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Geospatial Assessment of the State of the Samara River Floodplain in the Area of Coal Mining in Western Donbas

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Abstract. The discharge of highly mineralized mine waters of the Western Donbass negatively affected the Samara Bay area, which is of great fishery importance. Mine water storage ponds were built in deep erosional cuts in the territories of mine fields in the gullies of Kosminnaya, Taranova, Glinyana and Svidovok. The screening of the bottoms was not performed in any pond. The soils that make up the bottom are not aquicludes, which contributes to intensive filtration of mine waters and pollution of aquifers. Artificial ponds built without waterproofing of bottoms, rock dumps, mine water discharge routes and other sources of pollution are actively involved in the zone of influence of mine drainage and worsen the quality of drinking water, the reserves of which in the Western Donbass are limited. There is flooding and flooding by groundwater, as well as increasing (compared to the period before the violations) areas of land temporarily flooded during floods on rivers in the valleys of the rivers Samara, Velyka Ternivka and such large beams as Svydovok, Taranova, Kosminna due to subsidence of the earth's surface. Differences in the conditions of formation of mine waters determine the nature and degree of their impact on the environment. The main difficulties making complicated accurate comparison between calculated and field data in Samara river floodplain are following: a) changes in parameters of mining and pumping rates of water used for local needs; b) hydrological changes including formation of new channels, bed deformation; c) transformation of the monitoring network; d) increasing leakage through the clayey bottom of the ponds. The main objective is to provide a comprehensive geo-ecological assessment of the state of the Samara river floodplain in the area of coal mining in the Western Donbass. Multispectral imagery of Sentinel-2 satellite system was used for remote assessment within the study area. Geomorphologic assessment of the studied area was performed using Sentinel-1 satellite radar interferometry. Flooding of the territory is observed due to mine drainage and subsidence of the earth's surface. The risk of salinization of soils under the conditions of water use from the beam "Glynyana" and from the Samara river is estimated as insignificant, from the beam "Kosminna" – average. The SAR value of mine waters in "Taranova" and "Svydovok" beams corresponds to a high level of salinity. Samara river waters belong to the 3rd class and are characterized as highly mineralized, sometimes unsuitable for irrigation. Intensive natural overgrowth of the mine dumps that have passed the stage of mining reclamation has been recorded near the "Heroyiv of Space", "Pavlogradska" and "Samarska" mines. The rate of self-growth of the land cover around the mine "Ternovska" and "Blagodatna" is estimated as average. The self-healing levels of the "Ternovska" and "Blagodatna West Donbasska" mines are rated from low to high. The greatest risk of salinization of soils under conditions of use of water for irrigation is possible at a fence from artificial ponds located in Taranov's and Svidovok's beams. The conturs of "Verbsky", "Ternivsky", "Bogdanovsky" and "Boguslavskiy" piscicultural ponds can be corrected with map of remote sensing of Samara river floodplain geomorphology. The data obtained can be useful during development of econetwork of promising ecological corridors in the floodplain part of the Samara River as well.

Keywords: floodplain; remote sensing; coal mining; mine water; salinization.

Introduction

Coal mining in the Western Donbass is accompanied by intensive drainage of mine waters of high mineralization. The annual discharge of mine waters is so large (18–20 million m^3 / year) that their volumes have become comparable to the volumes of natural runoff of small rivers (Kharytonov & Lapyna, 2010).

Mine water accumulates in ponds that are built without bottom shielding and are a source of groundwater pollution. The area of land covered with mine rocks is constantly increasing. These rocks are an additional source of contamination of soils and groundwater with easily soluble salts (Kharytonov & Bondar, 2007).

The environmental situation of the region is deteriorating under the influence of these anthropogenic factors (Kharytonov et al., 2006).

The current state of the ecosystem of the Samara River is due to the duration and intensity of man-made stressors. Anthropogenic factor has led to significant eutrophication of the river along its course, shallowing, falling levels of biological diversity of most components of the ecosystem, especially in areas of municipal and industrial wastewater (Shmatkov et al., 1990;2012).

Irrigated lands and the water area of the Samara Bay are negatively affected as a result of the discharge of highly mineralized mine waters of the Western Donbass. As a result of subsidence of the earth's surface in the valleys of rivers such as Samara, Velyka

Ternivka and large beams such as Svydovok, Taranova, Kosminna, groundwater is flooded. The area of land temporarily flooded during floods increases (Kharytonov et al., 2009).

The total volume of mine water entering the settling ponds is 32 million m^3/year, and filtration losses can reach 60% of the existing flow. The mineralization of the Samara River increased gradually (in proportion to the expansion of the mining industry) in the first years of the coal mining process, but then significantly increased the volume of discharge and mineralization of water, respectively (Yevgrashkina, 2003).

This led to the intensification of the process of transformation of local hydrobiocenoses. Depletion of species composition was observed in some groups of aquatic organisms (Kochet et al., 2006).

There are many arguments in favor of continuing the partial treatment of mine water in reservoirs created separately or built directly in meanders, floodplains, bays, etc (Gore, 1985). This is due to the ability of biological systems to self-clean or inactive a certain proportion of pollutants.

The main goal is to provide a comprehensive geo-ecological assessment of the state of the Samara river floodplain in the area of coal mining in the Western Donbass.

Material and methods

Mine water storage ponds were built in deep erosional cuts in the territories of mine fields in the gullies of Kosminnaya, Taranova, Glinyana and Svidovok. The screening of the bottoms was not performed in any pond. The soils that make up the bottom are not aquicludes, which contributes to intensive filtration of mine waters and pollution of aquifers. The formation of water inflows into the mines of Western Donbass occurs according to two schemes (Yevgrashkina, 2003).

The first is typical for the eastern group of mines, where coal seams enter under the aquifers of the Meso-Cenozoic and are hydraulically connected with them (mines Pershotravneva, Stepnaya, Dneprovskaya, Stashkov, Yubileinaya). The values of water inflows into these mines are 500–1000 m^3/hour. Due to the significant overflow of fresh waters of the Cenozoic into the coal deposits, mine waters of relatively low salinity (2.0–2.6 g/dm^3) are formed here.

Sulfate-chloride and chloride-sulfate-hydrocarbonate water types are formed as a result of their mixing with saline waters of deep carboniferous horizons. The second scheme is inherent in the mines of the central group, where coal seams, limited by discharges, do not have access to the aquifers of the Meso-Cenozoic (mines Ternovskaya, Pavlogradskaya, Blagodatnaya, Zapadno-Donbasskaya, Heroes of Kosmos). The main source of the formation of tributaries and the composition of mine waters are the salt waters of the Carboniferous rocks. Mineralization of mine waters reaches 40 g/dm^3, chemical composition – sodium chloride.

Two approaches were applied for the assessment of the acceptability of the several sources of mine water for the irrigation. It is worthwhile to develop three classes of water for adherence to maturity at the first step: I – weakly neutralized (up to 1g/dm^3); II – medium-neutralized (1–3 g/dm^3); III – strongly neutralized (3–5 g/dm^3). Waters with a mineralization more than 5 g/dm^3 for irrigation are unauthorized. Assessment of the risk of salinization of irrigated soils is made with determining sodium adsorption rate (SAR) follow formula (Yıldız and Karakuş, 2020):

$$SAR = \frac{[Na^+]}{\sqrt{0.5(Ca^{2+} + Mg^{2+})}} \quad (1)$$

SAR = 0–10 − the risk of salinization is low; SAR =10−18 − medium; (18−26) − high; SAR >26 – very high.

Multispectral imagery of Landsate satellite system was used for remote assessment within the study area. Geomorphologic assessment of the studied area was performed using Sentinel-1 satellite radar interferometry.

Results

The results of calculations of the sodium adsorption rate (SAR) for the use of waste mine water accumulated in four beams and water from the Samara River for irrigation are shown in Figures 1 and 2.

The risk of salinization of soils under the conditions of water use from the beam "Glynyana" and from the Samara river is estimated as insignificant, from the beam "Kosminna" – average. The SAR value of mine waters in "Taranova" and "Svidovok" beams corresponds to a high level of salinity.

Note as a comment to figure 2 the following: the beam "Svidovok" accumulates wastewater from the mines "Heroes of Space" (1), "Blagodatna" (2), "Pavlogradska" (3), "Western Donbass" (4), "Ternovska "(5). Beam "Taranova" absorbs wastewater from the mines "Dniprovska", named after "Stashkov" and "Samara". The mineralized waters of the "Stepova", "Pershotravneva" and "Yuvileyna" mines flow into the "Kosminna" beam.

Differences in the conditions of formation of mine waters determine the nature and degree of their impact on the environment. The waters of the central group of mines, due to high mineralization, cause salinization of soils and increased mineralization of surface and groundwater in places of their accumulation and by discharge routes. Mine waters of the eastern group, have a relatively low mineralization, do not lead to a significant deterioration in groundwater quality and are used for irrigation of lands adjacent to storage ponds (Yevgrashkina et al., 2008).

However, the drainage of the eastern group of mines led to the formation of a depression funnel on an area of 500 km^2 with a decrease in the center to 40 m in the Buchak horizon, which is used for water supply to settlements. The depression funnel has a radius

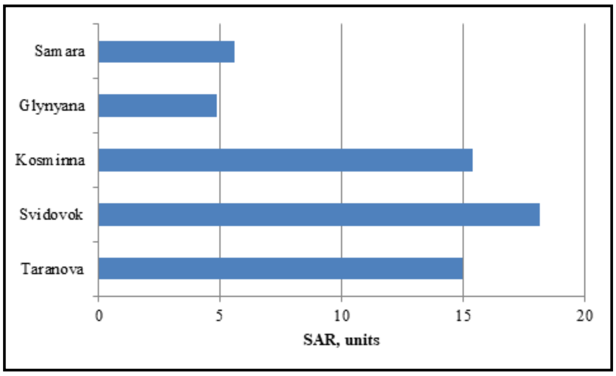

Fig. 1. The sodium adsorption rate for the mine water use of four ponds

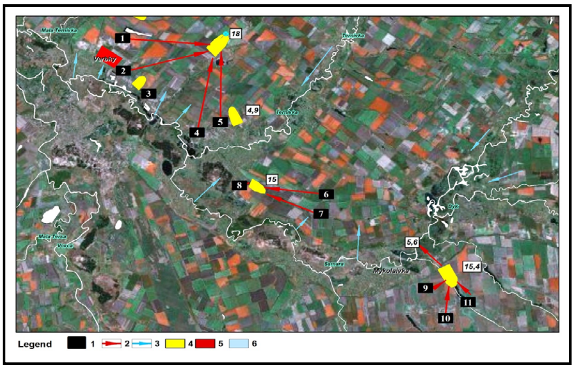

Fig. 2. SAR spatial distribution in the map of Samara river floodplain

of 8 km, the level decrease in the center is 15 m. The regime of the Sarmatian and Quaternary alluvial aquifers is disturbed. As a result, the conditions for water supply to settlements have worsened, and the conditions for feeding and unloading groundwater have changed over large areas. Artificial ponds built without waterproofing the bottoms, rock heaps, mine water discharge routes and other sources of pollution are actively involved in the zone of influence of mine drainage and deteriorate the quality of drinking water, the reserves of which are limited in the Western Donbass.

The results of the assessment of the mineralization of water in the Samara river for the Verbki village based on the data from the 40 samplings (2–4 times per day) for the period 2007–2016, are shown in Fig. 3.

Thus, river waters belong to the 3rd class and are characterized as highly mineralized, sometimes unsuitable for irrigation. A multi-year plan was developed at PA “Pavlogradvugyllya” back in the 80 s of the last century to carry out restoration work in the area of coal mining in the Western Donbass. This plan provided for a balanced approach to environmental management, including the geomorphological features of the landscape in the floodplain of the Samara River.

Part of the land was restored for arable land and pastures by the end of the last century. Their share was 66.8 and 10.2%, respectively, and for the cultivation of forest crops – 23%. The assessment of the projective cover of the earth's surface by vegetation is possible due to the assessment of the spectral reflective features of the surface (Stankevich et al., 2013). Remote sensing of the area was carried out to assess the current state of the vegetation cover after reclamation of mine dumps in the floodplain zone of the Samara river (Fig. 4).

The presence of territories with a high level of projective cover near the mines of Heroes of Space, Pavlogradskaya and Samarskaya indicates intensive natural overgrowing of mine dumps that have passed the stage of land reclamation. The rate of spontaneous growth of the land cover around the “Ternovska” and “Blagodatna” mines is estimated as average. The spontaneous growth rate of the three reclaimed areas of the “Zahidno Donbasska” mine varies from low to high.

Flooding of the territory is observed due to mine drainage and subsidence of the earth's surface. The results of the relief remote sensing upon completion of the reclamation of coal dumps are shown in Fig. 5.

Analysis of landscape features has revealed additional prospects for the creation of feeding ponds for fish breeding as well.

Discussion

Studies, such as coal mining monitoring (Demirel et al., 2011; Kong et al., 2016), reclamation of mine heaps (Gorokhovich et al, 2003) have been carried out in Turkey, China and the United States. Several models have been developed for the specific task of simulating the flooding of large underground mines and the associated rebound of the groundwater table (Rapantova et al., 2007). It was concluded that groundwater modeling, based on realistic assumptions on hydrogeological structure, boundary conditions, recharge and discharge areas can be used as valuable tool for verification of the conceptual models accepted. There are four different process models which integrate ground and surface water processes (Waseem et al., 2020). These models were compared on the basis of own data requirement, desired complexity level, and their ability to simulate relevant hydrologic and hydraulic processes.

The groundwater management model of a coal mining area was developed to optimize mine drainage, water supply and environmental protection (Wu et al., 2010). The results of this case study show that the economic-hydraulic management model can be useful in solving the multi-factor problems of mine drainage, water supply and environmental protection for coal mines. The main difficulties making complicated accurate comparison between calculated and field data in Samara river floodplain are following:

a) changes in parameters of mining and pumping rates of water used for local needs;

b) hydrological changes including formation of new channels, bed deformation;

c) transformation of the monitoring network;

d) increasing leakage through the clayey bottom of the ponds (Yevgrashkina, 2003; Yevgrashkina et al., 2009).

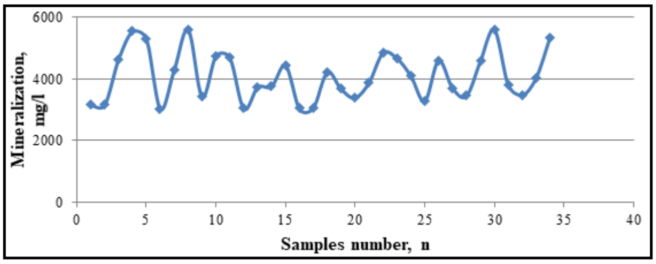

Fig. 3. Mineralization of water of the river Samara for the period 2007–2016

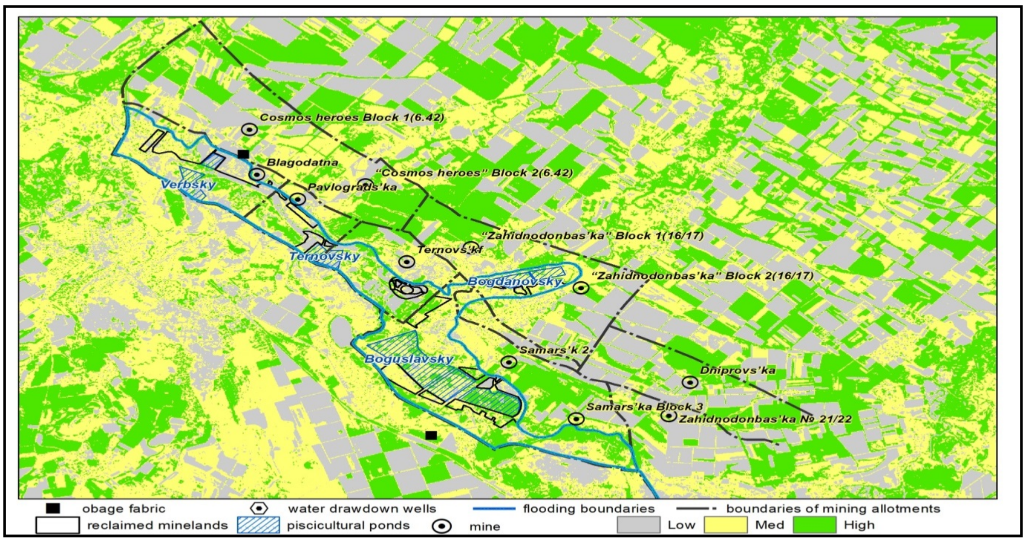

Fig. 4. Multispectral image of the Samara river floodplain (2020)

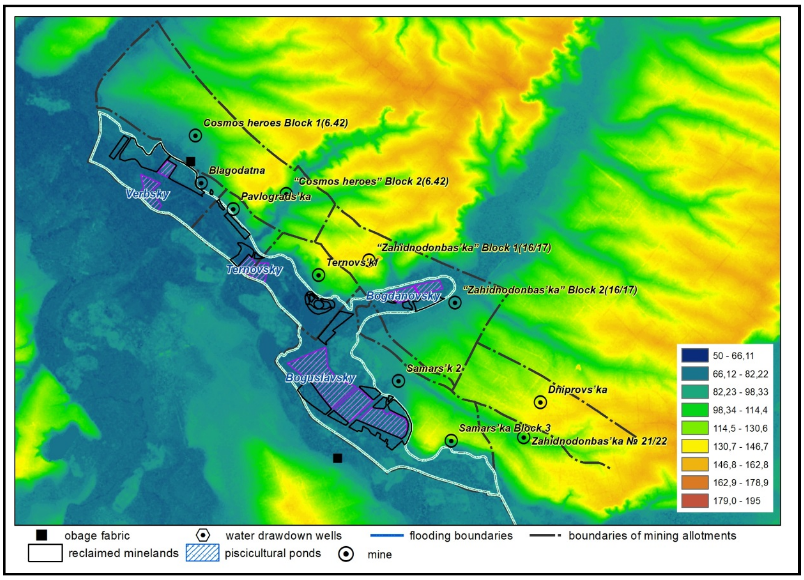

Fig. 5. Remote sensing of Samara river floodplain geomorphology

Lowering the surface floodplain leads to massive drying of the forest. Weak – and medium – saline meadows are gradually formed under these conditions. Long-term practice of biological reclamation in the conditions of technogenic subsidence of the territory has shown that horizontal drainage is a reliable means of ensuring the preservation of forest plantations located on existing minefields. Under conditions of increased anthropogenic pressure on water bodies, the biocenoses have gradually degraded (Fedonenko et al., 2018). Discharge mine water has the greatest negative impact on water bodies in the floodplain of the Samara river. This is due to their huge volume, low quality in many respects and the large-scale impact of coal mining processes on water bodies over time. Studies have shown that in the areas of inflow of mine water quality in some parameters is defined as "very polluted" (Kochet et al., 2004). The mineralization rate of mine waters in the area of the village of Verbky (mine runoff distribution zone) for the period 2007–2016 often exceeded 5 g / l. Modern studies of biota components in different parts of the river have shown that the Samara ecosystem has a high capacity for self-purification and self-recovery (Kulyk et al., 2003). The current scheme of mine water inflow to the Samara River is conditionally acceptable. The existence of reservoirs is to some extent justified. Therefore, the creation of new drives on the type of existing ones may be appropriate in terms of reducing the overall negative impact. Meanwhile, the relative balance of the components of the hydrobiota may be disturbed in the near future. The search for ways to solve this geo-ecological problem is conducted in many areas.

Conclusion

Intensive natural overgrowth of the mine dumps that have passed the stage of mining reclamation has been recorded near the "Heroes of Space", "Pavlogradska" and "Samara" mines. The rate of self-growth of the land cover around the mine "Ternovska" and "Blagodatna" is estimated as average. The self-healing levels of the "Ternovska", "Blagodatna" and Zakhydno Donbasska" mines are rated from low to high. The greatest risk of salinization of soils under conditions of use of water for irrigation is possible at a fence from artificial ponds located in Taranov's and Svidovok's beams.

The conturs of "Verbsky", "Ternovsky", "Bogdanovsky" and "Boguslavsky" piscicultural ponds can be corrected with map of remote sensing of Samara river floodplain geomorphology. The data obtained can be useful during the development of an eco-network of promising ecological corridors in the floodplain part of the Samara River as well.

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