

Ecological changes in geological media and Siverskyi Donets River basin under the condition of coal mines flooding

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Abstract. Complex economic, geological-technological state of coal mines and impact of the armed conflict factors (the breakdown of energy supply, objects of critical infrastructure, etc.) accelerated closure of coal mines by the method of "wet preservation" in particular. In most developed EU countries decommissioning of coal mines, which have great depth (up to 1,0-1,5 km) and areas of minefields, occurs according to the post-mining (PM) research and production complex, which is based on the scientific and technological activities regarding prevention of dangerous changes in the geological environment (GE) - subsidence of ground surface, lands flooding, emission of explosive and toxic gases as well as reduction of outflows of polluted water into the local river basins (RB) and the soil aquifer. Additionally, PM suggests some mining works turning into the hydraulic-filtration system of mine water retention at a depth of 250-350 m with a purpose of preventing pollution flow into the freshwater aquifers and river network, preserving regional aquitards, degassing of mountain surface. In general, the PM activities complex aims at maintaining the balance and protective potential of the GE as mineral and landscape basis of the biosphere, elimination of dangerous changes in ecological parameters of the hydrographical network. It is shown that new models of subsoil and water use, geological prospecting structure, scientific basis for permissible changes in GE and RB are required together with closure of "old" mining works (MW) and opening of new ones, improvement of the environment monitoring based on GIS technologies and Earth remote sensing.

1 Introduction

Market restructuring of the mining and industrial complex (MIC) of Ukraine has led to a significant increase of requirements to technic-economic and ecological-social parameters of the subsoil use. Critical acceleration (with the start of the armed conflict in 2014) of closure and liquidation of mines of Donbas mostly through "wet preservation" (auto-rehabilitation flooding) conditioned poor consideration of the object-territorial and regional changes in ecological parameters of the natural-technogenic geosystems (NTGS) "coal mining region - geological environment" under the current social-economic and geopolitical conditions [1-15].

From our point of view, during the period of restructuring of the leading coal mining sectors (CMS - Donbas, Lviv-Volyn coal basin, West Donbas, Dnipro brown coal basin) experience of EU countries (Great Britain, Germany, France, Poland, etc.) in creating a legal basis and substantiating the NTGS new state ecological safety parameters as a result of abnormal changes in ecological parameters of its leading element - technogenic-geological system (TGS) "mining complex - geological environment" has not been taken into

consideration. It was mainly connected with uncontrolled flooding of most mines at insufficient consideration of the new ecological state of the geological environment (GE) as a result of restructuring its accumulated long-term changes within the boundaries of various NTGS of Donbas [1-6, 9-14, 16-21, 23-25, 35].

Under these circumstances, substantiation and implementation of post-mining principles and technologies relate to significant difficulties as a result of gaps in ecology legislation as well as a big complex of accumulated and newly created irreversible and dangerous changes in the ecological state of the subsoil.

Taking the above-mentioned into consideration, we can conclude that further functioning of the coal mining of Donbas on the controlled and non-controlled territories is possible based on accelerated post-mining activities implementation to the subsoil use on separate areas with sufficient power of mine pumping at further mining of coal fields.

2 Analysis of previous publications

The mining industry is dynamic, with some resources being mined for centuries until reserves are depleted or

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technical and market conditions change, as has been the case in the former communist countries after 1990.

In almost all known cases, the cessation of exploitation of mineral resources has led to a number of serious problems [36-49]. The problems are similar in all mining regions [44-60], and the research in this paper points out these facts.

Research experience of the Institute of Telecommunications and Global Information Space of the NAS of Ukraine shows that use of the GIS can facilitate a significant increase of reliability of estimates of the ecological-technogenic conditions of the NTGS "waste polygon-environmental constituents" on the condition of reduction of the geological environment defensive ability as a consequence of the mines and pits flooding [5, 19-34].

The main factors which define the ecological state of the Donbas coal mining sectors are:

- geomechanical and hydrogeofiltrational imbalance of the rock mass as a result of conducting mining works with the exemption of large volumes of mineral raw materials, formation of a significant amount of polluted underground water flow into the local river network (up to 800 million m³ per year) and greenhouse gas (up to 6 bln m³ per year), destruction of regional aquitards and development of non-watertight areas of technogenic fissuring;

- formation of mining and recycling waste;
- destruction of hydrogeological and hydrological conditions of the territory.

All the other factors (development of hazardous geological processes, pollution of the surface atmosphere, soil, loss of biodiversity, etc.) in most cases derive from these three factors [1-9, 17, 18].

3 The research results

The biggest ecological-technogenic, social-economical and technogenic threats to the population occur when coal mining enterprises closure is ecologically imbalanced due to the accelerated flooding of coal minings, level rise and pollution of local underground and surface sources of drinking and economic water supply beyond the claim mine concessions, additional deformation of the land surface, increasing upward migration of polluted mineralized water and explosive and toxic gases (methane, radon, hydrogen sulfide, etc.), which is connected with the depletion of regional waterproof (low permeable) layers [13, 17, 18, 25]. At that, soil pollution surface centres can get in the zone of active water exchange (industrial and domestic waste polygons), surface flow and groundwater, which can actively move to the rivers and expand the area of water ecological risk.

In practice, it can result in disabling surface and underground drinking water supply systems, flooding and destruction of housing and industrial objects and communication (including ecologically dangerous objects such as oil and gas pipelines, chemical enterprises, etc.), complicated conditions of agricultural activities. Uncontrolled development of these processes, which are mostly irreversible in the coal mining sectors of Ukraine,

including the additional impact of the armed conflict complicating factors on the East, global climate change and so on can lead to an ecological disaster, consequences of which will be extremely long-term and regional (borderless).

At that, the analysis of long-term changes in the ecological parameters of various NGTS in Donbas allows concluding the leading impact under current conditions of the anthropization of the geological environment and the Siverskyi Donets river basin as a regional drain of the underground flow technogenic reformation.

The main factors of technogenic changes in ecological parameters of the GE and river basins (RB) in the Donbas region under the conditions of postmining are:

- chemical pollution of landscapes;
- significant lowering of the underground water level, undermining of surface water bodies (up to 600 cases with different level of the surface flow interception);
- highly mineralized aggressive mine water flow in the river system;
- accelerating exogenic geological processes (landslides, karst, flooding), development of the original ground subsidence and complicating the engineering-geological state of housing and industrial objects;
- decrease in engineering-seismic resistance of rock mass influenced by increase in mobility of rocks in the areas of their undermining by mining works, development of hydromechanical impulses, etc.;
- formation of a large amount of waste pits, which are also a source of water resources, ground and surface air pollution.

The most dynamic changes in ecological parameters of the geological environment and river basins in Donbas are connected with inflows of underground water into the coal minings, the overall flow level of which into the river network at a maximum development of mining works was 25,0 m³/sec (1990). At a regional amount of natural water resources equal to about 12,0 m³/sec, it indicated active drainage of surface water sources and hydraulic interconnection between mines [58-60]. At an average salinity of mine water equal to about 3,6 g/dm³, it conditions the outwash of salts mainly into the Siverskyi Donets river basin at a level of 2,7 mln tons per year, which significantly activates pollution of the transboundary river flow in the Don (at the territory of Russian Federation) and Azov sea basin.

In the context of the armed conflict surface water objects, first of all, those of the Siverskyi Donets river basin, which is the major source of drinking and economic water supply (40-80% of local water consumption) have a significant threat of dangerous deterioration of the geological state.

Evaluation of the ecological state of the reserve sources of drinking and economic water supply of Donetsk and Luhansk regions population, on the controlled and non-controlled by the Ukrainian government territories, is extremely important, as it is conditioned by the active use of pollution vulnerable local

dug wells, boreholes and reservoirs by the local population beyond the central water supply system.

The authors created an indicative scheme of carrying out express research in the given region, which allowed evaluating the most vulnerable section critical for the health and ecological safety.

An important component is defining the role of emerging technologies, use of contact, remote methods of monitoring and geoinformation technologies (GIS) in particular.

Based on the geodata integrated into GIS, authors built models of surface water pollution dynamics in the Siverskiy Donets river basin.

To build models of pollution space distribution and evaluation of surface water quality authors used geostatic methods that allowed receiving interpolation area of pollution level values and building relevant maps of surface water quality change probability in the whole basin and the territory overall.

Activation of technogenic changes in, first of all, the surface flow of Donbas, is influenced by undermining of 129 rivers and beams and 26 reservoirs (> 683 cases) caused by mining works as well as by continuous subsidence of the original surface on the territory up to 8000 sq.km in the area of impact of which there are up to 1000 different industrial and potentially dangerous objects (Fig. 1) [1, 13, 25].

A significant complication of the mines closure process creates up to 250 earlier flooded mines, hydraulically connected with the active ones. According to the current evaluation, total mining works exceed 2,3 km³ and contain up to 1,6 km³ of water which can significantly accelerate regional activation of flooding of cities and villages territories, migration of pollution into the surface and underground intakes and the river network, as well as increase threat of emergency water breakthrough into the active.

Additional above-mentioned evaluations allow concluding that transformation of water-ecological

parameters of natural-technogenic geosystems (NTGS) “mining complex - underground and surface hydrosphere” in the context of current auto rehabilitation flooding of mines in Donbas has considerable complexity and uncertainty during the implementation of post-mining activities. It is mostly conditioned by the fact that areas of the underground water level rise 5-10 times and more exceed areas of mining works, thus forming dynamic reformation of levels and chemical composition of underground water and its flow into the hydrographical network.

In our view, under the current conditions of social-economical and ecological-technogenic restructuring of subsoil use in Donbas, the biggest water-ecological threats to health and safety of a large number of people in the region (more than 50%) occur when mining enterprises are closed without a sufficient complex of protective and ecological-stabilizing activities. Taking into consideration a spatial-temporal structure of factors of the changes in ecological parameters of GE and the surface flow of Donbas, we have substantiated a scale of ecological impact of the coal industry zone post-mining initial phase on the state of life-supporting components of the environment (lithosphere, hydrosphere, etc.).

The authors’ evaluations showed that in the biggest by area and depth of mining works region of Donbas ecologically critical consequences of the auto rehabilitation flooding of mines (so-called “wet preservation”) are connected with the absence of a pumping-hydraulic system which should keep the underground water level on the ecologically optimal depth lower than the regionally permeable crust of weathering coal rocks (from the experience of the EU countries - 250-350 m.). The given approach excludes active lateral spreading of polluted and mineralized mine water and its flow into the overlying freshwater aquifers and surface streams.

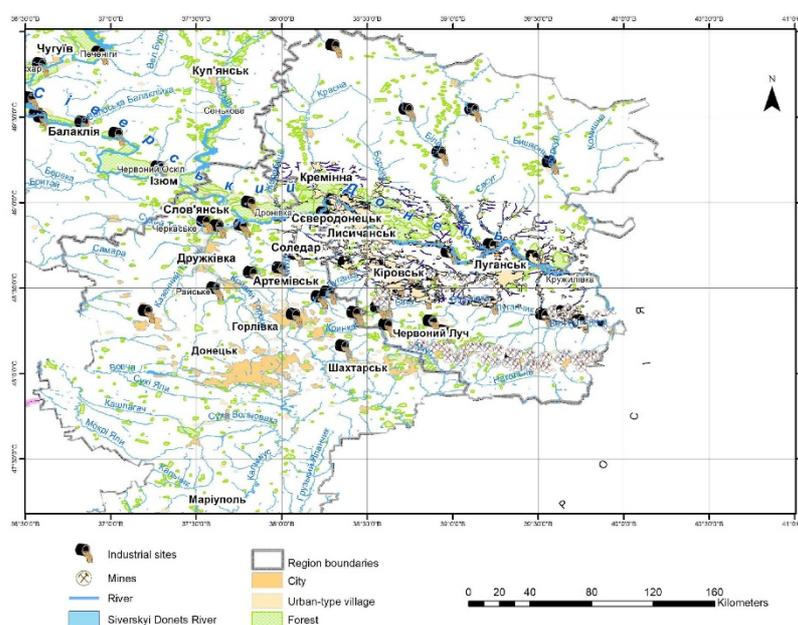


Fig. 1. Map of technogenic pressure on the Siverskiy Donets River Basin.

The experience shows that at that, underground water level rise beyond the claim mine concession, additional surface subsidence, increasing migration of polluted mineralized water to underground and surface sources of water supply and explosive and toxic gases to housing and industrial buildings also occur in the most MW, which is mostly connected with tectonic and technogenic depletion of waterproof layers. The Fig. 2 shows the fundamental scheme of formation of underground and surface water flows interaction during the coal mine flooding in Donbas.

Taking into consideration the above-mentioned characteristics of interaction between the underground

and surface water flows during the flooding of a coal mine in Donbas we have developed the “Scheme of the technogenic-geological system “mining complex - geological environment” transition into the post-mining phase”, is presented in Fig. 3.

The above-mentioned values show that disturbance of the balanced geomechanical state of the subsoil, level and hydrochemical mode of underground and surface water and deformation of the earth’s surface in the context of auto rehabilitation flooding of mines (“wet preservation”) are the main factors of development of potentially water-ecological threats and risks of emergencies of water-ecological nature.

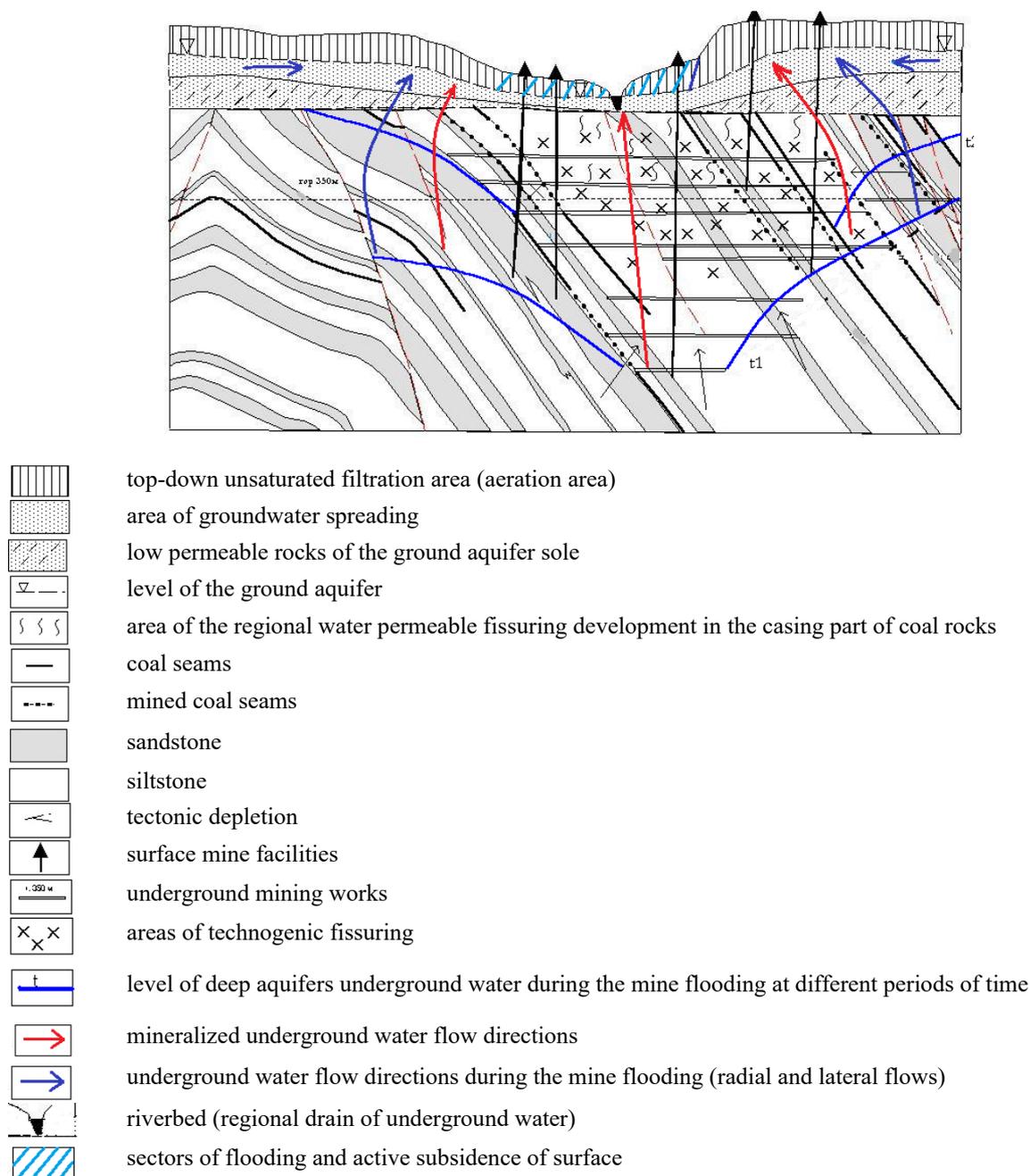


Fig. 2. Fundamental scheme of formation of underground and surface water flows interaction during the coal mine flooding in Donbas.

In general, results of the analysis of changes in the water-ecological state of developed (“old”) mining regions of Donbas considering critical technical-economical parameters of the natural resource potential achieved by them before the transition into the post-mining phase allow concluding possibility of partial realisation of correspondent activities on improvement of water-ecological safety of vital activities.

Mainly it is connected with the irreversible disturbance of balanced natural interaction between the underground and surface components of the Donbas region hydrosphere as a result of exemption of large

volumes of the coal mass followed by ruining regional aquitards and river valleys, subsidence of large areas of the earth’s surface, geochemical pollution of surface and underground water-collecting landscapes, the collapse of host and casing rocks.

In that regard, in our opinion comparison of renewal levels of geological environment ecological-protecting functions (mostly ground and rocks of the aeration area) and surface hydrosphere (sediment) of the Chernobyl Exclusion Zone and the zone of the flooding of Donbas Central region mines are illustrative, is presented in Table 1.

Table 1. Comparison of changes in the ecological status of the geological medium of the Exclusion zones and the unconditional (obligatory) resettlement of the Chernobyl NPP and the impact area of the massive closure of mines in the Donbas (Influences levels: red – critical, yellow – dangerous, green – background).

Types of changes in the ecological condition of the geological medium	Technogenic influence factors	
	Chornobyl NPP emergency area	The area of impact of a large-scale closure of the Donbas mines
Landscape and geochemical pollution	Auto-rehabilitating cleanup (up to 90% by 2035)	Irreversible changes
Lithospheric - equilibrium	No changes	Destructive changes
Hydrological	Short-term radionuclide pollution	Sustainable pollution
Hydrogeological	Low concentrations of radionuclides	Pollution and depletion of groundwater resources
Gas-geochemical	Short-term contamination of the atmosphere with radionuclides	Increasing pollution of surface air pollution
Engineering-geological	Almost no changes in engineering-geological conditions	Destructive changes
Seismic-engineering-geological	Relatively stable condition	Reduction of engineering and geological stability

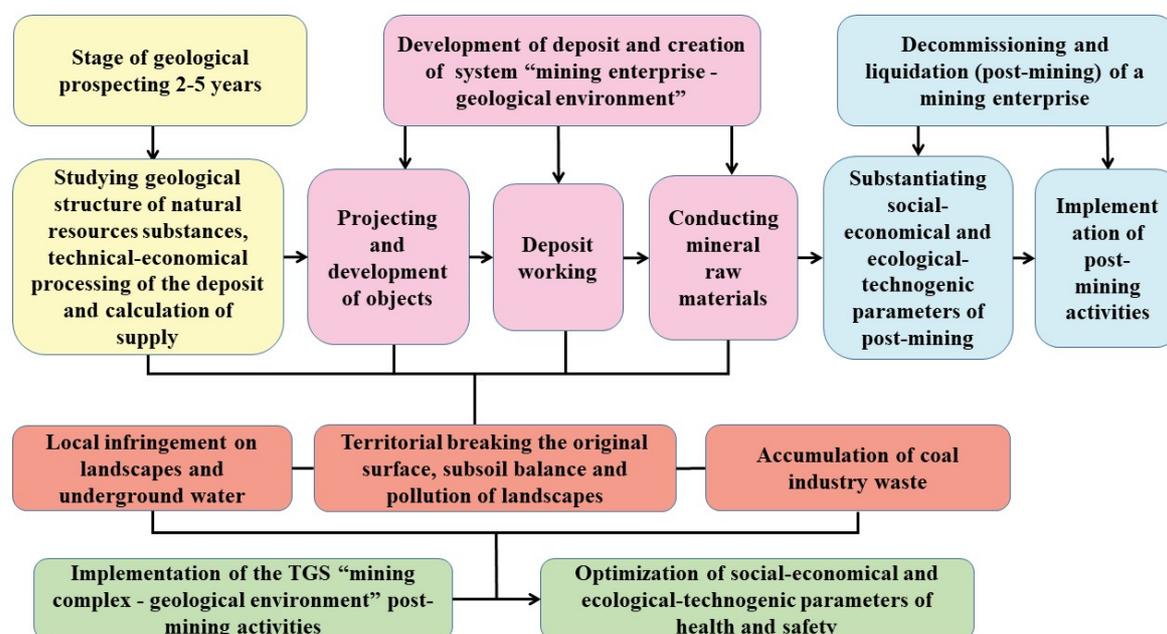


Fig. 3. Structural scheme of formation of the post-mining methodical base in the context of ecologically stable development of mineral raw materials deposits.

Based on the data given in table 1 ecological state of the geological environment as a part of an NTGS is a crucial parameter of the natural resource potential renewal and formation of water-ecological factors of health and safety.

4 Conclusions

Based on the above-given evaluations a complex of ecological-technogenic and social-economical post-mining activities in the most MS in Donbas can be partial, taking into consideration irreversibility of most changes in ecological parameters of a geological environment and surface hydrosphere, which have occurred or are at a stage of active development. At that, a large number of ecological functions of a geological environment (landscape-chemical, water-ecological, engineering-geological, etc.) are lost in almost all developed CMS at the post-mining stage due to complex violations of the subsoil balance during exemption of large volumes of copper rock raw materials and creation of "lack of mass" in the upper zone of the lithosphere.

Thus, the main task of the post-mining separate activities implementation focused on the improvement of health and safety of the local population in the mining sectors of Donbas can be the following:

- improvement of forecasting the changes in main life-supporting components of the environment (ground, hydrosphere, subsoil, etc.);
- proactive development of a compensatory model of a stable social-economical and ecological-technogenic development of mining sectors in Donbas taking into account the restructuring mining complexes experience in the EU countries (Germany, Great Britain, etc.);
- improvement of the monitoring structure based on the broadening the complex of evaluating parameters, implementation on mathematical models of TGS in the mining sectors, use of the GIS and ERS technologies (interferometry, spectrometry and so on);
- scientific basis for permissible changes in the ecological parameters of the environment components and long-term health and safety;
- provision of long-term exploitation of the critical infrastructure objects (energy, water and heating supply complexes, transport network, etc.);
- increase in consumption of fresh underground water resources as a protected from technogenic pollution resource of drinking and economic water supply;
- definition of farmland sectors which are geochemically safe for receiving agricultural commodities.

In general, the stage of creating basis and developing the post-mining policy in the CMS in Donbas for the economics and a large number of people is a strategic scientific-technological and social-economical task, taking into account the leading role of a coal-raw component in contributing to the GDP and providing resource and energy safety of the country.

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