PRES'23

Proceedings of the 26th Conference on Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction, 8 – 11 October 2023, Thessaloniki, Greece

Editors: Panos Seferlis, Petar S. Varbanov, Sakis Papadopoulos, Yee Van Fan, Xue-Chao Wang, Bohong Wang
Copyediting and Composition: Xuexiu Jia, Xue-Chao Wang, Hon Huin Chin, Bohong Wang

Hazardous Waste Generation and Management: a Case Study of Ukraine

Vitalii Ishchenko[a,*], Sun Xiaodong[a], Lilia Hlavatska[a], Igor Gritsuk[b]

[a]Vinnytsia National Technical University, Department of Ecology, Chemistry and Environmental Protection Technologies, Khmelnytske shose 95, Vinnytsia, 21021, Ukraine
[b]Kherson State Maritime Academy, Ship Power Plants Operation Department, Ushakov avenue 20 Kherson, 73000, Ukraine
ischenko.v.a@vntu.edu.ua

Nowadays, hazardous waste is a serious concern around the world. If such waste is delivered to landfills, this may lead to the leaching of toxic substances into the environment. In Ukraine, a significant amount of hazardous waste is landfilled. Thus, there is a significant risk of environmental pollution with toxic chemicals. For this research, the literature data, registers of the State Statistics Service of Ukraine, and other open information resources were used. Accounting for hazardous waste generation in Ukraine is provided by companies generating this waste. The control over this process is not sufficient. According to statistical data, about 600,000 t (or 15 kg/y per capita) of hazardous waste are generated annually in Ukraine. it is much less compared to developed industrialized countries. The largest share belongs to waste acids, alkalis, and salts. The rate of hazardous waste recycling in Ukraine has decreased in recent years and fluctuates between 42 - 45 %. The amount of hazardous waste generated as a part of household waste is estimated at about 0.5–3 kt/y. The share of hazardous household waste is 0.03 – 0.1 % or 0.24 kg/y per capita, or 0.08 – 0.14 % (up to 0.4 kg/y per capita), taking into account the commercial sector. This is an order of magnitude less than in EU countries. Official data on hazardous waste generation in Ukraine are probably underestimated.

1. Introduction

Nowadays, hazardous waste is a serious concern around the world. It is known that hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. LaGrega et al. (2010) define hazardous waste as a by-product of becoming a developed country. If such waste is delivered to landfills, this may lead to the leaching of toxic substances to the environment. This results in water pollution, air pollution, soil pollution, and then human health risks. The environmental impact of hazardous waste is quite complex and diverse. The assessment of environmental risks related to hazardous waste mismanagement is one of the most important areas of research. Besides, some components of hazardous waste (e.g., metals) can be recovered for recycling according to the circular economy principles.

The volume of hazardous waste generated in the European Union is constantly rising and currently exceeds 100 million t/y (Camacho et al., 2020). According to Kovach and Lysychenko (2017), Ukraine inherited many abandoned stores of expired pesticides and herbicides and dumps of toxic waste from the days of the Soviet Union.

In Ukraine, a significant amount of hazardous waste is landfilled. Thus, there is a significant risk of environmental pollution with toxic chemicals. The situation is complicated when more dangerous components are found in the waste every next year. Those of significant concern include, for example, batteries and accumulators, waste electrical and electronic equipment, persistent organic pollutants, particularly pesticide-containing waste, etc. Hlavatska and Ishchenko (2021) have found many toxic substances migrate from waste into the leachate and the soil due to hazardous waste. Many studies indicate the penetration of many harmful substances into the environment along with the leachate from landfills due to the presence of hazardous components in waste. Gautam et al. (2019) have revealed heavy metals and halogenated hydrocarbons (usual components of hazardous waste) from landfill leachate as the main source of groundwater pollution. Nair and Abraham (2018) have found more than 50 pollutants in the leachate, including heavy metals and many dangerous organic pollutants (phthalates, benzene, its derivatives, polychlorinated biphenyls, and many others). The amount and

variety of hazardous waste constantly increase. Some researchers studied certain hazardous waste and their environmental impact: waste batteries (Recknagel et al., 2014), waste electrical and electronic equipment (Su et al., 2020), proving the toxic substances present. Study on pollutants leaching from waste under laboratory conditions using landfill simulators has shown the long-term impact of landfills on the environment (Gu et al., 2020).

There is a trend of stable growth of total volumes of accumulated hazardous waste of I–III hazard classes in storage sites: an increase of 10.4 % in 2015–2021 (Pokataiev et al., 2021), about 12 Mt of hazardous waste is accumulated in Ukraine (Gubina et al., 2021).

While research articles cover well the topic of waste management in Ukraine, hazardous waste is poorly studied as a separate waste category. Usually, one can find only general data, without detailed analysis, or data on a few specific types of hazardous waste, e.g., Valyuk and Yakymchuk (2018) have focused on hexachlorobenzene from potassium ore mine, Niewiadomski et al. (2022) have studied oil refinery waste. The goal of this paper is to analyze hazardous waste generation, its structure, and management possibilities in Ukraine compared to world trends.

2. Materials and methods

For this research, the literature data, registers of the State Statistics Service of Ukraine and other open information resources were used. Accounting for hazardous waste generation in Ukraine is provided by companies generating the waste without relevant control. Companies submit data on the amount of hazardous waste generated to the State Statistics Service of Ukraine once a year. However, the reliability of these data depends on the companies' responsibility because it is quite difficult to control the data provided. This can be done by the State Environmental Inspection during an inspection once per several years (sometimes up to once per 10 y). However, in practice, it is not possible to check waste that has already been disposed of or sent for processing (only according to the official documents). When companies are interested in having the smallest possible amount of waste, there is a possibility of underestimating the amount of hazardous waste generated.

This paper includes an analysis of two hazardous waste streams: industry and households. Data on industrial hazardous waste are available, but there are limitations explained above. Data on hazardous waste from households is much less available due to the lack of a single accepted list, as well as the lack of efficient separate collection of waste. The data on hazardous household waste are available only for the commercial waste (all organizations submit data to the State Statistics Service of Ukraine). And there are no data on the content of hazardous components in household waste since this category is not separated and is included in the "other waste" category.

3. Industrial hazardous waste generation

According to statistical data (State Statistical Service of Ukraine, 2023), about 600,000 t of hazardous waste is generated annually in Ukraine (Table 1) with more than half in two regions: Sumy and Donetsk (due to the location of companies generating hazardous waste, mainly chemical waste). This corresponds to approximately 15 kg/y per capita and is about 2 % of the total mass of generated waste. For comparison, this is more than in many other countries: for example, in India, about 6 kg/cap of hazardous waste is generated annually (Basu and Chakraborty, 2016), in Poland – about 7 kg/y per capita (Gregorz et al., 2022). However, it is much less comparing to developed industrialized countries: for example, South Korea generates more than 100 kg/cap of hazardous waste annually (Lee et al., 2022), Spain – about 70 kg/cap (Camacho et al., 2020). By 2014 (before the start of military actions), the annual generation of hazardous waste in Ukraine reached more than 1 Mt, see Figure 1 (National report, 2021).

One can see a trend to reduce the amount of hazardous waste generated also after 2018, primarily due to a significant reduction in the generation of ferrous metal waste (almost twice), animal waste (more than twice), and other mineral waste (in 3 times). The decrease in the amount of ferrous metal waste can be explained by the tough economic condition of Ukrainian metallurgical companies, as the majority of raw materials were supplied from Donetsk and Luhansk regions, that is, territories that have been affected by military actions since 2014. However, the reduction of animal waste is difficult to explain since agriculture in Ukraine actively develops recently. An abnormally high animal waste generation was registered in 2018. It is possible that animal waste generation in 2019–2020 was significantly lower compared to the previous year. Apart from the abovementioned waste, a significant share also belongs to the waste acids, alkalis, and salts (30 % in 2020, a constant increase is observed), mixed and undifferentiated materials, sludges, and liquid waste from waste treatment. In other countries, the largest share also belongs to waste acids and alkalis. But the share of spent solvents in Ukraine is much smaller.

It is worth noting that the real amount of accumulated hazardous waste in Ukraine exceeds the amount registered in statistical reports since the data are not received from bankrupt and closed companies that have previously accumulated a large waste amount.

Table 1: Industrial hazardous waste generation in Ukraine, 2017–2020

Waste category	Weight, kt			
	2017	2018	2019	2020
Spent solvents	1.0	0.8	1.1	2.0
Acid, alkaline and saline waste	147.7	154.8	155.7	161.0
Used oils	17.0	14.6	14.2	19.0
Chemical waste	17.4	15.3	16.4	17.5
Industrial effluent sludges	41.0	49.8	24.8	49.0
Sludges and liquid waste from waste treatment	3.6	3.6	2.9	9.9
Health care and biological waste	0.2	0.2	0.2	0.3
Metallic waste, ferrous	139.9	135.7	117.1	72.2
Metallic waste, non-ferrous	7.5	6.4	4.6	3.4
Metallic waste, mixed ferrous and non-ferrous	0.9	0.6	0.7	0.5
Glass waste	0.1	0.1	0.1	0.7
Paper and cardboard waste	0.2	0.1	0.2	0.1
Rubber waste	3.7	2.7	1.8	2.1
Plastic waste	3.3	2.4	4.0	2.4
Wood waste	4.4	1.1	1.8	1.5
Textile waste	1.4	1.1	1.5	1.5
Waste containing polychlorinediphenyls	0.2	0.2	0.3	0.2
Discarded equipment	2.8	1.6	1.8	1.4
Discarded vehicles	0.0	0.0	0.1	0.1
Batteries and accumulators	4.1	3.8	4.5	4.2
Animal and mixed food waste	16.1	18.4	13.4	14.3
Vegetal waste	0.5	0.9	1.1	0.1
Animal faeces, urine and manure	15.7	50.7	20.1	21.5
Household and similar waste	0.2	0.2	0.1	1.5
Mixed and undifferentiated materials	72.7	72.1	73.5	61.2
Sorting residues	1.5	0.1	0.1	0.0
Common sludges	5.8	6.0	6.3	6.1
Mineral waste from construction and demolition, incl. mixed construction waste	0.7	2.0	0.6	0.3
Combustion waste	64.5	54.4	57.0	51.8
Other mineral waste	20.8	17.5	16.5	17.4
Soils	0.6	0.5	0.6	0.5
Dredging spoils	–	–	–	0.0
Mineral waste from waste treatment and stabilized waste	9.8	9.7	9.9	8.3
Total	605.3	627.4	553.0	532.0

The rate of hazardous waste recycling in Ukraine has decreased in recent years and fluctuates between 42-45 % (Figure 2). In contrast, waste incineration has increased slightly, although it is still the least common method of hazardous waste management, with a share of up to 2 %.

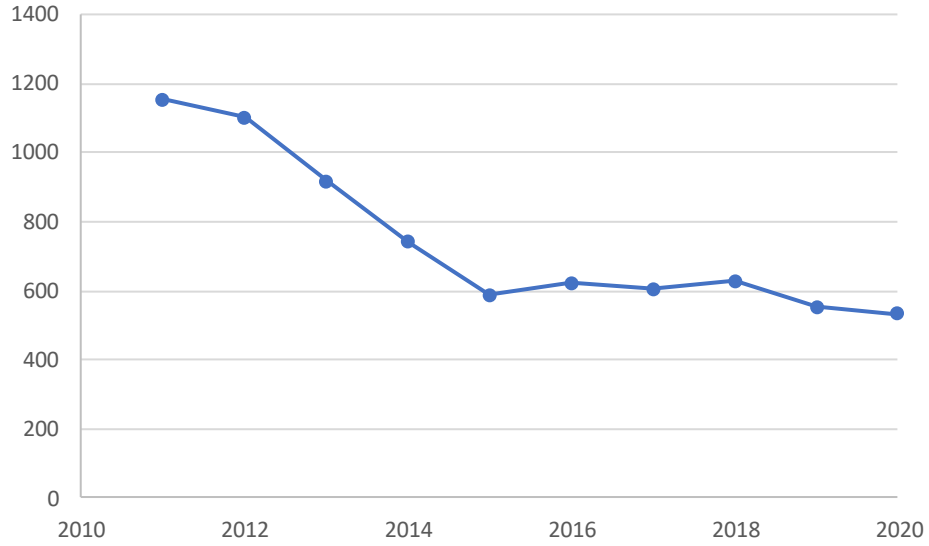

Figure 1: Industrial waste generation in Ukraine, kt, 2011–2020

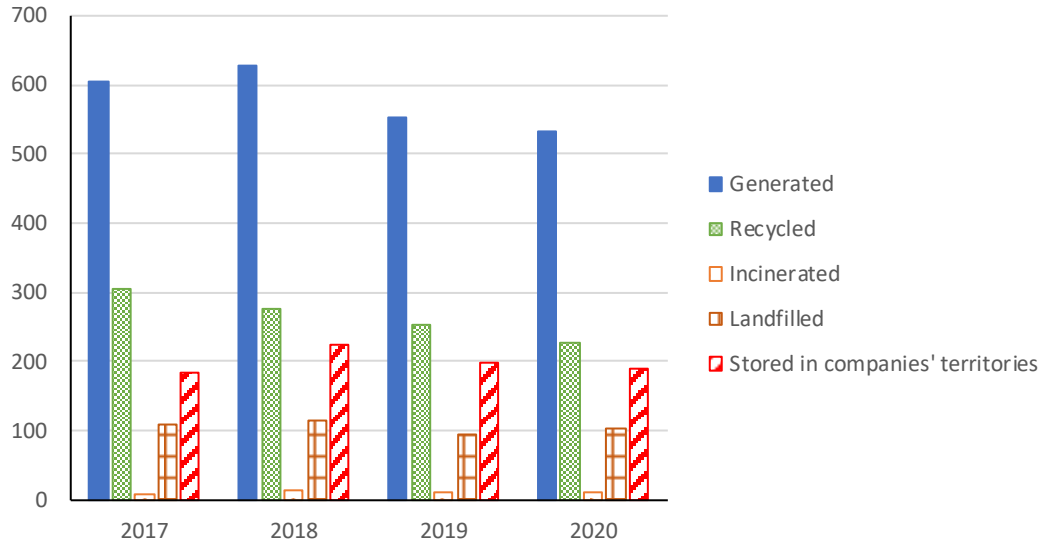

Figure 2: Hazardous waste management in Ukraine, kt, 2017–2020

Another 17–19 % of hazardous waste is landfilled in special places; the rest (over one-third) is temporarily stored in the territory of companies where it was generated. This is an issue because it is formally allowed only for a short time until the fate of the waste is defined. But, in practice, waste that was not immediately disposed of or delivered for recycling remains in the companies' territory for a long time without appropriate storage conditions. The recycling rate for the hazardous waste categories with the largest share varies significantly (Figures 2–5): from very low to average. Incineration remains the least used method for all waste categories due to the low capacity of incineration equipment. Up to 60 % of waste acids, alkalis, and salts are recycled, but also a significant part (more than 35 %) is landfilled, and only a small share (2–4 %, decreases over last years), unlike other categories, is stored in the territory of companies (Figure 3).

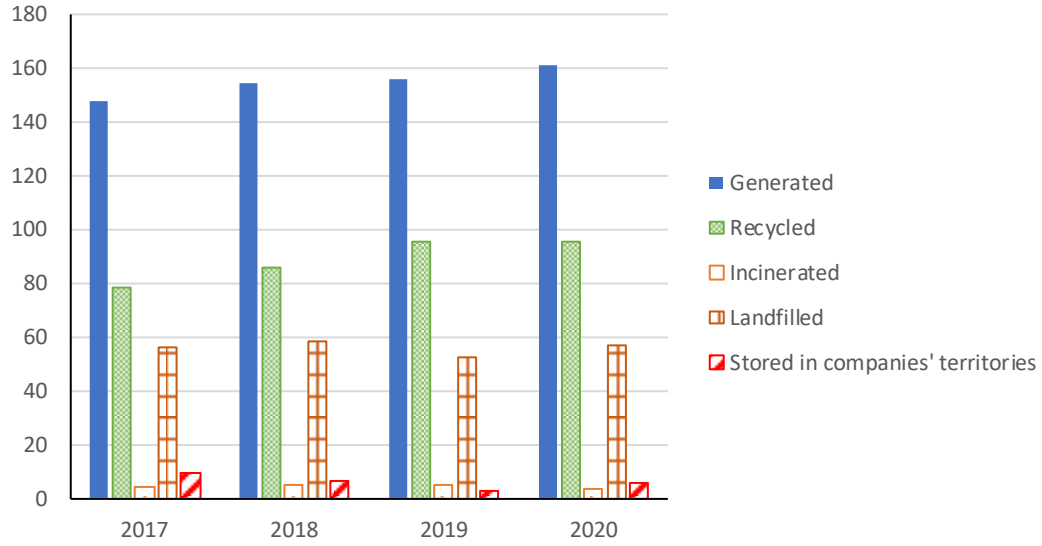

Figure 3: Waste acids, alkalis and salts management in Ukraine, kt, 2017–2020

For obvious reasons, ferrous metal waste is not incinerated or landfilled, but the recycling rate is extremely low – 16–29 %, it has been decreasing in recent years, and over 97 % of ferrous metal waste was stored in the companies' territories in 2020 (Figure 4).

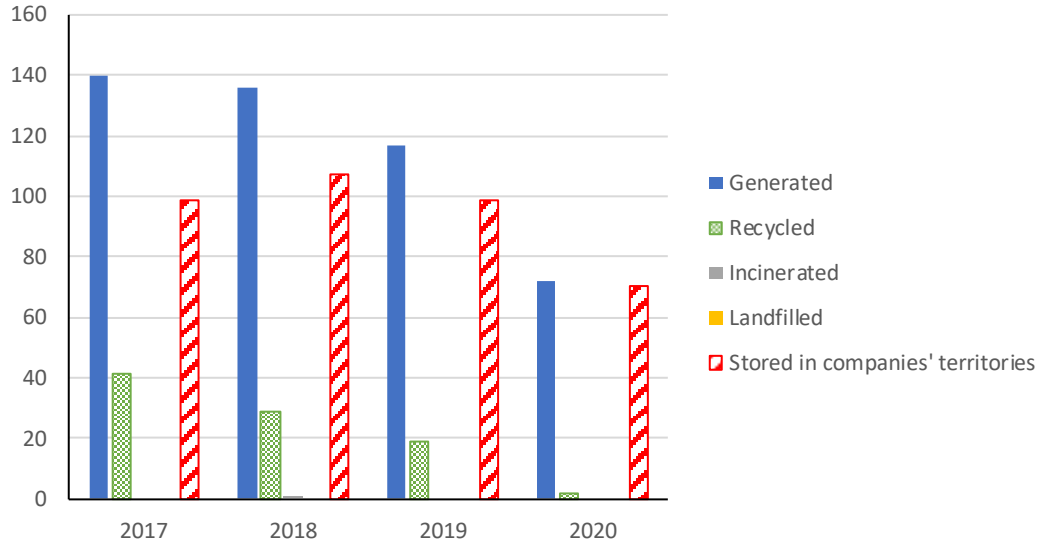

Figure 4: Ferrous metal waste management in Ukraine, kt, 2017–2020

Mixed and undifferentiated materials are mainly recycled, and only a small but growing share remains in temporary storage places in companies (Figure 5). Management options for other mineral waste are completely different: the recycling rate has sharply decreased in recent years to a minimum, and almost all waste is stored in the territory of companies (Figure 6). The data on sludges and liquid waste from waste treatment fluctuate year by year. Particularly, the amount of landfilled waste varies significantly every year (Figure 7). However, it is worth noting the gradual increase in the recycling rate (up to more than 30 %).

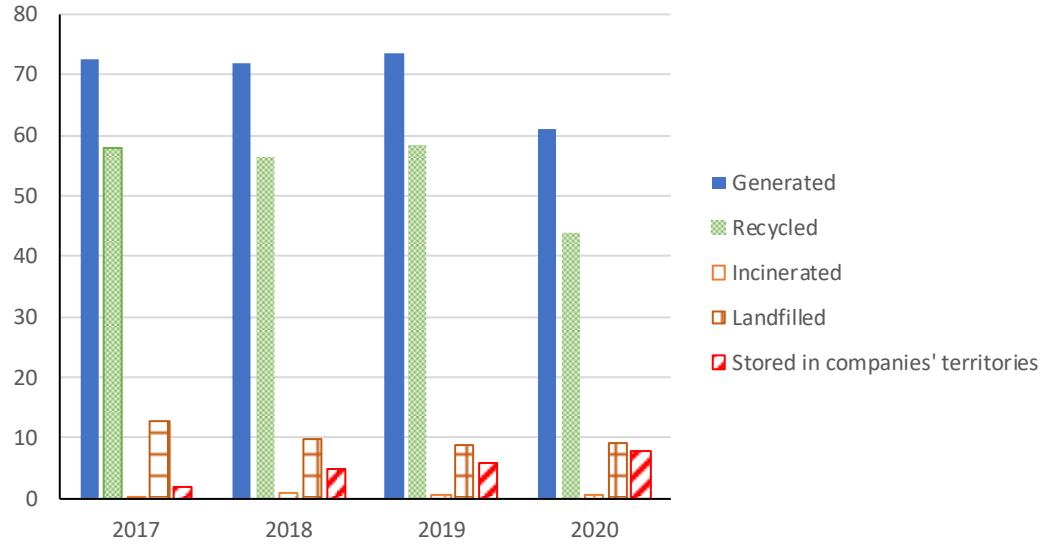

Figure 5: Mixed and undifferentiated materials management in Ukraine, kt, 2017–2020

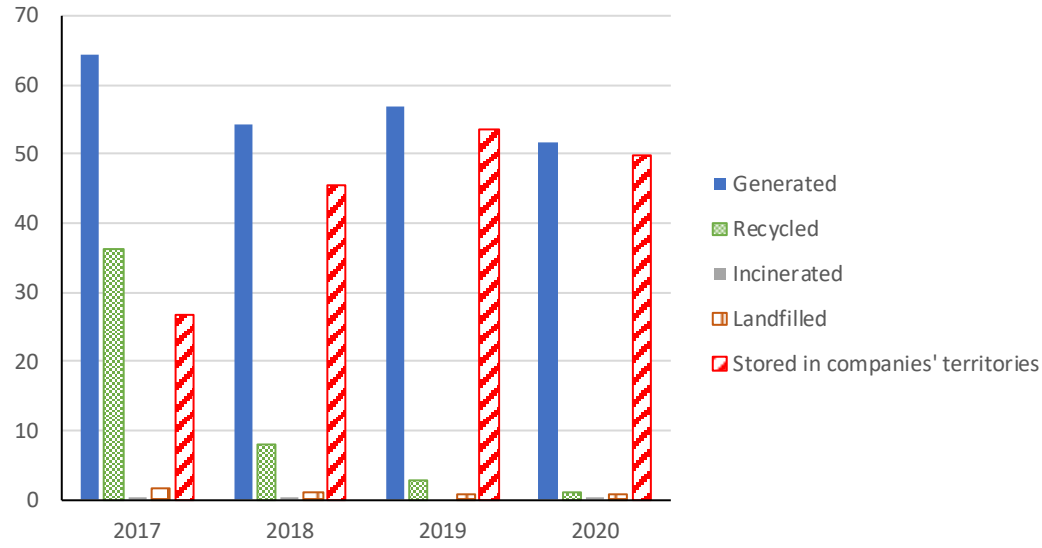

Figure 6: Other mineral waste management in Ukraine, kt, 2017–2020

In total, over 12 Mt of hazardous waste has been accumulated at special landfills in Ukraine. Other mineral waste constitutes more than half of this amount (over 6.5 Mt), the rest includes waste acids, alkalis and salts (2.5 Mt), sludges and liquid waste from waste treatment (over 0.9 Mt), and chemical waste (over 0.8 Mt). Almost 2/3 of the hazardous waste is accumulated in Zaporizhzhia region (National Report, 2020), though the share of this region in the annual generation is only about 3 % in recent years. As of 2020, the highest recycling rate is registered for common sludges (77 %), mixed and undifferentiated materials (72 %), waste oil (64 %), waste acids, alkalis and salts (59 %), and non-ferrous metal waste (53 %). Other waste categories are recycled below 50 % level.

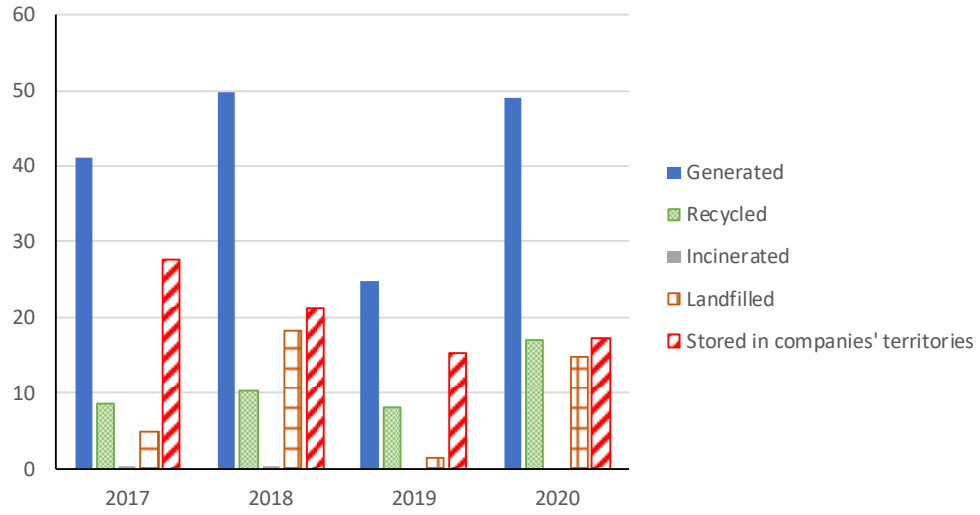

Figure 7: Management of sludges and liquid waste from waste treatment in Ukraine, kt, 2017–2020

There are also some waste categories with zero recycling: mixed waste of ferrous and non-ferrous metals, glass waste, rubber waste, textile waste, discarded vehicles, mineral waste from waste treatment and stabilized waste and mineral waste generated after processing. Besides, there is a large number of recycled batteries and accumulators exceeding their annual generation. This may be explained by the recycling of previously accumulated (for many previous years) waste.

4. Hazardous waste generation in households

Additionally, hazardous waste generated in households should be analyzed in order to provide data completeness. Hazardous household waste is not accounted for as a separate category. The estimated amount of hazardous waste generated as a part of household waste, according to the National environmental reports is about 0.5–3 kt/y (National Report, 2020).

The abovementioned data obviously do not take into account all hazardous household waste, but only those generated in households. However, household waste from commercial organizations is also included in the general household waste stream. They also need to be taken into account when estimating hazardous household waste generation. For this purpose, the data of the State Statistics Service of Ukraine were additionally analyzed. At the same time, these data are retrieved from the reports of companies. They actually cover only commercial waste.

Among hazardous household waste, the largest share was found for old equipment and devices (up to 3.5 kt/y), batteries and accumulators including electrolytes (over 3 kt/y), waste fertilizers (over 2 kt/y), oils and fats (around 1 kt/y), medical waste and fluorescent lamps and other mercury-containing waste (0.5 kt/y each).

Household waste generation in Ukraine is about 11–12 Mt/y (Ishchenko et al., 2019). The share of hazardous household waste is 0.03–0.1% or 0.24 kg/y per capita, or 0.08–0.14% (up to 0.4 kg/y per capita), taking into account the commercial sector. This is an order of magnitude less than in EU countries (up to 1.2 %) (Adamcova et al., 2016) or, for example, in Japan (about 2 kg/y per capita (Yasuda and Tanaka, 2006)). Therefore, Ukrainian data are probably significantly underestimated due to a large amount of unaccounted waste. Under insufficient control, the reliability of these data may be questionable.

5. Conclusions

Hazardous waste remains an important environmental issue for every country, regardless of the economic development level. Industrial hazardous waste generation in Ukraine slightly exceeds that in many other countries, which is related to the developed chemical and metallurgical industries: waste acids, alkalis and salts, as well as ferrous metals waste, prevail. However, hazardous waste generation decreases and is significantly less compared to developed industrialized countries. The average recycling rate of hazardous waste is below 50 %, while the highest level is registered for common sludges, mixed and undifferentiated materials, waste oils, waste acids, alkalis and salts, and non-ferrous metal waste. More than one-third of hazardous waste is temporarily stored in the companies' territories.

Hazardous waste generated in households is not recorded. The data obtained by the authors are very approximate and an order of magnitude smaller than, for example, in developed countries. The categories with the largest shares include waste equipment and appliances, as well as batteries and accumulators.
Official data on the hazardous waste generation in Ukraine are probably underestimated, because: a) there is a significant amount of unaccounted industrial hazardous waste stored in the territories of non-working companies; b) accounting of hazardous waste in households is not carried out. There is a need for further research on hazardous waste generation and management in Ukraine.

References

Adamcová D., Vaverková M.D., Stejskal B., Břoušková E., 2016, Household solid waste composition focusing on hazardous waste, Polish Journal of Environmental Studies, Poland, 25(2), 487–493.

Basu P., Chakraborty J., 2016, Environmental justice implications of industrial hazardous waste generation in India: A national scale analysis, Environmental Research Letters, 11(12), 125001.

Camacho J.A., Ruíz-Peñalver S.M., Rodríguez M., 2020, Identification of leading hazardous waste generating industries with high improvement potential in Spain, Science of The Total Environment, 731, 139207.

Gautam P., Kumar S., Lokhandwala S., 2019, Advanced oxidation processes for treatment of leachate from hazardous waste landfill: A critical review, Journal of Cleaner Production, 237, 117639.

Grzegorz P., Emilian M., Adrian C., Oana I., 2022, Hazardous Waste Advanced Management in a Selected Region of Poland, Processes, 10(10), 2032.

Gu Y., Wang L., Shen D., Ruan J., Lu S., Long Y., 2020, Characterization of solidification for disposal of hazardous waste landfill leachate, Environmental Science and Pollution Research, 27(4), 4227–4235.

Gubina V., Zaborovsky V., Mitsiuk N., Srat A.F., 2021, Differences in the generation of industrial waste from economic activities in Ukraine and the EU and the prospects for the integrated use of mineral raw materials, In: E3S Web of Conferences, vol. 280, EDP Sciences, 09008.

Hlavatska L., Ishchenko V., Pohrebennyk V., Salamon I., 2021, Material Flow Analysis of Waste Electrical and Electronic Equipment in Ukraine, Journal of Ecological Engineering, 22(9), 199–208.

Ishchenko V., Pohrebennyk V. Kochan R., Mitryasova O., Zawislak S., 2019, Assessment of hazardous household waste generation in Eastern Europe, In: SGEM2019 Conference Proceedings, Vol. 19, Issue 6.1, 559–566.

Kovach V., Lysychenko G., 2017, Toxic soil contamination and its mitigation in Ukraine, In: Soil Science Working for a Living: Applications of soil science to present-day problems, Springer International Publishing, 191–201.

LaGrega M.D., Buckingham P.L., Evans J.C., 2010, Hazardous waste management, Waveland Press, USA.

Lee D., Kim J., Park H.S., 2022, Characterization of industrial hazardous waste generation in South Korea using input-output approach, Resources, Conservation and Recycling, 183, 106365.

Nair S., Abraham J., 2018, Hazardous waste management with special reference to biological treatment, In: C.M. Hussain (ed.), Handbook of Environmental Materials Management, Springer International Publishing AG 2018, 1–27.

National report on environment in Ukraine in 2020, 2021, Ministry of Environment Protection and Natural Resources of Ukraine, Kyiv, Ukraine.

National report on environment in Ukraine in 2019, 2020, Ministry of Environment Protection and Natural Resources of Ukraine, Kyiv, Ukraine.

Niewiadomski P., Nieswiec M., Cisinski M., Sadowski L., 2022, Short review on the feasibility assessment of the recycling of oil refinery wastes in cementitious composites, Chemical Engineering Transactions, 94, 169–174.

Pokataiev P., Garkavyy I., Koltun V., Shamrai N., Kramarenko K., 2021, State and regional policy on industrial waste management: the EU experience for Ukraine, Natsional'nyi Hirnychyi Universytet. Naukovyi Visnyk, 3, 111–116.

Recknagel S., Radant H., Kohlmeyer R., 2014, Survey of mercury, cadmium and lead content of household batteries, Waste Management, 34(1), 156–161.

State Statistical Service of Ukraine. <www.ukrstat.gov.ua>, accessed 25.06.2023.

Su P., Liu Y., Zhang J., Chen C., Yang B., Zhang C., Zhao X., 2020, Pb-based perovskite solar cells and the underlying pollution behind clean energy: Dynamic leaching of toxic substances from discarded perovskite solar cells, The Journal of Physical Chemistry Letters, 11(8), 2812–2817.

Valyuk V., Yakymchuk R., 2018, Soil mutagenic activity in hazardous waste site of Kalush City (Western Ukraine), Ukrainian Journal of Ecology, 8(1), 880–886.

Yasuda K., Tanaka M., 2006, Report on hazardous household waste generation in Japan, Waste Management & Research, 24(4), 397–401.