UDC 528.71

V. LOZYNSKYI[1], I. KOLB[2], T. ILKIV[2]

[1] Department of Cartography and Geospatial Modeling, Lviv Polytechnic National University, 12, S. Bandera str., Lviv, 79013, Ukraine, tel.: 098-71-31-398, e-mail: viktor.lozynskyi@gmail.com
[2] Department of Photogrammetry and Geoinformatics, Lviv Polytechnic National University, 12, S. Bandera str., Lviv, 79013, Ukraine

RETROSPECTIVE-GEOGRAPHICAL ANALYSIS OF LVIV CITY LANDFILL

https://doi.org/10.23939/istcgcap2017.02.045

Aim. An annual increase in the amount of wasteburied at the solid waste landfill has forced the necessity to control activity of such communal and private enterprises and carry out both ecological and engineering performance monitoring. The parameters controlled by engineering monitoring include geometric size of land parcels, size and dynamics of the waste body, control for spreading of sewage disposal, and other numerical parameters which can be obtained by geodesic methods and by means of remote measuring. To define particularities of performance of solid waste landfills in the past, it is important to use data from archive paper maps and materials from aerial surveys. These materials can be used to solve some scientific and practical tasks, and thus, there is a need to design a correct presentation of archive data in geoinformational systems and develop technologies to acquire geodata from archive maps and images by means of modern instruments. The main aim of the work is to determine space-time peculiarities of the performance of the Lviv city landfill for the last 60 years. **Methodology and results of the work.** According to the set goal, the authors of this article collected and analyzed archive cartographic materials, designed from 1950 to 2006 in the territory of Lviv city landfill. Using topographic maps of 1972, 1985, 1991, drawn at the scales of 1: 10 000 and 1: 25 000. The research determines the area of the land of waste storage for the corresponding period and defines space-time peculiarities of the landfill performance. The work studies archive aerial images of 1988, making a base for the development of a digital terrain model for the determination of the quantitative parameters of the Lviv city landfill, in particular its area and capacity. Basing on the topographic plan of 2006, the work developed a digital terrain model. **Scientific novelty and practical value.** In Ukraine, retrospective-geographic analysis of the Lviv city landfill in the period from 1950-2006, was first made from the base of archive materials. Results of the analysis supply a possibility to define tendencies of changes of space-time particularities of its performance, which include the design of digital terrain models and determination of geometric parameters of the solid waste landfill. The obtained results of geoinformational modelling presented in the work can serve for specialists in the field of waste handling (specialists of housing and utilities infrastructure, ecological inspection, and scientific-research organizations) to control the keeping to the rules of solid waste landfill misuse.

Key words: solid waste landfill, archive maps and plans, archive materials of aerial survey, digital terrain model, comparison of topographic surfaces.

Introduction

Every year the rates of solid waste production increase. In Ukraine, their burying is often made at (un)authorized dumping grounds, which can cause technogenic disasters of local character. To control the burying of solid waste, it is necessary to determine the complete tendency of the solid waste landfill performance, starting from the stage of planning and up to its restoration. Nowadays, application of modern geoinformational technologies provide great opportunities for processing, storage, modelling, and analysis of various cartographic materials and data of distant probing. Their advantage is that they can integrate space-time data of different sources into a single coordinate system.

In Ukraine, retrospective-geographic researchis getting more popular. Particularly, Sossa R. I., in the manual "History of cartography of Ukraine's territory", presents main cartographic works, depicting Ukrainian lands considering the peculiarities of general geographic and branch mapping [Sossa, 2007]. Hulyk S. V., having compared sketch maps of different years, (1780, 1855, 1925), designed sketch maps of landscapes in the western Podillia during different periods, calculated areas, and demonstrated their reduction in the mentioned period [Hulyk, 2004]. Anthropogenic transformation of nature in the reserve land "Medobory" and adjacent area during the two time periods in the 1920s and 1980s is presented in the work [Volik, 2008]. The research makes calculations and comparison of the area of separate forest lands, agricultural lands, and built-up landson the base of different time maps of the same scale and proves the reduction of forest area in the region. Retrospective-geographic analysis of building works within Volyn region for Myshiv village during the 20th century were made by Nychai O. O. Drawing a digital vector model of the building dynamics, the authors of the article have studied topographic maps of different time periods (1910, 1933, 1975–1988) and space images (2014), making a base for the determination of the area differences and a depiction of the settled landscape [Nychaya, 2015].

Application of archive cartographic materials (topographic maps, aerial survey, space images, topographic plans, descriptive information about an object) can be useful for: creation of historic digital models of a location of the group of defense constructions "Tsytadel" in Lviv [Chetverikov, 2014], determination of places of mass-casualty burials in the period of the Second World War [Chetverikov, 2015], and studying dynamic processes at applied mining sites [Hryts'kiv, 2014]. The data about area and its extent can also be obtained by methods of remote probing of the Earth (RPE) and contact methods [Lozynskyi, 2015].

Traditional ***aerial survey*** is an efficient way to carry out different topographic-geodesic and cartographic work, and for implementation of a set of tasks. One of the first works using data of aerial survey for solid waste landfills is the work by Garofalo D. It proposed to use the methodology, which is based on visual analysis of territories and can supply the data about boundaries and amount of waste, as well as morphological characteristics. The information is stored in the database and can be used to increase the capacity of solid waste burial at landfills and dumping grounds [Garofalo and Wobber, 1974]. The USA Agency for Environmental Protection confirms that implementation of topographic surveys and aerial photography supplies one of the methods for determination of location, area, and historic changes for objects of dangerous waste. Particularly, aerial images were used for environmental purposes even at the beginning of the 20th century [Brilis, 2000]. Analysis of historic aerial images, supplied by the National Archive of the USA, taken in 1938, 1958, 1968 and 1978 of a solid waste landfill in the USA, were made in stereo mode at the scale of 1: 20 000, under the supervision [Erb, 1981]. However, the authors have not defined some important parameters of the landfill, such as its boundaries and extent.

Data of aerial survey are used for determination of various legal relations [Lath, 1974, Slonecker, 2007]. From 1918 to 1927, data of aerial survey supplied the possibility to obtain information about storage, testing, and utilization of dangerous waste. The information is presented in the work [Slonecker, 2011].

Combination of the data of aerial survey (1950, 1958 and 1964) and multispectral Landsat images provided the possibility to develop the methodology of determination and mapping of unauthorized dumping grounds in historical view. Findings of such research depict morphological changes of the landscape and territories that are adjacent to the dangerous waste landfill [Slonecker, 2010].

Digital terrain models (DTM) is another sphere of application of RPE, which can be used for forecastingsurface water runoff, measuringwater volume (which can accumulate in special places and in the landfill surface), as well as the calculation of the amounts of solid household waste (SHW) [Vincent, 1994].

Technology development has made aerial surveyunsustainable for creating small-scale maps and was substituted with space photography. The research done in Kwerteng in 2004 was one of the first works depicting application of the data of space images for monitoring of the Al-Qurain landfill in Kuwait [Kwarteng, 2004]. Using images of Landsat Multispectral Scanner, Landsat thematic Mapper, IKONOS, and synthetic aperture radar (SAR), the authors defined the dynamics of change of the solid waste landfill parameters during the period from 1972–2000.

Similar methodology was used by Turkish scientists Seker D and Kaya for monitoring a solid waste landfill in Istanbul agglomeration. Basing on the satellite images IRS 1C PAN (space resolving power 5 × 5 m, 2000) and IKONOS MS (space resolving power 4 × 4 m, 2004), it was possible to determine changes of the area and extent of the solid waste landfill in the period from 2000 to 2004. The researchers developed a digital terrain model, enabling analysis of the tendency of the landfill development. The analysis confirmed space-time changes of the solid waste landfill [Seker, 2011].

Basing on the stereo images of different times, Chinese scientists [Qingsheng, 2010], analyzed dynamics of change in the area of a landfill in Jiaozhou, China. Findings of the research demonstrated that the area of the landfill increased every year. It is proven that application of the methodology, which is based on the use of satellite images CBERS, is useful for operative monitoring of a dynamic change of the solid waste landfill.

One should note that most of the works demonstrate the tendency for solid waste landfills and unauthorized dumping grounds to increase in area and extent. However, an opposite tendency is observed in the research of Kazakh scientists, which used satellite images, obtained from the service SAS PLANET, to determine boundaries of two existing and one closed solid waste landfills in the period from 2003–2016, which are located in Alma-Ata (Kazakhstan). The researchers designed maps of changes of the boundaries of 5 unauthorized dumping grounds. The obtained data argue the necessity to control and implement intended measures concerning determination of the tendencies of pollution and to increasea buffer zone for solid waste landfills. It is an interesting fact that the Kasarai landfill (Alma-Ata, Kazakhstan) demonstrates the tendency to reduce the occupied area. In 2002, its area constituted 45.5 ha, in 2012 – 27.8 ha, and in 2016 – 10.65 ha. In the period, the area of the solid waste landfill was reduced by 34.35 ha due to the closure of access for a city in close proximity which did not meet the sanitary norms [Kaliaskarova, 2017].

Basing on the review of the published sources, one can affirm that archive cartographic materials, satellite and aerial images, topographic maps, and various descriptive materials can be a useful source of data for obtaining reliable information and for examining objects in retrospective-geographic context. Lviv city landfill in the context of the defined topic has been poorly studied concerning the objective, and needs further theoretical and experimental research.

Aim

The main aim of the work is to define the tendencies of changes of space-time peculiarities concerning performance of Lviv city landfill through application of archive materialsfrom 1950 to 2006.

To achieve the set aim, it was necessary to make the following steps:

- to collect and analyze materials obtained from 1950 – 2006 in the territory of Lviv city landfill;
- to determine changes of the land area of waste storage at Lviv city landfill, based on analysis ofdifferent years of topographic maps;
- to study archive aerial images of 1988 for drawing of a digital terrain model of Lviv city landfill;
- to draw a digital terrain model and define numerical characteristics of changes of the area and extent of waste storage in 1950–2006 at Lviv city landfill, based on the topographic plan of 2006.

Methodology and findings of the work

In 1950, a rapid growth of population of Lviv city forced the necessity to determine a place, where wastes were to be buried. Thus, the place was chosen near the village of Velyki Hrybovychi which is located. At that time, it was not a special selection of a land parcel for waste landfill, but a choice of a location, which was characterized with complicated forms of terrain, in particular ravines and level difference of 80 m. Officially, Lviv city landfill started its activity in 1959, and thus, analysis of archive cartographic materials were made, starting from that period.

Analysis of archive cartographic materials of 1950 – 1991 on the territory of Lviv city landfill

Considerable changes of location after the Second World War forced the need to update topographic maps and sometimes to make new topographic survey. According to the Resolution of the Council of Ministers of the USSR No. 760 on April 7, 1946, a common system of geodesic coordinates and altitudes was introduced in the territory of the USSR and was called a “System of coordinates of 1942”. The level of the Baltic Sea was approved as a reference level for altitude measuring. At the same time, in the middle of 1950, there was a substantial development of topographic survey at the scales of 1: 10 000 and 1: 25 000. The period is presented by a topographic map M-35-73-A-B (Fig. 1) of the location in 1957, drawn at the scale of 1: 25 000 with 5 m terrain cross cutting with CK-42 system of coordinates, using Baltic Sea level datum, and the Gauss–Krüger coordinate system. Peculiarity of the landfill is that it was formed between two ravines with 10-meter high walls. At that time, the map did not include any information about the waste landfill.

Basing on the map of 1957, the authors designed a TIN model (Fig. 2), which was used as an initial surface for measuring of waste volume at Lviv city landfill and for an accurate depiction of the ravines relief [Lozynskyi, 2016].

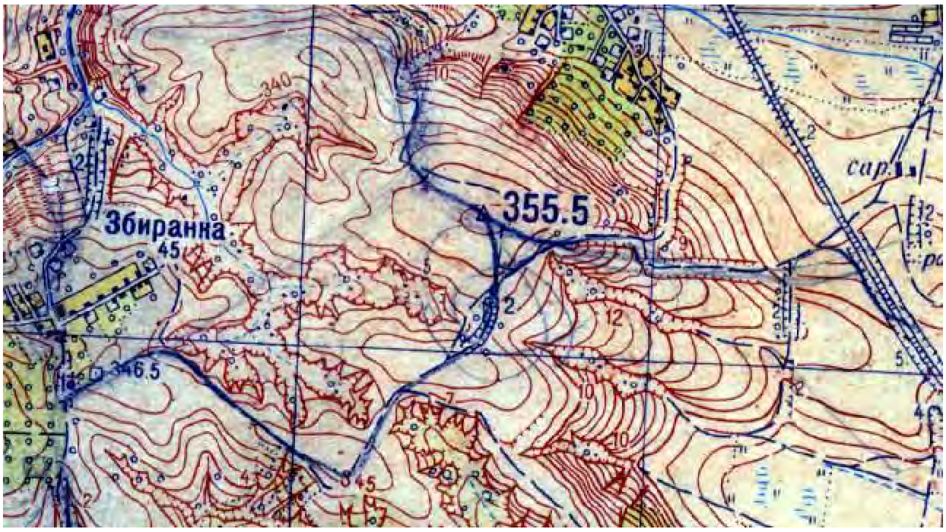

Fig. 1. A fragment of a topographic map scaled at 1: 25 000 with a contour interval 5 m (1957)

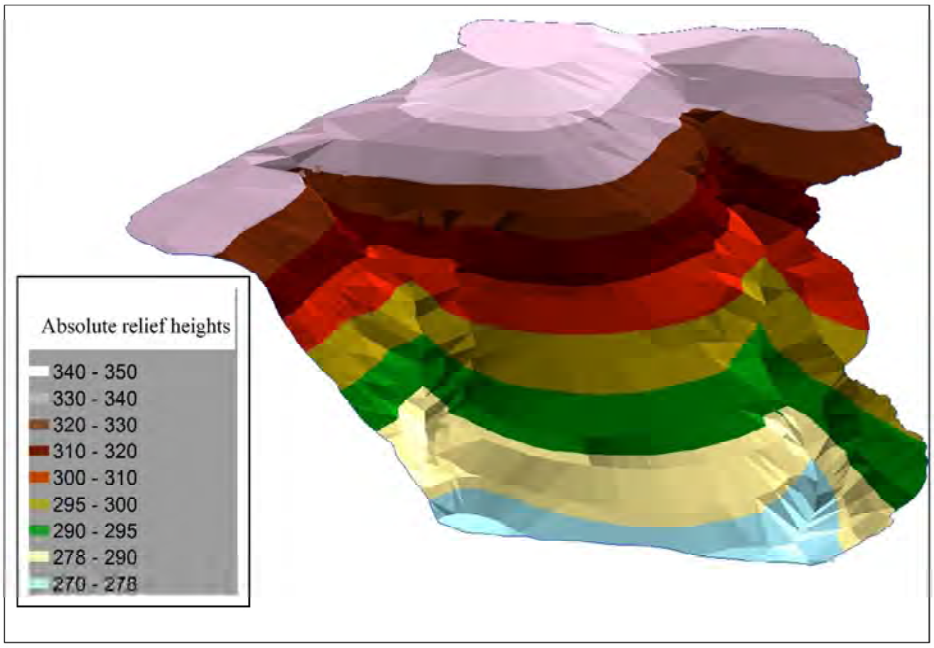

Fig. 2. TIN models initial terrain of Lviv city landfill in 1957

In 1972, a topographic map, drawn at the scale of 1: 25 000 with 5 m horizontal cross cutting was made with application of the system of coordinates of 1942, Baltic Sea level datum (Fig. 3). The map marks the waste landfill, having clearly determined contours. Values of growth and reduction of the heights of waste storage constituted 45 and 5 m in the north-eastern and north-western parts respectively. In 1971, there was no second ravine in the territory of the landfill. Obviously, it was already waste-filled and there was a symbol of a water reservoir with sludge ponds in it. It is worth mentioning that the topographic map has a convention of the asphalt road of 8 m width running near the waste landfill. On the north side of the road, one can see symbols of buildings which served as an economic zone with administrative, household and productive premises (8 buildings), as well as marks of two water bodies (sludge ponds).

In 1985, there was a designed topographic map with nomenclature M-35-73-A-B-1, drawn at the scale of 1: 10 000 with 2 m terrain cross cutting

(Fig. 4). Considering that fact, that the mentioned map was made at a larger scale, one can distinguish two maps of waste storage with a road8 meters in width between them. For one of the storage plots, the height of walls constitutes 20 meters. When comparing the 1972 to 1985 maps one can see that in the southern part of the landfill there were two new sludge ponds, some points of survey network, demonstrating height of a point location which were measured in meters above the sea level. The map does not include a mark of the first ravine, which was also waste-filled at that time.

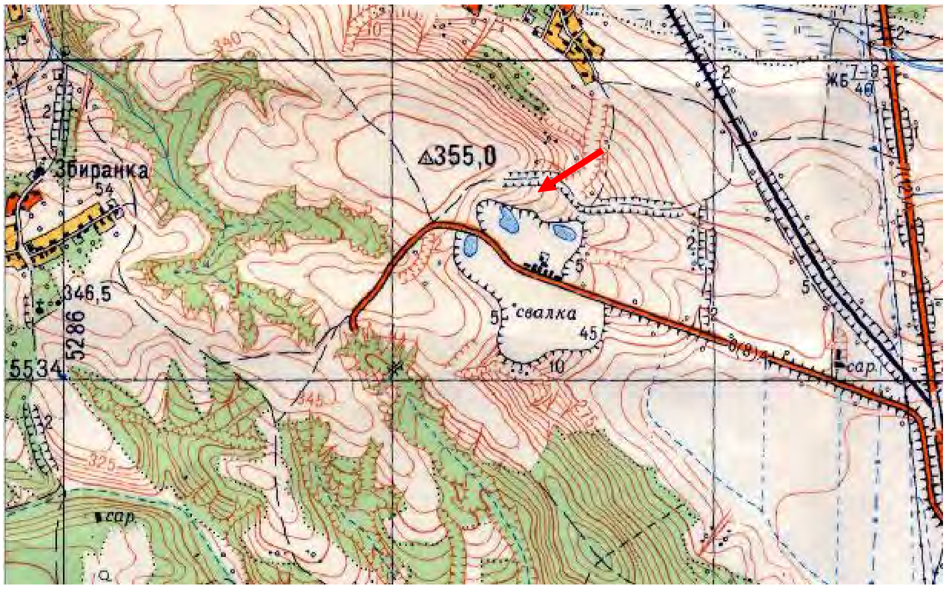

Fig. 3. A fragment of topographic mapat scale 1: 25000
with a contour interval 5 m (1972)

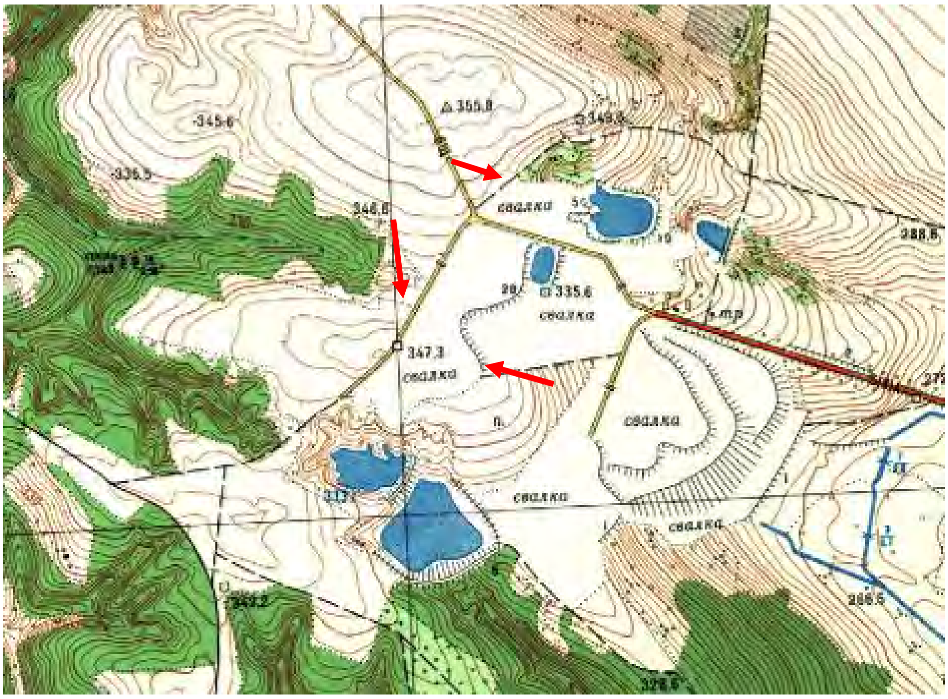

Fig. 4. A fragment of topographic map
with a scale 1:10 000 and contour interval 2 m (1985)

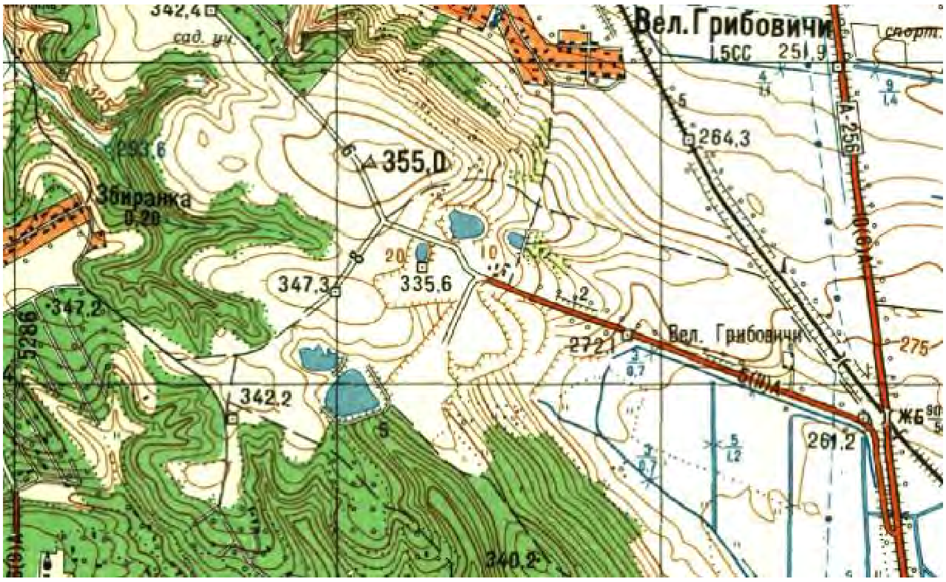

Fig. 5. A fragment of a topographic map o scale 1: 25000 and contour interval 2 m (1991)

Basing on the map, drawn at the scale of 1: 10 000 (1985), a topographic map, drawn at the scale of 1: 25 000, was designed in 1991, see Fig. 5, and thus, it was impossible to see substantial differences of the situation.

Study of archive topographic maps for monitoring of the land plot of waste storage at Lviv city landfill

To monitor the land plot of waste storage according to the coordinate system, archive cartographic materials are registered with the application of ArcGis software. At least 6 points on each map werechosen for registration, and a polynomial model of the 2nd order transformation was chosen for transformation. Maximum deviations of the registration of archive cartographic materials are presented in the Table 1, allowing the possibility offurther use of the materials in the research concerning changes in the waste storage land plot.

Table 1

The maximum registration errors of archival topographic maps

Archival materials	Scale	The maximum registration errors, m
Topographic maps (1957)	*1:25 000*	*4.89*
Topographic maps (1972)	*1:25 000*	*4.78*
Topographic maps (1985)	*1:10 000*	*1.85*
Topographic maps (1991)	*1:25 000*	*4.76*

The next step was to create shape files of polygonal type with corresponding boundaries for each map. The saved files were imposed on the topographic map of 1957 (Fig. 6) and define the area of waste storage in the land plot, which constituted 85 265, 67 m^2 in 1972, 185 690, 44 m^2 in 1985, and 177 690, 44 m^2 in 1991.

Study of archive aerial images of 1988 for drawinga digital terrain model of Lviv city landfill

The authors of the article made modelling of a topographic surface of the Lviv city landfill with application of the materials of topographic plan aerial survey, performed on the 5th of October, 1988. Four analog aerial images, taken with aerial camera AFA TE 100 with 60 % mutual interference, were digitalized with 2400 dpi resolution. See Fig. 7.

The images are of mediocre visual quality and low in contrast. Passport information of AFA and elements of the images' orientation are unknown. Thus, the authors of the article choose the following order of photogrammetric processing:

1) Formation of a terrestrial reference network (Fig. 8) of points, and geodesic coordinates of the points are obtained from the available materials of geodesic GNSS measuring and orthophotoplans at the scale of 1: 5000;

2) Formation of aerial triangulation by links method;

3) Formation of a close cloud of 3D points on the studied land parcel.

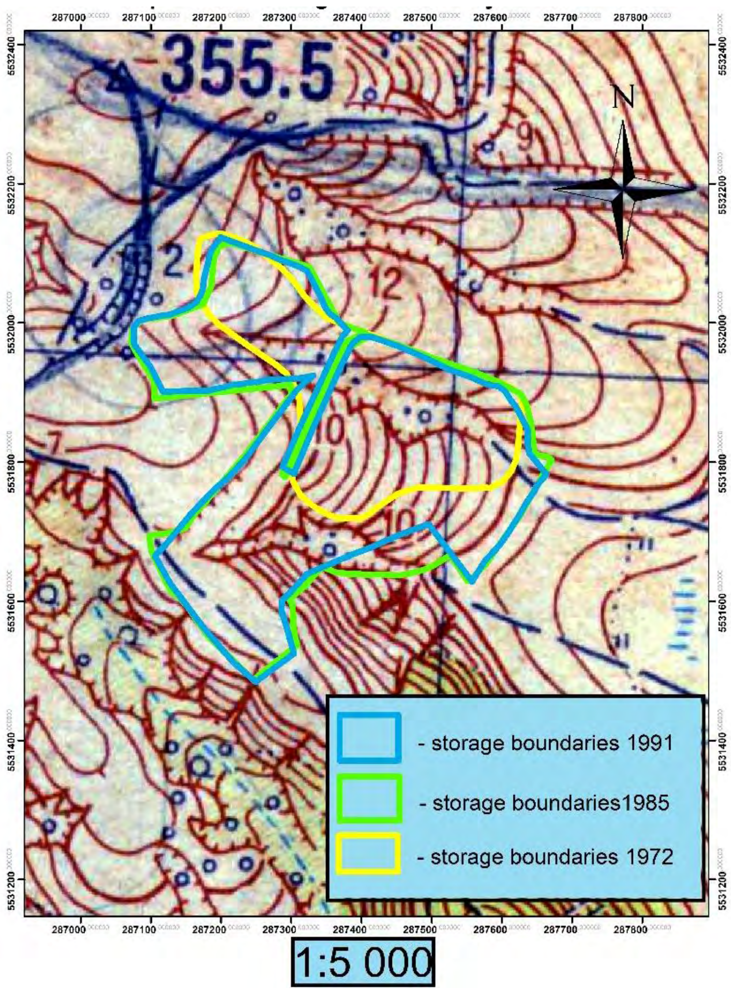

Fig. 6. Map of waste storage at the solid waste landfill (storage boundaries)

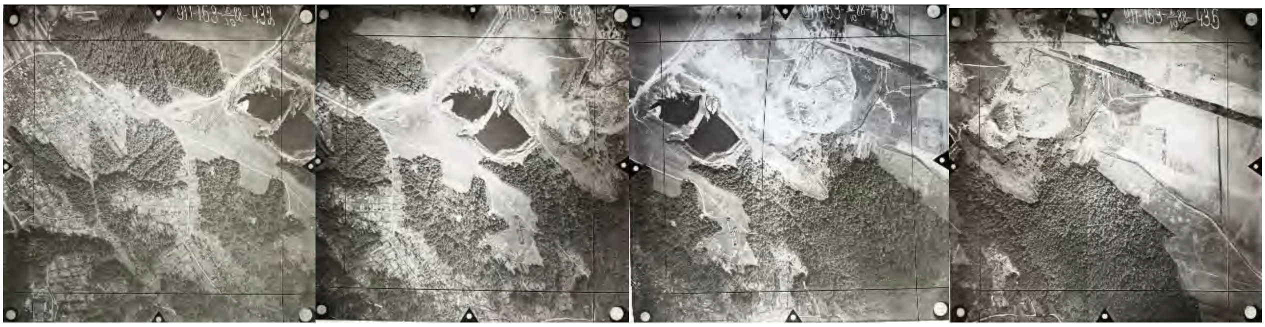

Fig. 7. Aerial photos of the Lviv city landfill October 5, 1988

GPS survey was performed on the studied territory in order to supply a course of the aerial images with reference and control points. The reference terrestrial network consists of 18 points with the space coordinates, which are determined with ±0,05m accuracy. Considering the fact that there has passed a long period (29 years) from the date of the aerial survey to the date of the geodesic reference of aerial images, it was a complicated process to choose the necessary number of contours, which were kept on the location during the mentioned period. Solid contours were chosen to perform the function, including corners of saved and destroyed buildings, as well as an electrical power converter. Crossroads, as spatially defined contours, were also used in the selection. See Fig. 8.

Fig. 8. Location of reference and control points at the image

Fig. 9. Process of field interpretation and coordination of the reference network

Points of the reference network were identified on archive aerial images by means of space depiction of Google Earth service, obtained in the time period between the dates of the aerial survey and the creation of the reference network (aerial survey – October 5, 1988, space image to November 3, 2005, GPS photography – November 5, 2017). Interpretation of such particular points was made at the location of the solid waste landfill and adjacent territories (Fig. 9).

In the mentioned territory, there is intensive economic activity. Content and contours of vegetation, as well as character of land use, are changing. Thus, it is impossible to detect a sufficient number of saved contours of the location which could be used as points of control. The authors of the article propose to apply a combined reference network (Fig. 10):

- Points of modern GPS survey at solid and absolutely identified contours are used as completion points of control;
- Points of modern GPS survey at unreliably identified contours are used as spots of control;
- Points, necessary for quality supply of a course with points of control at the corners of images, are obtained from the available orthophotoplans at the scale of 1: 5000, and the points are used as plan points of control.

Independent photogrammetric models were developed to confirm applicability of the reference network forphotogrammetric processing. Accuracy of reciprocal orientation of images is presented in the Table 2.

As demonstrated in Table 2, the number of points in the working areas of overlapping pairs was sufficient for drawing of the models, distribution of the points on the area of extreme overlapping pairs of the course is unequal, and the average values of residual cross parallaxes constitute 0.3–0.5 pixel. It confirms a satisfactory accuracy of the obtained photogrammetric models and thus, there is no any need of additional measuring of linking points.

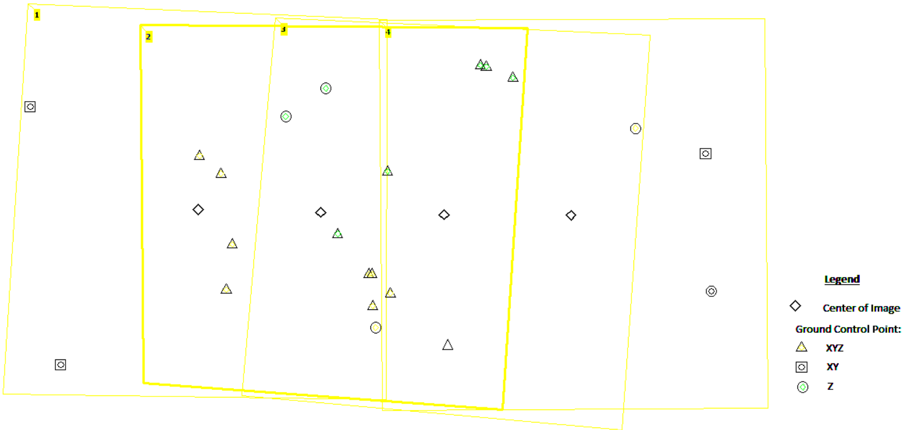

Fig. 10. Project of the reference network, developed by combining the points of GPS survey and the points obtained from orthophotoplans

Table 2

Accuracy of reciprocal orientation of archive images

Number of an overlapping pair	Number of points	Residual cross parallax, pixel			Difference of kappa angles, °	Equitability of distribution
		RMS	average (module)	max		
1 — 2	13	0.350	0.295	0.765	0.743753	Unequal
2 — 3	12	0.597	0.516	0.936	0.686162	Equal
3 — 4	10	0.401	0.297	0.879	0.147152	Unequal

Photogrammetric triangulation is the next step of photogrammetric processing. Photogrammetric triangulation network was developed by means of links method in the environment of PHOTOMOD software. Additional measuring of the linking points was not made due to the two circumstances:

1) high density of the available reference network, presence of reference points in the zones of double and triple overlapping of images;

2) insufficient viewing conditions of the images, making negative impact of the work of automatic correlator.

Photogrammetric triangulation has resulted in determination of the elements of aerial images orientation and assessment of the accuracy of compensating computations according to six control points. The work has also supplied obtainingquadratic standard error of coordinates determination at six control points: m_X=0.39 m, m_Y=0.62 m, m_Z=0.82 m.

There exists prospects for future researchin modelling of DTM in automatic mode in specialized photogrammetric systems, and in manual mode at the digital photogrammetric station “Delta”.

Creation of a digital terrain model on the base of a topographic plan of Lviv city landfill in 2006

In 2006, Lviv city council ordered a topographic plan (Fig. 11) at the scale 1: 1 000 with 0.5 m cross cutting of the terrain, in the Baltic Sea level datum. The mentioned topographic plan covers the territory of Lviv city landfill and includes topographic information in the form of horizontals, stakes and conventions of steps with height marks. It also depicts such objects as filtrate bowl lakes, sludge ponds, and features at the location that include buildings, constructions, roads, power lines and their characteristics. See Fig. 11.

There are 10 reference points chosen with solid contours, which currently exist and are obtained online (RTK), in WGS84 system of coordinates, to study the mentioned cartographic material and which can be further used for registration of the topographic plan. Concerning accuracy of the topographic plan registration, the maximum deviations constituted 0.17 m.

Creation of a shape file of point type, including information about heights on the body of waste storage (1200 points), was the next step of office analysis. Basing on the information, a TIN model was designed (Fig. 12). According to the results of modelling, the authors determined that the first terrace is located at the height of 290–300 m, having an area of 15 717.65 square meters. One can also affirm that the second terrace is located at the height of 300–330 m, and the third one started in 2006, being at the height of 330–350 m. To determine the height of the waste storage in 2006, applying the TIN model of 1957 (fig. 2) and 2006 (Fig. 12), the authors have drawn a map of isopachytes of the waste of Lviv city landfill (Fig. 13), and its depth differs from 0 to 40 meters. Using a Surface Difference instrument, the amount of waste has been measured for the corresponding period which constituted 2 835 756 m^3. The area of waste storage occupied 242 441 m^2. See Figs. 12 and 13.

To compare the volume, determined by the topographic plan and on the base of weight method [Lozynskyi, 2016], constituting 1 301 739 m^3 in the period, one can confirm a mismatch of the data, presented by the two methods already in 2006.

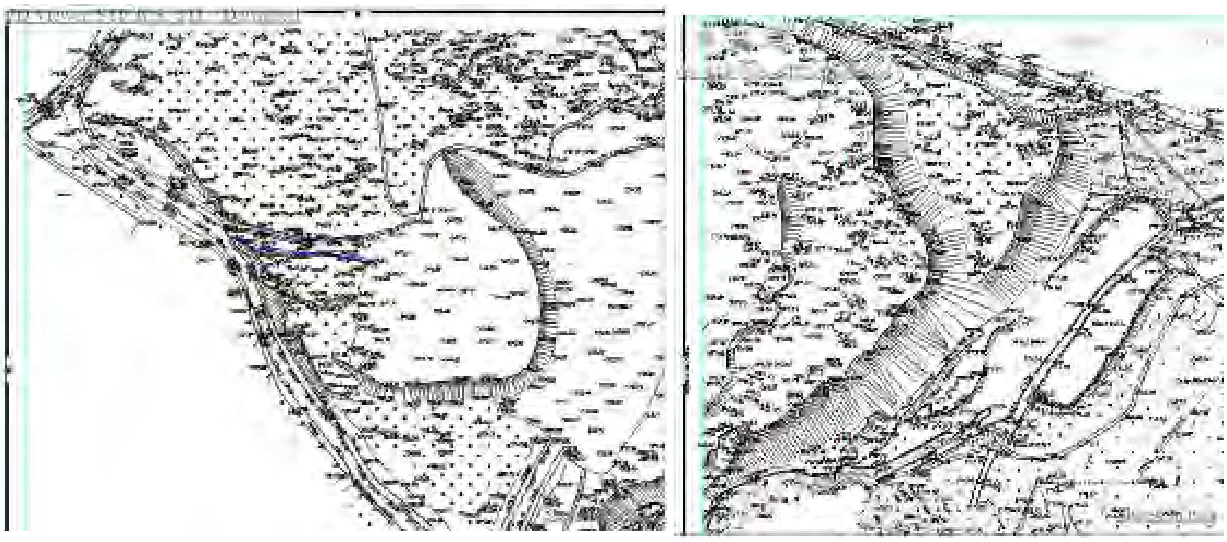

Fig. 11. A fragment of the topographic plan of 2006

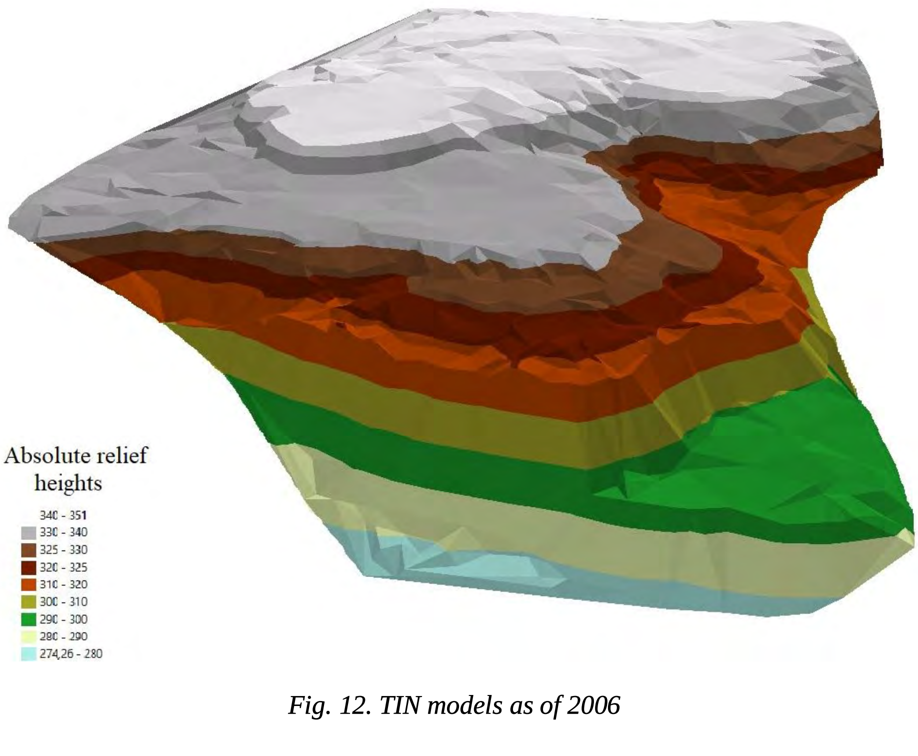

Fig. 12. TIN models as of 2006

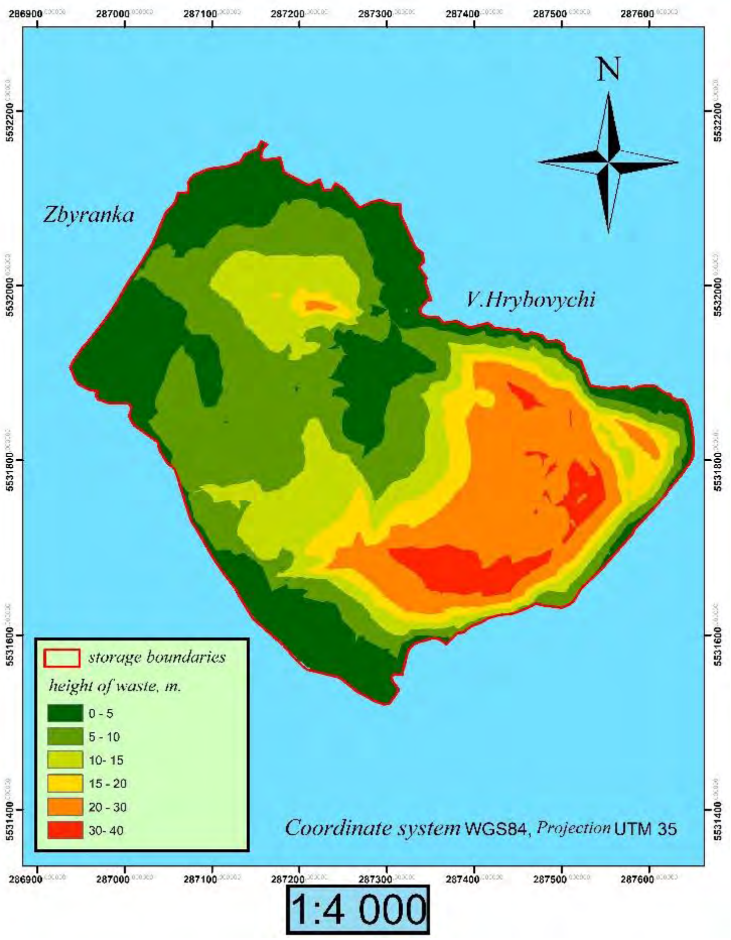

Fig. 13. Isopachytes of waste in Lviv city landfill as of 2006

Scientific novelty and practical importance

It is first proposed in Ukraine to use the technology of geoinformational modelling of the dynamics of performance of a solid waste landfill. Using the technology, the authors of the article have performed the retrospective-geographic analysis of Lviv city landfill in the period from 1950–2006, based on archive recordings. Results of the analysis give the possibility to determine tendencies of changes of space-time peculiarities of its performance, which include development of digital terrain models and determination of geometric parameters of the solid waste landfill. The obtained results of 3D modelling, which are presented in the work, can serve for specialists in the field of handling waste (specialists of housing and facilities department, ecological inspection, and scientific-research organizations) to control keeping to the rules of employment for any solid waste landfill. The described findings can be used by local authorities to control performance of dumping grounds in order to prevent ecological disasters and for monitoringthe adjacent territories.

Conclusions

Basing on the performed research, the following conclusions are made:

1. Collection of archive cartographic materials proves an opportunity of their application from the initial stage of performance of the solid waste landfill in order to determine changes of waste storage boundaries from 1950–1990;

2. Interpretation of cartographic materials enables determination of the area of the land plot of waste storage, which constituted 85 265, 67 m^2 in 1972, 185 690.44 m^2 in 1985, 177 690.44 m^2 in 1991;

3. Availability of archive aerial images (1988) enables application of modern photogrammetric systems with the proposed methodology of their

processing, that is further planned to be performed in automatic and manual modes at the digital photogrammetric station “Delta”;

4. Basing on the topographic plan (2006), the work determines quantitative parameters of the Lviv city landfill, in particular, area and volume, constituting 242 441.46 m^2 and 2 835 756 m^3 respectively. The research also develops isopachytes of heights of waste storage, relative to the initial surface, according to which the height of waste storage changes from 0 to 40 m;

5. Analyzing the data concerning quantity of the produced waste buried at Lviv city landfill, it was necessary to make periodical topographic-geodesic observations (topographic, aerial and terrestrial digital survey) in that period. The observations would have enabled not just prevention of landslides or other dangerous phenomena, but also be useful for extending the available period of exploitation;

6. Prospect of further research is in application of archive space images of extra high resolution in the period from 2006 to 2015 for mapping of the changes of waste storage boundaries.

REFERENSES

Brilis, G. M., Gerlach, C. L., van Waasbergen, R. J., Remote sensing tools assist in environmental forensics. Part I: traditional methods. J. Environ. Forensics, 2000, no. 1, pp. 63–67.

Chetverikov B. V., Bidyuk Kh. I. *The technology of creating a digital terrain models on the example of the ensemble of defensive structures "Citadel" (Lviv).* Geodesy, cartography and aerial photography. Lviv Polytechnic Publishing House, 2014, no. 80, pp. 111–119.

Chetverikov B. V., Protsyk M. T. *Determination of places of mass graves during the Second World War using GIS-technologies.* Geodesy, cartography and aerial photography. Lviv Polytechnic Publishing House, 2015, no. 81, pp. 104–111.

Erb, T. L.; Philipson, W. R.; Teng, W. L. Analysis of landfills with historic airphotos. Photogrammetric Engineering and Remote Sensing, 1981, 47 (3), 190–203.

Garofalo, D., Wobber F., Solid Waste and Remote Sensing, Photogrammetric Engineering. 1974, Vol. 40, no. 1, pp. 45−59.

Hryts'kiv N. Z., Horlatova V. O. *Investigation of dynamic processes on mining and industrial objects by methods of geoinformation modeling.* Geodesy, cartography and aerial photography. L.: Izd Nat. Univ “Lviv Polytechnic”, 2014, no. 80, pp. 91–100.

Hulyk S. M. *Methodical approaches to the study of landscapes on the basis of multi-time maps.* Ecological geography: history, theory, practice: Materials of II Intern. sciences conf. Ternopil, 2004, pp. 43–45.

Kaliaskarova K Modern condition of locations of municipal solid waste in a residential buffer suburb of the city of Almaty. Available at http://uest.ntua.gr/athens2017/proceedings/pdfs/Athens2017_Kaliaskarova_Ikanova_Aliyeva_Bekkuliev.pdf

Kwarteng A., Al-Enezi. Assessment of Kuwait's Al-Qurain Landfill Using Remotely Sensed Data. *Journal of Environmental Science and Health*, Part A: Toxic/Hazardous Substances and Environmental Engineering. 2004, vol. 39, issue 2, pp. 351–364.

Lath, H. A., G. W. Tannehill, and R- E. White, 1976. Remote Sensing Evidence and Environmental Law. California Law Review, vol. 64, represent. pp. 1300–1446.

Lozynskyi V. A. *Analysis of modern metods to obtain data to determine the volumes of waste and sediments*. [Modern achievements of geodesic science and industry]. Lviv. 2015. Issue II(30), pp. 87–97.

Lozynskyi V. A., Nikulishyn V. I., Tretyak K. R., Shylo Ye. O. *Methodology for determining the volume of the Lviv city landfill using archival cartographic materials and UAV TRIMBLE UX-5. Geodesy, cartography and aerial photography*. Lviv Polytechnic Publishing House, 2016, no. 82, pp. 61–82.

Nychaya O. O. *Retrospektyvno-heohrafichnyy analiz zabudovy yak vydu pryrodokorystuvannya na terytoriyi Volyns'koyi vysochyny (na prykladi volyns'koyi oblasti.* Actual problems of modern science. Lviv, 2015, part. II, pp. 20–22.

Qingsheng, L. Gaohuan, L.(2010). Using CBERS CCD Images to Monitor Dynamic Change of Jiaojiapo Waste Landfill Site, Environmental Sanitation Engineering. 18 (5), 17–20.

Seker, D. Z., Kaya, S., Musaoglu, N., Demirel, H., Tanik, A., Sertel E. Spatial Analyses for Environmental Impacts of Landfill Areas. Survival and Sustainability , Environmental Earth Sciences, Chapter: Spatial Analyses for Environmental Impacts of Landfill Areas, 2011, 691–697. DOI: http://dx.doi.org/10.1007/978-3-540-95991-5_63

Slonecker, E. T. Remote Sensing Investigations of Fugitive Soil Arsenic and Its Effects on Vegetation Reflectance: Ph.D. Dissertation. Fairfax, USA, 2007, 240 p.

Slonecker, E. T. The Use of Historical Imagery in the Remediation of an Urban Hazardous Waste Site, in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 4, no. 2, pp. 281–291, June 2011. doi: 10.1109/JSTARS.2010.2049254

Slonecker, T., G. B. Fisher, D. P. Aiello, B. Haack. Visible and Infrared Remote Imaging of Hazardous Waste: A Review. Remote Sensing. 2010, no. 2, pp. 2474–2508.

Sossa R. I. *History of mapping the territory of Ukraine*. Kyiv, 2007. p. 336.

Vincent R. K. Remote sensing for solid waste landfills and hazardous waste sites. Photogrammetric Engineering and Remote Sensing. 1994, no. 60, pp. 979–982.

Volik O. V., Svynko Y. M., Dem"yanchuk P. M. *Anthropogenic transformation of the nature of the "Medobory" reserve and adjoining territories during the twentieth century.* Protection and management of inhumane nature objects in protected areas, Jura, Ternopil, 2008, pp. 54–57.

В. ЛОЗИНСЬКИЙ[1], І. КОЛБ[2], Т. ІЛЬКІВ[2]

[1] Кафедра картографії та геопросторового моделювання, Національний університет “Львівська політехніка”, вул. С. Бандери, 12, Львів, 79013, Україна, тел.: 098-71-31-398, ел. пошта: viktor.lozynskyi@gmail.com
[2] Кафедра фотограмметрії та геоінформатики, Національний університет “Львівська політехніка”, вул. С. Бандери, 12, Львів, 79013, Україна,

РЕТРОСПЕКТИВНО-ГЕОГРАФІЧНИЙ АНАЛІЗ ЛЬВІВСЬКОГО МІСЬКОГО ПОЛІГОНУ ТПВ

Мета. Щорічне зростання об’ємів сміття, що захоронюються на полігонах твердих побутових відходів (ТПВ), призводить до необхідності контролювати діяльність таких комунальних та приватних підприємств та проводити як екологічний, так і інженерний моніторинг їхньої діяльності. Серед контрольованих параметрів під час інженерного моніторингу є геометричні розміри земельних ділянок, розміри та динаміка тіла складу відходів, контроль поширення стічних вод та інші числові параметри, що їх можна отримати геодезичним методом та за допомогою неконтактних вимірювань. Для встановлення особливостей функціонування ТПВ у минулому важливим джерелом даних є архівні паперові карти та матеріали аерофотозйомки. Ці матеріали можна застосувати для вирішення низки наукових і практичних задач, а отже є потреба у побудові коректного представлення архівних даних у геоінформаційних системах та створення технології добування геоданих з архівних карт і знімків сучасними засобами. Основною метою роботи є встановлення просторово-часових особливостей функціонування Львівського міського полігону ТПВ за останні 60 років його діяльності. **Методика та результати роботи**. Відповідно до поставленої мети ми зібрали та проаналізували архівні картографічні матеріали, які створені впродовж 1950–2006 рр. на території Львівського міського полігону ТПВ. Використовуючи топографічні карти станом на 1972, 1985, 1991 рр., створені в масштабі 1: 10 000, 1: 25 000, встановлено площі ділянки складування відходів на відповідний період, виявлено просторово-часові особливості функціонування полігону. Опрацьовано архівні аерофотознімки 1988 р., на основі яких планується в подальшому побудувати цифрову модель рельєфу. На основі топографічного плану 2006 р. побудовано цифрову модель рельєфу, визначено кількісні параметри Львівського полігону ТПВ, а саме: площу та об’єм. **Наукова новизна та практична значущість.** Вперше в Україні проведено ретроспективно-географічний аналіз Львівського міського полігону ТПВ у період з 1950–2006 рр. на основі архівних матеріалів. Результати цього аналізу дають змогу встановити тенденції зміни просторово-часових особливостей функціонування, яка містить побудову цифрових моделей рельєфу та встановлення геометричних параметрів полігону ТПВ. Отримані результати геоінформаційного моделювання, які подані в цій роботі, можуть слугувати фахівцям у сфері поводження з відходами (спеціалісти житлово-комунального господарства, екологічної інспекції та науково-дослідних організацій) для контролю за дотриманням правил експлуатації полігонів ТПВ.

Ключові слова: полігон твердих побутових відходів, архівні карти і плани, архівні матеріали аерофотознімання, цифрова модель рельєфу, порівняння топографічних поверхонь.

Received 12.05.2017