Mikoviny Sámuel Doctoral School for Earth Sciences
Faculty of Geological Engineering
University of Miskolc

Director of Doctoral School:
Dr.h.c.mult.Dr Ferenc Kovács university professor
ordinary member of the Hungarian Academy of Sciences

Effects of Mining Dewatering in the Mátra-Bükkalja Opencast Mining Area

Summary of PhD dissertation

Written by:
János Breuer
certified mining engineer
individual PhD candidate

Supervisor:
Dr József Molnár
associate professor
PhD in Engineering Sciences

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I. Research background, objectives

In the course of the exploitation of Hungary's mineral resources, as they mostly represent young geological formations, flood risk plays an outstanding role among the natural and mining hazards. The issue gains special importance in the mining of opencast areas, where besides the water stored in the underlying and top layers of the beds to be exploited, there is a risk presented by surface precipitation and water flows (floods) due to the considerable size of open surface areas.

After the structural changes in the last decades, the production in the Mátra-Bükkalja lignite area plays an outstanding role in Hungarian mining activities, as it tends to give an ever greater part of Hungarian coal production. In the area, an essential precondition for safe mining activities is the reduction of the pressure of the underlying water storing layers, the reduction of the pressure and water content (the dewatering) of the top water storing layers as well as the protection of open mining areas and refuse dumps against surface waters (precipitation and surface water flows).

Mining dewatering, the reduction of the pressure and water content in the water storing layers, preliminary dewatering and the liftover of water during mining in an area of considerable size – in the territory of the depression area - for the sake of the protection of the opencast mining areas causes a stress change in the top layers, which in turn induces consolidation and movements in both the top layers and on the surface. The dewatering of layers in the territory of the depression area may affect the water balance of the layers near the surface and influence water tables in the area concerned.

If the dislocations in the top and surface layers exceed a certain level or intensity, they may present a danger for both the facilities of mining and other industrial facilities as well as naturally for the infrastructure, residential buildings and other facilities in the area. It has become a 'tradition' to raise the issue of the responsibility of mining for any such damage caused.

Therefore, it is important in relation to this issue that scientific investigations define the spatial extension and level of the actual effects of mining dewatering activities so that decisions can be based on facts.

During the dewatering of opencast mines, primarily it is the gravitational water supply that leaves the pores, neutral stress is reduced, effective stress increases, and as a result, void ratio is reduced, consolidation water supply is squeezed out, and parallel with the start of the consolidation there is a subsidence of the top layers and the surface.

Water level falling is a complicated process in space and time. In its analysis, one of the fundamental issues is at what critical average water level lowering the consolidation resulting from the increase of effective stress starts.

In the analysis of the time flow of subsidence, the other fundamental issue is to define with what delay primary consolidation begins after the start of the dewatering (water liftover) process and with what delay surface dislocation (subsidence) presents itself.

In general (in the commonly used way), the time of the surface dislocation and the extent of the dislocation (in theory: the subsidence) and the unfolding in time of the whole phenomenon can be registered with surface levelling measurements. However, it is difficult to determine the time of the start of the subsidence and the extent of the dislocation accurately for two reasons. One is the accuracy of the particular levelling method (mean error of levelling), and the other – and with the present measurement technologies this is the more significant one – is that the surface and near-surface layers (where measurement points are established) may shift considerably (5-20 mm) depending on their clay content due to surface precipitation. Because of this, it is an extra task to distinguish dislocations due to the swelling or contraction of surface clayish soils resulting from the effect of precipitation from the values of consolidation and surface subsidence arising from mining dewatering (reduction of layer water level).

Among the effects of mining dewatering, it is a recurring issue whether water table falling and the running dry of groundwater wells are caused by mining activities or not. Therefore, it is an important research task to analyse the relation between precipitation and water tables and to define the fluctuation in time of these two parameters. Further, a related issue is the analysis of the fluctuation of precipitation and layer water levels and the interactions of precipitation, water tables and layer water levels. In this investigation, it is an important question to analyse and define the variation in time and extent of the relation.

II. Research methods applied

In the exploitation of opencast mines, the resources affected by dewatering generally have a highly complicated structure, where below the surface soil layers, sand, clay and coal(lignite) beds follow one another in the series of layers. These layers possess very different hydraulic, physical and mechanical parameters, which lead to different consolidation parameters under the changes of pressure and water content.

In the case of a relatively complicated layer structure and multi-bed resources, it is difficult to analyse the relation of water level falling and surface subsidence and it is generally hardly possible to calculate the actual expected value with the help of general laws (formulae). Therefore, in our investigations this issue has been studied by the processing of actually measured – practically "in situ" – data. Work has been based on the analysis of the measurement data of water level falling and surface subsidence with statistical methods.

Statistical methods have been applied in the processing of levelling data, precipitation, water table and layer water level values and data, and in the determination of the critical water level falling and the hydraulic gradient. In verifying or refuting the correlation between certain – presumably related – parameters, classic statistical methods have been applied.

In the analysis of the variation in time of certain parameters, in the determination of the parameters of periodic changes and in the comparison of periods, the method used in geophysics (spectral analysis) has been applied, which is probably a novelty of the dissertation.

III. Summary of scientific results achieved in the investigations

1. In the Bükkalja area, with rich and medium clayish soils, the soil shrinkage presenting itself in the surface layers below 50-60 mm/month and 500/550 mm/year precipitation values causes (may cause) an average 8-10 mm surface subsidence, whereas the swelling of the surface layers presenting itself above 60 mm/month and 600 mm/year precipitation values causes (may cause) a 6-8 mm surface rise. These surface dislocation values should be taken into account in the evaluation of levelling results. These movements should likewise be taken into consideration in the evaluation of the surface dislocations caused by mining activities (layer water lowering).

2. In the Bükkábrány area, surface subsidence already starts once 4-8 water column metre (0.4-0.8 bar) depression is reached. The condition for the start of surface dislocations (s>0) is a hydraulic gradient of 0.03-0.04 w.c.m./w.c.m. with a smaller bed depth and one of 0.08-0.10 w.c.m./w.c.m. with a larger bed depth. A s=10 mm subsidence is generally linked to a gradient value of 0.05-0.10 w.c.m./w.c.m. in the area concerned. According to some measurements, only a gradient value of 0.15-0.20 w.c.m./w.c.m. resulted in a surface subsidence of over 10 mm (s>10mm).

3. The time delay between water level falling and surface subsidence increases as a function of depth (top layer thickness).
   After the start of water level lowering, surface dislocations begin at a depth of 20-40 metres after 1-2 years (s≥0), while at a depth of 60-80 metres after 3-4 years and at a top layer thickness of over 100 metres after 5-7 years.
   A surface dislocation that can surely be detected (s>10 mm) – as it exceeds the extent of the swelling resulting from the changes in the water content of the surface clayish layers – occurs at a 20-40 mm bed thickness after 2-4 years, at a 60-80 m bed thickness after 4-6 years and at one over 100 m after 8-12 years.

4. Water tables vary in the same way depending on the amount of precipitation both in areas affected (Ludas, Detk) and unaffected (Mezőkövesd, Mezőkeresztes) by mining dewatering (in the case of layer water lowering). The amount of **monthly precipitation** only causes a direct rise in water tables with exceedingly high values of over 150-180 mm.

- during or after the months with precipitation values below 40-60 mm/month (especially if annual precipitation is also below 400 mm/year) groundwater tables fall considerably, with up to 2-3 metres,
- with 60-80 (100) mm/month precipitation values, generally no effect can be detected on water tables,
- a precipitation of 80(100)-120 mm/month generally causes no detectable effect, with an occasional minimal effect,
- with 120-140 (150) mm/month precipitation, there is generally a detectable effect to raise water tables, especially if annual precipitation values are also above 600 mm/year,
- a precipitation value of over 140(150) mm/month results in a considerable rise in water tables exceeding 1-2 metres within a short time (1 month).

5. The quarterly averages of monthly precipitation values and especially the average annual precipitation values display a distinct periodic variation in time.

- Water tables generally follow the changes in precipitation amounts after one year, as is shown in the diagrams broken down to years,
- in a period with a 600-700 mm/year precipitation value, exceeding the many-year average (560 mm/year) by 100 mm/year, there is a detectable rise in water tables, which in some years may amount to 1-1.5 m,
- a precipitation amount of over 700 mm/year, exceeding the many-year average by 150-200 mm, infallibly results in a considerable, 2.5-3 m rise in water tables,
- precipitation values of under 400 mm/year, lagging behind the many-year average (560 mm/year) by 150-200 mm, result in a well-detectable water table falling of 1-2 metres. This effect may be exerted over several years.

6. The variation in precipitation only affects layer water levels at very high, 140-200 mm/month precipitation values and only in the case of a water storage layer set at a limited depth. This effect is only exerted down to a depth of 35-45 metres (Detk: layer -1/0 at a depth of 30-40 metres). At a greater depth, not even an exceedingly high precipitation value causes any effect in layer water levels (Ludas: layer-1/0 at a depth of 45-65 metres).

7. The layer water level falling resulting from water liftover has no significant effect on the fluctuation of water tables according to the parameters of regression analysis. (Obviously with the exception of the case when ‘groundwater wells’ are established on a water storing layer near an opencast mine affected by mining dewatering.)

8. On the basis of the spectral analysis of the precipitation and water table parameters in Mezőkeresztes and Ludas, it can be stated that both the fluctuation (change in time) of precipitation and water tables display a distinct cyclic character.
There is a very strong correlation between these two parameters, which leads to the conclusion that the fluctuation (change in time) of water tables can be primarily traced back to the variation in the amount of precipitation.

9. As regards the variation in precipitation and water tables:
- **in both areas,** there is a **major** cycle of 3.1-3.8 years **in the variation** of annual **precipitation** and a **minor cycle** of the same duration **in the fluctuation of water tables,**
- in Ludas, the period of 4.6-4.9 years can be detected **as a major cycle in the variation of** annual **precipitation** and **as a minor cycle in the fluctuation of water tables,** whereas in Mezőkeresztes it presents itself **as a minor cycle** in the variation of both parameters,
- the period of approx. 7 years is present in both areas as a minor cycle for both parameters,
- **there is a distinct** (relatively regular) **major cycle of 11 years in both areas in both the fluctuation of precipitation and water tables.**

On the basis of the results, it is justified to postulate a **cause-effect relationship between annual precipitation values and the average annual fluctuation in water tables.**

10. The results of spectral analysis indicate a round **0.7 year difference in time** between **maximum precipitation and water table values.** (in Mezőkeresztes 0.76 years, in Ludas 0.68 years)

IV. Publications on the subject of the dissertation

1. **Breuer, János**: Múlt és jövő az észak-magyarországi lignitbányászatban [‘The present and past of lignite production in Northern Hungary’]. Bányászati és Kohászati Lapok. Vol. 134. (2001) No.6.
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3. Kovács, F., **Breuer, J.,** Kortmann, W., Estimated delay of surface subsidence resulting from a decreasing water table. High technologies: tendencies of development. Matters of XIII. International Technical Science Seminar, 12-17 September, 2003. Kharkov-Alusta, 2003. pp. 109-116. ISBN 966-7810-50-X
4. Kovács, F., **Breuer, J.,** Kortmann, W., The estimated primary stage of surface subsidence near Detk. High technologies: tendencies of development. Matters of XIII. International Technical Science Seminar, 12-17 September, 2003. Kharkov-Alusta, 2003. pp. 117-123. ISBN 966-7810-50-X
5. Molnár,J., **Breuer, J.,** Kortmann, W., Groundwater Table Influenced by the Amount of Precipitation in the Mezőkeresztes Region. Lucrarile Stiintifice ale Simpozionului International “UNIVERSITARIA ROPET 2003” Ecologie si protectia mediului. Editura UNIVERSITAS Petrosani. pp. 27-29.
6. Kovács, F., Molnár,J., **Breuer, J.,** Kortmann, W., Water Table of Sand and Gravel Layers Influenced by the Amount of Precipitation in the Visonta Mine District. Lucrarile Stiintifice ale Simpozionului International

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7. Kovács, F., **Breuer, J.,** Kortmann, W., The Estimated Duration of the Primary Stage of Surface Subsidence near Detk. The 4th International Conference on Carpathian Euroregion Ecology CERECO 2003 Proceedings. April 28-30, 2003, Miskolc-Tapolca, Hungary. pp. 107-112.
8. Kovács, F., **Breuer, J.,** Kortmann, W., Estimated Delay of Surface Subsidence Resulting from Decreasing Water Tables. Mining and Geotechnology. Environmental Management. Series A. Mining. Vol. 65 (203) pp. 11-20.
9. Kovács, F., **Breuer, J.,** Kortmann, W., The Estimated Primary Stage of Surface Subsidence near Detk. Mining and Geotechnology. Environmental Management. Series A. Mining. Vol. 65. (2003) pp. 21-28.
10. Kovács, F., **Breuer, J.,** Kortmann, W., Surface Movements Caused by Precipitation in Clay Soils. Mining and Geotechnology. Environmental Management. Series A. Mining. Vol. 65. (2003) pp. 63-72.
11. Kovács, F., Janositz, J., **Breuer, J.,** A rétegvízszintcsökkenés és felszínsüllyedés kapcsolatáról. ['On the relation of layer water level falling and surface subsidence'] Bányászati és Kohászati Lapok. Bányászat.Vol. 137. (2004) No. 2-3. (March-June) pp. 8-11.
12. **Breuer, J.,** Controlling the production of opencast mines equipped with machinery of fixed parameters. Acta Montanistica Slovaca, 1/2003, Rocnik 8. pp. 20-21.
13. Kovács, F., **Breuer, J.,** A vízszintsüllyedés és a felszínmozgások jelentkezése közötti késleltetési idő meghatározása. ['The determination of the delay time between the occurrence of water level falling and surface dislocations'] Bányászati és Kohászati Lapok. Bányászat. Vol. 137. (2004) No. 5. (September-October) pp. 2-3.