SIGNIFICANCE OF MODERN METHODS FOR SELECTION OF SANITARY LANDFILL LOCATION IN THE PROCESS OF ENVIRONMENTAL PRESERVATION

Dr Jelena Đokić[1]; Bojana Živković[2]
[1]Faculty of Technical Sciences, Kosovska Mitrovica, Serbia, jelena.djokic@pr.ac.rs
[2] Faculty of Technical Sciences, Kosovska Mitrovica, Serbia, bojanaz1981@gmail.com

Abstract
In the complex process of waste management, one of the crucial problems is the correct choice of location for the construction of communal landfills. Many pollutants from landfills reach the environment and degrade it. Therefore, the location where the waste will be disposed of must meet the legal regulations and standards related to its protection. The desire to ensure safe waste disposal, with minimal impact on the environment, has contributed to the development of innovative methods for the analysis of suitable waste disposal sites. Modern landfill site selection methods, such as GIS, MCDA method, PROMETHEE, Heuristic approach, logical methods, MCDM fuzzy methods and others, as well as combinations of these methods, have raised the process of determining a suitable site from the bottom to the top of the priority list for environment preservation. The first part of the paper emphasizes the sources of pollution and pollutants from landfills, while the second describes the most commonly used methods for site selection and examples of their application.

Keywords: communal landfills, environment, modern methods, GIS, site selection

1. INTRODUCTION

The adoption of new legislation related to the treatment of municipal waste, with the aim of reducing its generation and disposal, in order to minimize its harmful impact on the environment, has intensified in the last decade. However, waste disposal at sanitary landfills is still the most common final solution. The purpose of the landfill was to protect the environment and in that respect it brought certain solutions, but it also opened other, new problems, such as the creation of gas, wastewater, noise, fire, etc. [1].

The leading problems related to the environment and sanitary landfills are leachate, fires and methane generation. Considering the consequences for the environment, maximum efforts are made and new, modern solutions are found, in order to avoid any negative impact. Stopping the degradation of the environment, improper disposal of municipal waste, is supported by laws and regulations on measures that must be followed when building landfills and determining the location. The rules refer to the distance of landfills from settlements, parks, sports fields, rivers, agricultural goods, etc. However, additional efforts are needed to protect the air, land, groundwater and surface water. Complex problems require great effort, work, commitment and introduction of innovations in the planning and design of sanitary landfills.

The generation of municipal waste dates back to the time of human creation. However, until the relatively recent past, it did not receive adequate attention. As environmental degradation caused by "environmental pollution" grew rapidly, people faced a neglected problem.

Waste management is a complex, responsible and necessary work, encompassing environmental, social, technological, legal, economic and cultural aspects. Pursuant to the Law on Waste Management, all activities are carried out in a way that provides the lowest risk to endangering the life and health of people and the environment, by control and applying measures to reduce:

- water, air and soil pollution;
- dangers to flora and fauna;
- dangers of accidents,
- explosions or fires;
- noise levels and unpleasant odors [2].

2. DEGRADATION OF THE ENVIRONMENT BY LANDFILLS

Even if they are relatively rare, landfill fires are extremely harmful because they emit various pollutants into the air, water and soil. Landfill fires differ in the place of origin, in the materials that caught fire, the cause of the occurrence, etc., but they are all, without exception, a challenge to bring under control and extinguish [3]. In relation to the place of origin, there are underground and surface fires. Underground fires last for several weeks or months, unlike surface fires, but both emit large amounts of pollutants and toxic substances into the air, which due to high temperatures turn into a gaseous phase [4].

Air pollutants emitted during municipal solid waste fires are following: nitrogen dioxide (NO2), nitrogen monoxide (NO), carbon monoxide (CO), carbon dioxide (CO 2), sulfur dioxide (SO2), ammonia (NH3), hydrochloric acid (HCl), hydrofluoric acid (HF), hydrocarbons (HC), particles, ash. Fly ash consists of organic and inorganic components, which migrate and pollute the environment at great distances from the fire site by air currents or leaching from the atmosphere. Cr, Ni, Pb are heavy metals that are often found in ash and are extremely harmful, while the organic compounds in the ash include dioxins, furans, polychlorinated phenols, polychlorinated benzenes, esters, polyaromatic hydrocarbons and other highly toxic compounds [4].

By penetrating into the interior of the soil or moving through channels and cracks on the surface, leachate migrates from the body of the landfill to surface and groundwater and pollutes them. In addition to water, the soil through which the filtrate passes is also contaminated. Biological and chemical derradations that take place in the body of the landfill lead to the formation of leachate, i.e. filtrate. The composition of the filling is difficult to predict due to the influence of many factors, such as: waste composition, moisture content, temperature, body thickness of the landfill, phase of waste decomposition, etc. However, it is certain that they contain many organic and inorganic pollutants as well as pathogenic microorganisms. Heavy metals are most often separated from inorganic compounds, while benzene, vinyl chloride, dichloromethane, tetrachlorethylene, carbon tetrachloride, toluene, 1,1,1-trichloroethane, xylene are the most common. Coliforms, Pseudomonas aeruginosa and Aeromonas hydrophila are most often isolated from pathogenic microorganisms from the composition of landfill leachate. When it comes to viruses, hepatitis A and Norwalk viruses are often observed, while Giardia lamblia and Cryptosporidium parvum are the most common parasites [5]. As a solution to this problem, in the design of modern sanitary landfills, it is proposed to use clay (natural substrate), then as a sealing substrate HDPE foil and as a final, protective layer, geosynthetic substrates [6].

Noise from communal landfills can have an extremely negative impact on people, depending on the health profile of the inhabitants of the surrounding settlements. Noise emitters from landfills are transport vehicles, excavators, waste compactors, etc. Hearing loss and organ damage occur when exposed to noise of 120-130 dB, while stress and nervousness occur when exposed to much lower intensity. In the EU, as many as 4% of the population has a permanent hearing problem, due to frequent exposure to noise [7]. According to the World Health Organization, the noise level in populated areas must not exceed 55dB, so the localization of communal landfills in their immediate vicinity is unacceptable [8]. As a product of microbiological decomposition of waste in landfills, intense unpleasant odors are created that significantly affect the quality of life of the local population. The intensity and frequency of unpleasant odors depend on a number of microclimatic factors [9].

3. MODERN METHODS FOR SELECTION OF SUITABLE LOCATION FOR LANDFILL

Human activities in the protection of the environment must be intensified in a positive direction, by repairing the damage caused by improper waste disposal and planning future activities. In the complex process of waste management, choosing a location for the construction of a municipal landfill is a burning issue. In order to avoid the negative impact of landfills on human health and the environment, using the development of science and modern technologies, a multitude of methods for landfill site selection have been developed.

Modern methods, developed because of improvements in Informatics and Computier Science, have an invaluable role in the entire waste management process. Through various software programs that can be used for analysis, calculations, simulations, etc., the speed and accuracy of work is increased. When choosing a site for a sanitary landfill, modern methods such as: GIS, MCDA methods, PROMETHEE, Heuristic approach, logical methods, MCDM obscure methods, etc., have an advantage over earlier methods based on mathematical calculations or manual techniques, such as technique coatings [10].

Geographic information systems, ie GIS, is a tool that allows you to select the best location and the ability to create maps of exceptional quality (Figure 1) [11]. With the improvement of GIS, the possibility of screening, zoning, correlation, data storage and graphical display of sites was achieved [12] [13]. GIS enables data management and combination with other methods [14]. The application of GIS tools, alone or in combination with appropriate methods of analysis, offers solutions to structural problems encountered in the process of finding a suitable site for a landfill [15]. In practice, it is most often combined with MCDA [16], which results in time savings and cost reduction [17]. GIS and MCDM methods in combined application define optimal areas, while for precise determination of landfill location are used: subjective weighting method, sum of titles (RS), mutual rank (RR) and order of ranks (ROC) methods [12].
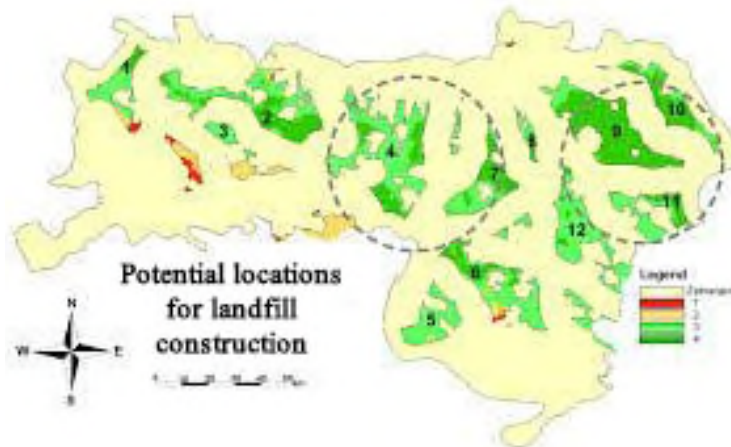
Figure 1: Map of potential sites for landfill construction, GIS view

The process of analytical hierarchy (AHP) is a method whose application provides a clear ranking of the final solutions for the landfill location [16]. Looking at the problem as an element or network of decision-making elements, enables the analytical network process (ANP), which is basically a generalized AHP [17]. Flexibility in the work of ANP and AHP, enables their application for all sites and declares them as extremely suitable for combination with other methods of analysis in the process of landfill site selection [18].

SAV (simple additive weighting) is often referred to in the literature as a "scoring method" and is used in the processing of spatial attributes [16]. The SAV format can be both raster and vector [14].

The fuzzy AHP method is applied to eliminate inaccuracies, while the integrated fuzzy VIKOR technique highlights priority in the event of conflicting decision-making criteria. The integrated obscure TOPSIS technique contributes to finding the optimal solution for the landfill site, while the integrated obscure ANP method is used to analyze the suitability of the site in an unclear environment. The heuristic approach is a two-phase method, where the first phase selects a significant area for the landfill, while the second specifies the location of the landfill, within the selected area. PROMETHEE is an extremely efficient technique that gives a final and complete ranking of selected locations, from the most desirable to the least desirable [16]. The Algorithm K method allows clustering, while methods such as MOORA, VASPAS and KORPAS are used to define locations based on priorities [17].

For precise standardization of the established criteria, the FUZZI LOGIC method is applied, while the Regulated Weighted Average (OVA) is a newer technique that achieves top results in site planning [14]. VLC (weighted linear combination) is a method used to select the right one from several offered alternatives [12]. FUZZI MADM method, unclear AHP method and Chang's FUZZI AHP method, are often combined, whereby FUZZI MADM in solving problems arising from obscure, subjective and imprecise information, unclear AHP for selection and ranking of obscure programs in simple while Chang's FUZZI AHP method is necessary in ranking alternatives [19].

Apart from the mentioned modern methods, the following are also significantly applied: weighted linear combination (VLC), unclear analytical hierarchical procedure (F-AHP), unclear analytical network process (F-ANP), TODIM, unclear TODIM, gray systems theory, etc. [20].

3.1. Criteria and evaluation

The basic criteria for determining the location for a sanitary landfill are grouped into three groups:
- social,
- environmentally friendly and
- technical-operative.

By applying GIS tools in the area where it is necessary to build a sanitary landfill, favorable and unfavorable location areas are singled out, and this is the basic step in the process of determining the most suitable location for the landfill. Elimination criteria in this case are legal regulations and terrain characteristics, such as slope, altitude, soil composition, etc. In this way, the number of localities is reduced to a smaller number of potentially suitable ones.

The number of restrictive criteria varies and is usually from 20 to 40 (Table 1). The next step is to form a value scale for the evaluation of criteria by experts. Quantitative grading from 1 to 5 or 10, is the grading format that has the greatest application. Obtaining the final values of the criteria, further, can be quite simple, by simply adding grades, or somewhat more complex where the criteria are classified into several groups and the most important criteria are favored from each group. The third option for evaluating criteria is to simply multiply all groups of criteria, without favoritism, by the same evaluation of significance. Depending on the importance of the quality value, the criteria are divided into three weight categories that have their own weight (specific value) which is multiplied by the evaluation of the corresponding criterion [21].

Table 1: Restrictive criteria

1.	Hydrogeology	11.	Underground waters
2.	Distance from the boundary zone of the water source	12.	Distance of surface waters
3.	Distance from the settlement	13.	Air temperature
4.	Location acceptability	14.	Precipitation
5.	Landscape characteristics	15.	Geological characteristics
6.	Distance from roads and railways	16.	Relief
7.	Distance from the natural good	17.	Land use
8.	Distance from cultural monuments	18.	Air flow
9.	Existing infrastructure	19.	Water supply
10.	Landscaping	20.	Seismicity

In the hierarchy-based AHP method, the Satie scale (Table 2) (named after the creator of the AHP method) is used to evaluate the problem. The Satie scale is used to classify elements from the same hierarchical level based on importance [22] [23].

Table 2: Saaty's scale of relative importance

DEFINITION	NUMERICAL VALUE
Same meaning	1
Weak dominance	3
Strong dominance	5
Very strong dominance	7
Absolute dominance	9
Intermediate values	2, 4, 6, 8

3.2. Examples of good practice

Choosing a site suitability analysis method is a complex process, depending on many factors. Goulart Coelho et al. emphasized the complexity of deciding on the selection of the appropriate multicriteria technique for the selection of the location of the communal landfill [24]. They analysed of 260 papers dealing with this topic, confirmed that the selection of tools is an extremely sensitive task, but that their application has raised the choice of location for the landfill from the bottom to the top of the priority scale.

In Morocco, in the Be ni Mellal-Khouribga region, using GIS, Boolean logic and the AHP method, results have been obtained which show that only 10% of the land designated as an alternative for the construction of a municipal landfill is highly suitable for this purpose [25]. For the Babylon Governorate in Iraq, 10 sites were identified in 5 districts that were responsible for building the landfill, using GIS, AHP and RSV methods [26]. Ouma et al. [27] presented the results of GIS analysis, multi-criteria analysis and overlay analysis, based on which they determined the optimal location for the municipal waste landfill in the city of Eldoret in Kenya. In the southwest of Colombia, a suitable location has been determined for the construction of a communal landfill, using AHP and TOPSIS techniques [28]. Elahi and Samadyar [29] have, by a combination of GIS and AHP methods, established suitable sites for a municipal landfill in the city of Tafresh in Iran. The complex analysis resulted in the selection of three appropriate locations and contributed to the city planning process. Us et al. [30] using GIS and multicriteria analysis, identified three potential municipal landfill sites for the city of Konya in Turkey.

CONCLUSION

The results of many years of environmental pollution tests have shown that landfills are at the very top of the list of pollutants. Pollutants such as nitrogen dioxide (NO_2), nitrogen monoxide (NO), carbon monoxide, carbon dioxide (CO_2), sulfur dioxide (SO_2), ammonia (NH_3), hydrochloric acid (HCl), hydrofluoric acid (HF), hydrocarbons, ash, heavy metals, benzene, vinyl chloride, dichloromethane, tetrachlorethylene, carbon tetrachloride, toluene, etc. arrive in nature, largely from "wild" landfills. Therefore, the disposal of municipal waste is a priority, which is based primarily on the correct choice of location for the construction of a municipal landfill, and then on the design and construction of landfills according to established standards. Human engagement and the development of science and technology have resulted in the emergence of many modern, precise and effective methods for selecting a suitable location for the construction of communal landfills. Modern methods for selecting the appropriate location for the landfill such as GIS, MCDA, PROMETHEE, Heuristic approach, logical methods, MCDM obscure methods, etc., as well as the possibility of combining them, represent a huge progress towards solving the problem of improper waste disposal and environmental pollution.

LITERATURE

1. Zamorano, M., Garrido, E., Moreno, B., Paolini, A., & Ramos, A. (1970). Environmental diagnosis methodology for municipal waste landfills as a tool for planning and decision-making process. *WIT Transactions on Ecology and the Environment*, *84*.
2. Zakon o upravljanju otpadom, (Sl. glasnik RS, br. 36/2009, 88/2010, 14/2016 i 95/2018).
3. Lendfill fires, Federal Emergency Management Agency United States Fire Administration National Fire Data Center, 2002.
4. Nikolaou, K. (2008). Environmental management and landfill fire accidents. *J. Environ. Prot. Ecol*, *9*(4), 830-834.
5. Preliminarna kvalitativna i kvantitativna analiza procednih voda i gasova sa deponija u cilju uspostavljanja kontinualnog monitoring, Fakultet tehničkih nauka, Novi Sad, 2009.
6. Karanac, M., Jovanović, M., Mihajlović, M., Dajić, A., Stevanović, D., & Jovanović, J. (2015). Landfill design in Serbia. *Recycling and Sustainable Development*, *8*(1), 27-37.
7. Belić, Č., Biočanin, I., & Papić, H. (2009). Buka kao fizički zagađivač i poremećaj radne i životne sredine. *Ecological Safety in post-modern environment*, *26*, 27.
8. Geotehničko istraživanje i glavni projekat proširenja tela deponije – regionalna deponija Duboko, Procena uticaja na životnu sredinu i društvo, Srbija, 2016.
9. Šobot-Pešić, Ž., & all, (2016). Analiza percepcije neprijatnih mirisa sa banjalučke deponije, Conference of chemists, technologists and environmentalists of the Republic of Srpka.
10. Mokhtarian, M. N., Sadi-Nezhad, S., & Makui, A. (2014). A new flexible and reliable interval valued fuzzy VIKOR method based on uncertainty risk reduction in decision making process: An application for determining a suitable location for digging some pits for municipal wet waste landfill. *Computers & Industrial Engineering*, *78*, 213-233.
11. Ajibade, F. O., Olajire, O. O., Ajibade, T. F., Nwogwu, N. A., Lasisi, K. H., Alo, A. B., ... & Adewumi, J. R. (2019). Combining multicriteria decision analysis with GIS for suitably siting landfills in a Nigerian state. *Environmental and Sustainability Indicators*, *3*, 100010.
12. Dereli, M. A., & Tercan, E. (2021). Comparison of GIS-based surrogate weighting methods for multi-directional landfill site selection in West Mediterranean Planning Region in Turkey. *Environment, Development and Sustainability*, *23*(3), 3438-3457.
13. Wani, S. A. S. M. A. (2014). Geospatial based approach for enhancing environment sustainability of Srinagar city-a study on solid waste disposal. *International Journal of u-and e-Service, Science and Technology*, *7*(3), 289-302.
14. Mohammed, H. I., Majid, Z., Yusof, N. B., & Yamusa, Y. B. (2017). GIS-based and Multi-Criteria Evaluation Method for optimised landfill site selection: A review. In *Global Civil Engineering Conference*.
15. Demesouka, O. E., Vavatsikos, A. P., & Anagnostopoulos, K. P. (2014). GIS-based multicriteria municipal solid waste landfill suitability analysis: A review of the methodologies performed and criteria implemented. *Waste Management & Research*, *32*(4), 270-296.
16. Mat, N. A., Benjamin, A. M., & Abdul-Rahman, S. (2017). A review on criteria and decision-making techniques in solving landfill site selection problems. *Journal of Advanced Review on Scientific Research*, *37*(1), 14-32.
17. Eghtesadifard, M., Afkhami, P., & Bazyar, A. (2020). An integrated approach to the selection of municipal solid waste landfills through GIS, K-Means and multi-criteria decision analysis. *Environmental research*, *185*, 109348.
18. Afzali, A., Sabri, S., Rashid, M., Samani, J. M. V., & Ludin, A. N. M. (2014). Inter-municipal landfill site selection using analytic network process. *Water resources management*, *28*(8), 2179-2194.
19. Nazari, A., Salarirad, M. M., & Bazzazi, A. A. (2012). Landfill site selection by decision-making tools based on fuzzy multi-attribute decision-making method. *Environmental Earth Sciences*, *65*(6), 1631-1642.
20. Rezaeisabzevar, Y., Bazargan, A., & Zohourian, B. (2020). Landfill site selection using multi criteria decision making: focus on influential factors for comparing locations. *Journal of Environmental Sciences*.
21. Josimović, B., Marić, I., & Manić, B. (2011). Methodological approach to the determination of landfill location for municipal solid waste: Case study: Regional landfill in Kolubara region. *Arhitektura i urbanizam*, (32), 55-64.
22. Srđević, B., & Srđević, Z. (2004). Standard and multiplicative AHP. *Letopis naučnih radova Poljoprivrednog fakulteta*, *28*(1), 5-15.
23. Lakićević, M., Srđević, B., Ninić-Todorović, J., & Bajić, L. (2017). Primena AHP metoda u višekriterijumskom vrednovanju parkova Novog Sada/Multi-criteria evaluation of parks in Novi Sad by AHP method. *Letopis naučnih radova Poljoprivrednog fakulteta*.
24. Goulart Coelho, L. M., Lange, L. C., & Coelho, H. M. (2017). Multi-criteria decision making to support waste management: A critical review of current practices and methods. *Waste Management & Research*, *35*(1), 3-28.
25. Barakat, A., Hilali, A., El Baghdadi, M., & Touhami, F. (2017). Landfill site selection with GIS-based multi-criteria evaluation technique. A case study in Béni Mellal-Khouribga Region, Morocco. *Environmental earth sciences*, *76*(12), 1-13.
26. Chabuk, A., Al-Ansari, N., Hussain, H. M., Laue, J., Hazim, A., Knutsson, S., & Pusch, R. (2019). Landfill sites selection using MCDM and comparing method of change detection for Babylon Governorate, Iraq. *Environmental Science and Pollution Research*, *26*(35), 35325-35339.

27. Ouma, Y. O., Kipkorir, E. C., & Tateishi, R. (2011). MCDA-GIS integrated approach for optimized landfill site selection for growing urban regions: an application of neighborhood-proximity analysis. *Annals of GIS*, *17*(1), 43-62.
28. Manyoma-Velásquez, P. C., Vidal-Holguín, C. J., & Torres-Lozada, P. (2020). Methodology for locating regional landfills using multi-criteria decision analysis techniques. *Cogent Engineering*, *7*(1), 1776451.
29. Elahi, A., & Samadyar, H. (2014). Municipal solid waste landfill site selection using analytic hierarchy process method for Tafresh Town. *Middle-East Journal of Scientific Research*, *22*(9), 1294-1307.
30. Nas, B., Cay, T., Iscan, F., & Berktay, A. (2010). Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental monitoring and assessment*, *160*(1), 491-500.

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