Ground Deformation Mapping of Solotvyno Mine Area Using Radar Data and GIS

O. Trofymchuk, *Y. Anpilova, Y. Yakovliev (Institute of Telecommunications and Global Information Space of NASU), I. Zinkiv (Mykola Lysenko Lviv National Music Academy)

SUMMARY

The analysis of the spatial-temporal changes of the salt-rock massif stress-strain state during the flooding of the Solotvyno mines was made by the authors using the data of terrestrial interferometry within the mine area. The models of geological structures deformation built in the GIS allowed to obtain more reliable estimates of mines impact within the Solotvyno agglomeration on the objects of critical infrastructure and the hydro-ecological state of the Tisza river transboundary basin. The purpose of the analysis was to compare velocities and obtain the volume-balance parameters of the geological environment upper area and the surface deformation. The use of modern technologies for the surface deformations measurement allows to estimate the initial phases of dangerous changes in the stress-strain state of the geological environment and to improve the risk forecast. The main result is identifying a mathematical correlation between the surface sediments and the radial distance of their increase.
Introduction

The current research subjects of the Institute of Telecommunications and Global Information Space are very diverse. One of the key areas of research are using geoinformation technologies (GIS) and remote sensing technologies (Trofymchuk et al., 2019; Korchenko et al., 2019; Trysnyuk et al., 2019), methods of mathematical modeling (Okhariev, 2019) to address pressing environmental safety issues. Among them, it is important to note the study of hazardous processes in geological medium and soils (Trofimchuk, 2002; Trofymchuk et al., 2017; 2018), in particular, the problems of landslides (Trofymchuk et al., 2013; Baum et al., 2014; Kaliukh et al., 2015). A new method for solving the inverse problem in well logging electrometry was also found (Myrontsov, 2019a; 2019b).

In this paper was touched the using spatial data analysis and GIS models to estimate the deformation of the upper area of geological structures of the Carpathian region in the post-mining stage (flooded Solotvyno salt mines, Zakarpattia region).

Method

The research was carried out using modern technologies for measuring the ground surface deformation, allowing to estimate the dangerous changes of the stress-strain state of the geological environment and to improve the risk forecast for the critical infrastructure objects and the public health and safety in the agglomeration.

Results

Solotvyno rock salt mine, located in the Tiachiv district of Zakarpattia region, is a part of the right-bank catchment area of the transboundary Tisza River.

Mine area are located within the first dry terraces, which contributes to the development and active infiltration feeding of aquifers, as well as the development of the flood processes that complicate mining-geological and ecological-geological conditions of opening, development and decommissioning of mines.

Within the fields of the flooded mines, karst-breakdown processes and subsidence of the land surface, which have a long-term character in the conditions of increasing deformations of mine workings and humidification of the saline body (Yakovlev et.al., 2016), are actively expanding.

With the help of the space images processing services, a retrospective analysis was conducted and the volume-balance dynamics of the destructive karst-breakdown phenomena and sediments of the land surface progress were studied by the authors. This material was obtained from the Wayback Digital Archive and used in the construction of surface deformation models in ArcGIS (Figure 1).

Figure 1 Space survey data of the Solotvyno territory as of 13/09/2017 (left) 07/08/2019 (right) (Source: https://livingatlas.arcgis.com/wayback/, 2019).

Overall, the dramatic increase in the freshwater infiltration inflow and the related active development of technogenic karst caused the formation of destructive deformations of the ground surface and rocks
of the residential and industrial buildings foundation, roads, and water-pumping networks of Solotvyno village.

The activation of the deformation field of the industrially destroyed part of the salt dome occurs mainly in the following directions: south to the Solotvyno agglomeration and the Tisza river floodplain and north to the landslide slope of the Magura Mountain (Figure 2).

Taking into account structural-geological and geodynamic heterogeneity of the Solotvyno structure, the authors have created a map of the main zones elements of geological structures (Figure 3) and calculated in percentage ratio the building area experiencing dangerous geodynamic influence in these zones (Figure 4).

**Figure 2** The map of ground deformation Solotvyno mining area map.

**Figure 3** Zones of geological structures of Solotvyno agglomeration
Conclusions

The obtained data of ecological and geological parameters assessment of Solotvyno salt mine post-mining in the phase of uncontrolled flooding of mines allow to distinguish the following dangerous changes of stress-strain state of Solotvyno salt dome section:

- Development of dangerous ground surface deformations outside the predicted subsidence project area;
- The increasing impact of the global climate change hydrometeorological factors (increase in precipitation quantity and unevenness, increasing altitude and frequency of flooding and high waters, warming);
- The danger of increased seismic earthquakes due to hydro-geo-mechanical deformations of the flooded mines under the impact of transit (Vranch zone) and local earthquakes;
- The threat of accelerated development of subsurface and deep-block landslide deformations on the south slope of Magura Mountain (unordered building, water-logging, the formation of weakened zones over the mine number 9 development).

To implement timely the mitigation and protection measures in the areas of flooded Solotvyno agglomeration salt mines impact, under the European Union Research Mission recommendations (Risk Assessment Report, 2016), the following actions are required:

- Improving the monitoring of the natural-technogenic geosystem “technogenic object – environment” based on remote data, physical-mathematical models, geological-geophysical survey and implementation of a program for the expertise development using radar interferometry and magnetic-electrical survey materials;
- Development and implementation of prioritised protective measures;
- Determination of the permissible geological environment changes limit as the main natural-technogenic geosystem safety element;
- Systematic health and safety risk assessment.

Figure 4 Geodynamic influence of the salt mine on the construction of the Solotvyno agglomeration: 1 - zone of potential mega-landslide of Magura Mountain, 2 - zone of volcanic tuffs development, 3-zone of karst-collapse impact, 4 - zones of flooding above historical (old) mines (XIX c.), 5 - flanks of the mine field No.9, 6 - boundary zone of rifts, 7- zones of rifts, 8- zones of development of local landslide and erosion processes, 9 - linear weakened zones above drainage galleries.
References


