EFFECTS OF MINING SUBSIDENCES ON THE GROUND WATER AND REMEDIAL MEASURES

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ABSTRACT

The underground mining as a local economic activity has an effect upon with its natural the lithological, hydrological and biological sphere. Therefore, as a rule, changes in the natural water utilization are inevitable. The most important effects in this regard will be explained. Moreover, the special problems of draining the areas of land subsidences caused by mining will be discussed. The difficulties, limits and possibilities of remedial measures in this regard will be discussed by means of models. The report ends with some principles of draining the areas of land subsidences caused by mining.

RÉSUMÉ


1. COMPONENTS OF GROUND MOVEMENT BY UNDERGROUND MINING

First it is necessary to make clear briefly the causal processes of such ground movements. This general view is mainly confined to conditions as they are present in hard coal mining in the Ruhr district (Federal Republic of Germany). Figure 1 shows in a simplified and

![Diagram of components of mining subsidence](image-url)
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schematic way how the hanging walls have fallen into the cavities caused by the extraction without stowing or packing. The so-called 'angle of break' (Niemczyk) depends on petrographic peculiarities, and on stratigraphic and tectonic conditions of the specific hanging formations as can be seen from figure 1: sandstone 75°, slate 65°, and sand 55°. The ground movements extend beyond the breaking edge. The so-called 'limit angle' leading to the extreme border of subsidence, in the figured case, amounts to 55°. Under a thick layer of overburden the upper strata are deformed according to their plasticity, whereas those hanging directly above the coal-drift fall down.

The effects of ground movements on the surface can be divided into the components: subsidence, subsidence slope, displacement and linear deformation. This deformation appears as a shortening or as an extension. In the centre of a greater mining area there is the zone of full subsidence (fig. 1). Besides the full subsidence itself which decreases towards the through edges, on both sides of this zone appear subsidence slope and displacements. Moreover in the zone of length extension elongations appear, and in the zone of length shortening compressions appear, resulting from the push to the trough centre. The movements in the hanging formations and the deforming of the surface are more or less dependent on number, thickness, and the tectonics of the worked deposits. Moreover they depend on the direction of the coa mining, and on the kind of stowed, if any, used.

2. DISORDERS OF WATER UTILIZATION AS A RESULT OF GROUND MOVEMENTS

The effects of ground movements appear very often—mainly in flat country—as disorders of the hydrologic conditions. For instance, if a scarcely workable, solid stratum forms the ground-water bed of an upper water-bearing layer, it can rip deeply in the elongation zone as can be seen from figure 2. The consequences are the lowering of the ground-water level (Koehne). Sometimes this can effect a troublesome inrush of water into the underground

infiltration of ground-water resulting from mining subsidence
(schematic cross section)

![Diagram of infiltration of ground-water resulting from mining subsidence](image)

FIGURE 2.
workings, which requires a greater effort for the pit-work (Oberste-Brink). Often this impairs the water utilization.

In case the ground-water bed is thick and plastic enough to withstand the elongations, subsidences can effect a reduction of ground-water level in reference to ground elevation, or even a cropping out of the ground water on the surface (fig. 3). If, at the same time, in the subsidence area the natural flow of water becomes impaired or is stopped, an expanse of water arises resulting in swampy neighbouring districts (fig. 4, 5).

cropping out of the ground-water in a subsidence trough
(schematic cross section)

![Diagram of ground-water bed and subsidence trough]

FIGURE 3.

Corresponding to the local morphological conditions, mining subsidences can have an important influence on the water cycle, and thereby also on the cultivation of land. In addition to the subsidences, the other components of ground movements also disorder the water utilization directly or indirectly. Elongations, compressions, displacements and subsidence slope are a disadvantage for hydraulic engineering, as for drainage and irrigation works.

3. REMEDIAL MEASURES

The provision of discharge and drainage for subsidence areas is an especially important task for the economic continuation and development of the mining fields of the flat country. The provision of discharge and the disposal of waste water in the Ruhr district were delegated to the water associations which were founded especially for this purpose. The dimension and importance of the measures taken by these association can be seen in the size of one area: the catchment areas of the pump works for artificial drainage, the so-called polder, have a size of about 20% of the drainage basin of the Emscher river, and are more than 170 square km. Great parts of these areas would be submerged, unless the inflow was artificially raised at the lowest level. When in 1945 the pump works stopped, many such areas were submerged (Ramshorn).

A sufficient discharge is a necessary adjunct to areal drainage for the agricultural and forestry areas in the subsidence districts. The difficulties, possibilities, and limits of the measures necessary for this purpose shall be explained by some examples.
First we deal with some cases in which the disorders can be resolved by relatively simple measures.

A subsidence trough without any drainage was formed on a formerly almost flat plateau with a deep ground-water level which was more than 5 m below the surface (fig. 6). The soil consists of loess or loam over porous sands, gravels or split-gravels. The water on the surface, resulting from heavy rain or melting snow, flows together at the lowest stratum on the surface of the subsidence trough. Here it becomes more or less continuous impounded water, according to the permeability of the loam.

It is most practical to drain this temporarily impounded water by an absorbing well, because this particular case the underground sand and gravel is permeable enough. The well drainage can be accelerated by some flat mole drains.

An absorbing well is out of the question if the underground of the loam stratum consists of impermeable or hardly permeable rocks (fig. 7). In this case the flowing surface water must be drained off by a drain-pipe from the subsidence trough to the nearest receiving stream. In the centre of the subsidence trough, it is practical to fill the drain with permeable material (fig. 7).

It is much more difficult to drain subsidence troughs of flat areas which have little natural discharge and ground water close below the surface. Figure 5, for instance, shows a water course in which the surface water flowed together in the subsidence trough and flooded a wider area with the out-flowing ground water, which turned its borders swampy. The drainage of such areas will be explained by means of schematic cross sections, longitudinal sections, and ground plans. Figure 8 shows a natural depression with a water course which flows in meanders through the centre of the ground plan shown. The water course has a sufficient and comparatively regular slope (longitudinal section C-D, fig. 8). The cross-section (A-B) shows that the water course and the ground water coincide with each other. Moreover, a superficial site of the ground-water level can be seen in the depression. This area is affected by mining subsidence in such a manner that the zone of full
subsidence is situated in the upper left edge of the ground plan (dotted line level of equal sinking: 1.5 m, etc.; fig. 8, ground plan). The mining subsidence ends in the lower right edge of the plan (line of equal sinking: 0 m). In this way a different relief develops (new

*FIGURE 5. Flooded subsidence trough, as a consequence of underground mining*
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Figure 6.

Figure 7.
FIGURE 8.
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contour lines: ground plan of fig. 9). The disordered area has in A a drainless basin which extends to the water course and hinders its free discharge (longitudinal section C-D in fig. 9). In the basin the ground water comes to the surface, and forms a coherent sheet of water with swampy neighbouring areas (cross-section A-B and grid-system in the ground plan of fig. 9). The receiving stream, too, is touched by the edge of the subsidence basin, but not strongly enough the completely stop the discharge (longitudinal section C-D).

In spite of the changed morphologic conditions this area can be drained sufficiently by building a receiving stream which flows into the lower course of the brook (outside of the ground plan of fig. 10). At the same time the brook bottom must be leveled and the brook profile must be planked for a sufficient length (longitudinal section C-D in fig. 10) to prevent backing-up of the surface water from the subsidence trough. A drainage system to the receiving stream must provide the conditions that will bring the flooded area back into a regular state and use (ground plan and cross section A-B in fig. 10).

An artificially created flow of water and a suitable ground-water level for the subsidence area can be successfull in the long run only if the ground movements stop. If ground movements continue, you cannot avoid building a pumping station. In spite of the artificially created flow of water, with or without a pumping station, however, drainage of subsidence troughs will remain difficult so long as ground movements go on. In this regard principles can be established for the following three eventualities:

a) It is very easy to plan and to put into effect the drainage measures, if mining leaves the concerned area and the ground movements stop. In this case the drainage can be the same as in those areas which have a natural excess of water. If this is ground water, special care must be taken in regard to foreign water from neighbouring areas, and to possible artesian water as a consequence of lasting disorders of the hydro-geological conditions. In addition, old drains have to be carefully checked (for changed slope) and possibly closed.

b) If there is not as yet a stop of the ground movements in time and dimension, if especially the future conditions of slope and discharge are very uncertain, there must be a temporary draining in a way that does not intensify possible future disorders. In this case one must generally avoid drain-pipes. Apart from open ditches which show further ground movements as they begin mole drains are possible as branch drains in heavy soil.

c) If the ground movements have not yet come to a stop, and if it is certain either that only subsidences are to be expected, or that displacements, compressions, and elongations will be of comparatively small dimension and the subsidence will not change the slope conditions, systematic drainages can be made. The single arterial drainage should be minimal, and the main collector drains and branch drains should be as short as possible, in order to have a better surface localization of actual disorders. An exact lay-out with reliable and fixed observation points in the grounds and a corresponding altimetry are of special importance in this regard.

CONCLUSION

Underground mining as an economic activity is necessarily an intervention in part of the earth with its natural well-established balance of the lithosphere, the hydrosphere, and —if the soil is included—of the biosphere. Changes of the water utilization are normally inevitable. The most important effects in this regard have been described. Moreover, entering into this are special problems of the drainage of mining subsidences. The difficulties, possibilities, and limits of the measures necessary for this purpose have been dealt with by means of examples. The paper ends with some principles for the drainage of mining subsidences.
FIGURE 9.

section A-B

section C-D

ground plan

ground water

bank

water level

base
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Figure 10.
PREDICTION OF HORIZONTAL MOVEMENTS DUE TO SUBSIDENCE OVER MINED AREAS

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ABSTRACT

Some interrelations between vertical and horizontal movements in ground subsidence problems are summarized. A case history of horizontal movements which develop as a result of subsidence over a sulphur mining area is discussed. The finite element method of analysis is shown to give a good prediction of the correct nature and magnitude of both vertical and horizontal movements resulting from this mining subsidence problem.

INTRODUCTION

Removal of material from below the ground, whether it be water, oil, gas, or solids, frequently results in subsidence of the ground surface unless special precautions are taken to prevent this from occurring. Not only do points on the surface move vertically down, but in many cases they also move laterally. Many engineering structures founded on or

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