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Geoinformation systems in monitoring studies of environmental pollution factors in the areas of municipal solid waste landfills

***O. T. Azimov** *(Scientific Centre for Aerospace Research of the Earth IGS of NASU)*, **O. V. Shevchuk** *(Institute of Telecommunications and Global Information Space of NASU)*

SUMMARY

The report highlights the possibilities of using the technologies of remote sensing of the Earth (RSE) and geographic information systems (GIS) for monitoring studies of pollution factors of the environmental within the municipal solid waste (MSW) landfill areas and in the ranges of their impact. It has been shown that the RSE data integrated to GIS allow to obtain accurate information about the current state of the studied area quickly, to conduct timely monitoring and forecasting the development of negative phenomena and processes, which significantly increases the level of environmental safety at national, regional and site levels and provides an opportunity to develop a set of measures to reduce the environmental impact of MSW disposal landfills.

The situation with waste, especially domestic waste in Kyiv's Oblast, is getting worse every year. As a result, there is an increasing threat to human and environmental health. The obtained results show that one of the reasons for the current situation is the selection of unfavorable sites for the allocation of waste disposal landfills.

The urgency of issue. Nowadays, the problem of environmental pollution from landfills is very acute. According to the State Statistics Service of Ukraine (Waste, 2019) 35–40 mln m^3 of solid waste is produced annually in our country. The total mass of accumulated waste in Ukraine is 25 bln tons, which, per one citizen, is about 600 tons. Specific solid waste generation for Ukraine averages 250 kg/per year per person, and in large cities reaches 330–380 kg/year and tends to increase.

The total mass of the municipal solid waste (MSW) stream is annually about 400 mln tons, 80% of which is destroyed by landfilling. For Ukraine this figure is over 13 mln tons of MSW generations, of which 95% goes to landfills.

To date, there are at least 12 sites in the Kyiv Region (landfills, sludge pits, ash disposal areas) that store industrial waste and 36 landfills. Their total area is 472 ha; the amount of accumulated waste is 56.14 mln tons. Unfortunately, 75% of unauthorized landfills and official landfills do not meet the sanitary requirements. Landfills and unauthorized landfills, acting as nature conservation facilities through landfill disposal and biodegradation, are themselves sources of negative environmental impact. Negative types of impact should include the removal of large areas of land for economic use for the long term, soil contamination and disturbance of their structure, pollution of air, groundwater and surface water, vegetation, increased fire risk and more.

The most serious problem is groundwater pollution. Seepage through the layers of landfilled waste leads to that the rainwater and melt water is “enriched” with various chemicals that are formed during the decomposition process, producing a dangerous leachate. Particularly problematic is the Kyiv Landfill No 5 near the village of Pidhirtsi, Obukhiv district (waste disposal services are provided by the Kyivspetstrans Joint-Stock Company), officially closed Landfill No 6 in the area of the village of Pyrohovo near Kyiv City and the Landfill in Bila Tserkva City (subordinate to CAHC-1028). Characteristic of all districts of the region is the presence of a large number of unauthorized landfills, which pose a serious environmental risk, since there is a possibility of removal of pollutants directly into the water bodies.

Purpose, methods, objectives and materials of research. The main ***purpose*** of the article is to formulate the general principles of creation and to determine the main components of the information system of geomonitoring of areas of impact of the MSW disposal landfills as part of an information-analytical system of analysis of the risk of emergencies of man-made and natural character, aimed at ensuring sustainable regional development of Ukraine (Azimov et al., 2006).

The research, based on the ***method*** of analytical comparison, consisted in the elaboration and in a certain way of generalization of materials published in the scientific literature regarding information technologies for MSW landfills monitoring and management, predicting technogenic-ecological transformation of territories under their influence. Special emphasis was placed on analyzing the role of geoinformation systems in the developed or proposed technologies (Munn, 1973; Kukharskyi et al., 2013; Lyashchenko and Patrakeev, 2015).

Some practical aspects of implementation, approbation of information system of geomonitoring of areas of impact of MSW disposal landfills, developed or improved by us using technologies of remote sensing of the Earth – RSE (Azimov et al., 2018a,b,c, 2019a,b,c,d; Trofymchuk et al., 2019a), demonstrated by the example of the Kyiv region and several typical objects within it. In this context, we have now pursued the following main ***tasks***:

- Study of the dynamics of landfill area change;
- Study of the status of individual sites (Sections) of landfills.

During the research, space imagery from IRS-1C and IRS-1D satellites (spatial resolution of 5.8 m/pixel for panchromatic image and 16 m/pixel for individual spectral bands, acquisition year of 2006) was used. For detailed exploration of the individual sites where the largest landfill sites and areas are located (northern Obukhiv district, Bila Tserkva district, Trypillya district), were also used images from the Quick Bird satellite (spatial resolution 0.6 m/pixel, acquisition year – 2006).

Outline of the main research material. Review and synthesis of scientific literature sources on the basic structure of the ***information system for monitoring*** the major environmental components of MSW disposal landfill impact areas (Ahmed et al., 2006; Iacoboaea and Petrescu, 2013; Demesouka

et al., 2014; Khan and Samadder, 2014; Deblina and Goel, 2017; Jimoh et al., 2019; Singh, 2019; Trofymchuk et al., 2019b) allowed to determine the following ***stages and components*** of its ***creation***:

1. Analysis of theoretical and scientific-methodological approaches and methods of geomonitoring of territories affected by MSW disposal landfills. The choice of approaches and methods based on geoinformation technologies, which are most suitable for practical implementation with the use of appropriate software.
2. Development of a model for estimation, analysis and forecasting of technogenic-ecological transformation of territories under the influence of MSW disposal landfills.
3. Modeling of environmental contamination situations in the area of MSW landfills exposure and their environmental consequences (including emergencies due to the accidental release of various toxicants).
4. Adaptation of estimation algorithms in accordance with the available information support to the input data.
5. Scientific and technical substantiation, design and program implementation of the prototype geomonitoring block of information-analytical assessment, analysis and forecasting of ecological and economic losses from the MSW disposal landfills activities in Ukraine.
6. Scientific and technical substantiation and development of the decision support block and its integration into a single structure of the existing prototype of the software complex of the information-analytical system for the MSW disposal landfills management.
7. Testing of the prototype system and its experimental operation.

In our opinion, modern technologies of geographic information systems (GIS) and technologies of RSE should take a prominent place in each of the mentioned blocks of the information system. In further improvement of the information system of environmental monitoring in the sites of MSW siting (or disposal) landfills and surrounding areas, which are affected by them, using the RSE/GIS-technologies, we see our prospects.

E.V. Shcherbina (Shcherbina, 2012) distinguishes the following periods of the ***life cycle of MSW disposal landfills***: passive (conducting engineering studies at the stage of investment justification, performing an assessment of the existing state of the environment); active (creation, operation, reclamation of landfills); passive (landfill closure). Therefore, the features of the use of geoinformation technologies, especially GIS and RSE technologies, will be discussed in more detail in the first of the specified periods of the cycle of existence and activity of the MSW disposal landfills.

Both at the beginning of the first (*laying*) and during the active cycle of a MSW disposal landfill for geomonitoring of the respective territory it is necessary to select remote images. The purpose of their use is to obtain the following information in the following: location (locality, district, coordinates), mode of operation (active, closed), characteristics (volume, area, ground, underground), type of waste and other characteristics of the MSW disposal landfill. To do this, use multiband satellite images of the highest spatial resolution acquired by such satellites as QuickBird, Ikonos, Eros A, GeoEye-1, WorldView-2, etc., that allow to obtain terrain images of functioning urban ecosystems with spatial resolution close to 1 m/pixel in panchromatic or multispectral ranges of electromagnetic waves.

Atmospheric and geometric correction of the images is required, which will allow them to be further camerally decoded, classified, and recognized by various objects on them. This can be done by both automated and semi-automated and interactive methods with the active participation of a specialist. However, it is also necessary to carry out standard measurements of the parameters of the MSW disposal landfill by geodetic methods, which will be able to make their identification more adequately.

During the *active period* of landfill functioning, the following types of monitoring should be carried out: monitoring of the MSW disposal process itself, monitoring of the ground cover temperature regimes, monitoring of biogas and leachate formation within its boundaries. Unmanned aerial vehicles should be used for modern landfill documentation, and should be presented as 3D models to improve the visualization of waste facilities. Thus, during the active period of the landfill functioning, the temporal surveys by the unmanned aerial vehicles will allow creating a database that will be useful for analyzing the operation of landfill, and the enterprise engaged in its operation and maintenance will be able to control the projected technological operations for waste disposal.

Such general control (of the entire MSW landfill disposal site) should occur twice a year in the inter-vegetation period (early spring and late autumn), when there is no vegetation at the landfill. Another function of control is to analyze the parameters of waste disposal on installed work sections (for example, the width of the working section up to 15 m and the length – 50–120 m), control of the degree of compaction of the waste of the working section (until the sealed layer of waste reaches 2.0–2.5 m), then cover it with an insulating layer (soil, clay, crushed construction waste) of at least 0.2 m thick. This must be done by modern GNSS receivers using the Global Time Satellite System in RTK (Real Time Kinematic) mode – real-time positioning, – or tachometric surveying. Unmanned aerial vehicles data can be used by housing and communal services specialists, research institutions to perform engineering and design work.

Below are some of the ***factors*** that have a ***negative environmental impact*** on the environment and the population of MSW disposal landfills and the possibilities of ***monitoring*** them by ***RSE methods***.

Monitoring the temperature of waste facilities. Landfill combustion has a high environmental risk because it leads to environmental pollution by toxic combustion products. A significant number of landfills have been burning for decades, despite their periodic extinguishing. There are theories that generally exclude the prevention of combustion and the burning of landfills. To ensure the proper quality of the environment and the health of population, it is necessary to eliminate the causes of fires in landfills and landfill sites and to control the prevention activities to prevent them.

One of such preventive measures are the use of space or aerial data in the infrared range of spectrum, based on the detection of thermal radiation of the surface and the objects placed on it, or data from specialized thermal imagers installed on the aircraft. The latter will help to fix the foci, areas of distribution of combustion, and subsequently – during their elimination. Therefore, these facilities can be used in the operation of MSW disposal landfills in general.

Monitoring of biogas and leachate production. The process of biogas formation results from the natural decomposition of organic matter. For its extraction it is necessary to install special wells located all over the body section of the landfill. Subsequently, gas is burned or processed for electricity.

Another component of the required monitoring is the leachate, which is mainly formed by the ingress of precipitation into the body of the landfill and seepage through it. The leachate enters the appropriate collectors. Thus, it is necessary to periodically measure the surface area of the leachate collectors and monitor their change on the basis of remote sensing images. The problem of overflow of filter ponds is the increased pressure on the protective dams that can induce their deformations. In addition, the uplowing of leachate through the protective dams of the sumps due to their overfilling is one of the ways of contamination of the surface and underground hydrosphere by the leachate.

Another way of the going the leachate into the groundwater is the outbreak of the protective through the protective liners in the body of landfill. In general, this process can be illustrated by the logical path of the leachate impact on groundwater and the quality of drinking water for the population (see Figure 1).

In the post-exploitation period *the spatial displacement of the body of MSW landfill* is monitored. The reason for the landfill closure may be the expiration of their service life or emergencies (landslides, fires), protests by residents, non-compliance with operating standards and disposal of waste at landfill sites and others. After the landfill is closed, the process of stabilization of the body of the landfill takes place, which provides for the slopes to be positioned and brought back to normal at 18º. When designing a reclamation project, it will be necessary to use topographic survey data, in particular: vertical planning, calculation of the required soil for insulation (top layer), to determine the distance from the MSW landfill to the nearest urban development sites, the area occupied directly by the waste. Subsequently, after technical and biological reclamation, it is necessary to carry out the laying of geodetic points, which will later serve to determine the spatial displacements of the body of the landfill.

As illustrative examples of the ***approbation*** of these approaches, in particular, we have established (Azimov et al., 2018c) that the detailed satellite images distinguish the ***state of the studied dumps***, first of all their *internal "structure"*: abandoned places covered by the soil layer; areas where waste is currently stored; the ponds for collection of leachate or separate areas where contaminated water is stagnant; access roads; ditches; etc.

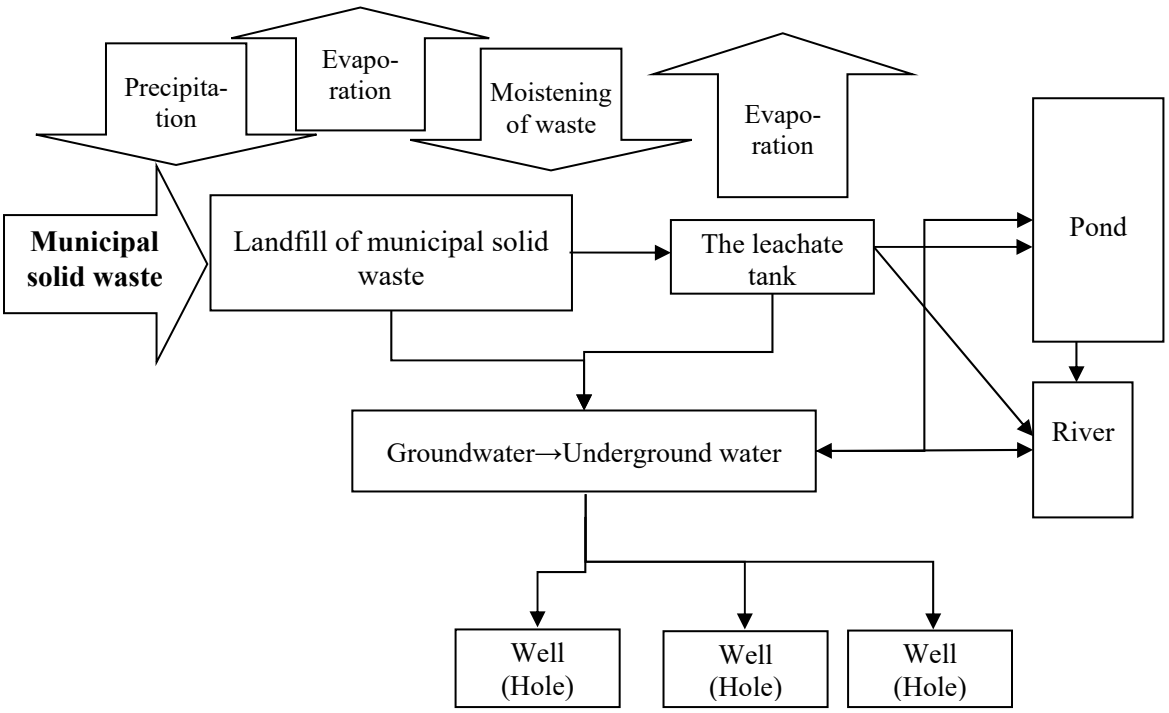

Figure 1 *Logical scheme of the effect of leachate on groundwater and drinking water quality for the population. Compiled using materials (Trofimchuk et al., 2019b), with additions.*

The satellite image shows the phenomenon of waste *self-ignition* in the MSW disposal landfill of Bila Tserkva City. This phenomenon is distinguished by a noticeable plume of smoke that spreads from the burning centre in the western part of the landfill.

The study of the *dynamics of change in the area* of the Bila Tserkva landfill range for a period of 20 years was performed using the spectrometric characteristics and texture of the images. Areas of the landfill that were used at different times were identified. Satellite images show the changes in vegetation in the surrounding areas, they provide the detecting of the paths to the landfill, which were used at different times.

Detailed studies of geodynamic safety and modern exogenous processes using Quick Bird images allow us to identify *potentially hazardous areas* on landfills, slurry pits and engineering infrastructure. These images also provide the distinguishing the landslides, active gullies, the areas of swamp development, deformations of the earth's surface at the places of old landfill sites, and other processes in need of attention.

In addition, the use of high spatial resolution images allow to identify the *illegal dumping,* sites of unauthorized discarding of waste (in particular, within the developments, in ravines, afforestation belts, etc.). Thus, several garbage dumps were made known within Kyiv City and its nearest outskirts: in a forest range near the Antonov State Enterprise, near the town of Vyshneve, in the area of low-rise buildings near the Sovsky ponds, in the area of summer residences near of Hlevaha settlement, etc.

The main conclusion. The most effective tool for the analysis, management and planning of activities in the field of waste management is the introduction of an information system for geomonitoring the affected areas of landfills for the disposal and accumulation of waste based on the use of the RSE/GIS-technologies. The RSE data integrated to GIS allow to obtain accurate information about the current state of the studied area quickly, to conduct timely monitoring and forecasting the development of negative phenomena and processes, which significantly increases the level of environmental safety at national, regional and site levels and provides an opportunity to develop a set of measures to reduce the environmental impact of MSW disposal landfills.

The situation with waste, especially domestic waste in Kyiv's Oblast, is getting worse every year. As a result, there is an increasing threat to human and environmental health. The obtained results

show that one of the reasons for the current situation is the selection of unfavourable sites for the allocation of waste disposal landfills.

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