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ON THE ISSUE OF ENVIRONMENTAL CONSEQUENCES OF CLOSING COAL MINES

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Abstract

According to the above research, the main factors determining the ecological situation as a result of the production activities of coal mining enterprises are the pollution of the atmosphere by dust and gaseous products, the change of the water balance as a result of the mixing of surface and underground waters, the deformation of the earth's surface with the formation of landslides. The closure of coal mines leads to a change in the ratio of the influence of these factors on the state of the ecosystem. This is due to the reduction of emissions of dust and gaseous products into the atmosphere, an increase in the level of underground water and its impact on

the stability of rocks in the zones of extinguished production, as well as flooding of adjacent territories. The study is based on the analysis, systematization and generalization of the results of the effects of coal mining enterprises on the environment from known literary sources and consists in establishing the conditions for the formation of processes that determine the ecological environment during the operation of a coal enterprise and comparing these processes with the processes after the cessation of production activities.

Introduction

The experience of operating and shutting down coal mining enterprises has shown a fundamental difference between the processes that accompany their activities at these stages in terms of the impact on the environment and the state of the earth's surface.

During the operation of a coal mine in the usual mode, the main attention is paid to creating safe conditions for underground mining, since in all cases they are classified as especially dangerous . These hazards are associated both with direct technological operations and the need to create conditions acceptable for human life in underground conditions. These such an influence, the scheme of the main flows of mine gases (Fig. 1) can conditions are provided, first of all, by ventilation of mine workings and pumping of water to the earth's surface. These forced technological processes over a long period of operation of a coal enterprise cause changes both in the state of the rocks enclosing the coal seams and affect the environmental situation in the vicinity of the operated mine. As an example of serve.

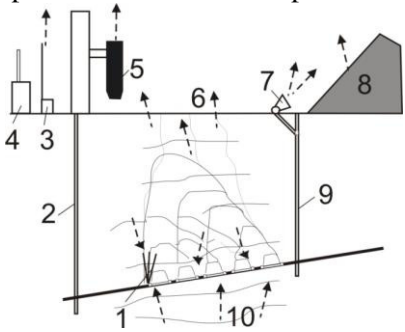

Fig. 1. Scheme of the main flows of mine gases [1]: *1* - capturing by degassing wells; *2* - transport along mine workings with rock mass and water; *3* - vacuum pumping unit; *4* - disposal plant; 5 - separation from coal in bunkers and warehouses; *6* - isolation from soils; *7* - emissions with ventilation flows; *8* – extraction from rock dumps; *9* - transport along mine workings with a ventilation jet; *10* - residual gas in the bowels

A similar scheme characterizes the processes of water movement during its pumping from mine workings and host rocks to the earth's surface, which also causes certain changes in the environment and in host rocks in the zones of influence of mine workings.

Dumps of coal mines and processing plants are objects of increased environmental hazard, as they are not only sources of constant release of harmful substances, but also in some cases the cause of landslides with the movement of the rock mass over long distances [2].

The history of the development of Donbass exceeds 200 years. More than 21 billion tons (up to 12 km^3) of rocks have been extracted from the bowels, including about 15 billion tons (10 km^3) of coal. As a result of such activity, deformations occurred with a violation of geomechanical equilibrium and continuity of 600 km^3 of the rock mass in the zones of influence of mining, and on 50% of the area, subsidence of the day surface averaged 1.5÷2.0 m with a simultaneous increase in rock permeability and increased interaction surface and ground waters [3].

It follows from the state of the issue that the main factors that determine the environmental situation as a result of the production activities of coal mining enterprises are air pollution with dust and gaseous products, changes in the water balance as a result of mixing surface and ground waters, deformation of the earth's surface with the formation of displacement troughs.

The closure of coal mines leads to a change in the ratio of the influence of these factors on the state of the ecosystem. This is due to a reduction in emissions of dust and gaseous products into the atmosphere, an increase in the level of groundwater and their impact on the stability of rocks in the zones of extinguished workings, as well as flooding of adjacent territories. Reliable forecasting of possible environmental consequences of mine closure is impossible without establishing the initial state of the ecosystem, which was formed as a result of production activities.

The methodology and idea research. The idea is to establish the conditions for the formation of processes that determine the ecological environment during the operation of a coal enterprise and compare these processes with processes after the cessation of production activities. The goal is to establish trends in the processes that

determine the environmental consequences after the closure of mines. The methodology is based on a comparison of the factors and processes that determine the state of the ecosystem in the conditions of an operating enterprise and after its liquidation.

Results and discussions. The safety rules [4] do not allow the operation of burning dumps. In Ukraine, there are approximately 220 rock dumps, which should be classified as burning, since, despite the fire extinguishing measures taken, there are separate fires and harmful substances are constantly emitted on them [2]. The amount of harmful substances emitted is about 500 thousand tons per year [5]. The restructuring of the Ukrainian coal industry through the liquidation of unprofitable and unpromising mines began in 1996. In the Donetsk region, 223 rock dumps were transferred for liquidation, including 48 burning ones. According to the project schedules, the reshaping, extinguishing, landscaping and other environmental protection activities at the rock dumps were to be completed in full by 2014. In fact, design solutions were implemented only for 63 waste dumps due to the systematic underfunding of mine liquidation projects. Along with this situation, a systematic monitoring of the temperature state of burning heaps was carried out, and on most of the burning dumps from 2006 to 2014, a decrease in temperature by 100-200 °C was established. On seven dumps, the temperature decreased to 80 °C, which made it possible to transfer them to the category of non-burning [6]. If we proceed from the dynamics of temperature decrease, then the attenuation of burning dumps without environmental protection measures can occur after the liquidation of the mine within 10-15 years. According to the results of the surveys, it was found that 90% of the dumps are self-greening , most of them have already been self-greened by 10-80%. This confirms the propensity of the considered system of the biosphere to self-healing [7]. Implementing environmental measures can significantly speed up the process of self-healing. The closure of coal mines contributes to the attenuation of fires in rock dumps and the restoration of the surrounding biosphere.

The elements of the biosphere that do not have the ability to reproduce include landscape and subsoil [7]. The change in the landscape of the earth's surface is caused by the extraction of coal seams

of different thicknesses and at different depths. The displacement of the earth's surface during the treatment works causes deformation of various structures and objects located on coal-bearing territories, and has an adverse effect on them. When mining under watered rocks, reservoirs and streams, the deformation of rocks leads to the formation of water-conducting (through) cracks in the rock mass, water breakthroughs into mine workings and their flooding. The subsidence of the earth's surface under the influence of underground mining can cause flooding of the settled areas of the earth's surface with groundwater, atmospheric and flood waters.

The main types of displacements and deformations that are dangerous for undermined structures and natural objects include: subsidence (vertical displacements of the earth's surface), slopes (differences in vertical displacements of neighboring points, referred to the distance between them), curvature (the ratio of the difference in slopes of neighboring sections to distance between them), horizontal displacements (displacements of the earth's surface in the horizontal plane), horizontal deformations (the ratio of the difference between horizontal shifts of neighboring points to the distance between them). The slopes of the earth's surface cause the instability of tall objects and lead to an unacceptable change in the profile of railway tracks, etc. The curvature and horizontal deformations of the earth's surface can cause damage to buildings, structures, industrial complexes, pipelines, mine workings and other objects. For vertical mine shafts and mine workings, compression or tension of rocks along the vertical is dangerous.

The study of the parameters of the displacement of rocks and the earth's surface, as well as the development of methods for protecting undermined buildings, structures, mine workings, natural objects from the harmful effects of underground mining are urgent tasks directly in the extraction of minerals:

1. Determination of the boundaries of the zone of harmful influence of underground mining on structures and other objects. This problem arises when placing the designed surface structures, mine workings, including mine shafts, when establishing the need to take measures to protect structures and planning mining under a built-up area.

2. Determination of the safe depth of development, which is understood as such a depth below which the mine workings cannot cause destructive deformations in the undermined objects, entailing the termination of operation, danger to the life of workers and living in protected buildings and structures.

3. The use of mining engineering and structural protective measures when excavating coal under structures. The basis for these activities are the magnitude of displacements and deformations of the foundations of structures.

4. Leaving safety pillars of coal as a protection measure used when other methods cannot guarantee the normal operation of the protected object or are economically unprofitable.

5. Establishment of conditions for rational extraction of coal under forest plantations, rock dumps and water bodies.

The practical solution of these problems is regulated by a normative document [8]. According to it, the boundaries of the zones of influence of mine workings and the duration of the process of displacement of the earth's surface, the calculated and permissible indicators of deformations of the earth's surface for residential and public buildings, industrial buildings, engineering structures and communications, railways and technological equipment are determined. Special requirements are imposed on the rational excavation of coal under water bodies, forest plantations and rock dumps.

When conducting mining operations, the main influencing factors that contribute to the achievement of the earth's surface by the processes of displacement of undermined rocks are [9] the thickness of the developed reservoir (m) and the depth of work (H). In all cases, without exception, the operation of modern coal mines causes the earth's surface to move. According to the nature of the manifestation, the process of displacement of the earth's surface can manifest itself in the form of dips, funnels, large cracks, ledges, microcracks, and smooth deformations. Subsidence of the earth's surface can cause flooding of settled areas of the earth's surface with groundwater, atmospheric and flood waters, but consideration of such issues at the stage of operation of a coal enterprise, as a rule, was not considered. More relevant during this period of mine operation are measures to prevent water breakthrough into existing mine workings [10, 11]. The watering of workings can be different, but even in slightly wa-

tered mines there are cases of water breakthrough from several tens to a thousand cubic meters per hour. The largest number of water breakthroughs is confined to sandstones and limestones. In the case of preliminary drainage, water inflow into individual wells is up to 20-40 m^3 /hour for three to six months [10]. Water breakthroughs into mine workings are emergency situations that are not typical for the period of normal seam mining. The main amount of water is pumped out of the mine workings during the stable operation of the mines. It is characterized by the volume of pumped water for each ton of mineral resources - the coefficient of water abundance . This figure for the Donetsk coal basin averages about 2.8 m^3/t [12]. With such abundance of water in the mines of Donbass, more than 30 billion m^3 of water was diverted to the surface during the entire period of their operation.

There are general, district and downhole water inflows . The total water inflow to the mines consists of: groundwater inflow (aquifers drained by mine workings); mine waters coming from flooded workings and neighboring mines; water supplied to the mine for backfilling, irrigation, well drilling, etc.; surface water and precipitation. The mode of water inflow into workings depends on the combination of interacting natural (climatic, geomorphological, hydrogeological) and technological (shape and size of the mining area, depth and intensity of field development, development system) factors [13].

The district water inflow consists of inflows into the development workings and into the goaf of the excavation area. Water enters the development workings from minerals, aquifers lying directly in the roof and soil of the workings, or from drainage wells. Water inflows , reducing the pace of tunneling, contribute to the intensification of the drainage of aquifers within the prepared excavation areas. Water enters the mined-out space mainly from aquifers that fall into the zone of water-conducting cracks, from neighboring worked-out areas, and sometimes from the surface of the earth.

Downhole water inflow is made up of the inflow of groundwater and water from the mined-out area, which enters directly into the bottomhole area of development and treatment workings.

The zone of water-conducting cracks is a disturbed rock mass, through the cracks of which underground and surface waters enter the mine workings. There are zones of natural water-conducting

cracks associated with large tectonic disturbances and karst phenomena, and artificial ones - with the displacement of rocks above the goaf and deformation of the rocks, as a result of which cracks form, causing the connection of aquifers and surface waters with the goaf [13].

In the Donetsk basin, on an area of up to 15 thousand km 2 , as the depth of mining operations increased (up to 900-1300 m) and the level of groundwater decreased under the influence of mine drainage, a regional imbalance in the system “mineral skeleton of rocks - groundwater” increased.". The consequence of the new hydrogeological conditions was the development of a local-regional depression level surface of groundwater. The deepening of active water exchange zones from 150÷250 to 450-550 m with a corresponding increase in atmospheric precipitation infiltration and the inflow of technogenically modified surface waters from rivers, reservoirs, ponds and other water bodies into aquifers led to a change in the natural balance. As a result of mine water exchange , hydrochemical conditions were leveled due to mixing of surface and ground waters and an increase in their mineralization due to leaching of salts from rocks and pore solutions. As a result of long-term drainage in the area of mining operations in the free-flow filtration zone (fractured-soil horizon), a regional depression funnel with a depth of 40-50 m was formed. those. 800-1000 m. The volume of dried rocks is 150÷200 km ^{3} [3]. Large radii of influence of depression surfaces indicate a high degree of depletion of water resources in the area of activity of mining enterprises and water intake facilities [7]. In the Donbass, in the upper zone of the geological environment, a quasi-equilibrium system "mine water - mineral skeleton" was formed for some time. This led to a change in the natural configuration and direction of groundwater flows, a technogenic increase in the activity of the relationship with surface waters, and a change in the structure of the sources of formation of their resources [3].

Changes in hydrogeological conditions give rise to the following negative changes in the geological environment, ecosystems: depletion of groundwater reserves; extraction of gravitational water from waterproof rocks; drainage of wells, streams and reservoirs; violation of the water-salt regime of rocks in the aeration zone; deterioration of the quality of ground and surface waters.

If we compare Dniprobass with Donbass, then the negative impact of coal industry enterprises on the environment, associated with changes in the ecological environment, is much stronger in Donbass. The mineralization of underground and surface waters in the Dneprobass does not currently exceed 1 g/l, and in the Donbass it is 2-35 g/l and more. Significantly different in these regions and the chemical composition of water, as well as the degree of influence of coal industry enterprises on rivers and reservoirs. These comparisons are not in favor of Donbass [14].

One of the urgent environmental problems of the coal-mining regions of Ukraine is the negative phenomena and processes that accompany the liquidation of mines and cuts. They are of a multivector nature and in one way or another are connected with the restoration of the natural levels of groundwater drained during the operation period. TO the main ones are flooding and swamping of the earth's surface, changes in the chemical composition of ground and surface waters, activation of the earth's surface movement over workings, deterioration of the physical and mechanical properties of rocks, and extrusion of mine gases [15].

In general, the flooding of mines in the Donbass from 1996 to 2014 led to flooding from 20 to 40% of the territories adjacent to them. The management of groundwater inflows at different stages of the post-operational existence of liquidated mines is a poorly understood process of water migration in a disturbed massif [16] and requires further detailed study.

The liquidation of individual mines also poses a threat of flooding of neighboring enterprises, since there is a risk of water breakthrough through the barrier pillars [17]. This makes it necessary to pump out water in volumes close to the productivity of drainage systems of previously operating mines [18]. In its essence, such a measure is limited to the life of neighboring mines, and after their closure, in any case, it is necessary to develop other measures to mitigate environmental consequences. They consist in strengthening buildings and structures; terrain planning, providing a runoff of atmospheric precipitation; on the surfaces of maximum subsidence of the earth's surface, a network of reclamation ditches is being built; water-reducing wells are being drilled , etc.

To develop such measures for each mine, information is needed on the degree of undermining of the earth's surface by the time it was liquidated. In this case, it is necessary to take into account the influence of the reworking on the parameters of the trough of the displacement of the earth's surface. Over the past few decades, coal seams in the Donbass, as a rule, have been mined in a descending order. For this reason, in many cases, the earth's surface was repeatedly undermined before clearing operations were carried out at deeper horizons. On the overlying horizons, coal was mined 50–80 years ago [19]. It must be borne in mind that such situations are not reflected in the regulatory document [8] and require detailed consideration for each specific case.

The environmental consequences of the operation of coal enterprises include gases released into mine workings and degassing wells, and then issued to the earth's surface. It is possible to estimate their approximate number for the entire period of development of Donbass coal deposits, but it is not possible to reliably establish environmental consequences. In addition to gas removed from mine workings by outgoing ventilation jets and captured by degassing systems during the operation of mining enterprises, it was also released directly onto the earth's surface. This had an impact on the safety of operation of ground facilities and the surrounding ecosystem.

The possibility of gas release to the day surface under the influence of mining is confirmed by cases of gassing of residential premises and the formation of cracks above the stopes. During the development of anthracite seams, the gassing of the premises was observed during the cleaning operations at a depth of 80–250 m. The width of the cracks reached 20 cm at a depth of 100 m for cleaning operations [20]. In a number of cases, the sources of methane release to the earth's surface are adjacent seams occurring at a distance of more than 35 thicknesses of the seam being developed [21].

Under the conditions of the liquidation of mines, it is possible to activate the release of gases directly onto the day surface by squeezing them out under the influence of an increasing level of the depression surface of groundwater. In projects for the liquidation of coal mines, it is necessary to provide for measures aimed at the safe operation of facilities in areas of possible gas extrusion.

Conclusion

On the basis of the research conducted, the trends of the processes that determine the environmental consequences as a result of the operation of mines and the change in these consequences after the liquidation of coal enterprises are established. To reliably predict the environmental situation after the liquidation of coal mines, the following circumstances must be taken into account:

1. The result of the operation of coal mines is the extraction of minerals and the associated removal of rock and water from the bowels, emissions of dust and gaseous products into the atmosphere. In addition, there is a change in the relief of the earth's surface under the influence of its underworking by treatment workings and causes a change in the water balance between surface and ground waters. The long-term operation of mines in the Donbass has led to the formation of a quasi-stationary ecosystem.

2. The closure and liquidation of mines caused a violation of the quasi-stationary state of the ecosystem in the regions. The changes consist in restoring the groundwater level with possible flooding of adjacent territories and water breakthrough into the mine workings of neighboring mines that are still in operation. Currently, to prevent such consequences, the operation of dewatering plants of closed mines continues. The time of production of intensive drainage from the workings of closed mines is largely related to the duration of operation of neighboring mines. After the closure of neighboring mines that are still in operation, the environmental consequences are unpredictable. For a reliable forecast of environmental consequences, it is necessary to establish the final parameters of the earth's surface displacement after the cessation of all mining operations in the region under consideration.

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