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Monitoring of the Environmental Condition of the Solid Waste Landfill Using GIS

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Abstract—The purpose of the article is to study the means that allow for environmental monitoring monitoring of the environmental condition of solid household waste landfills. The results of the research will have a great impact on the sustainable development of cities, which is inextricably linked with ecology. The authors suggested monitoring with the help of geoinformation technologies based on the software product from the company ESRI - ArcGIS. The study of the specialized geo-information system was carried out on the example of the Dergachy landfill of solid household waste in the city of Kharkiv, Ukraine. Authors proposed the structure of the geodatabase of the monitoring system and performed an analysis of the sanitary protection zones of the Dergachyv solid waste landfill using a vectorized map with attributive data. A typical algorithm for designing a similar monitoring system has also been developed. Authors show ways of using geoinformation systems in the field of environmental monitoring. This made it possible to significantly influence the improvement of the situation with environmental safety. Authors have developed an algorithm for designing a specialized GIS for monitoring. It was concluded that the use of geoinformation systems is promising at the current stage of development of digital cities.

Keywords—geographic information system, geodatabase, landfill, solid household waste, normalization, monitoring

I. PROBLEM STATEMENT

One of the problems of the modern city is the disposal of solid household waste (waste from the economic activities of the population - cleaning, cooking, large-sized household items, waste from the current repair of apartments, packaging, garbage from yard areas, squares, streets, waste from care for green spaces). As the population increases, the economy develops and the standard of living increases, the amount of production and consumption waste increases. The removal of solid household waste ensures sanitary cleaning of cities and creates the necessary sanitary and ecological conditions for the existence of a settlement. Solid waste (solid household waste) landfills are specialized enterprises designed for disposal and disposal of waste. Solid waste provides protection against contamination of the soil and atmosphere, prevents the spread of insects, pathogenic microorganisms, and rodents. Solid waste landfills are widely used all over the world. To minimize all the negative effects of solid waste landfills, it is necessary to carry out environmental protection measures. In addition to the fact that landfills are located outside cities and settlements, they must be constantly monitored for pollution of wastewater, air, radiation background and many other indicators.

In Ukraine, there are officially 5,455 landfills and landfills with a total area of more than 8.5 thousand hectares. Such data is provided by the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine [1].

There are unauthorized landfills, or as they are also called natural landfills. Their number is much greater than in official channels. They pose an even greater danger to the environment, compared to solid waste landfills, because their location is not only not monitored, but also not registered.

Many official landfills have already exhausted their capacity and are in a dormant state. Some of them already have permission to move to the stage of reconstruction for reclamation or construction of processing plants. With the support of the Ministry of Environmental Protection and Natural Resources of Ukraine, an electronic interactive map was created, with the help of which you can roughly track the accumulation of waste in certain cities of Ukraine. This database is not accurate, because all the information on the site is based on requests and messages from residents registered on this portal. Therefore, some cities are not marked as the necessary data are missing.

Thus, it is necessary that solid waste landfills are under close supervision. Therefore, to systematize the impact on the environment and to be able to control the current state of landfills more effectively and accurately, it is necessary to pay attention to the capabilities of geographic information systems (GIS). The situation with waste disposal in Ukraine is not encouraging. Many territories are under various layers of garbage, and it does not matter whether they are natural landfills or specially reserved for this area. The longer the territories remain in a polluted state, the less suitable and devalued they become for agricultural and industrial purposes. This is a consequence of the lack of a sufficient level of control and monitoring at various stages of operation of solid waste landfills.

II. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Specialists who study solid waste landfills and their impact on the environment identify several reasons. But the main problem is the lack of waste sorting, especially at the stage of transportation and storage at the landfill. For example, in Germany, the situation related to garbage has stabilized since the authorities began to pay attention to the sorting of garbage and take the necessary actions to monitor the environmental burden caused by such landfills. Such great achievements were made only through certain controls and compliance with certain requirements. That is, the modern method of monitoring and control can affect the unsatisfactory state of the waste disposal situation and stabilize it to a certain extent [2].

One solution to this problem is the integration of municipal district map layers with GIS. Drainage lines, drinking water lines, street names, house numbers can be added as feature attributes to make it a specialized GIS for environmental management. The use of Geo Eye data from the Google Earth or Cartosat website will allow monitoring updates of changes in land use and determining the current state of the environment for monitoring, including the ecological state of solid waste landfills [3].

The analysis of recent studies shows that there are trends towards the intellectualization of monitoring systems. Thus, collecting information about the urban environment in real time is very promising. The monitoring information system will be designed to collect and send data through the terminal

in the form of a message. Such a system can be used in the concept of smart city infrastructure using a wireless network [4, 5].

Many scientists dealing with this issue focus on maintaining databases, organizing logistics, and creating a consolidated report (digital passport) of the researched object. It is proposed to use the following methodological approaches: expert knowledge processing, web server user access and microservice structure of access to geoinformation resources [6].

Some studies suggest the use of unmanned aerial vehicles in the management of landfills and landfills. The modern level of technologies for the collection and processing of data from remote sensing of the earth makes it possible to identify and evaluate many factors of the impact of landfills and landfills on the environment and to monitor compliance with the norms of the operation of landfills, which can bring the management of these objects to a higher level [7, 8].

Researchers are offered to develop a specialized spatial decision support system and use ArcGIS software for these purposes. The analytical hierarchy process is proposed to be used to rank the criteria. The use of ArcGIS Online maps will allow decision-makers to check online laws, effective criteria, and results of spatial analysis to make an optimal decision [9 – 11].

III. Outline of the Basic Material

Our goal is to create a geo-information system for systematic monitoring of special-purpose objects, namely, a solid waste landfill.

A solid waste landfill or an uncontrolled landfill, especially at the stage of their reclamation, is the center of many chemical reactions whose impact on the environment needs to be monitored. This will make it possible to detect possible exceedances and avoid problems that may arise because of waste decomposition and the formation of harmful gases.

A. Development of a geodatabase for a geoinformation monitoring system

To build a full-fledged specialized geoinformation system designed for monitoring such an object, a certain number of technical problems must be solved. The main one is the development of a geodatabase.

To build a database, it is necessary to collect and analyze enough information about special purpose objects to have certain data for further action. The obtained data are compiled and collected with the help of special programs to be able to analyze and visualize them later. For these purposes, a geodatabase is used, which defines a generalized data model for geographic information. This model can be used to create various problem-oriented data models aimed at solving specific user tasks. A geodatabase (GDB) uses a data model based on topological connection classes of spatial objects.

Data is the main factor in GIS, based on which information products are created. In the planning process, at the stage of conceptual development of the system, it is necessary to perform an analysis of the subject area, determine the purpose of creation and requirements for the database, the main objects and the connections between them, the information needs of the user (analysis of requests), and clarify the sequence of actions of future users when working with the database and tasks to be solved. Based on the received information, a database scheme is developed.

Thus, we will define the following classes of BHD objects, considering the input data:

- Dotted (trees);
- Linear (borders of land plots, hydrography, roads, power lines);
- Polygonal (houses, sanitary zones).

The schema of the created database will represent a set of tables connected to each other using one-to-many relationship fields. The authors believe that the database should be normalized to the fourth normal form. That is, the data must be organized in the database in such a way that all tables are interconnected in accordance with the rules that ensure data protection. This makes the database more flexible, eliminating redundancy and inconsistent dependencies [12]. Excess data leads to unproductive use of free space on the hard disk and complicates database maintenance. Figure 1 shows the scheme of the geodatabase of the project.

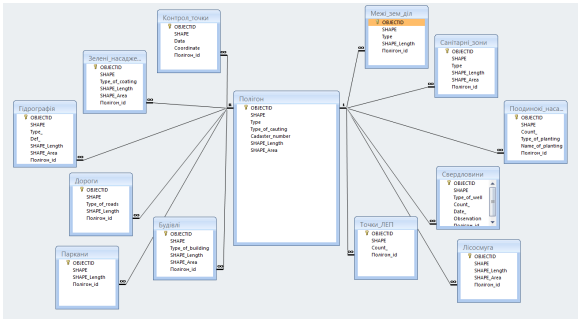

Fig. 1. Database schema view

The filling of the database and the formation of the object model should take place in parallel.

B. Rationale for hardware and software selection

When choosing a specific software product (PP) that supports GIS technologies, it is necessary to consider:

- PP must have effective means of creating and maintaining a modern user interface;
- PP must support powerful programming tools, which will allow creating software solutions to solve specific problems that arise when managing the object;
- PP must have means of implementing a new or expanding the existing model of the subject area;
- PP must provide multi-user mode.

Software in the field of geographic information systems is a set of various tools and functions that are necessary for the collection, storage, and visualization of geographic data. Such programs include database management systems, tools for organizing and managing various types of geographic data, tools for vectorization and visualization of spatial data, etc. In the world market, high positions are occupied by commercial companies that are producers of similar

programs that allow for the development of GIS and their operation. For example, the Autodesk company, which is the developer of such well-known products as AutoCAD Map 3D, or the Smallworld company, which created a fully instrumental geographic information system Smallworld GIS. You should pay attention to packages from companies ESRI and Intergraph, which are used by many organizations and have proven themselves as reliable tools.

Thus, if you compare these GIS products, you can find your pros and cons. But still, software from ESRI is more common, with more features and more reliable. The ArcGIS software product differs from its competitors in ease of use and a varied set of tools that can be easily supported on weak computers.

C. Visualization of main objects

After choosing the software, it is necessary to create vector layers of the necessary objects for the further addition of attributive information, its constant updating and visualization. Suggestions for solving this issue:

- Use a picture of the desired area taken with the help of satellite aerial photography.
- Use a map shot on the largest possible scale so that details are not lost. For these purposes, you can use Google Maps or SASPlanet.
- Use the AddBasemap function, which allows you to connect maps in the ArcMap program itself. This allows you to connect to the selected online geographic map service.

Vectorization of the raster map is performed according to previously created layers (Fig. 2.).

On the vectorized objects of the map, attribute information can be fixed, changed over time, and such a map can be used, for example, to build sanitary zones, and to find out whether the rules for the location of a landfill with solid waste (Fig.3).

Also, with the help of a vectorized map, it is possible to automate the calculation of areas of sanitary zones.

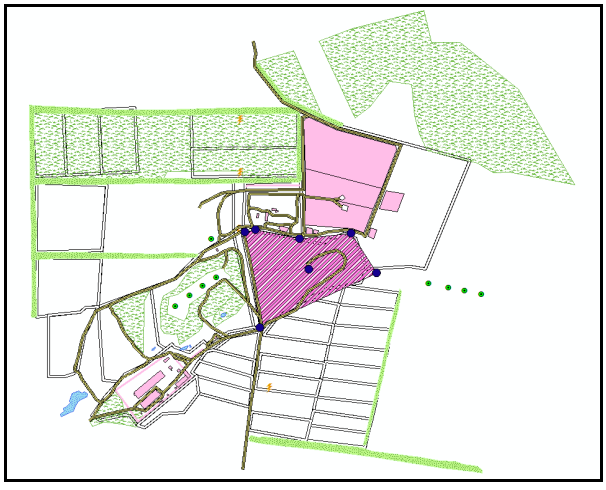

Fig. 2. Vectorized territory of the Dergachyv solid waste landfill (Kharkiv, Ukraine)

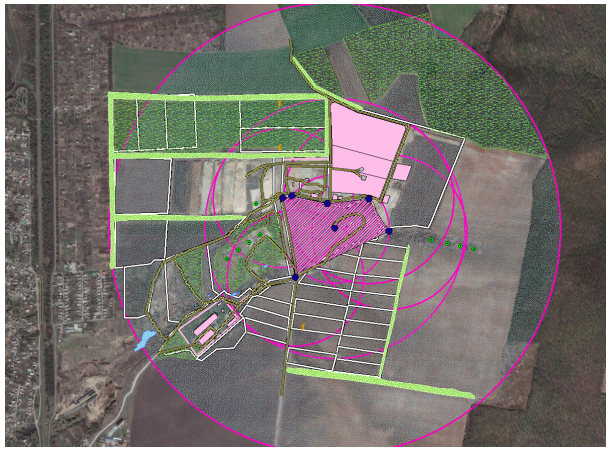

Fig. 3. Sanitation and protection zones were built to economic buildings and the nearest settlements on the territory of the Dergachyv solid waste landfill

It should be noted that this is far from the only thing that can be done thanks to the geodatabase and. Its possibilities depend on the quantity and quality of available information, which can be used by specialists in this field.

D. Development of the main constituent components of the geoinformation monitoring system

Means of obtaining input data for a geodatabase

To begin with, you need to understand who the target consumer of the ecological geoinformation system is. It is assumed that issues related to environmental monitoring will be dealt with by the organization responsible for transporting garbage to the landfill. Most often these are utility companies. They are the owners of solid waste landfills.

The first type of data that must be stored in the database is initial data (basic size and number of objects, years of construction, their location, etc.). In the archive of the company there are various construction plans and schemes that were created before the construction of the landfill itself.

The second type of data is related to the results of various environmental measurements. They can be in the same archives, or they can be supplied by the Departments of Ecology and Natural Resources, through a contract, regarding the possibility of obtaining the necessary results of measurements that are not in free public access, for the purposes of GIS monitoring. One part of landfill environmental monitoring data – leachate measurements, the state of groundwater, can be taken from the indicators of wells that are in certain places, at a certain depth and at a certain distance from the solid waste landfill. For all other indicators of the state of the environment, namely water, air, and land, most likely, it will be necessary to seek the paid services of specialists dealing with similar issues, if the organization itself is not able to carry out all these operations on its own. The approximate frequency of environmental measurements will be equal to the approximate frequency of monitoring itself, namely approximately twice a month. Also, one should consider various electronic resources that can facilitate the search for information. It is necessary to be careful, according to the sources from which the data will be borrowed, as this will affect the correct operation of the geographic information system. It is recommended to use verified databases that are freely available. That is, when using GIS for the purpose of monitoring the state of the

landfill, it is important to operate with verified data – this will allow the implementation of projects, the reliability of which cannot be doubted.

Modeling of possible user actions during the operation of the geoinformation monitoring system

The developed geoinformation system will be related to environmental ones. The very essence of environmental monitoring is to provide an opportunity for society and the environment to interact, and for people to understand the state of nature. The main legal documents on which this GIS will be based are the Law of Ukraine «On Protection of the Natural Environment», «On the Organization of the Interdepartmental Commission on Environmental Monitoring» and «On Approval of Standard Rules for Continuous Monitoring of Pollutant Emissions into the Atmosphere enterprises».

The modern structure of environmental types of monitoring includes four functioning blocks:

- information and measurement subsystem at environmental control posts;
- mobile posts of environmental control means (mini laboratories on wheels, and ordinary separate measuring devices);
- a communications subsystem that will allow communication with control posts;
- the geoinformation system itself with a full set of graphic and thematic geodatabases of environmental orientation, various modeling systems, the possibility of restoring and editing environmental and meteorological factors;
- a subsystem of information support for management decision-making.

The system for monitoring the environmental condition of solid waste landfills will be aimed at monitoring three main environmental indicators on the territory of the landfill and its surroundings, namely:

- land;
- air;
- water.

The concept of neighborhoods refers to areas that are in sanitary and protective zones.

Specialists should monitor the spread of harmful substances that occur during various chemical reactions in the middle of the landfill layer, which cause poisoning of the perimeter of the soil and groundwater. Thanks to data measurements, which will be taken from wells buried at different distances with a certain periodicity, engineers will be able to monitor the stage of chemical pollution in a certain area and make decisions about further actions. For example, if the level of the permissible norm is exceeded and there is even a small risk of biological danger near populated areas, it is necessary to urgently prepare reports that will describe the danger itself and recommendations for the evacuation of people who are closest to the red zone. As for the air, here it is necessary to analyze the direction of winds specifically from the MSW landfill itself on the map. The main task will be to observe possible changes in the state of the air in different parts of the landfill. And to determine how winds affect the spread of harmful gases (how far the spread is, what types of chemical elements are included). It is necessary to pay a lot of attention to individual chemical reactions in the landfill itself, first, to monitor the accumulation of leachate. Not only the ecological, but also the fire safety of the facility will depend on how diligently its quantity and frequency of formation will be controlled, since a large leachate concentration causes spontaneous combustion of garbage, and such fires are extinguished in an average of 5 – 8 hours.

Similar tasks should be solved by a specialized unit in the GIS system, namely, a unit for modeling the distribution of pollutant concentration fields based on general performance indicators of industrial facilities or other sources of pollution and the degree of their impact on the environment.

Based on the statement of the problem, the basic algorithm for designing a specialized GIS for monitoring was developed. The algorithm is presented in Figure 4.

Using a geodatabase will allow you to perform data management – edit and add new records. Monitoring data of a certain territory is collected in the system database. It is possible to add new data to the database and update, if necessary, old records.

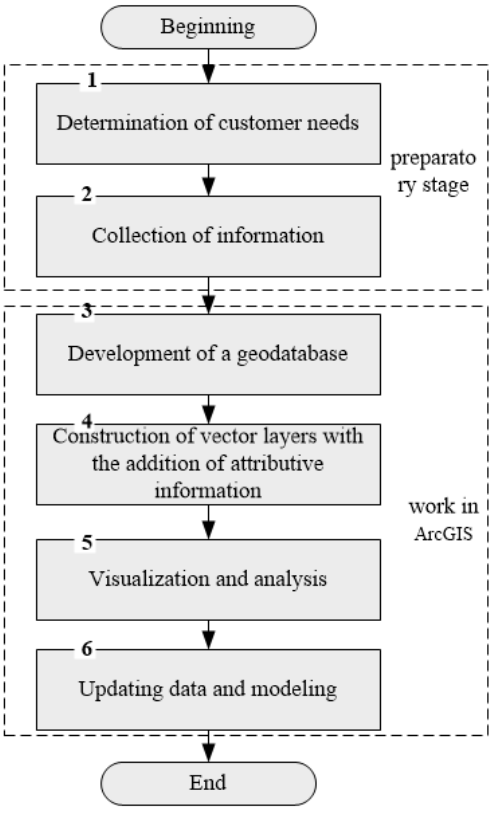

Fig. 4. GIS design algorithm for monitoring

The monitoring GIS database developed in the article should store:

- physical properties of pollution sources; maximum permissible-emissions of harmful substances;
- digitized terrain maps and base maps;

- the results of data processing using system procedures.

IV. CONCLUSIONS

1) Authors of the article analyzed how convenient, appropriate, and relevant the use of GIS can be for the purposes of monitoring the environmental condition of landfills with solid waste.

2) The authors solved the task of developing the structure of the geodatabase and vectorized the territory of the Dergachyv landfill in the city of Kharkiv, which makes it possible to investigate and solve complex technical tasks.

3) Authors proposed an algorithm for designing a specialized GIS for monitoring

4) Authors proposed the main structural components of a similar GIS monitoring system. Thus, the role of digital space in cities in solving and forecasting tasks of urban economy is growing.

Thus, it is possible to determine ways of using the geoinformation system in the field of environmental monitoring. Such a GIS will significantly improve the situation with environmental safety.

REFERENCES

[1] Saijt «Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine», www.minregion.gov.ua, last accessed 23/08/2022.

[2] Saijt «Abfallrecht in Deutschland | BMU», https://www.bmu.de/themen/wasser-abfall- boden/abfallwirtschaft /abfallrecht/national/, last accessed 23/08/2022.

[3] Zagoranski, F., Pernar, R., Seletković, A., Ančić, M., & Kolić, J., «Monitoring the health status of trees in maksimir forest park using remote sensing methods». South-East European Forestry, vol. 9 (1), pp. 81-87. doi:10.15177/seefor.18-08. (2018).

[4] Reddy, K. R. S., Satwika, C., Jaffino, G., & Singh, M. K., «Monitoring of infrastructure and development for smart cities supported by IoT method». doi:10.1007/978-981-19-0108-9_3. (2022).

[5] Oubrahim, Y., Lbazri, S., Ounacer, S., Rachik, A., Moulouki, R., & Azzouazi, M., «A new architecture for monitoring land use and land cover change based on remote sensing and GIS» A data mining approach. Periodicals of Engineering and Natural Sciences, vol. 6 (2), pp. 406-414. doi:10.21533/pen.v6i2.534. (2018).

[6] Sliusar, N., Filkin, T., Huber-Humer, M., & Ritzkowski, M., «Drone technology in municipal solid waste management and landfilling: A comprehensive review». Waste Management, vol. 139, pp. 1 - 16. doi:10.1016/j.wasman.2021.12.006. (2022).

[7] Izmailov, A. Y., Dorokhov, A. S., Briukhanov, A. Y., Popov, V. D., Shalavina, E. V., Okhtilev, M. Y., & Koromyslichenko, V. N., «Digital system for monitoring and management of livestock organic waste» doi:10.1007/978-3-030-97057-4_3. (2022).

[8] Kobzan, S., Pomortseva, O., «Monitoring of forest management. Problems of using satellite images for analysis», VI International Scientific and Practical Conference «SCIENTIFIC COMMUNITY: INTERDISCIPLINARY RESEARCH», pp. 816 – 825. Hamburg, Germany (2022).

[9] Amirsoleymani, Y., Abessi, O., & Ghajari, Y. E., «A spatial decision support system for municipal solid waste landfill sites (case study: The Mazandaran province, Iran)». Waste Management and Research, vol. 40 (7), pp. 940-952. doi:10.1177/0734242X211060610. (2022).

[10] Kutsenko, M., «Application of the project approach in the framework of the territory development strategy». IEEE 16th International Conference on Computer Sciences and Information Technologies (CSIT) , pp. 375 – 378, doi: 10.1109/CSIT52700.2021.9648772. (2021).

[11] Ćurić, V., Durlević, U., Ristić, N., Novković, I., & Čegar, N., «GIS application in analysis of threat of forest fires and landslides in the svrljiški timok basin (Serbia). Bulletin of the Serbian Geographical Society, vol. 102 (1), pp. 107-130. doi:10.2298/GSGD2201107C. (2022).

[12] Pomortseva, O., Kobzan, S., Yevdokimov, A., Kukhar, M., «Use of geoinformation systems in environmental monitoring». E3S Web of Conferences, vol. 90, article no. 01002. 6 p. doi: 10.1016/j.compenvurbsys.2021.101713. (2020).