EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2021, 22(5), 12–17
https://doi.org/10.12912/27197050/139785
ISSN 2719-7050, License CC-BY 4.0

Received: 2021.06.12
Accepted: 2021.07.10
Published: 2021.08.01

Solid Waste Management as Part of Sustainable Development of Lviv (Ukraine)

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ABSTRACT

Sustainable development includes the process of processing and recycling of solid waste. In Ukraine, a system of accumulation of solid waste without pre-processing in landfills has been formed. As a result, anthropogenically devastated landscapes have appeared in the country, causing environmental hazard. There is no waste processing plant in Lviv or in most cities of Ukraine. Non-recyclable solid waste is mostly transported to landfills throughout the region, as the Lviv municipal landfill has exhausted its resources and is in an unsatisfactory ecological and sanitary condition. The presented research shows the requirements for custom vehicles that transport household and hazardous waste at the "entrance" and "exit" of the environmental logistics system. It was established that three types of edaphotopes were formed at the Lviv landfill and in its impact zone due to the devastation processes: natural, which are not physically disturbed, but contaminated with filtrates; anthropogenic, which are disturbed by construction equipment and contaminated with pollutants due to the formation of the body of the landfill; bulk, which were formed due to the import of fertile soils in order to implement the mining stage of reclamation. The obtained data show that the filtrates penetrate into groundwater and surface water, changing the reaction of the substrate environment, thereby increasing the level of environmental danger in the region. The main method of landfills decommissioning is the biological stage of recultivation, namely – vegetative reclamation.

Keywords: solid waste, landfill, ecology landscapes.

INTRODUCTION

Sustainable development is impossible without a well-established system of solid and liquid household waste management. In this context, the problem of waste disposal is particularly acute in Ukraine, as 92% of wastes are stored in landfills or waste dumps [1]. The same situation with waste concerns Lviv. According to the subject of regulation of waste management, the EU regulations are divided into III groups: acts regulating certain waste management operations; acts regulating the management of certain types of waste; and acts regulating the movement of waste.

Acts governing specific waste management operations include: Directive № 99/31/EC on landfill of waste; Directive 2000/76/EC on the incineration of waste.

The acts regulating the management of certain types of waste include:

- Directive № 94/67/EC on the incineration of hazardous waste;
- Directive № 91/157/EC on batteries and accumulators containing hazardous substances;
- Directive № 91/689/EC on hazardous waste;
- Directive № 75/439/EC on the disposal of waste oils;

- Directive № 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment;
- Directive № 94/62/EC on packaging and packaging waste;
- Directive № 78/176/EC on waste from the titanium dioxide industry;
- Directive № 2000/59/EC on port reception facilities for ship-generated waste and cargo residues;
- Directive № 2009/40/EC on roadworthiness tests for motor vehicles and their trailers;
- Directive № 2002/96/EC on waste electrical and electronic equipment.

The acts governing the movement of waste include:

- Directive № 84/631/EEC on transfrontier shipments of hazardous waste;
- Council Regulation № 259/93 on the supervision and control of shipments of waste within, into and out of the European Community;
- Council Regulation № 1420/1999 establishing common rules and procedures to apply to shipments to certain non-OECD countries of certain types of waste;
- Council Regulation 1547/1999, determining the control procedures to apply to shipments of certain types of waste to certain countries.

The processes of collection, transportation and disposal of solid waste are provided by special transport vehicles. Among these vehicles, a special place belongs to garbage trucks, which are operated in cities and must meet the requirements of sanitary norms, operational safety, and environmental safety. Currently, a significant number of garbage trucks are produced in Ukraine and abroad. All of them differ in the body space, the mass of waste transported, the load capacity of the manipulator, the base chassis [2, 3].

Thus, one of the most important components of waste management is a mobile vehicle. Since there are no waste processing plants in Lviv, or in most cities of Ukraine, household waste is stored in an open space – landfills for solid waste.

MATERIALS AND METHODS

The research was conducted using a comprehensive theoretical and experimental approach. During theoretical research, such methods as typology, synthesis, logical constructions, and analysis, were used. During experimental research the following methods were used: general scientific; floral; phytocenotic; chemical; mathematical and statistical.

Sampling was carried out in accordance with the requirements set out in the relevant state standards (GOST 17.4.3.01-83, GOST 17.4.4.02-84, GOST 28168-89) and guidelines. The acidity of the substrates was measured by the device "KC-300B".

RESULTS AND DISCUSSION

At the state enterprises, there is insignificant quantity of custom vehicles for transportation of hazardous substances as a component of household waste; the vehicles include: KrAZ K16.2, OT-10A, OT-20. Besides OT-20 based on ZIL-433360 and CA-11 are operated on potentially dangerous objects. The operational and technical characteristics of vehicles used for transportation of dangerous freights are the highest for: KrAZ K16.2 – 0.4 t (on specific weight); OT-20 – 30.7 kW (on engine power-to-weight ratio); OT-20 (ZIL-433360) – 3.04 (on volume-to-size ratio). The average annual productivity of OT-20 (ZIL-433360) of 96780.2 t km per year is the highest [3].

When choosing the most optimal rolling stock, attention should be paid to the priority requirements that must be met at the "entrance" to the environmental logistics system (i.e. compliance with the objectives): proper technical characteristics, environmental and radiation safety, ergonomics, economy, reliability, and operational safety. At the "exit" from the ecological logistics system (i.e. the requirements to the efficient collection of waste by custom vehicles) vehicles must have high performance characteristics, namely, distance of transportation; average annual productivity; driver safety; volume-to-size ratio; specific weight of custom vehicle; and engine power-to-weight ratio. General requirements for custom vehicles that transport household and hazardous waste at the "entrance" and "exit" of the environmental logistics system are shown in Figure 1.

Unfortunately, there is no waste processing plant in Lviv, or in most cities of Ukraine. Non-recyclable solid waste is mostly transported to landfills throughout the region, as the Lviv municipal landfill has exhausted its resources and is in unsatisfactory environmental and sanitary condition.

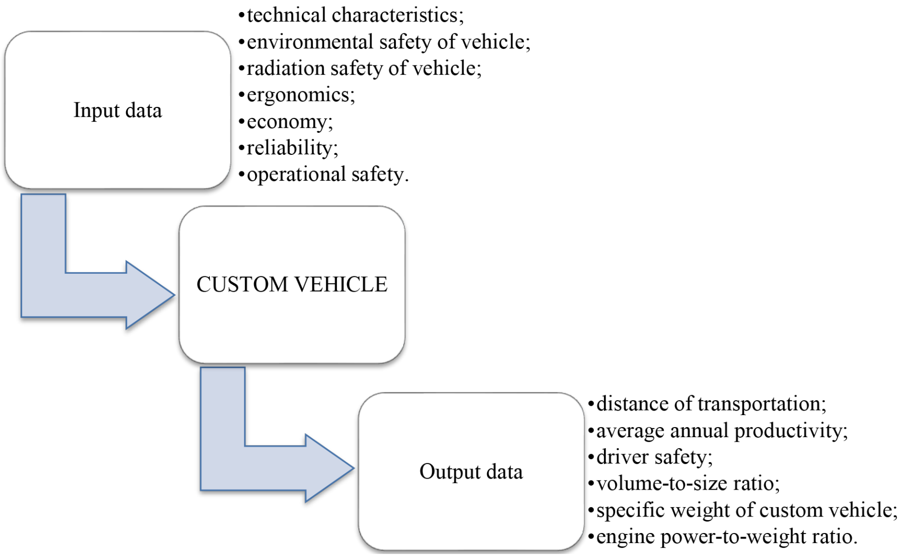

Figure 1. Requirements for custom vehicles that transports household and hazardous waste at the "entrance" and "exit" of the environmental logistics system

In techno-edaphotopes of landfills, which are formed in the same landscape conditions as natural ones, there is a change in the construction of their morphological profile and properties. There is a transformation and restructuring of a number of geochemical processes [4]. The morphological profile of edaphotopes of landfills differs from the background ones, which are developed under similar lithological and geomorphological conditions [5]. In the upper parts of their profile there is the development of 5-30 cm of technogenic sediments, which are characterized by bulk or aerially formed material of black-brown color, usually with inclusions of organic construction waste. The lower part of this profile borders the layer of pressed waste. Regardless of the composition of the soil-forming rocks (sand or loam), landfills compact the soil profile, especially the upper horizons (inherent in recultivated areas), which leads to a change in their structure: the enlarged aggregates are compressed, resulting in increasing of soil cohesion.

Lviv municipal landfill is one of the largest in Ukraine, as it has accumulated waste from the territory where more than 1 million people have lived for 60 years. It is located 3 km from the northern border of Lviv. The landfill was operated from 1957 to 2016. During operation, the landfill has accumulated about 55 million m^3 of garbage. Until 1990, it contained not only solid household but also toxic industrial waste. Their volume reaches 2 million tons. In addition, more than 200,000 tons of acid tars – waste of OJSC "Lviv Research Oil Refinery" – have been accumulated on the territory of the landfill. The total area of reservoirs with tars is about 5 hectares; they have accumulated about 250 thousand m^3 of refining waste containing sulfuric acid and 60 thousand m^3 of acidic water [3]. The landfill filtrates are characterized by extreme environmental hazards [6].

In order to investigate the physicochemical composition of edaphotopes and their influence on the development of landfill vegetation, the samples of neorelief were taken directly on the surface and in the impact zone: on the surface of the Lviv city landfill (5-15 cm); 20 m to the west of the landfill surface (5-15 cm and > 15 cm); on the northern exposure of the slope (5-15 cm and > 15 cm); near the foot at the east side (in places of movement of geochemical flows); 100 m east of the foot (5-15 cm and > 15 cm); 500 m to the east of the foot (5-15 cm and > 15 cm). Heterogeneity and versatility of sampling are caused by the natural location of the landfill (on the site of a former sand quarry); chaotic dumping of garbage; geoflows of pollutants and aeration, mainly in the eastern direction; insignificant depth of the newly formed edaphotope, especially on the surface and sides.

As a result of devastation processes, three types of edaphotopes were formed at the Lviv landfill and in its impact zone: natural, which are not physically disturbed, but are contaminated with filtrates; anthropogenic, which are disturbed by construction equipment and contaminated with pollutants due to the formation of the body of the landfill; and bulk, which were formed as a result of the import of fertile soils in an attempt to implement the mining stage of reclamation.

The conducted research has shown that the maximum pH of edaphotopes is inherent in areas at a certain distance from the landfill (neutral reaction). Minimum values (pH = 3.0-5.0) were found on the surface of the landfill (acid reaction). At a depth of 5 cm, the maximum pH value was found at 100 m from the foot of the landfill and near the lakes with the filtrate (pH = 7.0), the minimum –east of the landfill in its middle part (pH = 3.5) and north of the landfill in the middle part of it (pH = 4.5). At a depth of 10 cm, the maximum pH value was also found 100 m from the foot of the landfill and near the lakes with the filtrate (pH = 7.0), the minimum – north of the landfill in its middle part (pH = 3.5). At a depth of 20 cm, the maximum pH value was noted at 500 m from the foot of the landfill, as well as 100 m from the foot and near the lakes with filtrate (pH = 7.0), the minimum – north of the landfill in the middle part of it (pH = 3.0) and at the top from the western side (pH = 4.0).

At the average exposure of landfill slopes, the acidity of edaphotopes has the lowest values (pH = 3.0-4.5). The pH of the medium changed from acidic to neutral at a distance from the accumulation of solid waste. High pH values of landfill edaphotopes are associated with the release of carboxylic acid into the soil, along with precipitation. It is established that the following species of grass and tree-shrub vegetation have developed the best on acid edaphotopes: *Calamagrostis epigeios* (L.) Roth., *Taraxacum officinale* Wigg., *Arctium lappa* L., *Equisetum arvense* L., *Humulus lupulus* L., *Artemisia absinthium* L., *Artemisia vulgaris* L., *Hippophae rhamnoides* L., *Betula pendula* Roth. (stand-alone). Trees and shrubs develop in a neutral media: edges at 50 m on the west of the landfill - *Populus tremula* L.*, Pinus sylvestris* L. (stand-alone); top at 20 m on the north of the landfill - *Acer negundo* L., *Robinia pseudoacacia* L. (stand-alone), *Alnus glutinosa* (L.) Gaerth*., Ligustrum vulgare* L., *Hippophae rhamnoides* L .; 100 m from the foot in the east of the landfill – *Populus alba* L., *Betula pendula* Roth., *Salix caprea* L., *Pyrus communis* L., *Malus silvestris* Mill.; 500 m from the foot in the east of the landfill – *Populus alba* L., *Crataegus ucrainica* Pojark., *Thelycrania alba* (L.) Pojark., *Ligustrum vulgare* L.

Thus, acidic techno-edaphotopes (pH = 3 ÷ 4.5) inhibit the development of tree and shrub vegetation on the surface of the Lviv municipal landfill.

The mathematical model for determining the pH in the impact zone of the landfill at a depth of 0.05 m may be described as follows:

$$|pH|_{0.05} = -0.6071 l_{0.05}^2 + 3.0929 l_{0.05} + 3.1 \quad (1)$$

where: l is the distance from the foot of the landfill, m.

For pH determination in the impact zone of the landfill at a depth of 0.1 m, the following equation may be used:

$$|pH|_{0.1} = -0.3214 l_{0.1}^2 + 1.5786 l_{0.1} + 5.2 \quad (2)$$

The pH in the impact zone of the landfill at the depth of 0.2 m may be described by the following equation:

$$|pH|_{0.2} = -0.0357 l_{0.2}^2 + 0.0643 l_{0.2} + 7.0 \quad (3)$$

Thus, the surface of the Lviv municipal landfill is dominated by acid edaphotopes with pH = 3.0-4.5. At a distance of up to 500 m from the landfill pH is neutral. It is important to investigate the acidity of edaphotopes for the adequate choice of plant communities for recultivation and vegetative reclamation.

The obtained data show that the filtrates penetrate into groundwater and surface water, changing the pH of the substrate environment, thereby increasing the level of environmental hazard in the region [7, 8]. The main method of landfills decommissioning is the biological stage of recultivation, namely – vegetative reclamation.

In the system of regional environmental safety of waste management, hierarchical structural subdivisions are clearly distinguished – local environmental safety and objectal environmental safety [3]. It should be noted that the symbiosis of these two components determines the environmental safety of the region. Moreover, the local and objectal components of environmental safety have a practical solution, and considering the regional environmental problem of waste management, it can be concluded that it needs a theoretical justification and solution (Fig. 3).

Requirements for custom vehicles that transport household and hazardous waste at the

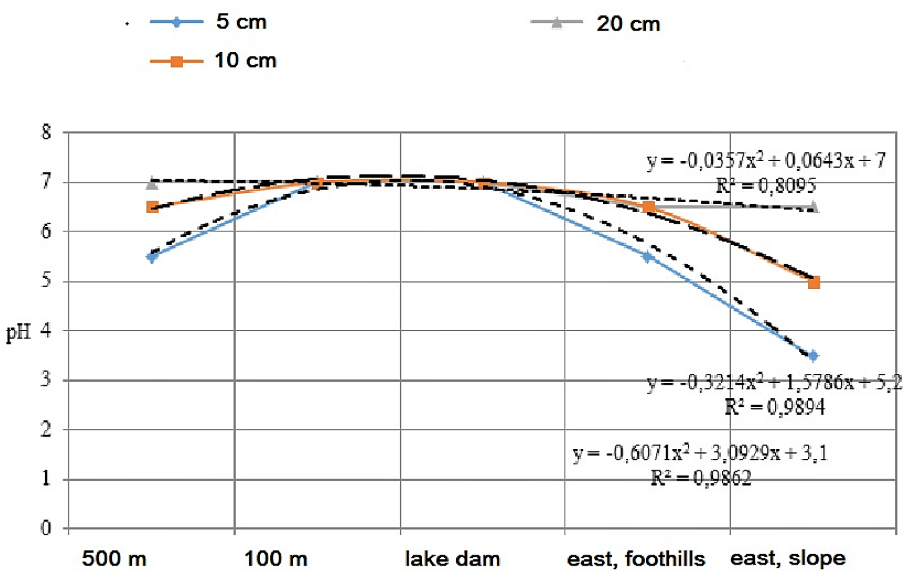

Figure 2. Simulation of pH change from acid to neutral in the edaphotopes of the impact zone of the landfill at different depths

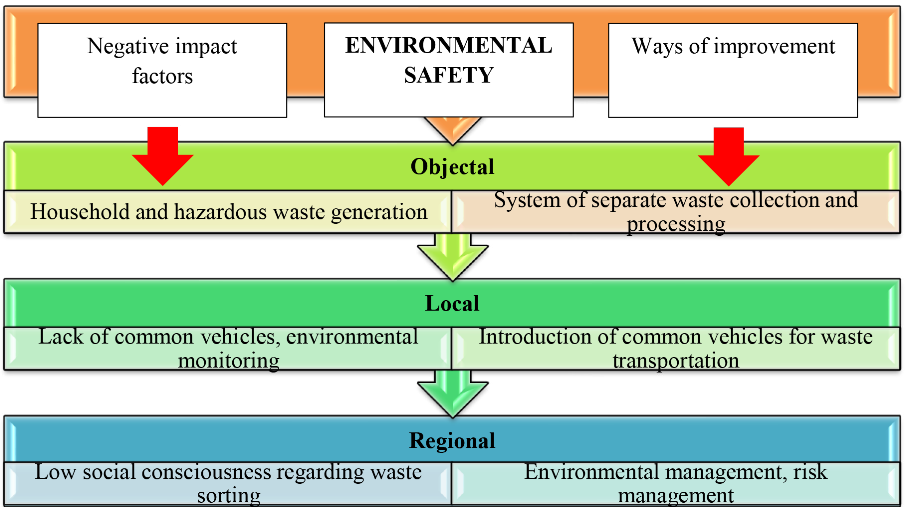

Figure 3. Impact factors and ways of regional environmental safety improvement

"entrance" and "exit" of the environmental logistics system must ensure the safety of personnel, sanitary-epidemiological and environmental safety; in the system of regional ecological safety of waste management there are two structural subdivisions – local and objectal ecological safety.

CONCLUSIONS

Municipal waste management in Lviv, which provides for the final stage – storage in the open spaces, is a negative phenomenon that contradicts the principles of sustainable development and requires the introduction of facilities and waste processing lines. The filtrates that accumulate at the foot of the landfill, according to the conducted research, are the most environmentally and anthropogenically hazardous to biota.

REFERENCES

1. Kucheryavyi V.P. 2010. General ecology [in Ukrainian]. Lviv, pp. 520.
2. Popovych V.V., Prydatko O.V., Sychevskyi M.I., Popovych N.P., Panasyuk M.A. 2017. Efficiency of operation of garbage trucks in the environment „city--landfill" [in Ukrainian]. Scientific Bulletin of the National Forestry University of Ukraine, 27(10), 73–76.

3. Popovych N.P. 2019. Environmentally safe collection, transportation and disposal of solid household waste [in Ukrainian]. Thesis for the Candidate Degree in Technical Sciences (Doctor of Philosophy): Speciality 21.06.01 „Environmental safety", „Ecology", pp. 101, Lviv.
4. Popovych V., Stepova K., Prydatko O. 2018. Environmental hazard of Novoyavorivsk municipal landfill. MATEC Web of Conferences 247, 00025. FESE 2018. https://doi.org/10.1051/matecconf/201824700025
5. Vodyanitskii Yu. N. 2016. Biochemical processes in soil and groundwater contaminated by leachates from municipal landfills (Mini review). Annals of Agrarian Science, 14(3), 249-256. https://doi.org/10.1016/j.aasci.2016.07.009
6. Suchecka T., Lisowski W., Czykwin R., Piatkiewicz W. 2006. Landfill leachate: water recovery in Poland. Filtration & Separation, 43(5), 34-36, 38. https://doi.org/10.1016/S0015-1882(06)70891-6
7. Renou S., Givaudan J.G., Poulain S., Dirassouyan F., Moulin P. 2008. Landfill leachate treatment: Review and opportunity. Journal of Hazardous Materials, 150(3), 468-493. https://doi.org/10.1016/j.jhazmat.2007.09.077
8. Uygur A., Kargı F. 2004. Biological nutrient removal from pre-treated landfill leachate in a sequencing batch reactor. Journal of Environmental Management, 71(1), 9-14. https://doi.org/10.1016/j.jenvman.2004.01.002