Research on Hydrogeological and Geological Conditions of the Slatinice Dump Base

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Abstract. The aim of this article is to clarify the geological structure of the area of interest (in particular the atmospheric water supply area), the assessment of hydrogeological conditions (determination of dominant collectors, flow directions of shallow and deep groundwater flows). From the aspect of the future process of the bordering Vršany quarry, part of the Slatinice dump will be extracted in the future. Since the basic factors that predispose to sliding (slope of the base, the orientation of the base, the character and nature of the deposited soil, etc.) cannot be influenced at the present or in the future, the only way to improve stability of the dump and to minimize the possibility of larger slope deformations, the long-term improvement of the shear contact strength at the interface of the dump with its subsoil.

1. Introduction

For this reason, the article deals with the geographical and geomorphological description of the area of interest. Then the geological characteristics of the quaternary sediments, burned clay (baked clay) and watered horizons (aquifer) of the Slatinice dump and the hydrogeological characteristic of the area of interest together with the results of the hydrogeological monitoring with description and graphic illustration of the monitored period are followed.

In the northern part of the dump, in contact with the highest level of the Slatinice dump and the heel of the Ressl hill, an increased spatial movement of the measuring points was registered at the beginning of geodetic monitoring of the hopper, with a negligible horizontal component of the motion vector. The body of the hopper seats in these places on a very steep backrest of the Ressl hill (up to 25°).

The southern part of the hopper occupies an area that was largely hit by a landslide in May 1983, at that time still active dumps. As a result of rapid sloping movements massive mixing of the masses inside the hopper body resulted in a partial transfer of softer aquifer into the lower and middle positions of the hopper. As a result of the slope crash, there were local qualitative and structural changes of the dump body. It is obvious that the initial way of setting up the Slatinice dump was not right, as a result of which the dump after 10 years of complicated founding eventually collapsed in 1983, [1].

2. Specification of the area of interest

The area of interest belongs to the Slatinice-Bylan area of the Mostecka basin and represents the elevated body of the internal dump of Slatinice and its immediate vicinity. In the north, the territory reaches the southern edge of the Saxony reservoir. The eastern constraints of the area of interest represent the adjacent slopes of the Ressl hill up to the area beneath the garden colonies, in the south the area is limited by a corridor of coal exits from the Vršany quarry, [2]. In the west, the boundary of the area of interest touches the road in the direction of Bylany - Komořany.
The Slatinice hopper fills the area of the residual shaft of the former Slatinice surface brown coal quarry. Almost the whole area of interest lies in mining area Slatinice. The northern part of the wider surroundings of the area of interest belongs to DP Holešice, south to DP Vršany. The vast majority of the surrounding area is affected by mining activities.

Geomorphologically it is the connection of the Mostecka basin with the volcanic ridges of the Bohemian Central Mountains. The morphologically dominant element is the clearly volcanic elevation of the Ressl hill (413 m above sea level) and the following back ridge of the so-called "Čepirohyheights". The Ressl hill is the westernmost elevation of the Bohemian Central Mountains, and the surrounding terrain is approximately 120 m high. At present, in the mining area Slatinice, the original pelvic sediments are occurred only to a limited extent. Some of these sediments are located in a narrow lane at the foot of the Ressl hill and between the northern part of the Slatinice dump and the southern edge of the Saxony reservoir. In the west, the original pelvic sediments are located in the area between the Slatinice dump and the conveyer section of the Vršany quarry. The area of interest is greatly influenced by the anthropogenic activity associated with mining and the preparation of brown coal mining. A large part of the area was extracted from the Slatinice quarry, and the residual pit was subsequently filled with the Slatinice internal dump [3].

The clear situation of the area of interest is shown in Figure 1 below.

![Figure 1. Digital model of terrain relief of interest area (2x exceeded)](image)

3. **Geological and hydrogeological characteristics of the area of interest**

3.1 Geology of the Slatinice dump and its immediate surroundings

In 2009 a hydrogeological survey was begun at the Slatinice dump. In 2011, the monitoring system was completed with new facilities in the area under the gardening colony at the foot of the Ressl hill. From 2013 onwards, an intensive hydrogeological survey is being carried out in the Slatinice dump and its surroundings, which aims at specifying the groundwater flow regime and ensuring a reduction...
in the strained groundwater level in the collectors encountered. During the exploration work, dozens of monitoring boreholes were fitted into the collectors. These boreholes are deployed throughout the whole area, but most of them are concentrated in the north-eastern and eastern parts of the Slatinice dump, under the Ressl hill. Several important drained collectors, quaternary sediments, burnt clays, weathered volcanic rocks, dump soils, and a contact layer between the dump and its subsoil were found in the area of interest, [4, 5, 6].

3.1.1 Quaternary sediment collector. The original, large-scale collector of quaternary sediments was largely extracted by the overburden works of the former Slatinice quarry. At present, the sediments of this collector are located at the foot and slopes of the Ressl hill. From the lithological aspect, the quaternary sediments are represented by dislodged proluvial sutures and deluvial sediments, the character of sandy clays. Drills monitoring the drainage of this collector are located in two areas. The first area is located in the northern and north-eastern part of the area at the foot of the Ressl hill. The second area consists of monitoring wells situated in the eastern part of the territory, under the gardening colony at the foot of the Ressl hill.

3.1.2 Collector of burned clay (baked clay). In the area of interest, eleven monitoring boreholes observe the groundwater level in the collector of burned clay. One borehole “SLO 1” from this collector draws groundwater. These boreholes are deployed from the northern edge of the Slatinice dump to its south-eastern part. The vast majority of wells are situated in the north-eastern part below the Ressl hill. There is also a pumping bore called SLO1. The originally large body of this collector, located at the foot of the Ressl hill, was largely extracted from the former quarry of Slatinice. The material was used for the construction of reinforced service roads and parking areas.

3.1.3 Watered horizons of monitored area. The actual body of the dump consists of a heterogeneous mixture of soils of predominantly clayey and sandy character, which were founded in the past century in the excavated area of the former quarry of Slatinice. A hydrogeological survey conducted in recent years has shown significant drainage of the contact layer between the hopper and its subsoil. At the same time, in some parts of the territory, the watered horizons, located within the own dump body, are encountered. The overwhelming majority of the monitoring boreholes are equipped for groundwater level monitoring, flowing over the dump body contact layer, [7].

3.2 Hydrogeology of the Slatinice dump and its immediate surroundings
At all monitoring boreholes carried out continuously on the territory of the Slatinice dump and in its immediate surroundings, systematic and regular monitoring of the level of groundwater levels was started as soon as the boreholes were put into operation. At present, part of the boreholes is measured at two-week intervals, while the remaining part of the boreholes is continually monitored, [7,8 ].

In the north and northwest part of the area, the collector of quaternary sediments monitors a total of 5 wells (HY 457 / H2, HY 459 / H4, HY 460 / H5, HY 463 / H9 and HY 468 / H14). The groundwater level at the wells HY 457 / H2 and HY 459 / H4 stagnates for a long time below the lower geological boundary of the collector. The covered collector is therefore unsaturated in this part of the area and there are no preferential paths of shallow groundwater flow. For boreholes HY 460 / H5, HY 463 / H9 and HY 468 / H14, the shallow groundwater flow regime is very dynamic; the movement of the surface in these objects is influenced by climatic factors (atmospheric precipitation, temperature, melting snow cover). This year, due to landscaping and the removal of vegetation in the northern part of the area, the groundwater level in the catchment area decreased gradually. Figure 2 shows the time course of the water level movement of the above-mentioned wells.

In the area under the garden colonies, aquifer quaternary sedimentation is monitored by four boreholes (SL 302, SL 303, SL 304 and SL 317 / H20). At SL 302, the groundwater flow regime is very dynamic. For boreholes SL 303 and SL 304, the groundwater flow regime in 2011-2015 was characterized by frequent fluctuations in water levels. In the rest of the monitoring period, the water level was gradually declining, with no fluctuations. The time course of the water level of these boreholes is shown in Figure 3. Borehole SL 317 / H20 is characterized by a dynamic movement of
the groundwater level. During February to April this year, the water level in the catchment area was temporarily increased by about 0.6 m. The level then dropped to the original level and in the rest of the monitoring period a gradual drop in water levels accompanied by frequent fluctuations could be observed. The movement of the groundwater level at this borehole is shown in figure 4.

Figure 2. Movement of groundwater level in the quaternary sediment collector (N and NW part of the territory)

Figure 3. Movement of groundwater level in the quaternary sediment collector (the area under the gardening colony)
3.2.1 Collector of burned clay. The drainage of this collector must be assessed individually in terms of the location of the monitoring boreholes. During mining operations, the originally large collector, which lined the foot of the Ressl hill and the barren zone (in the northern part of the territory), was completely or partially removed. As a result of this intervention, there have been fundamental changes in the groundwater flow regime in this collector. In the northern and north-eastern part of the area, an aquifer of burned clay, overburdened with the Slatinice dump, so-called "buried", was found by drilling. From the point of view of the geological structure of the body of burned clay, both the starting points (at the foot of the Ressl hill) and the overburdened sections, which partially removed this body, were encountered.

In the northern part of the area, the collector of burned clays only monitors the H1 well. An analysis of the groundwater level of this borehole shows that during the current monitoring period, the water level in the aquifer is decreasing. Only in periods with abnormal precipitation or snow melting there is a sudden increase in the groundwater level followed by its rapid drop to the original level. It is clear that the collector is very permeable in this part of the area, [9, 10, 11].

The results of the current monitoring confirm the original assumption that the H28 is a natural hydrogeological distribution of this collector. Most of the groundwater flows through this structure towards the drainage centre (SLO1 borehole) and along the sloping slopes of the former Slatinice quarry toward the north. The remaining part of the groundwater flows very slowly after the slope of the base of the hopper toward the southeast.

The depression cone produced by the SLO1 drainage borehole has an atypical character. The results of the groundwater levels indicate that it has an oval character with a significantly longer axis extending in the direction of the NW-SE. From the results of the monitoring of water levels at the boreholes H7, H12 and H15, it is obvious that the pumping of groundwater on the SLO1 borehole influences the behavior of the water level of these boreholes and thus can determine the extent of the depression cone created by the borehole. The results of the groundwater levels of the H13 and H16 wells further indicate that there is a hydraulic barrier in the area defined by the central drainage line.

The movement of the water levels in the burned clay collectors at the wells H1, H7, H12, H13, H15 and H16 is shown in the following figures 5-8.
Figure 5. Movement of the groundwater level (GWL) in the collector of burned clay (borehole HY 456 / H1)

Figure 6. Movement of the GWLs in the collector of burned clay (boreholes HY 462/H7, HY 466/H12 a HY 469/H15)
Figure 7. Movement of the GWL in the collector of burned clay (borehole HY 467/H13)

Figure 8. Movement of the GWL in the collector of burned clay (borehole SL 321/H16)
3.2.2 Watered horizons of Slatinice dump. Watered dumping horizons have been encountered throughout the area of interest. Major the part of monitoring boreholes were equipped to monitor hydrogeological conditions on the basis of the hopper (contact layer). From the point of view of hydrogeology, it is essential to give increased attention to the eastern part of the hopper (an area affected in the past by extensive sliding movements). In this part of the area, the drainage basin has an artesian character. The first mention of the artesian strained groundwater level in this part of the territory dates back to 1984 (Brus). The survey conducted in 2014-2017 confirmed this fact.

A part of the boreholes was designed and equipped to monitor the drainage of the Slatinice hopper base in places with a low power of the dump body. The flow regime of these waters can best be documented on the H21 and H22 monitoring wells. For both boreholes the water level is typical of its considerable variation in short and longer time intervals. Depending on the depth of groundwater circulation and rock formation, the flow mode is more or less dynamic, [12].

![Figure 9. Groundwater level movement based on the Slatinic Dump (low-power area)](image)

4. Conclusion
The activity and velocity of the displacement of the hopper layer over a steeply inclined, deflated substrate is correlated with the amount of water flowing into the hopper. The results of the drilling hydrogeological survey from 2013 to 2017 confirm that there is a considerable amount of underground water flowing from the Ressl hill into the hopper, which is culminating in precipitously rich seasons. The endowment zone of the eastern part of the area is an extensive valley deeply cut into the adjacent slopes of Ressl hill. The water from the atmospheric precipitation, which falls into the basins of this valley, runs down the slopes into the area of the garden colony, where the deluvial body dug up with a dump. The results of the monitoring show that groundwater flowing through this body saturates both the dump soil and the hop base in this part of the area.
Watered horizons of dump have been encountered throughout the area of interest. Most of the monitoring objects were equipped for tracking hydrogeological conditions on the basis of the hopper (the so-called contact layer). In terms of solved problems, it is essential to give increased attention to the eastern part of the area of interest (a region affected in the past by extensive sliding movements). In this part of the area, the drainage basin has an artesian character. The movement of the groundwater level is quite uneven in this part of the area.

The results of this research can contribute greatly in the future to the project of the design of a complex drainage system. Such a drainage system should contribute to the elimination of incoming groundwater into the area of the Slatinice dump and to the reduction of the strain on its basis.

Due to the subsequent processes of the neighbouring Vršany quarry, the stability of the future shape of the Slatinice dump will be a prerequisite for the exploitation of the remaining part of the bearing.

References
[1] Burda, J. „Long-term forecasts of the future development of voltage-deformation and gravitational processes and movements on the Slatinice Dump“, VÚHU a. s. 2017
[2] Bejšovec, Z. „Assessment of groundwater regime changes caused by SHP mining activities, indicative determination of groundwater resources and reserves and possibilities of their use“, VÚHU a. s., 1994
[3] Burda, J. „Assessment of groundwater regime changes caused by SHP mining activities, indicative determination of groundwater resources and reserves and possibilities of their use“, VÚHU a. s. 2017
[4] Brus, Z. „Evaluation of the drilling survey in the Vršany quarry dump“, VÚHU a. s., 1984
[5] Fultner, J. „Evaluation and design of measures to ensure the stability of the wider area of the eastern slopes of the Vršany quarry during the mining in the DP Slatinice“, VÚHU a. s., 2012
[6] Kemel, M. „Climatology, Meteorology, Hydrology“, ČVUT, Praha, 1996, ISBN 80-01-01456-8
[7] M. Drusa, J. Vlcek.: Importance of Results Obtained from Geotechnical Monitoring for Evaluation of Reinforced Soil Structure – Case Study, Journal of Applied Engineering Sciences, De Gruyter Open, ISSN: 2247-3769. Vol 6. Issue 1/2016. DOI: 10.1515/jaes-2016-0002
[8] Giang N., Vondráčková, T., Drusa, M., Kovalčík, L., Stopka, O., Sensibility of Sandy Soils Shear Strength Parameters on a Size of Spread Foundation, Procedia Earth and Planetary Science. - ISSN 1878-5220. Elsevier 2015 - S. 304-308. doi:10.1016/j.proeps.2015.08.075
[9] Žižka, L. „Continuous monitoring of the ground water level in the base of the waste dump body (Slatinice wastewater, North Bohemia, Czech Republic)“, 17th International Multidisciplinary Scientific Geoconference, SGEM 2017, Albenia, Bulgaria, ISBN 978-619-7105-99-5
[10] M. Drusa, J. Vlcek.: Importance of Results Obtained from Geotechnical Monitoring for Evaluation of Reinforced Soil Structure – Case Study, Journal of Applied Engineering Sciences, De Gruyter Open, ISSN: 2247-3769. Vol 6. Issue 1/2016. DOI: 10.1515/jaes-2016-0002
[11] Žižka, L. „Implementation of geotechnical and hydrogeological survey in the wider area of DP Slatinice“, VÚHU a. s., Most, 2015