**ANALYSIS OF MODERN METHODOLOGICAL APPROACHES TO
DETERMINATION OF LOCATIONS OF SOLID WASTE LANDFILLS**

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Abstract. *The need to introduce resource-saving technologies and environmental policies at both international and regional levels, the rapid growth of the world's population in recent centuries and related processes of industrialization, urbanization, intensification of agricultural production, increasing energy demand and, consequently, increasing waste, polluting the environment further complicates the task of substantiating the location of new landfills and assessing existing ones.*

In Ukraine, the issue of waste management is regulated by a number of legislative acts, plans, strategies, recommendations, they contain high-quality criteria for assessing the selected site for solid waste, but none of them has clear guidelines for identifying places for potential landfills. That would meet all the above criteria.

The authors consider the problem of the lack of methods for selecting sites for landfills in Ukraine in terms of decentralization and reform in the field of waste. The experience of scientists from Russia, USA, Serbia, Ethiopia, Italy, China, etc. is also analyzed, their systems of site selection, features, advantages and disadvantages are clarified.

In such circumstances, an important scientific and practical task is to improve methodological approaches to determining the location of landfills and the development of land management projects for the allocation of land for landfills, because currently there is no such methodology. At the same time, the methods

developed by foreign scientists need to be improved and even if they are used in Ukraine, they require adaptation to local, regional and other conditions.

Keywords. *Household waste, landfill, methodological approaches, waste management, environment, environmental safety, waste management, multi-criteria approach, methods of fuzzy logic.*

Topicality. The problem of solid waste management continues to become relevant, primarily due to the need to implement resource-saving technologies and environmental policy at both international and regional levels; rapid growth of the Earth's population in recent centuries and the associated processes of industrialization, urbanization, intensification of agricultural production, increasing demand for energy resources and, consequently, increasing the amount of waste that pollutes the environment, violates environmental and man-made safety. For Ukraine, as for many other countries, this issue is extremely acute, and ignoring it leads to serious consequences. Thus, the tragedy at the Lviv solid waste landfill gained public resonance and showed that neglect of environmental safety issues leads to serious consequences.

An important task is to substantiate the location of new landfills and assess existing ones, as they are objects, the location of which requires strict compliance with sanitary, environmental, demographic, social and other requirements for their location. Under such circumstances, an important scientific and practical task is to improve methodological approaches to determining the location of landfills and development of land management projects for the allocation of land for landfills, because currently such a methodology is absent and it is not included in the reform plans [1]. At the same time, the methods developed by foreign scientists need to be improved and even if they are used in Ukraine, they require adaptation to local, regional and other conditions.

Analysis of recent research and publications. Both domestic and foreign scientists have studied the issues related to the search for the optimal location of landfills, among them the works of Z. Davletbakova [2,3], Z. Daniel [4], B. Harun [5], B. Josimović, [6], A. Adefris [7], V. Baiocchi, K. Lelo, P. Poletti, R. Pomi [8],

W. Guqina [9], S. Sheina. [10], A. Aterekova [11] and others. Their proposed methods and methodological approaches to the selection of sites for solid waste are based mainly on the use of GIS technologies in combination with methods of Boolean, fuzzy logic, AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), multicriteria analysis, etc. A critical analysis of the latest research, publications and regulations on the selection of sites for solid waste allows us to state that in Ukraine the issues related to the development of methods for determining the location of landfills and further development of land management projects for land allocation remain insufficiently addressed plots for such landfills.

The aim of the study. Thus, the main purpose of the study is to analyze modern methodological approaches to determining the location of landfills.

Materials and methods of research. The study used a theoretical method, methods of synthesis, analysis, comparison, modeling, forecasting and generalization. The theoretical basis was the regulations of Ukraine, the European Union Directives in the field of waste, the work of foreign scientists to find the optimal location of landfills, the Interactive Map of the Ministry of Ecology and Natural Resources and the statistics of the Ministry of Regional Development.

To achieve the goal of the study, the current state of landfills is analyzed, how many are there, how many are needed and the method of comparison was used to study different sources and check by modeling the number of regional landfills proposed in [1]. Modern methodological approaches to determining the location of landfills are critically studied and methods of choosing such places in terms of decentralization of power are substantiated.

Research results and their discussion. The Government's approval at the end of 2017 of the «National Waste Management Strategy in Ukraine until 2030» [1] started a new stage in the waste management system. According to the Ministry of Regional Development in 2018, there were 6107 landfills and dumps in Ukraine, 26,6 thousand unauthorized landfills are detected annually, and the need for new landfills is 421 units. The number of overloaded landfills is 256 units. (4,2%), and 984 units. (16%) do not meet environmental safety standards. See statistics by region. table. 1.

According to the Interactive Map of the Ministry of Ecology and Natural Resources, as of December 7, 2019, 6902 appeals of citizens were received regarding the detection of natural landfills. According to [1], by 2030 the number of waste disposal sites will be reduced to 300 units. and construction of 50 units. regional landfills for household waste. Although according to [1] when calculating that one landfill should optimally serve 400 thousand people, and the population of Ukraine 42 million people - the minimum number of regional landfills is 105 units.

Table 1. Number of landfills and the need for them*

Administrative-territorial division	Total number of landfills and dumps, units			The need for new landfills	
	Total	Overload ed	Which do not meet safety standards	Quantity, units	Area, ha
Vinnytska	41	28	0	8	35,5
Volynska	482	3	0	6	34
Dnipropetrovska	225	7	147	55	200,89
Donetska	47	1	18	13	55,98
Zhytomyrska	767	8	56	24	60,66
Zakarpatska	123	40	50	44	125,8
Zaporizka	113	7	43	42	126,04
Ivano-Frankivska	16	1	2	9	42,5
Kyivska	37	12	36	11	95
Kirovohradska	417	10	74	21	69,9
Luhanska	18	0	13	9	26,2
Lvivska	20	11	20	18	105,7
Mykolaivska	267	3	69	6	33,04
Odeska	628	58	147	11	31,5
Poltavska	570	9	233	11	36
Rivnenska	339	3	0	27	28,7
Sumska	165	14	22	7	42,4
Ternopilska	31	4	3	11	33
Kharkivska	49	5	13	42	135,19
Khersonska	54	1	0	4	50
Khmelnyska	33	6	0	14	36,5
Cherkaska	21	3	1	6	68,5
Chernivetska	283	2	0	13	22,4
Chernihivska	659	20	37	7	26,7
c. Kyiv	2	0	0	2	50
Total in Ukraine:	6107	256	984	421	1572,1

*data of the Ministry of Regional Development, 2018

Currently in Ukraine the issue of waste management is regulated by a number of legislative acts, plans, strategies, recommendations, among which first of all [1], [12-22], but in none of them there are clear guidelines for determining places for

potential landfills. The current building codes concerning the basic provisions of landfill design [15] are quite detailed and take into account a number of issues related not only to the design but also to the operation of landfills [23]. According to paragraphs 1-3, 5, 36 of the National Waste Management Plan until 2030 [21] it is planned to develop a bill «On waste disposal», state and industry building codes for landfills for hazardous waste, non-hazardous waste and inert , methods of environmental risk assessment from waste treatment facilities, guidelines for sustainable green public procurement, the procedure for developing and approving regional waste management plans, determining the location of regional landfills that are not hazardous, based on pre-determined optimal areas coverage/clusters, etc.

Annex 16 «Example of determining regional waste treatment facilities for household waste» [22] provides recommendations for determining the location of regional landfills. At the same time, these recommendations are not a full-fledged methodology, but only help in some issues, namely: the list of source information for site selection, minimum and optimal requirements for waste generation capacity (t / year) and the population that will use the selected landfill. , communication with service clusters and waste transshipment stations, application of the iterative method, etc. In turn, [22] does not specify how to choose sites, what technologies and methods to use, and also does not take into account the environmental criteria, which are given in [15].

Interpreting paragraph 2.1 [15] «The site for the placement of landfills should be selected on a territorial basis in accordance with the scheme of sanitation of the city or region and the project of district planning or master plan of the settlement». Schemes of sanitary cleaning of the city or region provide definition of quantity of garbage trucks, garbage containers, urns, interaction of these elements among themselves and maintenance of their functioning, treatment of animals, etc. The design of new burial sites is provided only as recommendations without special work. District planning projects provide for the determination of design locations of landfills, but they do not take into account all the requirements, including requirements [1]. The choice of land for waste disposal on the basis of the master

plan of the settlement contradicts environmental standards, as landfills are located at a distance of at least 1 km from the city limits and 0,5 km from residential and public buildings (sanitary protection zone).

Analyzing the works [2-11] of scientists who have their experience in developing methods for determining the optimal location of landfills, we can see that as the study improved the set of methods used, however, the basic approaches remained unchanged. The method of site selection for waste management involves two successive steps. The first stage is the selection of potentially suitable places. The definition of the primary sample of territorial areas for the placement of waste management facilities includes two successive phases: macroanalysis and microanalysis (multifactor spatial analysis). Macroanalysis aims to exclude unsuitable and potentially suitable territorial areas for the location of «dangerous» infrastructure. The assessment is based on an analysis of current land use by «exclusion» criteria. The «exclusion» criterion is a factor that indicates the unsuitability of the territorial zone and implies the impossibility of placing the object within it. These factors are usually determined based on environmental requirements and information contained in the research literature. Selection of suitable sites is carried out by spatial analysis using geographic information systems (GIS). Based on the existing land use, taking into account environmental requirements, terrain, landscape morphology, socio-economic factors, potential areas for landfill are identified.

In the second phase, a more detailed study of the identified areas is carried out in order to form a list of specific places. The analysis is based on «preferential criteria» and penalizing criteria. The factor of «advantage» indicates the presence of signs of acceptability and even desirability of placing an incinerator or recycling plant or landfill in the area. The «limitation» factor indicates the presence of contradictions and possible difficulties and provides for the possibility of construction of a waste management facility only if additional requirements are met during the design and operation of the facility.

All potentially suitable sites for waste management are then assessed and prioritized. Ranking is performed according to many evaluation criteria by applying the method of analysis of hierarchies (Analytic Hierarchy Process - AHP) or the method of analysis of network processes (Analytic Network Process). The place with the highest score is the best. For a generalized sequence of actions when choosing a site for a landfill based on foreign experience, see Fig. 1.

Fig. 1. Stages of site selection for landfills according to foreign scientists [2, 4-9, 11]

The method of hierarchy analysis was developed by Thomas L. Saaty in 1980 and has become widespread in the research literature to solve the problem of finding the best solution. According to the AHP method, the decision-making problem is divided into several levels of hierarchy, forming one-way paired connections between all levels. The top of the hierarchy is the main goal. Levels below are quantitative and qualitative criteria and sub-criteria. At the lower level - solutions that are evaluated according to previously formulated criteria. The method uses a pairwise comparison, measuring the importance of each element relative to each other on a scale from 1 to 9. As a result, the weight estimate for each alternative is determined. To check the consistency of the judgment, the A Consistency Ratio (CR) is calculated, which should be in the range of 0, 1.

The disadvantage of the AHP method is its strict hierarchical structure - the elements of each level are unidirectionally interconnected, while the problems in real life often have more complex connections. This limitation can be eliminated by the ANP (Analytic Network Process) method, which is a modification of the hierarchy analysis method. When using the ANP method, the decision problem is presented in

the form of a network of criteria and options grouped into clusters. All elements of the network can be interconnected in any direction, forming relationships within and between clusters. This allows for more accurate modeling of complex systems.

In some studies there are certain methodological nuances designed to more fully solve the problem of the study [11].

In the Ukrainian reality, there are cases when landfill sites are selected on the principle «where there was previously an unauthorized landfill», or first selected site, then checked for compliance with applicable regulations, or justify the design site of the landfill is not all criteria, as required [15]. In this regard, it is proposed to improve existing approaches to the location of landfills following the principles (see Fig. 2) and based on three stages (see Fig. 3). It should be noted that foreign experience shows that the environmental impact assessment is performed before the design of the landfill, so it is not dependent on the investor, and the risk of developing a faulty construction project disappears [24].

Fig. 2. Principles of improving approaches to determining the location of landfills

Fig. 3. Stages of site selection for landfills according to the authors

The existing experience in selecting sites for landfills needs to be improved by taking into account Ukrainian realities, the opinion of the surrounding landfill population, reducing the investment attractiveness of neighboring land plots, integration into the selection process of regional, district emerald network planning schemes cards. Since the optimal location of the landfill is determined not only by environmental but also economic criteria, the authors plan to develop a buffer criterion economically maximum allowable distance from the place of largest waste to the landfill, which will significantly reduce the size of the area for further analysis. The authors also consider it appropriate to take into account endangered and extinct villages when choosing a site, because it can provide the designer with additional areas that meet all the requirements.

Conclusions and prospects. The reform in the field of waste in Ukraine, which was initiated [1], requires the creation of a methodology for determining the location of landfills. You need to develop your system by improving, updating, simplifying and adapting existing experience. The authors propose three stages of site selection, following five principles, taking into account a number of factors, applying the buffer criterion and the area of disappearing villages. The lack of methods leads to unsystematic determination of the location of landfills, which in turn leads to disregard for the law, disregard for all criteria, time-consuming and ineffective decisions in the future in the implementation of regional waste management plans.

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АНАЛІЗ СУЧАСНИХ МЕТОДИЧНИХ ПІДХОДІВ ДО ВИЗНАЧЕННЯ МІСЦЬ РОЗТАШУВАННЯ ПОЛІГОНІВ ТВЕРДИХ ПОБУТОВИХ ВІДХОДІВ

Анотація. Необхідність запровадження ресурсозберігаючих технологій та природоохоронної політики як на міжнародному так і на регіональному рівнях, швидке зростання протягом останніх століть народонаселення Землі і пов'язані з цим процеси індустріалізації, урбанізації, інтенсифікації сільськогосподарського виробництва, збільшення потреби в енергетичних ресурсах і, відповідно, збільшення кількості відходів, що забруднюють навколишнє середовище ще більше ускладнює завдання обґрунтування місць розташування нових полігонів ТПВ та оцінці існуючих.

В Україні питання поводження з відходами регламентовано низкою законодавчих актів, планів, стратегій, рекомендацій, вони містять досить якісні критерії по яким оцінюють обране місце під полігон твердих побутових відходів, але в жодному із них немає чітких методичних рекомендацій щодо визначення місць для потенційного розміщення полігонів ТПВ, які б задовольняли всі згадані критерії.

Авторами розглянуто проблему відсутності методик по вибору місць для полігонів ТПВ України в умовах децентралізації та реформи у сфері відходів. Також проаналізовано досвід науковців Росії, США, Сербії, Єфії, Італії, Китаю та ін., з'ясовано їхні системи вибору місць під полігон, особливості, переваги та недоліки.

За таких обставин важливим науковим і практичним завданням постає вдосконалення методичних підходів до визначення місць розташування полігонів ТПВ і розроблення проектів землеустрою щодо відведення земельних ділянок під полігони ТПВ, адже наразі така методика відсутня. Водночас, розроблені зарубіжними вченими методики, потребують вдосконалення і навіть за умови їхнього застосування в Україні вимагають адаптації до місцевих, регіональних та інших умов.

Ключові слова. *Тверді побутові відходи, полігон, методичні підходи, поводження з відходами, навколишнє середовище, екологічна безпека, управління відходами, багатокритеріальний підхід, методи нечіткої логіки.*

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АНАЛИЗ СОВРЕМЕННЫХ МЕТОДИЧЕСКИХ ПОДХОДОВ К ОПРЕДЕЛЕНИЮ МЕСТ РАСПОЛОЖЕНИЯ ПОЛИГОНОВ ТВЕРДЫХ БЫТОВЫХ ОТХОДОВ

Аннотация. *Необходимость введения ресурсосберегающих технологий и природоохранной политики как на международном и региональном уровнях, быстрый рост в течение последних веков народонаселения Земли и связанные с этим процессы индустриализации, урбанизации, интенсификации сельскохозяйственного производства, увеличение потребности в энергетических ресурсах и, соответственно, увеличение количества отходов загрязняющих окружающую среду еще больше усложняет задачу обоснования мест расположения новых полигонов ТБО и оценке существующих.*

В Украине вопросы обращения с отходами регламентировано рядом законодательных актов, планов, стратегий, рекомендаций, они содержат достаточно качественные критерии по которым оценивают выбранное место под полигон твердых бытовых отходов, но в одном из них нет четких методических рекомендаций по определению мест для потенциального размещения полигонов ТБО, которые бы удовлетворяли все упомянутые критерии.

Авторами рассмотрена проблема отсутствия методик по выбору мест для полигонов ТБО Украины в условиях децентрализации и реформы в сфере отходов. Также проанализирован опыт ученых России, США, Сербии, Ефиопии, Италии, Китая и др., Установлено их системы выбора мест под полигон, особенности, преимущества и недостатки.

При таких обстоятельствах важной научной и практической задачей является совершенствование методических подходов к определению мест расположения полигонов ТБО и разработки проектов землеустройства по отводу земельных участков под полигоны ТБО, ведь сейчас такая методика отсутствует. В то же время, разработанные зарубежными учеными методики, нуждаются в совершенствовании и даже при условии их применения в Украине требуют адаптации к местным, региональным и другим условий.

Ключевые слова. *Твердые бытовые отходы, полигон, методические подходы, обращение с отходами, окружающая среда, экологическая безопасность, управление отходами, многокритериальный подход, методы нечеткой логики.*