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FLORISTIC AND ECOLOGICAL STRUCTURE OF THE LANDFILL VEGETATION IN THE WESTERN FOREST STEPPE OF UKRAINE

Purpose. To establish the taxonomic and ecological structure of the flora and to make conclusions about the course of natural vegetative reclamation processes of the Western Forest Steppe landfills of Ukraine.

Methodology. The analysis and study of the ecological and floristic structure of the landfill flora was carried out in accordance with generally accepted methods: floristic, monitoring, general scientific, mathematical and statistical ones.

Findings. It has been established that the flora of the studied landfills (large, medium, small ones) is represented by tree-shrub and herbaceous (mainly ruderal) vegetation. During the reconnaissance and field surveys, 53 species were identified, including 18 species of trees, 8 species of shrubs and 27 species of herbaceous plants. The formation of a natural process of plant improvement at various landfills in the Western Forest Steppe is mainly due to the participation of the *Magnoliopsida* and *Magnoliophyta* phylum classes, which make up 84–89 % of plant species. The distribution of landfill vegetation according to the requirements for lighting intensity showed that heliophytes (50–67 %) predominate at all types of landfills. This indicates good illumination of all areas of the studied landfills and a positive light regime. The heterogeneity of vegetation cover and ecological conditions of its development at typical landfills in the Western Forest Steppe is primarily due to negative factors caused by the operation of these technogenically hazardous facilities.

Originality. The degree of risk is determined to the ecological system due to the technogenic load of the region under study caused by landscape-transforming factors of landfills, as well as methods for overcoming negative situations using phytomeliorative approaches. The main scientific principles are based on the decommissioning of landfills through the use of phytocoenoses-reclamation, the implementation of which contributes to the improvement of environmental safety. Spatial patterns are established of ecological succession at landfills, which allows predicting the effects of man-made pollution of landfills on biota.

Practical value. Understanding the processes of natural phytomelioration depending on edaphic and climatic factors will allow the selection of effective plant species for the stage of reclamation at landfills.

Keywords: *landfill, phytomelioration, technogenic safety, ecology, vegetation*

Introduction. In recent years, as advances in observational technology have provided data with higher spatial and temporal resolution, the interactions between processes occurring in the Earth's solid surface, atmosphere, hydrosphere and biosphere have become increasingly clear. Indeed, as more and more scientists apply their knowledge, tools and methods to interdisciplinary research, the interaction of metamorphism with classically diverse areas of Earth science, such as economic geology, natural hazards, biogenetic science, etc., is becoming increasingly clear. Paper [1] provides an overview of metamorphism and the role that metamorphic wastes play in various Earth systems, and identifies some areas for future research that could lead to major breakthroughs in our understanding of the overall structure and function of the Earth.

An analysis of the morphological composition of Ukrainian and foreign landfills shows that food waste and paper accumulate the most, while ash and wood accumulate the least. The accumulation of plastic, metal, glass, battery, electronic, medical and chemical waste at landfills leads to the release of hazardous substances and compounds into the environment, which change over time, poisoning biota [2].

Solid household waste is accumulated at illegal dumps and landfills. It is known that natural dumpsites are places of waste disposal as a result of human activity that are not subject to regulations and landfills are engineering structures designed to manage solid household waste and should prevent negative impacts on the environment and meet sanitary, epidemiological and environmental standards [3]. Dumps and landfills have a negative impact on the environment, polluting air, soil, water, etc. in the surrounding areas.

There are over 6,000 landfills in Ukraine with a total area of over 9,000 hectares, of which 22 % do not meet environmental safety standards. The regions with the largest number of such landfills are Odesa, Kharkiv, Kirovohrad, Ternopil, Zakarpattia, Zaporizhzhia, Vinnytsia and Lviv regions. Of the 3,500 landfills that need reclamation, more than 100 have actually been reclaimed. Due to the lack of solid waste management systems in cities (especially in large cities), often in the private sector, more than 23,000 unauthorised landfills covering an area of more than 700 hectares have been created. More than 50 million m^3 or more than 10 million tonnes of solid waste is generated annually [4].

In Ukraine, more than 90 % of solid household waste is stored at specialised landfills. Undoubtedly, Ukraine ranks among the top European countries in this respect. Waste incineration plants are a source of air, water and soil pollution. The incineration of waste releases harmful substances such as dioxins, phosgene, carbon monoxide, benzene, toluene, acetone, chlorine and fluorine-containing compounds.

The accumulation of waste is a major challenge for sanitation and cleaning of residential areas. Inadequate sanitation of landfills can lead to spontaneous and unauthorised dumping. The city council and the executive committee of the regional military administration annually carry out work to eliminate unauthorised dumpsites, but this work is phased and not systematic. There are many problems with construction waste, which is generated in large quantities during the demolition or installation, reconstruction and new construction of buildings and structures. Municipal solid waste landfills accept only a small amount of this waste as insulation material, so companies are forced to place and accumulate it on their premises. The accumulation of plastic, metal, glass, battery, electronic, medical and chemical waste in landfills leads to the release of toxic substances and compounds that can poison the environment, changing from one form to another over the years [5].

Today, experts consider the landfill to be an operating bioreactor. The complex bioreactor system continuously receives waste at uneven intervals. Under the influence of aerobic and anaerobic microorganisms, organic matter is biodegraded, resulting in the conversion of biodegradation products into biogas and leachate. All processes of microbial destruction of organic substances occur under heterogeneous conditions [6].

The level of environmental pollution resulting from landfill operations is determined by the topography, climate and river density. The hazardous factors of solid waste landfill impact on the environment include a hygienic and epidemiological one, which is the creation of a favourable environment for the growth of pathogenic microorganisms at landfills; a chemical one, which is manifested by the release of harmful substances and emissions of leachate and biogas that enter the air and subsequently plants and water bodies; a zoological one, which includes the movement of birds, reptiles and mammals on solid waste polygons; a pyrogenic one, which is associated with the generation of heat that leads to +80 °C self-heating of waste and becomes visible in the form of surface ignition and intra-layer smouldering with the release of smoke; and a social one, which is associated with the fact that operating landfills create a dangerous area for the population living or working near landfills. Other negative impacts of landfills include alienation of fertile land, mechanical impact on the soil, noise pollution during landfill operations and solid waste transport, unpleasant odours, etc. [7, 8].

In general, landfills are environmentally and technologically hazardous facilities that violate the requirements for their operation. In the event of insufficient funding for their maintenance and reclamation, the most appropriate way to decommission them is through natural rehabilitation. This tool involves regulating the natural processes of vegetation improvement and promoting the natural overgrowth of landfills. The development of plant communities at landfills contributes to the emergence of new landforms and the formation of humus layers, which has a positive impact on the development of tree and shrub vegetation and becomes the main means of improving the ecological situation and environmental aesthetics.

Literature review. A scientific article [9] shows that municipal solid waste in EU countries accounts for an average of only 10 % of the total waste generated. However, despite their environmental impact and risks to human health, as well as the fact that they are the least popular option in the waste hierarchy, landfills are still widely used as solid waste disposal sites (Circular Economy Directive, 2008/98/EC). Directive 1999/31 and the Waste Directive 2008/98/EC as recently amended (2018/850 and 2018/851) and the Circular Economy Package, which provides for the closure of open or illegal dumpsites and the control of engineered landfills, and structure requirements. New targets have been set to ban the disposal of biodegradable waste, reduce the amount of solid waste sent to landfill by 10 % and gradually divert 75 % of waste to recycling. Despite this, landfill in Europe accounted for over 30 % of total municipal solid waste in 2012 and 23 % in 2017. Although landfill targets have reduced the amount of municipal solid waste disposed of, there are still large differences in waste management performance between EU Member States. While countries such as Germany, Belgium and the Netherlands, among others, have already reached their 2030 targets and have advanced waste and landfill management solutions, others may find it more difficult to achieve their goals. Due to differences in socio-economic conditions, there are significant differences in waste generation levels, availability of waste management technologies and their respective performance across EU countries. Against this backdrop, the overall objective of the study is to provide an overview of the current scale of sanitary landfill impacts in Europe. This study will provide an understanding of how landfill management objectives and requirements relate to the environmental impacts associated with solid waste disposal sites.

When landscaping landfills, cultivated plants are used that can thrive in extreme conditions of air and soil pollution, perform a phytosanitary role and help cleanse the soil of contaminants. Plant improvers are sown after the surface layer has been laid and complex agrotechnical work has been carried out in several stages using special machinery and equipment. The scientific paper [10] describes the conditions for sowing grasses for preliminary detoxification and sowing humus-forming plants at landfills. There is also a list of forest crops that should be grown at landfills based on soil fertility. However, no specific site was studied, and no account was taken of environmental conditions, landfill geometry, soil photometry and climatic conditions.

The artificial phytomelioration involves the use of hydroseeding devices for environmental sanitation [11]. To carry out hydroseeding at landfills, the mining phase of reclamation is first required, as well as rodenticide (rat control) and disinsection (insect control). The biological phase of landfill reclamation is not necessary when using hydroseeding, as plant amendments can be made on a soil-free substrate. The natural restoration of territories and decommissioning of potentially hazardous waste storage facilities goes through two main phases, namely vegetation overgrowth and the formation of stable phytocoenoses at landfills [12].

The results of the research [13] demonstrate that a landfill creates a very specific environment. Studies show that the species composition at the landfill is not stable and is a place of specific plant succession. Vegetation at landfills is not stable in terms of species composition, so constant monitoring is very important. This site has a high potential for invasive species that can change the species composition of vegetation in the surrounding ecosystems. We also identified species that are problematic for agriculture. It is necessary to pay attention to the species composition of landfill vegetation, and some species can even be controlled [14, 15]. An extremely environmentally hazardous factor in the operation of landfills is the formation of leachate, which is concentrated in settling ponds and often seeps into adjacent soil horizons [16]. It should be noted that at Lviv city landfill, acidic tar is stored in storage ponds, which leak to an area of more than 1,500 m from the landfill during accidental spills [17]. Scientific paper [18] presents data from a two-year experiment on the extraction of hazardous elements and substances from landfill leachate. It was found that poplar showed significantly higher removal rates of Cd, Cu, P and N than willow. Furthermore, when treating high levels of hazardous compounds, poplar is also more effective than willow in reducing the concentration of specific pollutants (BOD5, COD and As) in wastewater. The results of the study [19] demonstrate that vegetation reduces CH_4 oxidation at high levels of pollution, regardless of the type of vegetation. Vegetation at landfills can affect the microbial population, stabilise and accumulate minerals, thus contributing to the remediation of the contaminated site [20]. Importantly, studies have shown that compost promotes the spread of weeds. The ability of vegetation to survive and reproduce on the territory of composting plants increases the importance of monitoring vegetation and controlling the surrounding areas [21].

Unsolved aspects of the problem. Landfills are subject to reclamation after the end of their service life [22]. The legal and regulatory documents governing the operation of landfills in Ukraine do not regulate the possibility of natural overgrowth of landfills. The basic rules for the design of solid waste landfills [23] stipulate that perennial grasses can be planted only in the southern and northern regions of Ukraine, as well as tree and shrub vegetation, and this should last for more than four to five years. When selecting the species composition of vegetation for forest or agricultural phytomelioration, not only the location of the landfill should be taken into account, but also the soil environment and microclimate conditions, morphological composition of waste, age of the landfill, burning conditions, etc. [24, 25].

Purpose. The aim of the work – is to establish the taxonomic and ecological structure of the flora and draw conclusions about the course of natural phytomelioration processes at the landfills of the Western Forest-Steppe of Ukraine. The development of vegetation cover at landfills contributes to the development of new relief and the formation of humus layers, which positively affects the development of trees, shrubs and herbaceous vegetation, improves the ecological condition and aesthetic appearance of the environment.

Methods. There are 5 forestry regions in the Western Forest Steppe region: *1* – Volyn Upland; *2* – Malopoliska lowlands; *3* – Rostotsko-Opilskyi; *4* – Prut-Dniesterskyi; *5* – North-West Podilskyi. Taking into account the identified forest management areas, the sites for further research were selected. Ten landfills in the Western Forest Steppe region were investigated, in particular: Lviv, Ternopil, Lutsk, Chervonograd, Tysmenytsia, Sokal, Rava-Ruska, the villages of Lavrykiv, Maheriv and Vereshchytsia. The landfills in the study region are divided into three types in terms of volume and area: large – Lviv, Ternopil and Lutsk; medium – Chervonohrad, Sokal, Rava-Ruska, Tysmenytsia, Maheriv; small – Lavrykiv and Vereshchytsia (Fig. 1).

In the above-mentioned settlements, groundwater and surface water are contaminated with toxic substances, and soil is radioactive. In general, the environmental conditions of air and soil are assessed as polluted and highly polluted. The main sources of environmental pollution are the Lviv-Volyn coal basin, the Carpathian oil region, peat bogs (Small Polissia, Forest Steppe, Carpathians and Prykarpattya) and the operation of numerous chemical plants and testing stations.

The relief of the Western Forest-Steppe is crossed by deep river valleys and ravines. The climate of the Western Forest-Steppe is temperate continental with mild and hot summers and warm winters. The average annual temperature is +7.3 °C. Western winds prevail, with speeds of over 5 m/s. In the winter months, wind gusts can reach 7 m/s and more, and stronger winds are quite rare. Precipitation ranges from 600 to 750 mm per year. In some dry years, for example, in 1961, the amount of precipitation decreased to 300–350 mm, and in wet years, such as 1975, it increased to 1,000 mm. The growing season lasts over 210 days, and with an average daily temperature above +10 °C, it is over 150 days [26].

The ecological structure of the vegetation was carried out according to the standard methodology. To study the similarity of the flora of the studied landfills, the Jaccard floral community coefficients were used. The phytomeliorative efficiency of phytocoenoses-reclaimers was determined by the method of V. P. Kucheryavyi.

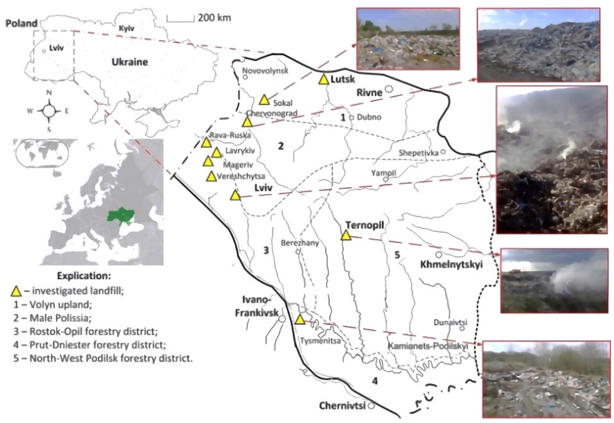

Fig. 1. Scheme of the West Ukrainian Forest Steppe district with studied landfills:

1 – Volyn Highlands; 2 – Malopoliska lowlands; 3 – Rostotsko-Opilskyi; 4 – Prut-Dniesterskyi; 5 – North-West Podilskyi

Results. Potentially hazardous objects and an increased number of technogenically hazardous objects in the study area directly affect the morphological composition of the landfill, thereby affecting its environmental condition. It is clear that most of the landfills studied, especially those that were in place before 1991, contain waste from industrial enterprises and factories, as well as household waste. Solid waste landfills often have high radiation levels. Currently, the regulations on the operation of landfills prohibit the storage of hazardous waste together with household waste. However, the regulations do not address the problem of hazardous waste already accumulated at existing landfills. Such landfills pose a double threat to the environment and people.

General description of Lviv landfill. It has been in operation since 1957. The landfill is located 3 km from the northern border of Lviv. Over 60 million m^3 of waste has been accumulated during its operation. In addition to waste, more than 300 thousand tonnes of acidic tar from enterprises and toxic waste, according to various estimates, more than 1 million tonnes, have been accumulated. The composition of the landfill's solid waste includes food waste, paper, sand, construction waste, wood, glass, rubber, stones, plastics, etc. The sanitary protection zone of the landfill includes agricultural land where crops are grown. It is currently undergoing biological remediation.

Ternopil city landfill. It is located 25 km from Ternopil. The landfill is dangerous because it is located in the II–III zone of the sanitary protection zone of the Ternopil water intake, which provides 75 % of the city's drinking water. As a result, harmful substances penetrate through underground aquifers. The composition of solid waste at the landfill includes food waste, paper, construction waste, wood, glass, metals, etc. The sanitary protection zone of the landfill includes agricultural land where crops are grown. Currently, it operates in violation of sanitary and environmental standards and regulations.

Sokal landfill. It is located 2 km from the town of Sokal, Lviv region. It has accumulated over 60 thousand tonnes of household waste. According to various estimates, the landfill area is over 10 hectares. The surface of the landfill is overgrown with spontaneous vegetation and in areas of high substrate moisture. The composition of solid waste at the landfill includes food waste, paper, construction waste, metals, rubber, etc.

Rava-Ruska landfill. Located 3 km from the town of Zhovkva in Lviv Oblast, it covers an area of over 6 hectares and was formed on the site of a sand quarry. Vegetation overgrowth mainly occurs at the foot of the landfill. The following species are most prevalent at the landfill: ground bentgrass, creeping wheatgrass, common wormwood, urban quinoa, etc. The composition of solid waste at the landfill includes food waste, paper, construction waste, sand, glass, etc. The sanitary protection zone of the landfill includes agricultural land where crops are grown.

Tysmenytsia landfill. Located 2 km from the town of Tysmenytsia, Ivano-Frankivsk region. The landfill covers more than 5 hectares. It is currently inactive. There are cases of garbage and hazardous waste storage. Vegetation species composition at the landfill: aspen, common oak, black alder, goat willow, wild carrot, urban quinoa, large plantain, large burdock, etc. In the sanitary protection zone of the landfill, there are agricultural lands where products are grown.

The flora of the studied landfills is represented by tree-shrub and herbaceous (mainly ruderal) vegetation. During the reconnaissance and field surveys, 53 species were identified, including 18 species of trees, 8 species of shrubs and 27 species of herbaceous plants. The general distribution of the flora of the Western Forest-Steppe landfills showed that the vegetation inhabiting large landfills belongs to 4 divisions, medium-sized landfills – to 2 divisions, and small landfills – to 1 division (Table 1).

According to the research results, the following plant families dominate among the plant families: *Asteraceae* – ten types; rose (*Rosaceae*) – seven species; birch (*Betulaceae*) –

Table 1

Data on the flora of the studied landfills

Landfills	Phylum	Class	Order	Family	Genus	Species
Large	4	5	15	22	41	45
Medium	2	3	13	18	30	32
Small	1	2	9	10	17	18

four species; willow (*Salicaceae*) – four species; plant families represented by two species: legumes (*Fabaceae*), cirrus (*Apiaceae*), plantain (*Plantaginaceae*), olive (*Oleaceae*), sapindus (*Sapindaceae*), cereals (*Poaceae*), pine (*Pinaceae*) and also represented by one species of plant family: beech (*Fagaceae*), walnut (*Juglan-daceae*), hemp (*Cannabaceae*), nettle (*Urticaceae*), olive (*Elaeagnaceae*), turf (*Cornaceae*) and pressberry (*Adoxaceae*), *Amaranthaceae*, buckwheat (*Polygonaceae*), cabbage (*Brassicaceae*), sedge (*Cyperaceae*), chilly (*Asparagaceae*), horsetail (*Equiseta-ceae*) and runny (*Polytrichaceae*).

In terms of species diversity at large landfills, the following plant families predominate: *Asteraceae* – nine species; *Rosaceae* – seven species; *Betulaceae* – three species; *Salicaceae* – three species; plant families: *Fabaceae, Apiaceae, Oleaceae, Sapindaceae, Poaceae* – two species; plant families: beech (*Fagaceae*), walnut (*Juglandaceae*), hemp (*Cannabaceae*), nettle (*Urticaceae*), olive (*Elaeagnaceae*), turf (*Cornaceae*) and bindweed (*Adoxaceae*), *Amaranthaceae*, buckwheat (*Polygonaceae*), sedge (*Cyperaceae*), horsetail (*Equisetaceae*), runyon (*Polytrichaceae*), pine (*Pinaceae*) – one species.

The formed set of plant species common to large landfills in the Western Forest Steppe is represented by the following types according to the classification structure: *Magnoliophyta, Pinophyta, Polypodiophyta, Bryophyta*; and classes: flowering plants (*Magnoliopsida*), monocotyledons (*Liliopsida*), naked-seeded plants or conifers (*Pinopsida*), vascular plants (*Equisetopsida*), perennial mosses (*Polytrichopsida*). In particular, the taxa of higher plants, namely flowering plants (*Magnoliophyta*) are represented by 42 species, which is more than 95 % of the total number. Coniferous plants (*Pinophyta*), ferns (*Polypodiophyta*) and bryophytes (*Bryophyta*) are represented by one species (over 3 %).

According to the classification structure, the formed set of plant species at the medium-sized landfills of the Western Forest Steppe is represented by the following divisions: *Magnoliophyta* and *Pinophyta*, as well as classes: flowering plants (*Magnoliopsida*), monocotyledons (*Liliopsida*), naked-seeded plants or conifers (*Pinopsida*). Also, the department of flowering plants (*Magnoliophyta*) is represented by 30 species, which is more than 90 % of the total number. Coniferous plants (*Pinophyta*) are represented by only two species (over 7 %).

In terms of species diversity, the following families have an advantage in the medium-sized landfills of the Western Forest Steppe: *Asteraceae* – seven species, birch (*Betulaceae*) – three species, and willow (*Salicaceae*) – three species. The families *Fabaceae, Apiaceae, Poaceae* and *Pinaceae* are represented by two species, and the families *Fagaceae, Rosaceae* and *Urticaceae* by two species, horsetail (*Equisetaceae*), *Adoxaceae*, *Amaranthaceae*, buckwheat (*Polygonaceae*), plantain (*Plantaginaceae*), olive (*Oleaceae*), cabbage (*Brassicaceae*) and coldwort (*Asparagaceae*) are represented by one species.

According to the classification structure, the formed set of plant species in small landfills of the Western Forest Steppe is represented only by the type of plants of the *(Magnoliophyta)* and two classes of flowering plants *(Magnoliopsida)* and monocotyledons *(Liliopsida)*. In particular, the class of flowering plants (*Magnoliopsida*) is represented by 16 species, which is more than 90 % of the total number. The class *Liliopsida* is represented by only two species, which is more than 10 %. Among the families at small landfills, *Asteraceae* dominate with five species. The families of birch (*Betulaceae*), rose (*Rosaceae*), plantain (*Plantaginaceae*) and cereal (*Poaceae*) plants are represented by two species, and the families of willow (*Salicaceae*), legumes (*Fabaceae*), nettle (*Urticaceae*), circle (*Apiaceae*) and sapindus (*Sapindaceae)* plants are represented by one species.

The distribution of plants at the landfills by soil moisture shows that representatives of all vegetation communities developing at the landfills are hydrophilic. It should be noted that the small distribution of xerophytes (large landfills over 13 %; medium-sized landfills over 14 %; small landfills over 1 %) indicates a favourable soil moisture regime at the above-mentioned landfills. Also, the highest distribution of plants growing in moderately moist habitats (mesophytes) and moisture-loving plants (mesohygrophytes) is observed at landfills. The percentage of plants growing in moderately moist habitats at large landfills was over 18 %, at medium-sized landfills over 21 %, and at small landfills over 60 %. The proportion of plants growing in humid conditions (hygrophytes) at all landfills ranged from 17 to 21 % (Fig. 2).

The morphological and trophic classification shows that plants requiring nutrient rich soils are found mainly at small landfills – over 60 %. The reason for this lies in the content of humus and nutrient microorganisms in the soil, which is slightly higher at small landfills than at other landfills. Plants and microorganisms that live on soils and water bodies with low nutrient content (oligotrophs) grow on all types of landfills, but the largest number of them is concentrated on medium-sized landfills – over 62 %. The largest percentage of plants that are moderately demanding on soil nutrients (mesotrophs) is over 38 %, and plants that grow on fertile soils (megatrophs) were not found at the study sites at all. At large landfills, the percentages are relatively equal: oligotrophs – 35 %, mesotrophs – 35 % and megatrophs – 30 %. It is worth noting that the significant development of oligotrophs at landfills indicates the low fertility of technogenic substrates (Fig. 3).

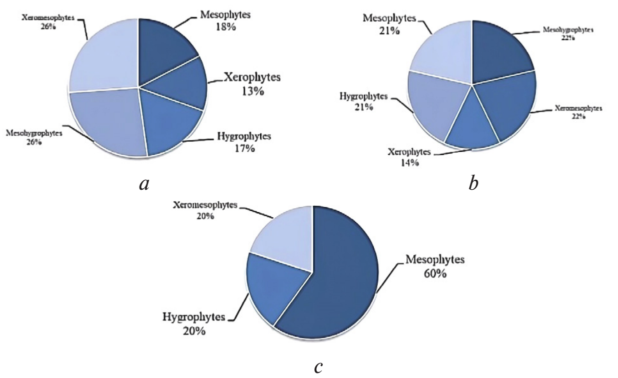

Fig. 2. Distribution of landfill vegetation by substrate moisture: a – large; b – medium; c – small

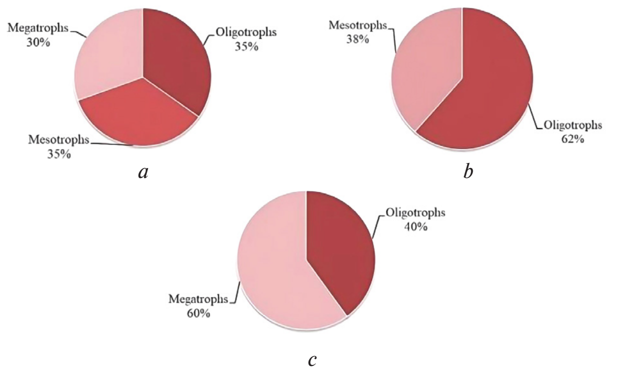

Fig. 3. Distribution of landfill vegetation by substrate fertility: a – large; b – medium; c – small

The high acidity of edaphotopes at landfills has led to the development and dominance of acidophilic bacteria at different types of landfills (41 % at large, 39 % at medium and 40 % at small). Azotobacter is a nitrogen generator. Its roots are home to aerobic bacteria that fix molecular nitrogen in the air and convert it into a form that plants can use. Azotobacter is typical for large (9 %) and medium-sized (15 %) landfills, where stable phytocoenoses have already formed. *Robinia pseudoacacia* L. was found to be the most common nitrogen-bacterium. Calciophylla at landfills develops on the northern and western exposures of the relief (large – 36 %, medium – 23 % and small – 40 %). The smallest fractions are nitrophilic vegetation, which grows well only on soils rich in assimilated nitrogen compounds, nitric acid salts, ammonium, etc. (large – 14 %, medium – 23 % and small – 20 %) (Fig. 4).

The low levels of salt tolerant species indicate that the soil is highly saline at the landfills (17 % at large, 23 % at medium and 20 % at small landfills). Soil salinity at landfills is caused by sulphates (SO_4^{2-}) and chlorides (Cl^-). The most salt-resistant species were found only in large landfills, but their share is very small (over 5 %).The vegetation with the highest salt tolerance is of low and very low salt tolerance. For large landfills, their shares are as follows: low salt tolerant and very low salt tolerant over 39 %; for medium-sized landfills: low salt tolerant over 62 %, very low salt tolerant over 15 %; for small landfills: low salt tolerant – 20 %, very low salt tolerant – 60 % (Fig. 5).

Persistent and relatively aerobic species dominate. This is especially noticeable at medium and large landfills with burning areas. At large landfills, the share of resistant species was over 38 %, and the share of relatively resistant species was 19 %. At medium-sized landfills, the share of adapted species was 36 %. At small landfills, resistant species accounted for 20 % and relatively resistant species accounted for over 20 %. The largest proportions of unstable and weakly resistant species are concentrated in small landfills (40 and 20 % respectively). The absence of biogas production processes due to the destruction of waste and garbage combustion products at these types of landfills leads to the exclusion of parameters of harmful effects on species that are not resistant to gas (Fig. 6).

The distribution of vegetation at landfills by lighting intensity requirements shows that light-loving plants predominate at all types of landfills (large – 50 %, medium – 67 %, small – 60 %). This demonstrates good lighting and positive lighting conditions in all areas of the studied landfills. Facultative light-loving plants (heliophytes) found at large and small landfills in the study area contain small particles. Shade-loving plants (sciophytes), which are predominantly ruderal species, were distributed as follows: 45 % on large landfills, 33 % on medium-sized landfills, and 20 % on small landfills. This distribution indicates the existence of shaded areas caused by soil subsidence, landslides at large and medium landfills (Fig. 7).

The results of the research show that wet soils are common at landfill sites. This is caused by insufficient drainage on the territory, which leads to waterlogging. Peat was found on the adjacent territories of the landfills, which is a major component of the landscape, where various biogeochemical and migration processes take place and acts as a natural adsorbent for various chemicals and an indicator of large-scale damage to natural ecosystems.

Engineering and technical measures to protect phytomelioration plantations from filtered runoff are of great importance. The most important harmful factor affecting plant growth is leachate. At some landfills, filtration ponds are formed in the natural terrain near agricultural land. The air is polluted with toxic fumes and has an unpleasant odour. The colour of the leachate is brownish-black with local yellow

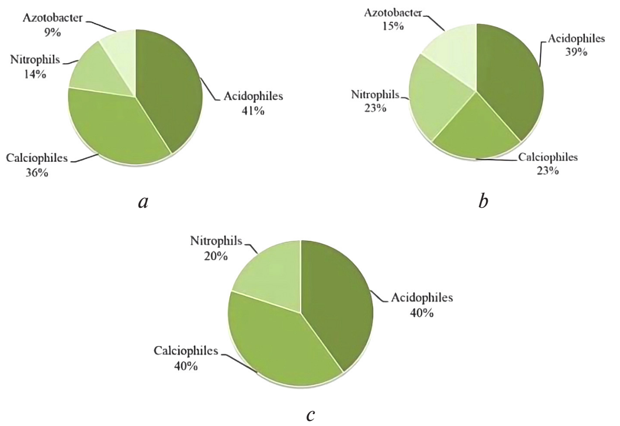

Fig. 4. Distribution of landfill vegetation by substrate chemistry: a – large; b – average; c – small

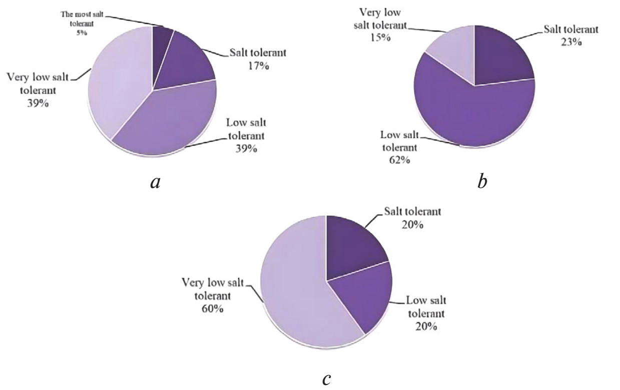

Fig. 5. Distribution of landfill vegetation by salt tolerance: a – large; b – medium; c – small

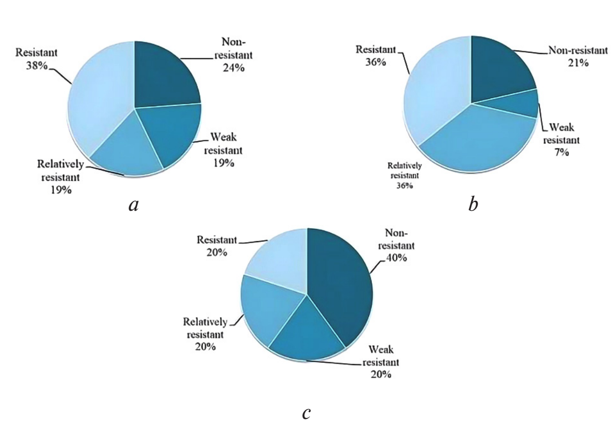

Fig. 6. Distribution of landfill vegetation by gas resistance: a – large; b – medium; c – small

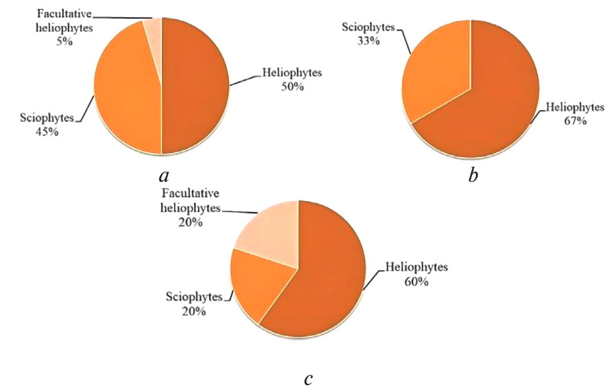

Fig. 7. Distribution of landfill vegetation by light intensity demand: a – large; b – average; c – small

spots. Its level is reached during precipitation and snowmelt. Plants such as sea buckthorn, hanging birch, wild carrots and others grow in the areas where leachate is discharged. Leachate effluents from Lviv and Tysmenytsia landfills have the highest salt content (pH 4.5–6.5). Leachate from all landfills is acidic. The salt content at all studied landfills ranges from 4,500 to 5,500 mg/l.

An analysis of the main life cycle of a landfill shows that the greatest impact on the environment occurs after its closure or reclamation. Hazardous substances released into the environment from landfills can persist for decades before they fully adapt to the natural conditions of the geological and ecological environment. Thus, the relevance of phytoremediation efforts to landfills is undeniable, as vegetation is the most effective geochemical transformer of the environment.

Conclusions. Depending on edaphic and climatic factors, the distribution of species by geometric size of landfills (large, medium and small) showed, that vegetation in landfills is inhabited in different ways. The largest species composition is found in large landfills (45 species, 85 % of the total number), the average – in medium-sized landfills (32 species, 60 %), and the smallest – for small ones (18 species, 34 %).

The taxonomic structure of the flora of the Western Forest-Steppe landfills is represented by 4 phyla and 5 classes. The *Polypodiophyta* and *Bryophyta* phyla are represented by 1 species, the *Pinophyta* phylum by 2 species. The largest number of species – 49 (92 % of the total number) is represented by the Angiosperms (*Magnoliophyta*), among them dicotyledons (*Magnoliopsida*) prevail – 45 species (85 %), monocotyledons (*Liliopsida*) are represented by 4 species (7 %).

The formation of natural phytomelioration processes at all types of landfills in the Western Forest Steppe takes place with the participation of the *Magnoliopsida* class of the *Magnoliophyta* phylum, which accounts for 84–89 % of plant species.

The small distribution of plants (0–14 %) that can tolerate prolonged drought (xerophytes) demonstrates a favourable soil moisture regime at landfills. At the same time, the maximum distribution of mesohygrophytes and mesophytes was observed. Plants living on soils with low nutrient content (oligotrophs) develop on all types of landfills, but they are most concentrated on medium-sized landfills (over 62 %).

The high acidity of landfill soil has led to the development and dominance of organisms that are able to survive in conditions of high acidity at all types of landfills (39–41 %). The most salt-tolerant species were found only at large landfills, but their share is very small (over 5 %).

The distribution of landfill vegetation by light intensity requirements showed that light-loving plants (heliophytes, 50–67 %) predominate at all types of landfills. This indicates good illumination of all areas of the studied landfills and a positive light regime.

The heterogeneity of vegetation cover and ecological conditions of its development at typical landfills in the Western Forest-Steppe is primarily due to negative factors caused by the operation of these technogenically hazardous facilities.

Therefore, when carrying out phytomelioration works at landfills, it is not enough to select the optimal forest crops for their elimination. An important means of developing cultivated phytocoenoses is the care of plants and forest crops. Phytomelioration measures at landfills should be carried out in two directions: aesthetic and forestry.

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Флористична та екологічна структура рослинності сміттєзвалищ Західного Лісостепу України

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Мета. Встановити таксономічну та екологічну структуру флори і зробити висновки щодо перебігу процесів природної рослинної рекультивації сміттєзвалищ Західного Лісостепу України.

Методика. Аналіз і вивчення екологічної та флористичної структури флори сміттєзвалищ проводилися згідно із загальноприйнятими методиками: флористичні, моніторингу, загальнонаукові, математико-статистичні.

Результати. Встановлено, що флора досліджуваних сміттєзвалищ (великих, середніх, малих) представлена дерево-чагарниковою та трав'яною (переважно рудеральною) рослинністю. Під час рекогносцирувальних і польових досліджень виявлено 53 види, із них 18 видів дерев, 8 видів чагарників і 27 видів трав'янистих рослин. Формування природного процесу поліпшення рослин на різних звалищах Західного Лісостепу відбувається переважно за участі класу *Magnoliopsida* та *Magnoliophyta phylum*, що становить 84–89 % видів рослин. Розподіл рослинності сміттєзвалищ за вимогами до інтенсивності освітлення показав, що на всіх типах сміттєзвалищ переважають геліофіти (50–67 %). Це свідчить про добру освітленість усіх ділянок досліджуваних полігонів і позитивний світловий режим. Неоднорідність рослинного покриву та екологічних умов його розвитку на типових сміттєзвалищах Західного Лісостепу зумовлена насамперед негативними чинниками, спричиненими експлуатацією цих техногенно небезпечних об'єктів.

Наукова новизна. Визначено ступень небезпеки екологічної системи внаслідок техногенної завантаженості досліджуваного регіону, спричиненої ландшафтно-трансформуючими чинниками функціонування сміттєзвалищ, а також обґрунтовано методи подолання негативних ситуацій за допомогою фітомеліоративних підходів. Основні наукові принципи ґрунтуються на виведенні з експлуатації сміттєзвалищ шляхом використання фітоценозів-меліорантів, реалізація яких сприяє покращенню стану екологічної безпеки. Встановлені просторові закономірності розвитку екологічної сукцесії на сміттєзвалищах, що дозволяє прогнозувати наслідки техногенного забруднення сміттєзвалищ на біоту.

Практична значимість. Розуміння процесів природної фітомеліорації в залежності від едафо-кліматичних чинників дозволить здійснити вибір ефективних рослинних видів для проведення етапу рекультивації на сміттєзвалищах.

Ключові слова: *сміттєзвалище, фітомеліорація, техногенна безпека, екологія, рослинність*

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