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Geodetic monitoring of the protective dam of the Lviv MSW landfill after reconstruction

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SUMMARY

The main purpose of the work is the geodetic monitoring of the protective dam of the lakes of the filtrates of the Lviv MSW Landfill after reconstruction, as well as the analysis and interpretation of the obtained results. In order to achieve this goal, four cycles of geodetic monitoring of the reconstructed protective dam were conducted from May to August, 2018. A geodetic network, which consisted of 2 base and 18 monitoring points, was created for monitoring. To determine the coordinates of the points, a complex of GNSS and linear-angular measurements with using modern geodetic instruments was performed. The processing of the results was performed in specialized geodetic software. On the basis of the determined coordinates of the points of the geodetic network, horizontal and vertical displacements of the points on the reconstructed protective dam in each measurement cycle were calculated, their schemes were constructed and analyzed. For analysis and interpretation of the reconstructed protective dam deformation processes, the transformation from the calculated vectors of horizontal and vertical displacements of points to their average linear velocities over a given period, as well as to the dilation parameter, was made, and schemes of their distribution were constructed. It is established that, the maximum velocities of vertical displacement are identified at the edges of the reconstructed protective dam, while the minimum velocities are at the center; the central part of the reconstructed protective dam is characterized by an increase in the area, that is, expansion; the northern and southern parts of the reconstructed protective dam are characterized by a decrease in area, that is, compression.

Introduction

After waste-slide at the Lviv MSW landfill on May 30, 2016, engineering projects were executed and continue to be implemented to resolve the issues of the safe functioning of the landfill. The purpose of such projects are to rehabilitate and stabilize the body of the landfill according to international standards, in compliance with all technical and environmental standards. In particular, in 2017 and 2018, emergency work was carried out and strengthening and augmentation of the dam of the lakes of the filtrates were executed. The protective dam of the Lviv MSW landfill is located near the village of Velyki Hrybovychi, at a distance of 4-6 km north of Lviv, Ukraine (49°54′04″N, 24°02′15″E) (Figure1). Topographic plan obtained by Lozynskyi, Nikylishyn & Ilkiv (2016) as well as orthophoto map obtained by Savchyn & Lozynskyi (2019) and Nikulishyn et al. (2020) after waste-slide in June 2016 using an aerial survey from UAV Trimble UX-5, were used as the initial data for designing of the dam. The purpose of strengthening and augmentation was the need to reduce the pressure on the soil dam, which was caused by the waste that entered the lakes of the filtrate after displacement and raised the water mirror mark.

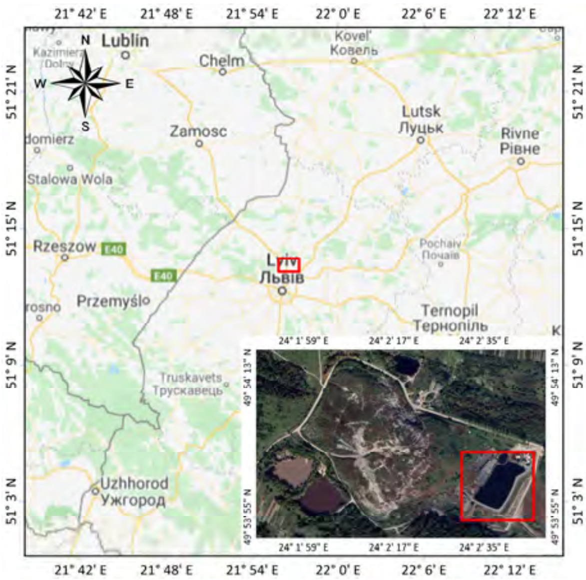

Figure 1. *The geographical location of the protective dam of the Lviv MSW landfill*

It is known, that the structural stability of the dams of the lakes of the filtrate collectors is crucial for the safe functioning of the landfill, as a breakthrough of the dams can lead to the sudden release of a large amount of filtrate into the surrounding areas. Therefore, it is important and necessary to identify the dam deformation processes, the purpose of which is to solve the problem of preventing accidents and to facilitate the normal work of such objects. In this regard, four monitoring cycles of reconstructed protective dam of the lakes of the filtrates of the Lviv MSW landfill were conducted between May and August 2018 (I cycle - 07-09, May; II cycle - 09-12, June; III cycle - 09-12, July; IV cycle - 12-17, August) with using modern geodetic methods and detailed analysis of the obtained results was conducted.

Method

For the monitoring of the reconstructed protective dam of the lakes of the filtrates of the Lviv MSW landfill, a geodetic network, which consisted of 2 bases and 18 monitoring points, was created. The coordinates of the base points were determined by the static GNSS method using Leica TPS1200 receivers. To determine the coordinates of the monitoring points, linear-angular measurements were performed from the base points using electronic tachymeter Leica TCRP1201. From the base points, five sets of measurements on the reflectors (Leica GPR121) mounted on tripods above the monitoring points were performed. Optical centres were used to centre the reflectors and equipment.

The processing of the measured GNSS vectors, lines and angles were performed in the software package LeicaGeoOffice Combined version 7.2. Calculation of corrections for the influence of the ionosphere in GNSS measurements was conducted according to the Hopfield model. Linear measurements include atmospheric corrections for changes in temperature, pressure, and humidity during measurements. Results of GNSS observations were processed by the method of free network adjustment. The coordinates obtained from GNSS observations became the base point during the processing of linear-angular measurements. As a result of processing, the coordinates of base and monitoring points in all measurement cycles were obtained. The accuracy of determining the coordinates of the monitoring points was 2-5 mm, and the accuracy of determining the height was 5-9 mm.

Results

On the basis of the determined coordinates of the points of the geodetic network, horizontal and vertical displacements of the points on the reconstructed protective dam in each measurement cycle were calculated, their schemes were constructed (Figure 2 and Figure 3).

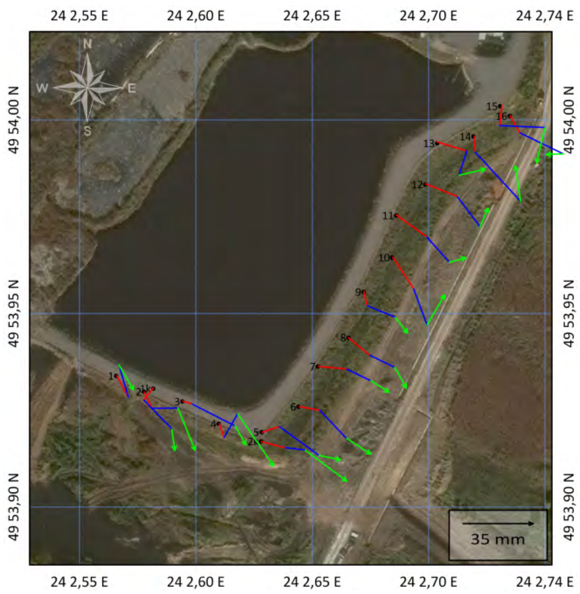

Figure 2.*Scheme of the horizontal movements of the points (→ - between II and I cycles; → - between III and II cycles; → - between IV and III cycles)*

Figure 3. *Scheme of the vertical movements of the points (→ - between II and I cycles; → - between III and II cycles; → - between IV and III cycles)*

Analyzing the presented schemes (see Figure 2 and Figure 3), it can be observed that:

1. The lengths of horizontal displacement vectors between II and I cycles (May and June, respectively) are in the range from 1.2 to 26.0 mm. The maximum vector is detected at point 5. The lengths of the vertical displacement vectors are in the range from +9.2 to –26.1 mm.
2. The lengths of horizontal displacement vectors between III and II cycles (July and June, respectively) are in the range from 1.4 to 32.6 mm. The maximum vector is detected at point 14. The lengths of the vertical displacement vectors are in the range from +3.4 to –12.0 mm.
3. The lengths of the horizontal displacement vectors between the IV and III cycles (August and July, respectively) are in the range from 4.5 to 30.6 mm. The maximum vector is detected at point 4. The lengths of the vertical displacement vectors are in the range from –3.4 to –18.7 mm.

It should be noted that in all cycles, the movements have mainly east and south-east directions.

For analysis and interpretation of the reconstructed protective dam deformation processes, the transformation from the calculated vectors of horizontal and vertical displacements of points to their average linear velocities over a given period, as well as to the dilation parameter (change in area), which characterizes the relative expansion (increase in area) or compression (decrease in area), is performed. The obtained values of the average linear velocities of the vertical displacements of the points were used to illustrate the spatial distribution of the velocity field of the vertical displacements of the reconstructed protective dam (Figure 4). A graphical illustration of such distribution allows to identify zones of uplift and lowering the territory [Savchyn et al., 2019]. The obtained dilatation values were used to illustrate its spatial distribution in the reconstructed protective dam (Figure 5). It should be noted that the algorithm presented in [Savchyn & Vaskovets, 2018] was used to calculate the dilation parameter.

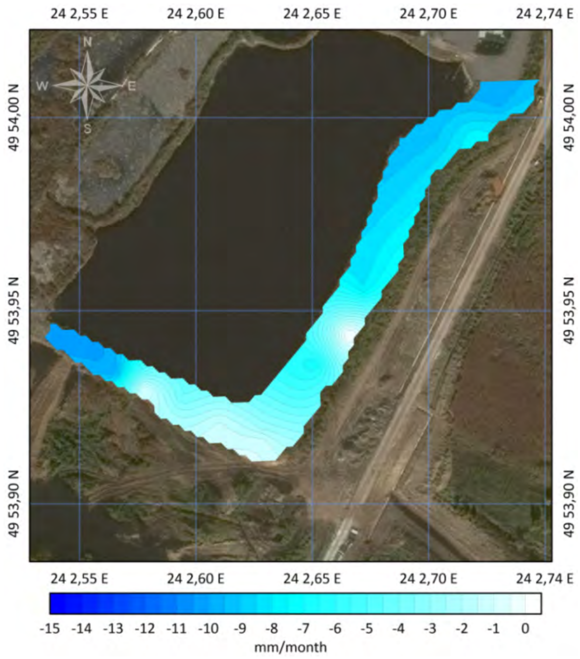

Figure 4. *Spatial distribution of the velocity field of vertical movements*

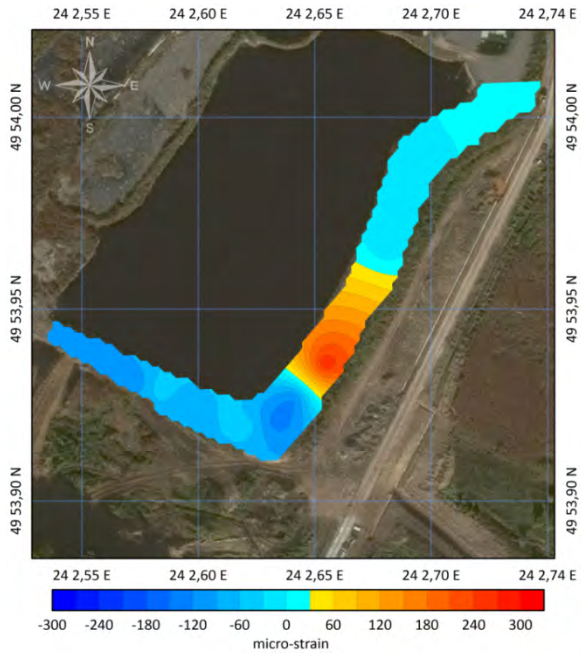

Figure 5. *Spatial distribution of the Earth's surface dilatation velocity*

Analyzing the spatial distribution of the velocity field of vertical movements (see Figure 4), it can be observed that, in general, the reconstructed protective dam is subsided, but the subsidence velocity is different. The range of vertical velocities varies from -0.5 to -10.8 mm/month. The maximum velocities of vertical displacement are identified at the edges of the reconstructed protective dam, while the minimum velocities are identified in the centre.

Analyzing the spatial distribution of the dilatation velocity field (see Figure 5), it can be observed that the central part of the reconstructed protective dam is characterized by an increase in the area, that is, expansion. Instead, the northern and southern parts of the reconstructed protective dam are characterized by a decrease in area, that is, compression. The values of the calculated average linear velocities of horizontal displacements are quite large and are in the range from 0.9 to 12.2 mm/month. The highest values of the average linear velocities of horizontal displacements, from 10.3 to 12.2 mm/month, are observed in the northern part of the reconstructed protective dam, and the lowest values, from 0.9 to 2.8 mm / month, are observed in the southern part.

Conclusions

The complex of GNSS and linear-angle measurements for determination of coordinates of points of base and monitoring geodetic basis for monitoring of the reconstructed protective dam of the lakes of the filtrates of the Lviv MSW Landfill were conducted.

It is established that most of the vectors of horizontal displacements of points have east and south-east direction. Such direction of movement of points is caused by the pressure of the filled lake on the reconstructed protective dam. The lengths of the horizontal displacement vectors ranged from 1.2 mm to 32.6 mm. The maximum horizontal displacements of the points are recorded in the first measurement cycle. In the following cycles, the attenuation of landslips processes is observed. Most of the points are subsided. Vertical displacements of points occur in the range from +9.2 mm to -26.1 mm. The maximum vertical displacements of the points are also recorded in the first measurement cycle.

The performed complex of works confirms the presence of horizontal and vertical movements in the reconstructed protective dam of the lakes of the filtrates of the Lviv MSW Landfill, so for their control, we recommend to continue monitoring.

Acknowledgements

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