Improving the Quality of Mine Water Treatment

V A Dmitrienko\textsuperscript{1}, S N Armeiskov\textsuperscript{1}, N A Dmitrienko\textsuperscript{1}

\textsuperscript{1}Institute of service and business (branch) Don state technical University in town Shakhty of Rostov region, Shevchenko street 147, 346500, Russia

E-mail: VADmitrienko@rambler.ru

Abstract. The article deals with the features of groundwater treatment in town Shakhty after the closure of mining enterprises. A high concentration of salts and solids in the treated waters was noted. The positive experience of phyto purification by using aqueous hyacinth - Eichornia is considered. The existing scheme of pumped ground water purification is presented and the results of studies of water temperature regime in ponds sumps of mine water are given. The possibility of providing a nutrient medium and extending the growing season of a thermophilic plant during the groundwater treatment of groundwater and wastewater is indicated.

1. Introduction

On earth, groundwater is the second largest volume after the world ocean, and therefore plays a very important role for environmental in the region. Mining enterprises have the greatest impact on the state of groundwater and for their normal functioning it is necessary to pump huge amounts of water to the surface during the entire service life. [1]. Intensive filtration of water on the destroyed massifs with a lack of oxygen leads to the removal of a huge mass of substances in free form to the surface. Since water is an excellent solvent, as a rule, groundwater in its composition contains a large amount of dissolved substances [2]. Discharge of untreated mine water could cause extreme pollution of small rivers.

2. Significance of the problem

The specifics of coal mining lead to a huge area of undermining, and it demands large volumes of water pumping. So in town Shakhty purified groundwater is discharged into three rivers: Ayuta, Atyukhta and Kadomovka. This fact significantly affects water drainage and wastewater treatment. Among other things, in addition to servicing hundreds of kilometers of drainage networks, it is also necessary to treat pumped mine water.

In Eastern Donbass, 3 m\textsuperscript{3} of water had to be pumped per 1 ton of coal, so after the closure of mines and the cessation of pumping groundwater out of the mines, it led to the filling of the worked-out spaces with water and increasing water level, creating a threat of flooding of some areas of residential buildings. This required pumping water from old mine workings.

After the closure of the mines in the town, the organization "Operation of drainage complexes" was created consisting of three sections on the territory of the former mines of Yuzhnaya, Maiskaya and Glubokaya with a total volume of pumped water exceeding 1500 m\textsuperscript{3}/hour. The organization's activities are aimed at pumping water from old mine workings and treating it. For comparison, the actual wastewater consumption of the entire town is 750 - 920 m\textsuperscript{3}/hour.
Chemical analysis of composition of the pumped water shows that the content of magnesium and calcium in 1 m³ exceeds 0.7 kg, and iron 0.3 kg with a total dry residue of up to 9 kg. Given the large volume of pumping water per day, tens of tons of polluted water can be thrown into small rivers.

During the period of operation of coal enterprises and groundwater discharge, anthropogenic pollution in small river basins reached a critical level, and they practically lost the ability to clean themselves, especially in terms of sulfates, carbonates and iron. The main source of iron content in surface and underground waters is the processes of mechanical destruction and dissolution of rocks [3-4].

3. Discussion of research results

In groundwater, iron is usually found in the form of Fe²⁺ ions. Since the pH of mine water rarely reaches 6.5, water purification from iron compounds is a very difficult task, associated with a set of physicochemical and biological factors, the concentration of oxygen, free carbon dioxide, hydrogen sulfide and organic compounds in water [5].

Despite the complexity of mine water pumping in all areas, the issue of iron removal is solved quite effectively by intensive water aeration, preliminary purification of mine water from suspended solids in sections of sumps tanks and in four to five cascades of shallow ponds (Fig. 1).

![Figure 1. A complex of treatment facilities on the territory of the former "Glubokaya" mine: 1 - a mixer; 2 - aerator; 3 - the first pond sump; 4 - the second pond sump; 5 - third pond sump; 6 - fourth pond sump.](image)

The introduction of a large amount of oxygen in the system and anionic polymer flocculants, allows you to intensify the oxidation process with the deposition of a significant part of the iron-containing hydroxide precipitate in the section sumps.

The adopted mine water treatment scheme ensures the passage of mineralized water through the cascade of ponds during 3.5 days with normal flow, allows reducing iron emissions in three times and suspended particles twice, but salt content cannot be reduced. Therefore, small rivers around mining towns are at risk of salinization.
Analysis of the chemical composition of treated domestic water shows that the degree of treatment of household waste water by suspended substances, BOD₅, COD, ammonium ions and SDWW is very effective. For phosphorus and phosphates, it does not exceed 60%, and for nitrites, chlorides, sulfates and dry residue, there is practically no cleaning. A similar picture is observed for mine waters.

The tendency to increase the share of nitrogen-and phosphorus-containing organic substances in the composition of domestic wastewater complicates the work of existing biological treatment facilities, and they do not always provide the necessary purification from biogenic substance [6].

The analysis of world experience shows that a very effective way of further treatment of urban wastewater from nutrients is the use of higher aquatic vegetation (HAV) - macrophytes (cane, reed, Urut, duckweed). The ability of HAV to accumulate, recycle, transform many pollutants makes them indispensable in the overall process of self-purification of water bodies [7-8]. However, these plants accumulate pollutants and therefore require disposal, which is usually very expensive.

In this regard, in our opinion, special attention is paid to further wastewater treatment by means of using the highest floating aquatic plants of the Pontederia family – Eichornia [9] on the root surface are formed selective microbiocenoses (algae, protozoa, microinvertebrates), contributing to a more active biological degradation and absorption of organic and mineral substances. The peculiarity of this heat-loving aquatic plant is that, when wastewater is treated, eichornia oxidizes and breaks down industrial and organic sewage, water impurities into simple elements with high speed and assimilates them as nutrition. [6,10]. In this case, the role of the oxidizing agent is played by oxygen, which is produced in excess by eichornia. Thus, by purifying household and industrial effluents from harmful impurities, the plant does not accumulate them in itself, but rather “eats” it, while actively growing.

The dirtier the pond, the faster hyacinth grows and multiplies [8,11]. That is, the plant absorbs, oxidizes, and breaks down into constituent chemical elements, ammonia, phenols, sulfides, phosphates, manure, feces, salts of heavy metals, radionuclides, gasoline, fuels and lubricants, any oil products, surface-active substances, toxic chemicals, rocket fuel at a fairly high speed [12-13].

With the help of this plant, most nutrients can be extracted from effluents, and indicators such as biological oxygen demand (BOD) and chemical oxygen demand (COD) can be improved. Water hyacinth breaks down chemical contaminants, improves the quality of treated effluent in terms of BOD (from 150 to 20-30 mg / l), COD (from 300 to 25-30 mg / l) and suspended solids.

In the autumn period, when the average water temperature reaches below 14 °C, water-hyacinth protected from the wind can resist short-term temperature drops of up to 6 °C, but in this case the plant’s growth stops and, accordingly, the ability to purify water decreases. That is, despite the undoubted positive effect of phyto-treatment of wastewater in the town, serious problems hinder its implementation.

The first one is associated with the excess of element concentrations acceptable for plants, which requires dilution of treated domestic wastewater. At the same time, the ingredients necessary for feeding Eichornia are absent in the pumped mine waters. The second reason is the limited period of plant vegetation due to lower temperatures in winter time. That is, for at least four months, the treatment plant will cease to function.

We carried out a number of studies, as a result of which it was found out that the thermal regime necessary for the Eichornia vegetation can be maintained for almost the entire year as it was done at the treatment facilities of the former Glubokaya mine. The fact is that the water temperature is 19.1 °C all year-round with pumping volumes of 930 m³/h. Having passed the aeration tank and the first pond sedimentation tank, even in December it decreases only to 18.6 °C. Moreover, the influence of external factors is within the accuracy of determining the average temperature of the pond.

At the exit from the fourth pond of the sump, the water purified from iron had a temperature from 13.7 °C to 17.2 °C. During the relatively long cold period of January - February, the temperature was 11.4 °C outside the sumps.

Thus, it can be noted that the temperature regime of the treated mine water allows cultivating Eichornia almost all year round. Though there is another problem - air temperature. The conducted studies show that at a distance of 0.2 m from the surface of the water, the average air temperature is lower...
than the water temperature by 2.3 °C, with a wind speed of not more than 3 m/s. That is, the air temperature above the water does not reach the critical temperature of 6 °C for eichornia.

As a result, it can be noted that under certain conditions and low financial costs, a phyto-ranger can be arranged near the aerator for growing Eichornia, and adult plants can be put into sumps tanks at a water temperature of 14 °C or higher. This will ensure quick plants adaptation and increase the period of effective purifying to 9 - 11 months.

Of course, there is another problem - the nutrient medium. It is practically absent in mine water, but the problem can be successfully solved within the city if part of the household wastewater is directed to the mine water treatment facilities. In this case, there will be a positive effect. The fact is that the sewage drains from settlements located near the mine through the system of pressure stations are pumped to the town treatment facilities, located at a distance of 9 km from the facilities. Directing wastewater to nearby mine treatment plants will provide a significant reduction in operating costs.

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4. Conclusion
The experience of cultivating water hyacinth in Russia shows that it can vegetate in the northern regions of the country, up to the latitude of Arkhangelsk.

Further treatment of mine waters with higher water plants will allow to significantly reduce ecological load on water resources of Rostov region, as consumption of carbon dioxide from impurities in the water by plants leads to precipitation of insoluble and hardly soluble basic salts, that is, the rigidity and salt content of water can be significantly reduced.

The study of the temperature regime of ponds of mine water sumps allows providing a relatively favorable vegetation regime of eichornia for 9–11 months and, accordingly, increasing the efficiency of wastewater and mine water treatment.

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