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APPLICATION OF MATHEMATICAL-CARTOGRAPHIC MODELING IN OPTIMIZING THE STRUCTURE OF THE REGIONAL LANDFILL OF SOLID NON-HAZARDOUS WASTE OF THE LUTSK MANAGEMENT CLUSTER

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Abstract
Ukraine is one of the countries where the problem of waste management is particularly acute and deteriorating every year. The Regional Waste Management Plan in Volyn region by 2030 envisages a reduction in the total amount of landfilled waste from 97.68% to 30%, and the number of sites for their disposal – up to 4-8 regional landfills per region. Ecological-economic mechanism of solid non-hazardous waste (SNHW) management is based on a harmonious combination of environmental constraints with the economic attractiveness of regional landfills and involves working with geographically defined objects based on the use of methods of processing geospatial information, one of which is mathematical-cartographic modeling. Thus, the main purpose of this work is to substantiate the possibilities of applying the method of mathematical-cartographic modeling in the design of the system of regional landfills of SNHW in the Volyn region. In order to address the issue of placement of SNHW management facilities, the territory of the region is divided into four management clusters. The division of the territory took into account the composition, properties, methods of solid waste collection, logistics, load on waste processing complexes, volumes of waste generated, spatial planning, etc. Three probable options for the location of regional landfills have been developed for the Lutsk SNHW cluster. The results of the study can be used in the development and adjustment of regional plans, waste management programs, as well as in the work of the executive bodies of the united territorial communities.
Key words: solid non-hazardous waste, regional landfills, united territorial community, mathematical-cartographic modeling, multi-criteria decision analysis.

Introduction

One of the important steps of waste management reform in Ukraine is the National Waste Management Strategy until 2030, which provides for a gradual transition from landfill to sorting and reuse, recycling or disposal of waste with landfill disposal at "regional" landfills that meet requirements of the European Union. In this direction, it is proposed to develop regional waste management programs, first of all a plan to determine the rational area of coverage and location of "regional" landfills. Solving this problem requires decision-making support based on the processing and analysis of heterogeneous spatial information about municipal solid waste facilities and modeling the impact of environmental, economic, social factors and geomorphometric parameters of the territory The authors aim to consider the possibility of solving these problems with the help of mathematical-cartographic modeling. First, it is necessary to analyze the existing methods and assess the situation with landfills in the region, which will serve as a basis for the model of placement of regional landfills of SNHW.

Methodology of research and materials

This article used methods of analysis, generalization, theoretical method and cartographic. Using the cartographic method, author's maps were created, which show the current state of the object of study. The source of information for the creation of author's tables were the previously mentioned maps. The basis for the maps were statistical data, programs and waste management plans in Volyn region, data of the modern administrative-territorial structure of Ukraine, but because their format was not suitable for this study, they needed to reformat and identify new information by analyzing existing data. The map GIS software MapInfo Professional was used to create the maps.

In most cases, if there are several criteria for optimality and the necessary degree of completeness of the description of the real situation, the solution cannot be obtained by analytical methods in an acceptable time. The complexity of the algorithms increases significantly with increasing factors that influence the decision. Considering the fact that the problem of disposing of solid household waste objects is multifactorial, with the information provided in the form of judgments and wishes of experts and often subjective and fuzzy in nature, is proposed that combines the methods of multi-criteria analysis of

solutions, the theory of fuzzy sets with GIS-technologies. The synergy of these approaches provides a more flexible tool that takes into account various decision-making strategies, i.e. adds missing functionality to the geographic information system that cannot be implemented by selecting locations for objects based only on spatial overlay operations. Thus, the urgent task is the development and improvement of models, methods and software tools that can be integrated into the geographic information system and provide increased decision-making on the disposal of solid waste in conditions of multi-criteria and uncertainty (Kuznichenko et.al., 2018).

GIS-oriented fuzzy two-stage multi-criteria decision analysis (MCDA) model for the deployment of SNHW facilities combines geospatial information about the SNHW landfills with estimates and opinion of experts, and also considers the attitude of decision maker (DM) to risk when making decisions. Description of the MCDA model in geographic space is formalized, where alternatives, criteria and other elements of solving the issue have spatial dimensions. A two-stage MCDA model is proposed to increase the analysis efficiency, which allows, at the first stage of macroanalysis, to form a set of acceptable alternatives considering the restrictions imposed by sanitary-construction standards using GIS tools, and at the second stage of microanalysis, to rank the set of acceptable alternatives according to their degree of suitability for SNHW objects deployment based on the MCDA methods with obtaining results in the form of a base map (Buchynska, 2018).

A fuzzy model for processing heterogeneous geospatial information on the location of solid waste includes a procedure for discretization of vector layers of criteria in a raster model by calculating Euclidean proximity metrics and a procedure for fassification of criteria, i.e. converting their attribute values into fuzzy set expert assessment of the fuzzy membership function (Wang et.al., 2009). The model allows decomposition of heterogeneous geospatial information into layers of criteria, identify many alternatives, as well as formalize expertise in the subject area, which increases the adequacy and validity of the decision-making process for the disposal of solid waste (Trofymchuk et.al, 2014).

An important tool for processing heterogeneous geospatial information about the location of solid waste objects is GIS-modeling as an integrative theory, which on a new methodological basis combines known methods of design, compilation, use and analysis of GIS-models to study real world objects using systems of ordering and transformation of information about these objects. Unlike theoretical modeling methods, GIS-modeling is a high-tech process and serves as a tool that provides collection, storage, processing, access, display and dissemination of spatially coordinated data.

GIS-modeling uses a powerful arsenal of spatial analysis tools, in particular: network analysis as a group of spatial-analytical operations, the purpose of which is to study the topological and geometric properties of solid waste landfills that form network structures; analysis of objects within the buffer zones, which allows to solve the problems of assessment of the zone of influence of the existing or projected network of landfills for solid waste; operations of the calculated geometry by means of which calculation of areas and coordinates of centroids of polygons, lengths of broken and curved lines, etc. is carried out; overlay operations, the essence of which is the imposition of two layers of different names with the generalization of derived objects and the inheritance of their attributes, which arise when they are geometrically combined.

In addition to standard functions, GIS-modeling for spatial analysis uses special programs created on the basis of deterministic and stochastic models, as well as special programs of GIS applications to predict the situation. One of the most important components of GIS-modeling is a cartographic module that provides cartographic representation of source, derived or resulting data in the form of digital, computer and electronic maps, while acting as an element of the user interface and a means of documenting the final results.

GIS-modeling includes the use of such types of modeling as geographical, cartographic, mathematical-cartographic, aerospace, computer, electronic-graphic. The defining function of cartographic modeling as part of GIS-modeling is the ability to analyze the available necessary information. Mathematical-cartographic modeling is understood as organic complexing of mathematical and cartographic models in the system of "creation-use" of maps for the purpose of constructing or analyzing thematic content of maps with the possibility of processing large amounts of information by one algorithm and processing of one array of information by different algorithms. The application and combination of these types of modeling provides researchers with a variety of created models of spatial objects that are suitable for spatial analysis (Король та ін., 2012).

This combination of two universal research methods has become possible due to the ability of the cartographic method to be elementary combined with other methods in the creation of any thematic or special maps. The involvement of the mathematical method in the process of creating maps gave

mathematical models spatial certainty and imagery, and at the same time allowed to create original cartographic models based on mathematical processing of huge amounts of information.
The whole process of mathematical-cartographic modeling can be represented in the form of elementary links that form the levels of modeling. Each elementary link always consists of a mathematical model and a map created on the basis of this model, and their number depends on the complexity of the modeled system and the number of steps required to create a final map and ranges from one to infinity. The vast majority of systems are complex and super-complex, i.e. includes an extensive set of internal and external system-forming elements and their relationships, which necessitates a variety of combinations of elementary links in chains, i.e. the construction of complex mathematical and cartographic models (Король та ін., 2012, 2013, 2013).
At the final stage of mathematical-cartographic modeling with the help of created models the basic principles of organization and integration of systems, possibilities of forecasting and management of solid household waste are revealed.

Discussions and results

General characteristics of the object of study. As part of the implementation of the reform of local self-government and territorial organization of power in 2015-2019 in Volyn region was created, and the order of the Cabinet of Ministers of Ukraine dated June 12, 2020 № 708-r "On the definition of administrative centers and approval of territorial communities of Volyn region" approved a list of 54 territorial communities in the Volyn region (11 urban, 18 urban village and 25 rural), which are united within 4 districts (Lutsk - with an area of 5247.8 km² and a population of 451.5 thousand people, Kovel with an area of 7647.9 km² and a population of 261.5 thousand persons, Volodymyr-Volynskyi with an area of 2558.2 km^2 and a population of 181.9 thousand people, Kamin-Kashyrskyi with an area of 4693.4 km^2 and a population of 136.6 thousand people). The object of this study is the territory of the Lutsk solid waste management cluster, which is spatially identified with the territory of the newly created Lutsk district. The Lutsk district includes the territories of Lutsk City, Lutsk, Kivertsi, Rozhyshche, Horokhiv, Berestechko urban, Kolky, Tsuman, Olyka, Torchyn, Marianivka urban village, Boratyn, Horodyshche, Pidhaitsi, Dorosyni and Kopachivka rural united territorial community (UTC) (Figure 1).

Figure 1. Administrative-territorial structure of Lutsk district **(**UTC**)**

SNHW landfills. As of April 15, 2020, there are 478 SNHW landfills in the Volyn region, only 110 of which are certified. For the Lutsk cluster, the corresponding indicators are 151 and 26 landfills (their location and main characteristics are given in Figure 2 and 3, and in Table 1).

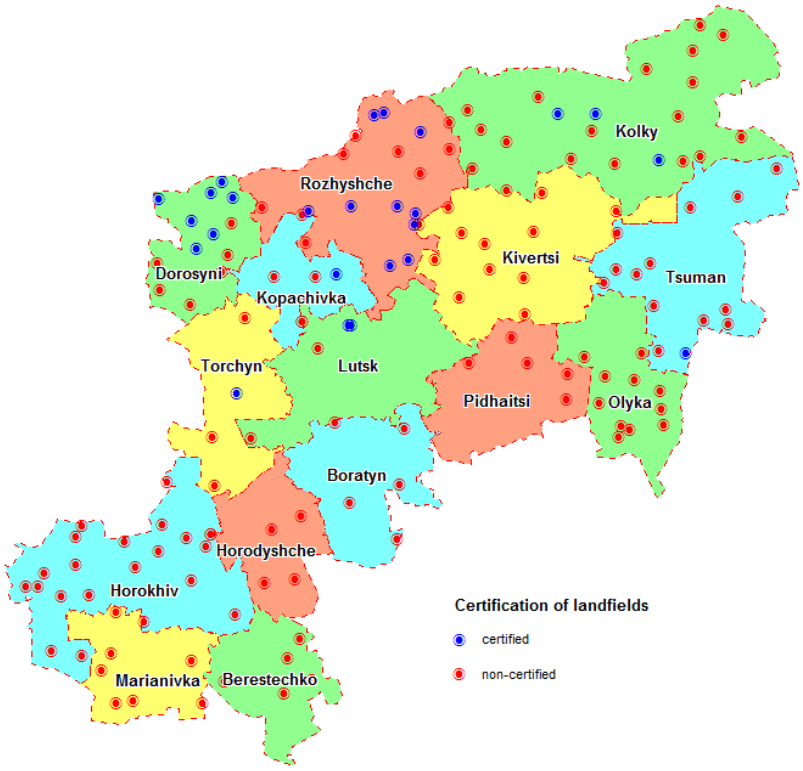

Figure 2. Location of existing SNHW landfills in Lutsk cluster

Table 1

Characteristics of existing SNHW landfills in the Lutsk cluster

№	UTC	Number of landfills	Number of certified landfills	Share of certified landfills,%	Actual area of landfills, ha
1	Lutsk	5	2	40	20.2797
2	Kivertsi	12	0	0	17.1178
3	Rozhyshche	18	11	61	14.9157
4	Horokhiv	20	0	0	15.9500
5	Berestechko	5	0	0	5.0000
6	Kolky	22	3	14	16.5425
7	Tsuman	14	1	7	15.3438
8	Olyka	11	0	0	12.4043
9	Torchyn	4	1	25	2.1010
10	Marianivka	7	0	0	8.3000
11	Boratyn	5	0	0	5.8400
12	Horodyshche	5	0	0	12.1331
13	Pidhaitsi	5	0	0	5.5300
14	Dorosyni	13	7	54	7.5800
15	Kopachivka	5	1	20	5.2310
	Total	**151**	**26**	**17**	**164.2689**

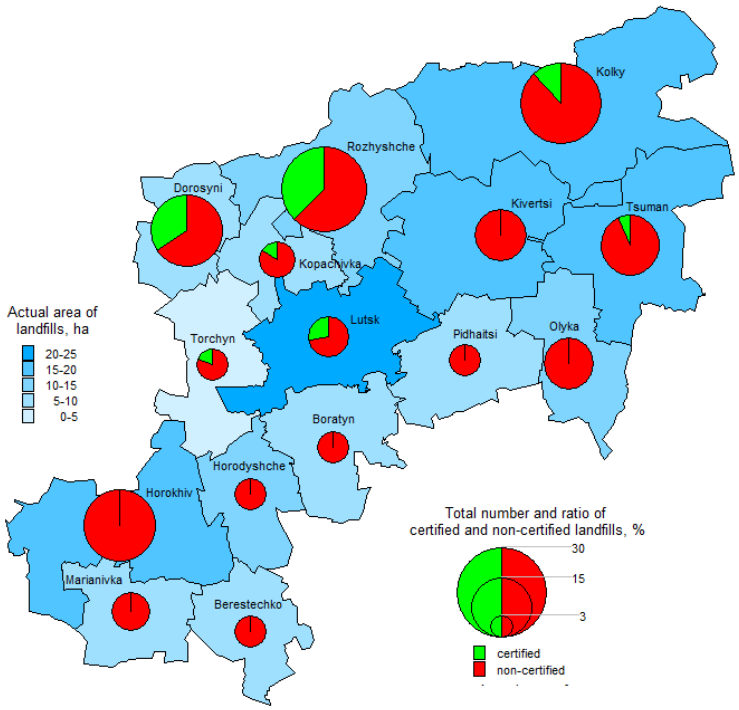

Figure 3. Characteristics of existing SNHW landfills in Lutsk cluster

Forecasting the amount of SNHW. The lack of complete and reliable information on waste management volumes and their composition at the time of development of the "Regional Waste Management Plan in Volyn Region until 2030" (Регіональний план, 2020) does not allow to perform reasonable forecasting of waste generation for the period up to 2030 taking into account different waste streams.

According to the norms of SBC B.2.2-12: 2019, the annual rate of solid waste generation (on average in the settlement, taking into account organizations and institutions, pendulum migration) is 300 kg/person or 1.8 m³/person. Given that the share of waste organizations and institutions is 12% of the total waste generation in the settlement, and the density of mixed solid waste - 166.7 kg/m^3, the estimated volume of solid waste generation in the region is 314900 t/year.

Criteria for determining the areas of optimal coverage. When determining the optimal coverage areas for SNHW management, the following types of alternative scenarios are usually considered: cluster boundaries or different ways of collecting and treating SNHW within certain clusters. The main technological objects of waste management, which are focused on servicing the whole or at least a significant area within the cluster (technological cores of clusters), are considered: regional landfills; mechanical-biological processing facilities or incinerator; other waste treatment facilities, such as waste sorting complexes.

The regional landfill is a part of the waste management complex, which is operated in accordance with construction, sanitary and ecological norms and serves several settlements and districts. The construction of modern regional landfills allows to reduce the area of land used for waste disposal in settlements, to organize the collection of biogas and filtrate from the landfill, to prevent negative impact on the environment and public health. In the future, a gradual reduction of the total number of landfills and construction of modern regional landfills with an approximate area of 8-13 hectares is envisaged (Програма поводження, 2018).

When determining the zones of optimal coverage for SNHW management are guided by the following main criteria: the recommended coverage of the population is 150-400 thousand people; there is a potential to create a regional landfill in each cluster; developed plans and prospects for the creation of facilities for in-depth processing of solid waste, in particular with energy production, and determined their technological parameters; minimized costs for transportation and disposal of waste, as well as the volume of waste disposal. In addition, there is a possibility to use additional criteria for determining clusters, including the current and future administrative structure of the region, established links between

communities, districts, developed projects of cooperation of territorial communities, etc., local restrictions on the location of the landfill due to flooding, proximity to protected areas, etc.

Assumptions about the choice of methods of in-depth waste treatment. Analysis of the technological potential of measures aimed at reducing the amount of solid waste disposal shows that to ensure the implementation of the national target for reducing the amount of landfill (30% - by 2030) in the region it is necessary to introduce separate collection of secondary raw materials, composting of organic waste and extraction of individual fractions of waste suitable for the production of solid fuels. Among such technological solutions can be considered, including decision on obtaining solid fuel from solid waste. The following technological scenarios of in-depth solid waste recycling are considered for the Lutsk solid waste management cluster: creation of a waste processing plant, an incineration plant, mechanical and biological processing facilities and waste sorting complexes.

Assumptions about the location of regional landfills. In determining the location of regional landfills, the following factors were taken into account: the possibility of using the existing capacity of the landfill as a regional one while building a new landfill (or expanding the existing one by creating new maps); existing potential for the use of land resources near the existing facility to create new capacity; possible risks of social rejection of the construction of a new landfill in a new location (Регіональний план, 2020).

Taking into account the above assumptions, as well as taking into account the need to optimize the cost of transporting waste to waste treatment facilities, the options for dividing the area into solid waste management clusters are obtained. The clusters are formed taking into account the new division of the region into districts, taking into account the fact that the united territorial communities are mostly created within the existing districts. In cases where the boundaries of the established UTCs do not coincide with the existing boundaries of the districts, the presentation of the boundaries of the clusters will need to be adjusted accordingly (Петрович, Євсюков, 2020, 2021, Регіональний план, 2020).

In all the proposed options, the division of the Volyn region into four clusters: Lutsk (A); Volodymyr-Volynskyi (B); Kovel (C) and Kamin-Kashyrskyi (D). Within any cluster, there are alternative options for additional division into subregions - 2 subregions in each cluster, in particular for the Lutsk cluster - Lutsk (A1) and Horokhiv (A2) subregions (Table 2).

Table 2

Population and solid waste generation in the Lutsk cluster (Регіональний план, 2020)

№	Cluster/Subregion	Population, persons	Volumes of solid waste generation, m^3/year
1	Cluster A	451463	49719.4
2	Subregion A1	402872	44576.6
3	Subregion A2	48591	5142.9
	Total	451463	49719.4

According to the results of analysis and consultations as potential regional landfills for non-hazardous waste, for the Lutsk cluster can be considered: in the variant of a single cluster (Figure 4) – landfill (v. Bryshche), in the variant of two subregions (Figure 5) - landfill (v. Bryshche) and landfill (v. Tsegiv), in the variant with the main landfill for 4 central subregions - landfill (v. Bryshche), landfill (v. Tsegiv) and sand quarry (v. Radoshyn).

In all cases, the creation of regional landfills will require the expansion of existing or construction of a new landfill. It is assumed that the existing landfills will be operated until their capacity is exhausted with subsequent reclamation (Регіональний план, 2020).

Figure 4. The first variant location of regional SNHW landfills

Figure 5. The second variant location of regional SNHW landfills

Disposal of solid non-hazardous waste. The amount of waste disposal at regional landfills depends on the coverage of the territory (population and business entities), as well as the effectiveness of the implementation of measures to minimize the amount of waste disposal. When analyzing the expected volumes of municipal waste disposal, it is taken into account that industrial waste of hazard class III-IV can also be buried or used for landfill layers at landfills. The expected (planned) volumes of waste disposal at regional landfills are given in the Table 3.

Table 3

Expected volumes of waste disposal at regional landfills of the Lutsk cluster
(Регіональний план, 2020)

Landfill location	**Coverage territory**	**Volumes of waste disposal, t/year**	
		in general (including industrial)	**population waste**
v. Bryshche	Subregion A1	44576.6	32956.6
v. Tsegiv	Subregion A2	5142.9	3771.4
v. Radoshyn	Subregions A1, B1, C1, D2	73691.2	54414.1

The capacity of regional landfills must meet the need for waste disposal of the relevant clusters for a period of at least 20 years. Technological parameters of regional landfills are given in the Table 4.

Table 4

Technological parameters of regional landfills of Lutsk cluster (Регіональний план, 2020)

Landfill location	Coverage territory	Approximate landfill area, ha	Total power, t	Population, persons
v. Bryshche	Cluster A	6.1	994400	451463
v. Bryshche	Subregion A1	5.5	891500	402872
v. Tsegiv	Subregion A2	1.9	102900	48591
v. Radoshyn	Subregions A1, B1, C1, D2	15.3	1473800	690329

Conclusions and proposals

The problem with garbage in Ukraine requires a reduction in the amount of waste that is disposed of and, accordingly, a reduction in the number of landfills. In this regard, the division of regions into clusters and the creation of regional landfills is envisaged. The location of such landfills in the Lutsk cluster using mathematical-cartographic models makes it possible to take into account the modern administrative-territorial division, the established links between communities,
districts, developed projects of cooperation of territorial communities, etc., local restrictions on the location of landfills due to flooding, proximity to protected areas, etc., location of existing landfills, taking into account their certification and area.

A promising area of further research is the creation of a unified cartographic resource "GIS of solid waste management", which is designed to serve as a tool for decision-making in the field of solid waste management, a means of visualizing the current state and stages of local and regional solid waste management programs. The product is developed in accordance with the "National Waste Management Strategy in Ukraine until 2030", which was approved by the Order of the Cabinet of Ministers of Ukraine dated 08.11.2017 № 820-r. and Resolution of the Cabinet of Ministers of Ukraine of February 20, 2019 № 117-r "On approval of the National Waste Management Plan until 2030", is recommended for implementation at the regional (oblast) and local (territorial community, city) levels and will be used as a collection tool, accumulation, processing, analysis and dissemination of information on waste management. This GIS is designed to solve a number of problems related to the collection of information on the current state (inventory) of landfills, certification of landfills, visualization of sanitation schemes, development and optimization of logistics schemes and route collection removal of solid waste in the relevant territory, development of environmentally and economically optimal practices of solid waste management.

The main advantages of this cartographic resource are: the availability of tools for operational inventory of landfills by means of mobile technologies (including real-time) and technologies of unmanned aerial vehicles (UAVs), the creation of a database based on them (including 3-D models) places of solid waste storage; certification of landfills and dumps, creation of databases on solid waste storage sites and morphological features of landfills; visualization of existing and perspective vector schemes of sanitary cleaning of settlements in the mode of combination with town-planning documentation and land cadastre, system of popular cartographic services (Google Maps, Open Street Maps, etc.), which allows to take a comprehensive approach to solid waste management; formation and display of optimal logistic schemes of garbage collection routes; planning specific promising measures for technical and operational equipment of landfills, forecasting the future state of areas and other geometric parameters of landfills, developing a strategy for optimal concentration of storage sites and waste disposal; availability of a subsystem of electronic appeals of citizens and a platform for their operative analysis; providing the function of information support of local governments in decision-making in the field of environmental safety, risk management, automation of reporting on the results of environmental work.

The practical implementation of this cartographic resource will provide an opportunity to take into account the location of landfills; logistical support for the implementation of regional and local targeted waste management programs; minimization of costs for sanitary maintenance of territories; increasing the level of landscaping, improving the environment; strengthening the interaction between the government and the community, mobilizing members of the relevant territorial communities in solving problems of solid waste management; achieving a high level of awareness of citizens on solving the problems of collection, removal and disposal of solid waste.

The indicative structure of the database "GIS of solid waste management" will include basic and thematic information resources (Ільченко, Коцюба, 2011). The basic information resources will include: a single electronic cartographic basis that reflects the modern administrative-territorial structure of the territory, natural resource potential (orography, hydrography, soil and vegetation, mineral resources) and geographical conditions of the territory, road transport and engineering infrastructure, register geographical names, etc. Thematic information resources will include layers of the GIS, reflecting landfills, waste disposal sites, waste collection equipment (containers), transport bases, transshipment and sorting sites (waste transshipment or sorting stations), landfills or waste processing (plants), vector schemes of sanitary cleaning of settlements, etc.

References

1. Buchynska I.A. (2018) GIS-based decision support system for placing solid waste landfill // Monograph. Processing, Transmission and Security of Information. Wydawnictwo Naukowe Akademii Techniczno-Humanistycznej w Bielsku-Białej, Poland. Vol. 2. P. 33-40.
2. Kuznichenko S., Kovalenko L., Buchynska I., Gunchenko Y. (2018) Development of a multicriteria model for making decisions on the location of solid waste landfills // Eastern-European Journal Of Enterprise Technologies. Vol. 2. No 3(92). P. 21-30.
3. Trofymchuk O., Trysnyuk V., Novokhatska N., Radchuk I. (2014) Geoinformation Technologies in decision issues of municipal solid waste //Journal of Environmental Science and Engineering. No 3. P. 183-187.
4. Wang G., Qin L., Li G., Chen L. (2009) Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. Journal of Environmental Management. 90(8). P. 2414-2421.
5. Ільченко А.В., Коцюба І.Г. (2011) Використання програмного забезпечення з метою оптимізації системи поводження з твердими побутовими відходами міста Житомира (Use of the software to optimization system for the treatment of hard domestic waste in Zhytomyr) Екологічна безпека 1(11). С.13-16. (in Ukrainian)
6. Король П.П., Волошин В.У, Рудик О.В. (2012) Математико-картографічне забезпечення моніторингових досліджень ерозійно-небезпечних земель із застосуванням анаморфованих зображень (Mathematical-cartographic support for monitoring studies of erosion-prone land using pseudo cartograms). Геодезія, картографія і аерофотознімання. № 76. С. 110-116. (in Ukrainian)
7. Король П.П., Волошин В.У, Рудик О.В. (2013) Математико-картографічне забезпечення моніторингових досліджень ерозійно-небезпечних земель із застосуванням методу оцінювання пластики рельєфу (Mathematical-cartographic support for monitoring studies of erosion-prone lands using a method of relief plastics) Сучасні досягнення геодезичної науки та виробництва Вип. 1 (25). С.110-116. (in Ukrainian)
8. Король П.П., Волошин В.У., Фесюк О.В. (2013) Математико-картографічне моделювання водної ерозії ґрунтів на основі комбінованого універсального рівняння втрат ґрунту (Mathematical-cartographic modeling of soil erosion on the basis of combined universal soil loss equation). Вісник геодезії та картографії. №6. С. 35-42. (in Ukrainian)
9. Петрович О. М., Євсюков Т. О. (2020) Аналіз сучасних методичних підходів до визначення місць розташування полігонів твердих побутових відходів (Analysis of modern methodological approaches to determining the location of landfills for solid non-hazardous waste). Землеустрій, кадастр і моніторинг земель. № 2-3. С. 27-38. (in Ukrainian)
10. Петрович О. М., Євсюков Т. О. (2021) Еколого-економічний механізм вибору земельної ділянки для регіонального полігону побутових відходів Луцького кластеру Волинської області (Ecological-economic mechanism of land selection for the regional landfill for solid non-hazardous waste of Lutsk cluster of Volyn region). Львів: Західноукраїнський Консалтинг Центр. С. 310. (in Ukrainian)
11. Програма поводження з твердими побутовими відходами у Волинській області на 2018-2021 роки (2018) (Solid waste management program in Volyn region for 2018-2021) Луцьк: Волинська обласна рада. 25 с. (in Ukrainian)
12. Регіональний план управління відходами у Волинській області до 2030 року (2020) (Regional waste management plan in Volyn region until 2030) За заг. ред. І.В Сліпця. Київ: ATON GROUP. 230 с. (in Ukrainian)
13. Схема санітарного очищення м. Луцьк Волинської області (2018) (Scheme of sanitary cleaning of Lutsk City, Volyn region) За заг. ред. І.В Сліпця. Київ: ATON GROUP. 178 с. (in Ukrainian)
14. Шевчук І.Л., Даценко Т.С., Матвійчук Н.М. (2018) Особливості утворення та поводження з відходами у Волинській області (Features of waste generation and management in Volyn region) Луцьк: Молода наука Волині: пріоритети та перспективи досліджень. Економіка. С. 319-321. (in Ukrainian)

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