analysis is the comparison of crime statistics separately in 2017 and from 2021 by months (Fig. 4). We have a qualitatively identical picture of the number of offenses, which indicates an almost equidistant (equidistance of all points of one curve relative to the other) of these data by months. As expected, we tend to increase the number of such criminal offenses, which also indicates a significant connection with the use and handling of medical supplies, drugs and PPE.

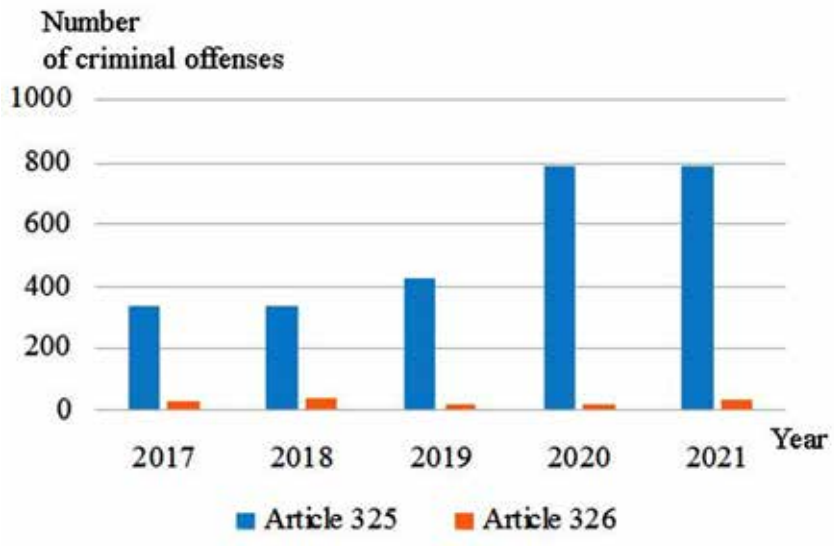

Figure 3. Dynamics of the criminal offenses number under Article 325 of CCU and Article 326 of CCU in the period for 2017–2021

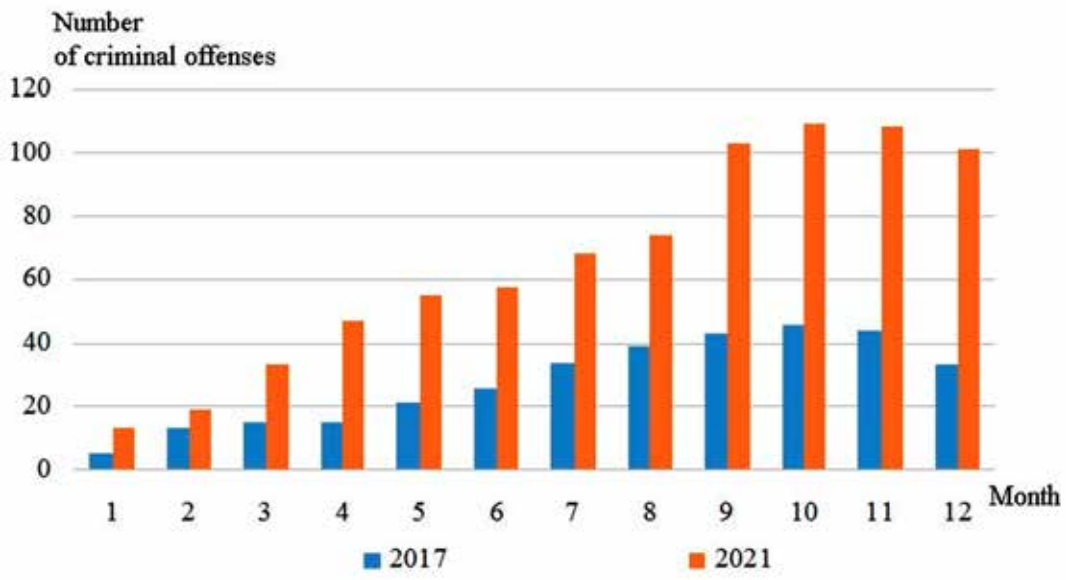

Figure 4. Comparison of the number of criminal offenses under Article 325 of CCU in 2017 and 2021

As noted above, administrative responsibility is not a very effective mechanism in dealing with the issue of waste management. Understanding what risks and dangers for a person associated with the epidemiological situation arise from reckless waste management, it is necessary to take an adequate, effective system of measures.

In our opinion, only two mechanisms can be identified that will work together and complement each other at the same time. This, of course, is an increase in the general culture of the population in the field of environmental safety and the development and implementation of legal norms that provide for criminal liability for improper handling of medical waste.

In addition, special attention needs to be given to issues that may cause threats in the future:

- Absence in the Poltava region of operating facilities for the disposal of medical waste;
- The problem of getting infected PPE into category A waste to landfills along with household waste from the population;
- Classification of personal protective equipment, namely medical masks, to category B – infected and potentially infected waste that has come into contact with biological media of infected material. Since they were previously classified as Category A waste;
- The untimely solution of these problems will lead to the emergence of a complex of threats of a sanitary-epidemiological, environmental and psychological nature and, ultimately, to a significant increase in the epidemiological risk of people living, primarily in cities.

5. Conclusions

Based on the results of the study, we can draw conclusions about the need for an integrated approach to solving the problem of medical waste generation and management:

1. In the context of the fight against the pandemic and as a result of the growth in the volume of medical waste, it is necessary to organize constant monitoring of the volumes of waste generation and management using modern approaches to collecting and solving the problems of routing their location (Tirkolaee & Aydın, 2021; Tirkolaee et al., 2021), as well as modern methods for emergency treatment of medical waste (Ma et al., 2020) and disinfection strategies for COVID-19 hospitals (Ilyas et al., 2020).
2. The existing infrastructure for the treatment of medical waste requires improvement in terms of both the volume of processing and the improvement of existing processing technologies.
3. The dynamics of the formation of medical waste, including in everyday life, indicates the need to introduce a system for sorting and controlling household waste, as a measure to reduce the risk of medical waste entering municipal solid waste landfills.
4. It is the combined actions of municipal services, medical institutions and the commission on technogenic and environmental safety at the regional level that will contribute to solving the problem of accumulation of medical waste and its handling.

5. The volumes of reported medical waste should be critically reviewed (increasingly), as in the pursuit of good performance and reducing fees for waste generation, these figures may be somewhat underestimated.
6. The legislation of Ukraine in the field of offenses for improper handling of medical waste should be revised and articles should be developed and implemented providing for stricter liability, namely criminal liability for offenses in this activity field.

Acknowledgements

The authors are grateful to the Main Department of Statistics in the Poltava region for providing statistical data and to the administrations of National University "Yuri Kondratyuk Poltava Polytechnic" (Poltava, Ukraine) and State Biotechnological University (Kharkiv, Ukraine) for the opportunity to conduct the study.

References

Aung T.S., Luan S. & Xu Q., 2019, Application of multi-criteria-decision approach for the analysis of medical waste management systems in Myanmar. Journal of Cleaner Production 222: 733–745. DOI: 10.1016/j.jclepro.2019.03.049.

Barua U. & Hossain D., 2021, A review of the medical waste management system at Covid-19 situation in Bangladesh. Journal of Material Cycles and Waste Management 23(6): 2087–2100. DOI: 10.1007/s10163-021-01291-8.

Bucătaru C., Săvescu D., Repanovici A., Blaga L., Coman E. & Cocuz M.E., 2021, The implications and effects of medical waste on development of sustainable society – a brief review of the literature. Sustainability 13(6): 3300. DOI: 10.3390/su13063300.

Chisholm J.M., Zamani R., Negm A.M., Said N., Abdel daiem M.M., Dibaj M. & Akrami M., 2021, Sustainable waste management of medical waste in African developing countries: A narrative review. Waste Management & Research 39(9): 1149–1163. DOI: 10.1177/0734242X211029175.

Husain Khan A., Abdul Aziz H., Khan N.A., Ahmed S., Mehtab M.S., Vambol S., Vambol V. & Islam S., 2020, Pharmaceuticals of emerging concern in hospital wastewater: removal of Ibuprofen and Ofloxacin drugs using MBBR method. International Journal of Environmental Analytical Chemistry, p. 1–15. DOI: 10.1080/03067319.2020.1855333.

Husyeva Ya. & Kopytsya Ye., 2021, Problemni pytannya pravovoho rehulyuvannya povodzhennya z medychnymy vidkhodamy v Ukrayini. Zbirnyk naukovykh prats LÓHOS, 2021 (5 hrudnya), p. 108–110. DOI 10.36074/logos-26.11.2021.v1.36.

Illyash O.E. & Yurchenko A.O., 2020, Menedzhment medychnykh vidkhodiv razovoho vykorystannya pry pandemiyi COVID-19. 72-a naukova konferentsiya profesoriv, vykladachiv, naukovykh pratsivnykiv, aspirantiv ta studentiv universytetu, prysvyachenoyi 90-richchyu Natsional'noho universytetu «Poltavs'ka Politekhnika imeni Yuriya Kondratyuka», (Poltava, 21 kvitnya – 15 travnya 2020 r.), T.1: 281–282.

Ilyas S., Srivastava R.R. & Kim H., 2020, Disinfection technology and strategies for COVID-19 hospital and bio-medical waste management. Science of the Total Environment, 749: 141652. DOI: 10.1016/j.scitotenv.2020.141652.

Khan N.A., Vambol V., Vambol S., Bolibrukh B., Sillanpaa M., Changani F., … & Yousefi M., 2021, Hospital effluent guidelines and legislation scenario around the globe: A critical review. Journal of Environmental Chemical Engineering 9(5): 105874. DOI: 10.1016/j.jece.2021.105874.

Ma Y., Lin X., Wu A., Huang Q., Li X. & Yan J., 2020, Suggested guidelines for emergency treatment of medical waste during COVID-19: Chinese experience. Waste Disposal & Sustainable Energy 2(2): 81–84. DOI: 10.1007/s42768-020-00039-8.

Mao K., Zhu Y., Zhao Z. & Shan Y., 2020, Authoritarian environmentalism and environmental regulation enforcement: A case study of medical waste crime in northwestern China, [in:] A. Brisman and N. South (eds), Routledge International Handbook of Green Criminology, 2nd Edition, p. 382–400. Routledge.

Parida A., Capoor M.R. & Bhowmik K.T., 2019, Knowledge, attitude, and practices of Bio-medical Waste Management rules, 2016; Bio-medical Waste Management (amendment) rules, 2018; and Solid Waste Rules, 2016, among health-care workers in a tertiary care setup. Journal of Laboratory Physicians 11(04): 292–296. DOI: 10.4103/JLP.JLP_88_19.

Safranov T.A., Shanina T.P., Prykhodko V. Yu., 2021, Peredumovy formuvannya i realizatsiyi rehionalnoho planu upravlinnya tverdymy munitsypalnymy vidkhodamy v Odeskiy oblasti. Ukrayinskyy Hidrometeorolohichnyy Zhurnal 27: 86-96. DOI: 10.31481/uhmj.27.2021.09.

Shulha Ye.V. & Karnaukh-Holodnyak O.V., 2020, Problemy administratyvno-pravovoho zabezpechennya povodzhennya z medychnymy vidkhodamy v period pandemiyi v Ukrayini. Pravo i Suspilstvo 3: 120–126. DOI: 10.32842/2078-3736/2020.3-2.19.

Strelchenko O.H. & Bukhtiyarova I.H., 2021, Osoblyvosti administratyvno-pravovoho rehulyuvannya povodzhennya iz medychnymy vidkhodamy. Visnyk Luhans'koho Derzhavnoho Universytetu Vnutrishnikh SpravimeniE.O.Didorenka2(94):156–170.DOI:10.33766/2524- 0323.94.156-170.

Tirkolaee E.B., Abbasian P. & Weber G.W., 2021, Sustainable fuzzy multi-trip location-routing problem for medical waste management during the COVID-19 outbreak. Science of the Total Environment 756: 143607. DOI: 10.1016/j.scitotenv.2020.143607.

Tirkolaee E.B., Aydın N.S., 2021, A sustainable medical waste collection and transportation model for pandemics. Waste Management & Research 39(1_suppl): 34–44. DOI: 10.1177/0734242X211000437.

Zamparas M., Kapsalis V.C., Kyriakopoulos G.L., Aravossis K.G., Kanteraki A.E., Vantarakis A. & Kalavrouziotis I.K., 2019, Medical waste management and environmental assessment in the Rio University Hospital, Western Greece. Sustainable Chemistry and Pharmacy 13: 100163. DOI: 10.1016/j.scp.2019.100163.