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GEOINFORMATION SYSTEMS FOR MONITORING OF TERRITORIES OF MINING AND CHEMICAL ENTERPRISES

Summary: This article considers the features of creating a geographic information system for environmental monitoring of a mining and chemical enterprise in the post-liquidation period. The purpose of the work is to develop the methodological bases and approaches for creating the geoinformation system of monitoring of the mining and chemical enterprise territory.
In the research on the example of Rozdil State Mining and Chemical Enterprise "Sirka" one of the main parts of the system of geoinformation system of ecological monitoring – remote ecological monitoring is carried out.

Keywords: mining and chemical complexes, liquidation stage, monitoring of soils and water objects, geoinformation system, ecological balance

SYSTEMY GEOINFORMACYJNE DO MONITORINGU TERENÓW PRZEDSIĘBIORSTW GÓRNICZYCH I CHEMICZNYCH

Streszczenie: W artykule rozważono cechy tworzenia systemu informacji geograficznej do celów monitoringu środowiska przedsiębiorstwa górniczo-chemicznego w okresie po likwidacji. Celem pracy jest opracowanie podstaw metodologicznych i podejść do tworzenia geoinformacyjnego systemu monitoringu terenu przedsiębiorstw górniczych i chemicznych. W badaniach na przykładzie Państwowego Przedsiębiorstwa Górniczo-Chemicznego Rozdil „Sirka" jedną z głównych części systemu geoinformacyjnego monitoringu ekologicznego - prowadzony jest zdalny monitoring ekologiczny.

Słowa kluczowe: kompleksy górniczo-chemiczne, etap likwidacji, monitoring gleb i obiektów wodnych, system geoinformacyjny, bilans ekologiczny

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1. Introduction

The activity of the mining and chemical enterprise leads to the activation of dangerous natural and man-made processes, which cause disturbance of land and degradation of landscapes, pollution of the atmosphere and water environment, impoverishment of the plant and animal world, and endanger the life and health of people. These impacts can be implemented at all stages of mining, from research of mineral resources to the closure of an enterprise.

Mining landscapes that have been formed in Ukraine are characterized by a complex internal structure. Their peculiarities depend on the method of extraction, the technology of extraction of raw materials, terrain, hydrological regime and soils of exhausted areas, the nature of the surrounding landscapes. For the most part, these are azonic landscape complexes, in the structure of which there are 3 types: quarry-cavernous, peat-wetlands, slag heap and pseudo karst.

The process of functioning of the ecosystem "mining enterprise - the environment" can be divided into the following stages: design and implementation of the project, optimal operation of the mining enterprise, cessation of mining activities and liquidation of the enterprise, and the after liquidation period.

There are three possible ways of liquidation a mining enterprise:

1. Planned liquidation of the enterprise, in accordance with the plan of development of the enterprise in case of the completion of the stock of the exploited field.
2. Emergency liquidation resulting from sudden decisions on the elimination connected with the catastrophe, economic decline or other causes.
3. The temporary closure of mines, quarries is associated with economic and technological problems that prevent the continuation of mining of minerals and activities. During partial liquidation work it is necessary to take into account the possibility of re-exploitation of the deposit [1, 2].

Liquidation of Ukrainian mines and quarries usually is the emergency. The liquidation program is often created after the decision to terminate the activity. The consequence of the existing approach to solving the problem of liquidation of an enterprise is the problem of proper organization of rehabilitation works and the danger of the development of negative anthropogenic changes.

It is necessary to carry out the reclamation of postmining landscapes in the process of liquidation of a mining enterprise: to implement a complex of engineering, mining, reclamation, biotic, sanitary and hygienic and other measures aimed at the return of areas affected by the industry in various types of nature management: agricultural, forestry, recreation, etc. The development of deposits of minerals cannot begin until the project of reclamation of disturbed landscape systems is developed.

Until today, reclamation was considered the only effective measure to address the issues of rational use of natural resources and nature conservation.

All mining areas and objects, where changes in the thickness of sediments, relief, soil and vegetation are subject to reclamation. Monitoring is one of the main stages of the reclamation and liquidation of the mining complex [3, 4, 5, 6].

1.1. Study area

Rozdil State Mining and Chemical Enterprise "Sirka" is in the West of Ukraine (Lviv region). Large-tonnage wastes like phosphogypsum (over 3 million tons) were formed

on its territory in connection with the production of mineral fertilizers for 22 years (from 1974 to 1996), and also there are about 60 million t of sulfur ore tailings on the territory of the enterprise. In addition, on the territory of the enterprise 17,195 tons of "MG" type modifiers, made from neutralized tar residues and residues boiler anhydrite maleic acid were imported from Hungary. The wastes contain heavy metals that migrate in the soil and the water environment. Currently, the enterprise does not work and is in the stage of liquidation. It poses an environmental hazard to the Dniester River and surrounding settlements. (fig. 1) [7]

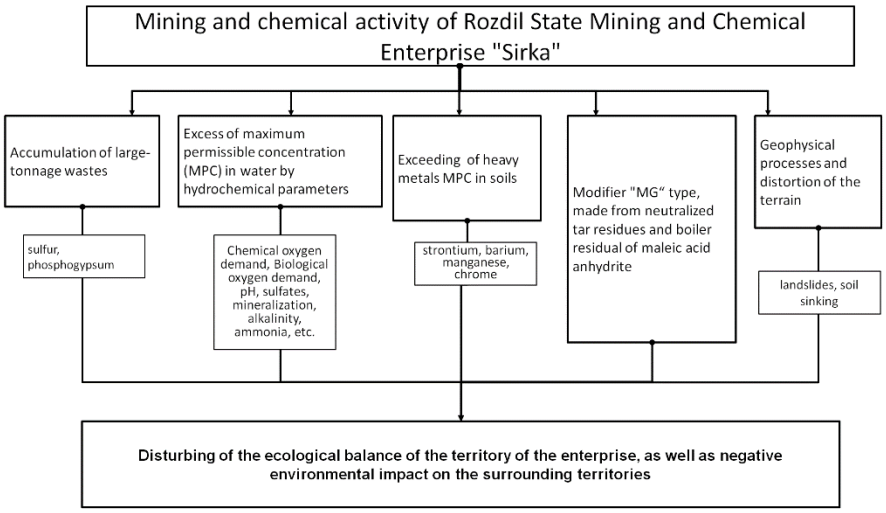

Figure 1. Sources of ecological danger of the Rozdil State Mining and Chemical Enterprise "Sirka"

1.2. The existing approaches to the reclamation of postmining landscapes

The territories of the mining and chemical enterprises, which are in the stage of liquidation, are subject to reclamation that is the restoration of valuable properties, in accordance with the existing legislation. The industrial enterprises that destroyed these lands are responsible for carrying out reclamation works, and the cost of reclamation should be included in the cost price of the finished product. General requirements for soil remediation in Ukraine are regulated by GOST (state standard) 1-7.5.3.04-83.

Sequence of reclamation works: technical reclamation, then biological. Technical reclamation is to prepare disturbed lands for further use in the household. Biological reclamation involves measures that promote the improvement of physical and agrochemical properties of soils on reclaimed lands (liming, sanding, mineral, organic, ash, slag fertilizing, etc.) [8].

There are such types of technical reclamation:

– agricultural (preparation of land for use as agricultural land);

– forestry (preparation of land for forest plantation);

– water management (preparation for the creation of a reservoir on the territory of mining complex);
– construction (preparation of land for industrial and civil construction);
– recreation (preparation of land for recreation facilities);
– sanitary-hygienic (preservation of disturbed lands, if their reclamation for another purpose for some reasons is not feasible).

Forestry reclamation is usually carried out where there is a possibility to restore the forest area due valuable breeds of trees. Its cost and requirements for the agrochemical characteristics of the reclaimed soils are lower than in the course of agricultural reclamation. Water management reclamation is carried out in spent quarries, which often fill groundwater. Recreational reclamation is carried out not far from cities and large settlements in order to create recreation areas for the population. Mostly it is combined with water management and forestry reclamation. Sanitary hygienic reclamation is used in areas where harmful substances are stored in order to prevent their harmful effects on the environment.

The volume of work of the technical stage of reclamation depends on the condition of the affected areas and the type of planned use. Plots prepared for eligibility for non-agricultural use (for parks, reservoirs, industrial and municipal construction, etc.) are transferred to the relevant organizations in accordance with the established procedure. Areas intended for agriculture and forestry, after the technical stage of reclamation, shall be returned to or transferred to the relevant agricultural or non-agricultural enterprises for the purpose of biological reclamation and further intended use.

In the mining industry, the reclamation of the territory is a complex system of measures to reduce or eliminate the direct and indirect action of mining activities on the environment. No less important is its monitoring stage.

Environmental monitoring of the territory of Rozdil State Mining and Chemical Enterprise "Sirka" involves multidisciplinary research on the state of soils and water bodies, tar residues, phosphogypsum dumps, and the evaluation of geological and geophysical processes, in particular environmental degradation.

The open pit mining is characterized by such kinds of negative changes in the environment:
– gas polluted atmospheric pollution during explosive mining operations in quarries, airborne exhaust gases of technological and transport vehicles, formation of mineral dust during blasting, crushing, loading and transportation of rock masses;
– changes in the water regime of groundwater (closest to the surface of the horizons) and surface water due to the drainage and drainage from the mining;
– pollution of soil and surface water by quarry waters, formation of filtrate during water erosion of waste dumps;
– violation of soil-vegetation cover and use of land under mining and dumps.

The process of liquidation of the mining and chemical enterprise has the following stages:
1) monitoring and forecasting of hazardous phenomena which may arise after the exploitation of deposits and activities of the enterprise;
2) assessment of environmental risk for the population and property;
3) comparison of the cost of active and passive methods for eliminating risk;
4) substantiation of rational use of renewable territories;
5) the development of the necessary measures for the prevention of environmental hazards and the preparation of areas for economic use.

The existing approaches to the reclamation of postmining landscapes are often outdated. The results of various studies and the analysis of the experience of implemented projects allow us to state that in the conditions of reclamation and phytomelioration of postmaying geosystems in areas of development of various types of minerals (coal, oil, sulfur, salts, etc.) for the purpose of their further agricultural use will never be redeemed. Alignment and terracing of slopes with the application of a fertile layer of soil compositions are (costly) expensive and ineffective optimization measures. For industrial forestry it is also necessary to level the surface and ensure the permeability of the area and proper microclimate, which also requires significant costs. In addition, there is the problem of large-tonnage wastes in the mining area, as well as pollutants in the environmental elements, which also needs to be solved.

The liquidation project should contain an environmental analysis of the enterprise activities, environmental forecasting, a system for monitoring the territory during the liquidation and after the elimination period, and it should be completed the formation of the information system of the ecological state of the territory of the influence of enterprise with the provision of free access to information [9].

The main threats to be considered at the stage of the completion of the exploitation of the deposit are chemical pollution of soils, waters and violations of the ecological stability of the territory. Attempts to systematize and identify selected problems are solved in the process of monitoring and forecasting negative impacts of mining activities. The systematic recording of indicators and changes in individual environmental components is the diagnosis and forecasting of existing conditions, i.e. monitoring. Monitoring should be carried out not only during the first stage, but also during the liquidation and reclamation of the enterprise. The object of research may be the entire territory of the mining industry or part of it, which is actively exposed to the mining activity or the results of this activity. On the territory of the Rozdil SMCE "Sirka", monitoring objects can be large-tonnage wastes (dump of phosphogypsum, tailings storages, place, where is situated the tar modifier), soils, water objects, geophysical changes. It is necessary for the implementation of the main monitoring tasks: a set of constituent systems for registering the state of the selected characteristics of the environmental elements that control; analysis of the obtained results, their transformation and distribution; use of the generated database. At each of these stages, there is a need to adapt the accepted method to the specificity of the phenomenon being monitored, the properties of the environmental element under the influence of this phenomenon. All this requires the assessment of technical and analytical capabilities, in this connection, the development of monitoring system design and planning is essential, which would provide the most probable assessment of the behavior of the selected phenomenon with the least financial cost [6, 10, 11].

Various types of sensors can be used to monitor the mining industry. Examples are enzyme-based fluorescent biosensors based on enzymes. This sensor type is commonly used in clinical diagnostics, environmental protection, and the defense industry, and also in those areas where rapid and reliable measurements are required. Initial data for monitoring are maps of the location of the objects of technological influence, which are mining, zones of accumulation of industrial waste with brief information of each of them (height (m), width (m), area (m^2), volume of composite rock (m^3)). The result of the research is the maps with the allocation of zones of technogenic impact of each source. This information is an integral part of the

information system of the territorial complex for the period of completion of operation. Part of the information will present the existing ecological losses of the natural and man-made system, for example, the allocated zones of acidification (depth, area, distribution intensity, habitats of soil pollution, ground waters, fallings (depth (m), diameter (m), slope angle (degree), area (m^2)). In the absence of adequate and timely financing of reclamation works, the issue of studying the processes of self-rehabilitation of environmental elements remains to be necessary: the hydrogeological regime of the region, the activation of off-hazardous processes. Water quality control remains a priority task at the period of postliquidation [1, 5, 12, 13, 14, 15, 16].

1.3 Remote ecological monitoring of the territory of the mining and chemical enterprise at the stage of liquidation

Using data from the website https://earthengine.google.com/timelapse/, which provides space images of the territory of Rozdil State Mining and Chemical Entrerprise "Sirka" from 1985 to 2018, we analyzed the natural state and negative environmental changes of the study area due to anthropogenization. Google Earth Engine is a geospatial processing service. With Earth Engine, we can perform geospatial processing at scale, powered by Google Cloud Platform. Timelapse is a global, zoomable video that lets you see how the Earth has changed over the past 34 years. It is made from 35 cloud-free annual mosaics, one for each year from 1984 to 2018, which are made interactively explorable by Carnegie Mellon University CREATE Lab's Time Machine library, a technology for creating and viewing zoomable and pannable timelapses over space and time. Using Earth Engine, the website combined over 15 million satellite images acquired over the past three decades by 5 different satellites. Most of the images come from Landsat, a joint USGS/NASA Earth observation program that has observed the Earth since the 1970s. For 2015 through 2018, the website combined Landsat 8 imagery with imagery from Sentinel-2A, part of the European Commission and European Space Agency's Copernicus Earth observation program. Exploring Timelapse it could be search, pan, or zoom around. Timelapse is an example that illustrates the power of Earth Engine's cloud-computing model, which enables users such as scientists, researchers, and journalists to detect changes, map trends, and quantify differences on the Earth's surface using Google's computational infrastructure and the multi-petabyte Earth Engine data catalog.

As can be seen from the space photos, Lake Serednie began to form in 1989. Lake Chyste began to form in 1997, and Lake Hlyboke – in 2003. In 2009, the level of flooding of Lake Hlyboke reached 252.4 m. Compared to 1989, in 10 years Lake Serednie has increased its area by about 2 times. Since 2003, the area of Lake Hlyboke has tripled (fig. 2-4) [17].

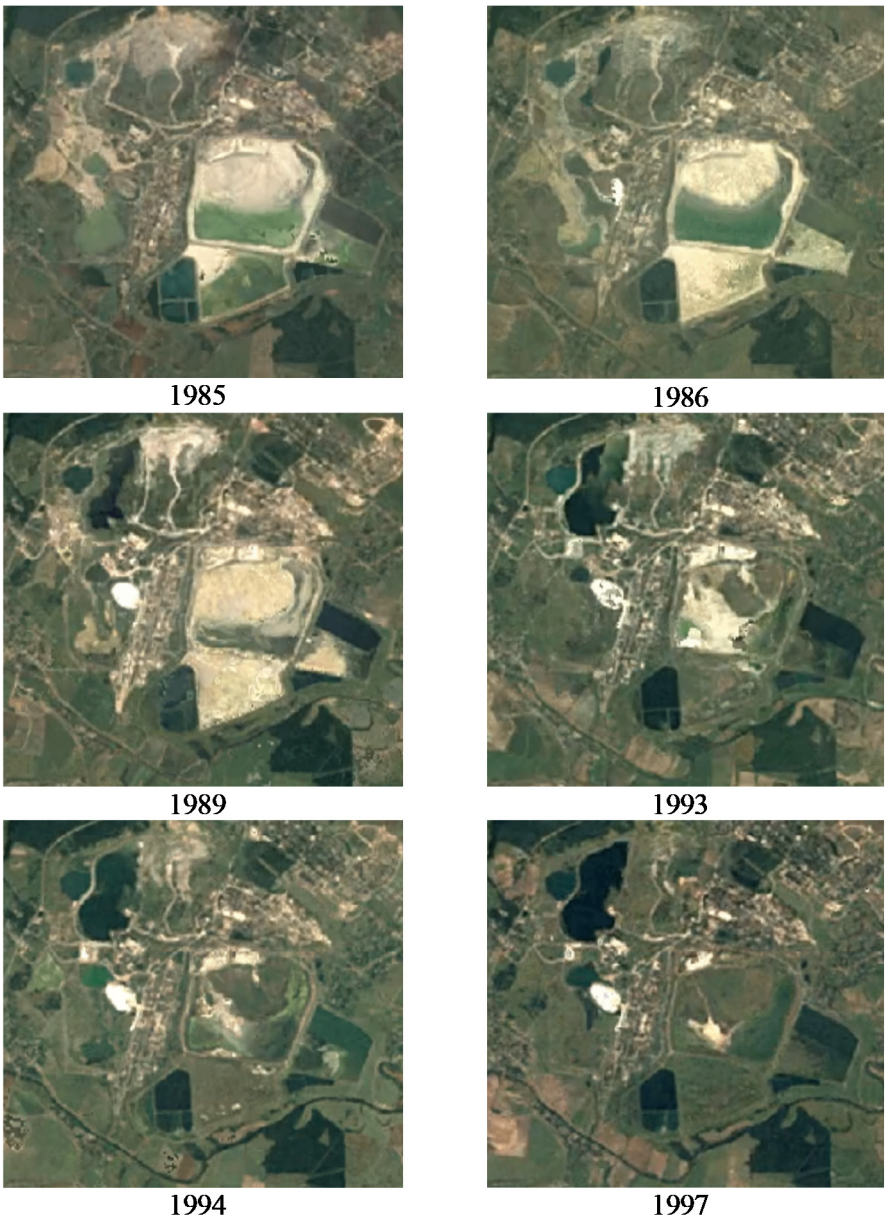

Figure 2. Space photos of Rozdil State Mining and Chemical Enterprise "Sirka", 1985-1997

By analysing space images, it was found that the area of lump sulfur residues over the past 12 years has decreased significantly (fig. 5).

Due to the combustion of elemental sulfur, sulfur dioxide is formed. Combustion areas are marked by a molten surface, and the storage area of lump sulfur over the past 12

years, according to the analysis of space images has decreased significantly. Decrease in the storage area of lump sulfur due to its burning over the last 12 years, established on the basis of the analysis of space images of 2004 and 2016.
Due to the fact that the monitoring of the air quality of the territory of the enterprise and neighbouring settlements was not carried out and is not carried out, you can use the web platform Giovanni.

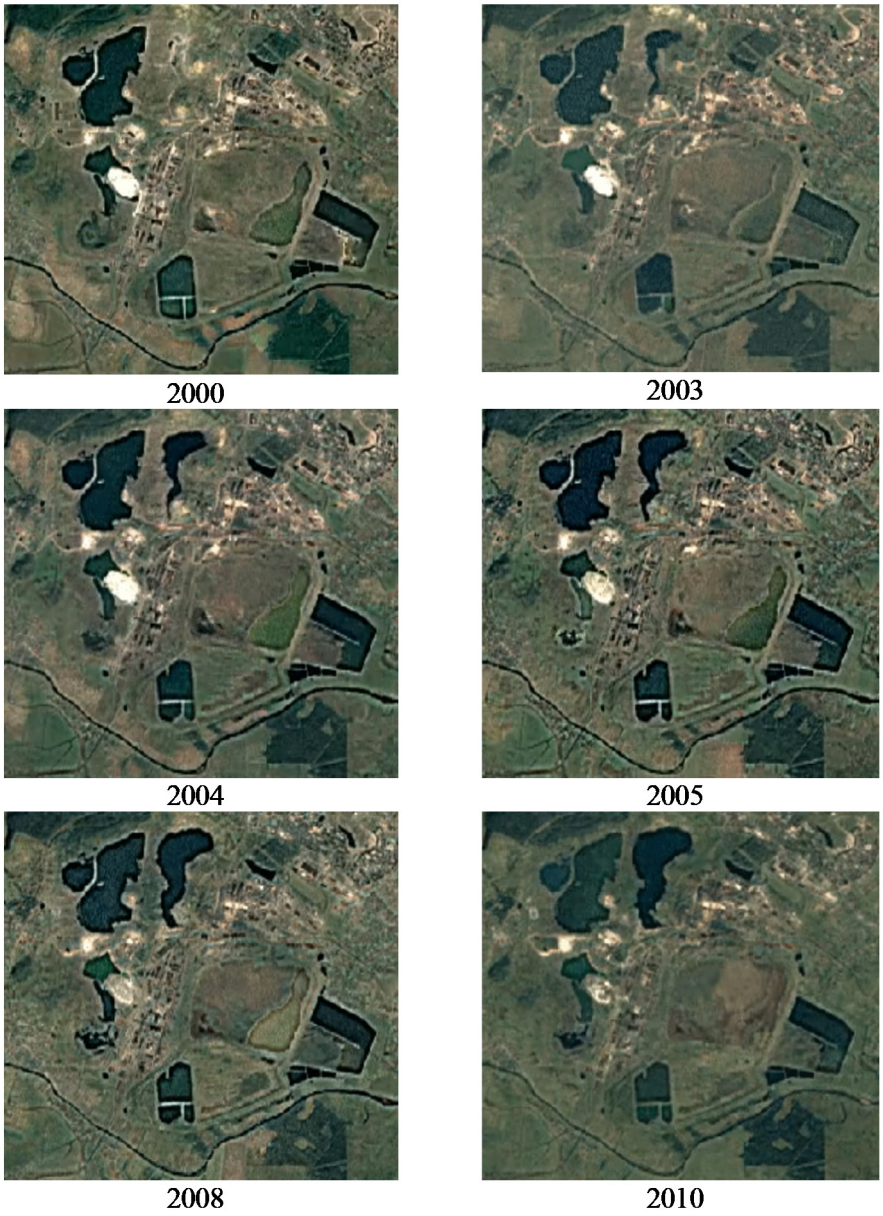

Figure 3. Space photos of Rozdil State Mining and Chemical Enterprise "Sirka", 2000-2010

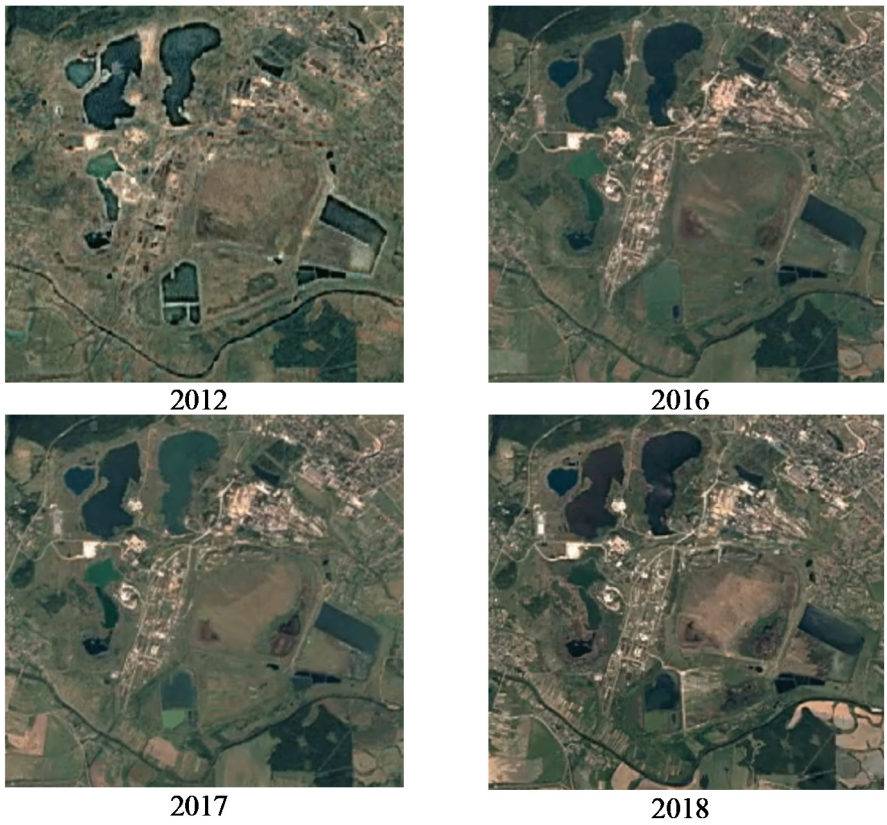

Figure 4. Space photos of Rozdil State Mining and Chemical Enterprise "Sirka", 2012-2018

Figure 5. Space photo of lump sulfur storage 2004 (left) and 2016 (right)

Giovanni, a Web-based tool, eases access, visualization, and exploration for many of NASA's Earth science data sets. The main analytical functions performed by Giovanni are performed by the grid analysis and display system (GrADS). Giovanni was initiated and developed for faster and easier access to and evaluation of data sets at GES DISC. The first implementation of Giovanni was an online visualization and

analysis system for tropical rainfall data sets from NASA's Tropical Rainfall Measuring Mission (TRMM). As the project gained popularity, scientists requested that more satellite data sets be included in Giovanni. To address this demand, developers created multiple discipline- or mission-based data portals. The current Giovanni has evolved further, featuring a new unified Web interface to support interdisciplinary Earth system research, allowing synergistic use of data sets from different satellite missions [18]. This platform displays spatially bound data from NASA satellites in a variety of formats, including animation, planar visualization, time series, averaged values (meridional and zonal), vertical profiles, and more [19, 20].

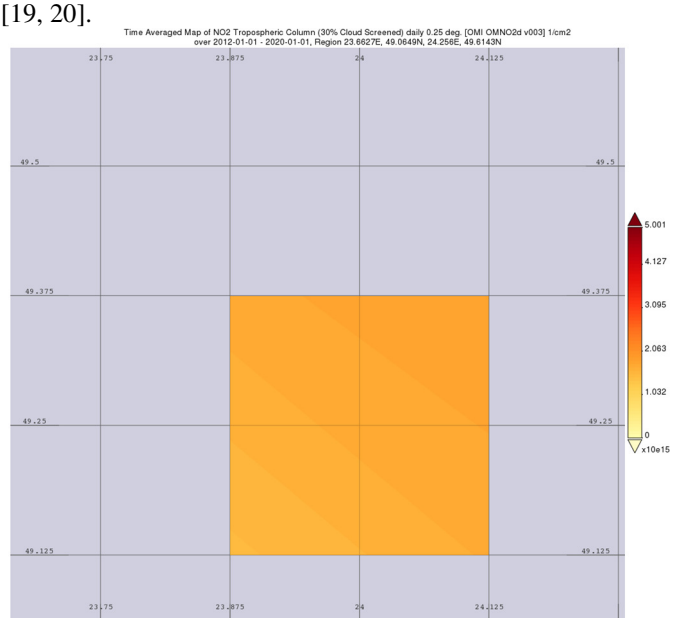

Figure 6. Mapping of zonal division by NO_2 concentration on the territory of the enterprise

The concentration of nitrogen dioxide in the atmospheric air of the troposphere on the territory of Rozdil State Mining and Chemical Enterprise "Sirka" for the period 2012-2020 is mapped (fig. 6) and the dynamics of the amount of nitrogen dioxide on the same territory for the same period is visualized in the form of a graph (fig. 7).

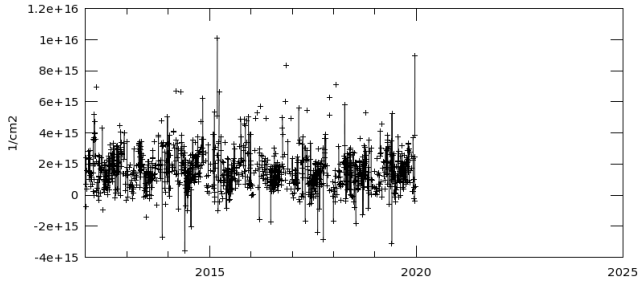

Figure 7. Dynamics of NO_2 quantity on the territory of mining and chemical enterprise

The NASA Giovanni data analysis system has been recognized as a useful tool to access and analyze many different types of remote sensing data. The variety of environmental data types has allowed the use of Giovanni for different application areas, such as agriculture, hydrology, and air quality research. The use of Giovanni for researching connections between public health issues and Earth's environment and climate, potentially exacerbated by anthropogenic influence, has been increasingly demonstrated.[21, 22].

2. Conclusion

Monitoring is one of the main stages of the process of liquidation and reclamation and should be carried out at all stages of liquidation. In addition to the monitoring system in the process of liquidation and in the post-reclamation period, the liquidation project should include an environmental analysis of the enterprise activities, environmental forecasting. This should be completed by the formation of the information system of the ecological state of the territory of the enterprise influence with the provision of free access to information. Compliance with all conditions will allow increasing the ecological safety of the territory and react in a timely manner to unusual ecological situations, which will reduce environmental, social and economic losses.
By analyzing space images, it was found that the area of lump sulfur residues has decreased significantly over the past 12 years. It was analyzed the natural state and negative environmental changes of the study area due to antropogenization.

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