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Complex technology of bioremediation and bioelectric power generation in wastewater treatment of gold mining enterprises

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Abstract

Wastewater from mining and processing plants is characterized by a high content of suspended solids, low transparency, relatively high mineralization and a variety of specific ingredients, a high content of metals, cyanides and their complexes with metals, rhodanides, toxic organic pollutants (flotation reagents and flocculants). The content of water circulation in such industries requires special research and development highly efficient methods of circulating water treatment, ensuring not only the return of water of the required quality, but also the extraction of valuable components. The article summarizes data on the development and testing of an integrated technology of bioremediation and bioelectric generation in plant-microbial fuel cells, which allows the energy-consuming process of wastewater treatment to turn the method of generating electricity. Experimental data on the selection of plant organisms – the most effective for the implementation of complex technology – are presented.
It is proposed to use submerged aquatic plants in the form of a bio-plateau in combination with plant microbial elements. The bio-plateau consists of two blocks: a phyto-garden with aquatic plants fixed in peat or straw with sludge applied to them and a plant-microbial fuel cell. The frame of the bio-plateau is made of hollow retaining frame structures made of sealed plastic pipes, inside which a cage made of non-woven material is installed. Biological loading will be placed in the cage - aquatic plants, peat with applied strains of destructor microorganisms. The second unit is a plant-based microbial fuel cell with pistia plantings.

Keywords: gold mining, wastewater, treatment, phytoremediation, vegetable-microbial fuel cells.

1. Introduction

Large-scale global changes in the natural environment are now becoming more and more apparent. They can be traced at various levels in all geospheres of the Earth and have an ever-increasing impact on the development of human society. Anthropogenic impact has already reached such a level that it is felt on a planetary scale. Today, there is a significant shortage of fresh water. According to UN information sources, currently 1.2 billion people on the planet live in conditions of constant shortage of fresh water and more than 2 billion suffer from it in the dry season.

The Republic of Uzbekistan belongs to the states where, due to the hot and arid climate and the intensive development of industry and agriculture, the problem of water supply to the population and wastewater treatment that has passed technological cycles is extremely acute. Among the problems in terms of water supply and sanitation is the

Navoi region, located in the central part of Uzbekistan, rich in natural gas, oil and precious metals, and where mining, metallurgical and chemical production complexes are successfully operating, cotton and sheep breeding are developed.

The greatest contribution to the economy of the region is made by the Navoi Mining and Metallurgical Combine, which supplies uranium and gold to the world market. The company is a consumer of a large amount of water, for example, only one division of NGMK - Hydrometallurgical Plant No.3 (GMZ-3) of the Northern Mining Administration, with a consumption of 1.8 m3 of water per ton of ore during the processing of 15 million tons of ore, takes 27 million m3 from the Beshbulak water intake and the volume of wastewater in the tailings dump will be about 67500 m3 [1,2].

One of the promising technologies for wastewater treatment is biotechnological treatment, based on the principles of bioremediation in structures that are wetland systems (constructed wetlands, bio-plateau, FOS - phyto-treatment systems or structures, BIS - bioengineering facilities) through which wastewater is filtered and due to the accumulation and metabolic transformations of pollutants in the biomass of plants and microbial communities, developing in the root zone [3-4]. The literature describes many designs of such structures, each of which has its own advantages and disadvantages and areas of application [4-9]. For gold mining enterprises, such technologies are intensively developed and tested, including such work is carried out on the wastewater of the NGMK tailings dump.

The purpose of this work was to assess the possibilities of creating an integrated technology for bioremediation and bioelectric generation in the treatment of wastewater from gold mining facilities.

2 Study Objects and Methods

The paper summarizes data on the development and testing of an integrated technology for bioremediation and bioelectric generation in plant-microbial fuel cells, which allows the energy-intensive process of wastewater treatment to turn the method of generating electricity. Experimental data on the selection of plant organisms – the most effective for the implementation of complex technology – are presented.

Aquatic plants growing in the wetlands of the valley of the Zarafshan River were tested as phyto-cleaners. The conditions for conducting and sampling are described in detail in [10]. Wastewater taken from the GMZ-3(HMF-3 hydrometallurgical factory) tailings was placed in a 10 liter tank, and the studied hydrophytes were introduced at the rate of 200-500 g of raw biomass per^{m2} the area of the aquarium was exposed to the light and after 1, 5, 10 and 20 days samples were taken and the residual content of anions and cations in wastewater was analyzed in the accredited laboratory of water problems at the CNIL of the NMMC using spectral methods[23-32].

As part of the development of phytoremediation regimes, a series of experiments was carried out to study the possibilities of generating electricity in installations using plants - plant-microbial fuel cells (RTME).

The following plants were used in the work: Eichhornia *Eichhornia crassipes (Solms.) Pontederiaceae),* pistia *(Pistia stratiotes L., Araceae);* small duckweed *(Lemna minor (L.), Lemnaceae).* Plants are free-floating, grow and multiply on the surface of the water and have a root system on which microorganisms attach. As a reference, the use of RTME with rice, the most studied plant used in laboratories.

In the work, the design of a plant-fuel cell developed by employees of the Research Institute of Biology of Irkutsk State University was tested. RMTE is a modification of a microbial fuel cell and includes, in addition to the cathode and anode with microorganisms placed on it, living plants that produce rhizodeposits - a substrate for electroactive bacteria.

Plant-microbial fuel cells have the form of a plastic container with a volume of 0.5 liters and a size of 5×8×10 cm. At the bottom of the tank there is a layer of fine sand (250 g, 5×8×3 cm), above it is a layer of fine coal (100 g, 5×8×3 cm), on the surface there is a layer of fine sand (250 g, 5×8×3 cm). The sand served as a supporting medium for the root system of plants and served as a filter, coal was a medium for the adhesion *of Micrococcus luteus 1-l microorganisms and an additional anode.* Plants were stirred into the top layer of sand. At the bottom of the tank there is one hole with a tube: – for the introduction of aqueous solutions and a bioagent into the anode region. The cathode is located in the surface layer. The emerging potential of the RMTE anode was determined using a DT 838 multimeter (Fig. 1).

Fig.1. Plant-microbial fuel cell

Swamp sludge was used as a bioagent, which was applied to the bottom of the device with a height of no more than 3 cm. Plants were pre-grown to the following leaf sizes: eichornia up to 20 cm, pistia up to 10, duckweed -2, rice had a stem up to 15 cm. and placed in plastic containers and supplied with wastewater taken from the tailings dump and dilutions of 1:1, 1:10, 1:100 and measured the current-voltage characteristics at certain intervals.

Plant-microbial fuel cells (PMFC) are a new sustainable technology that generates electricity using living plants. It is important to note that this system does not affect plant growth and does not harm the environment. Plant-microbial fuel cells (RMTs) are new derivatives of microbial fuel cell (MTE) devices. Organic matter is produced by the root systems of plants. Further, they are consumed by microorganisms, located in the anode layer of the structure and electricity is generated.

Table 1 shows the average of the set of main components of wastewater from the tailings dump under study.

Table 1. Average composition of the studied wastewater.

Cation	Cation content, mg/l	Anion	Anion content, mg/l
magnesium	534	Nitrites	1,2
Iron total	162	nitrates	6,6
copper	5,9	Rhodanides	340
zinc	0,4	Cyanides	10,1
lead	0,16	Sulphates	5,9
manganese	0,13	Chlorides	478,6
nickel	8,4		

3 Results and Discussion

The use of Phyto technologies is increasingly used in various fields of human activity, including wastewater treatment and additional extraction of useful components. Research is conducted in more than 80 countries of the world, primarily Europe, America, Southeast Asia, and the number of publications in this direction is growing geometrically progression, doubling every 2-4 years. China has especially succeeded in this direction, where from 15 to 30 such structures are put into operation annually. The main advantages of such technologies are the versatility of use for almost any contaminants, the absence of side effects, the long life and low cost of operation of structures and installations, simple infrastructure and low resource and energy consumption, and when creating an integrated technology in combination with plant microbial fuel cells, power generation can be provided [11-16].

Plants used in the treatment of wastewater from heavy metals must meet certain requirements: be tolerant to metals, grow rapidly, be resistant to diseases, have a developed root system and shoots, are able to synthesize root substrates, be unattractive to animals, so as not to transmit pollutants along the trophic chain [17].

The main mechanism of such purification is phytoextraction / phytoaccumulation of metals - accumulation in the body of plants and Phyto stabilization - the transfer of compounds into a less mobile and active form. At the same time, active biosorbents are both living plants and dead biomass and sludge microorganisms.

Earlier, Timofeeva S.S. [18-22] studied the patterns of extraction of cyanides, rhodanides and heavy metals from the wastewater of the gold recovery plant and revealed the mechanisms of detoxification involving plants of different geographical zones.

With regard to the wastewater of NGMK, we have studied the patterns of extraction of wastewater components given in Table. 1. In fig. Figures 2-4 show data on the efficiency of extracting the studied anions and cations from wastewater.

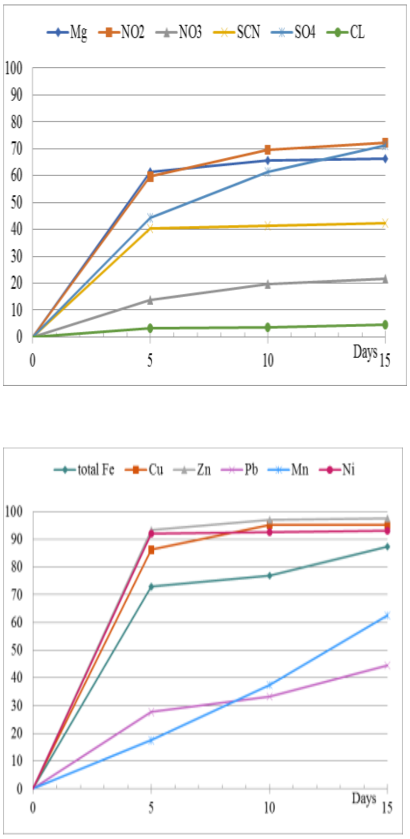

Fig. 2. Dynamics of accumulation of pollutants by eichornia, 500 mg/m2

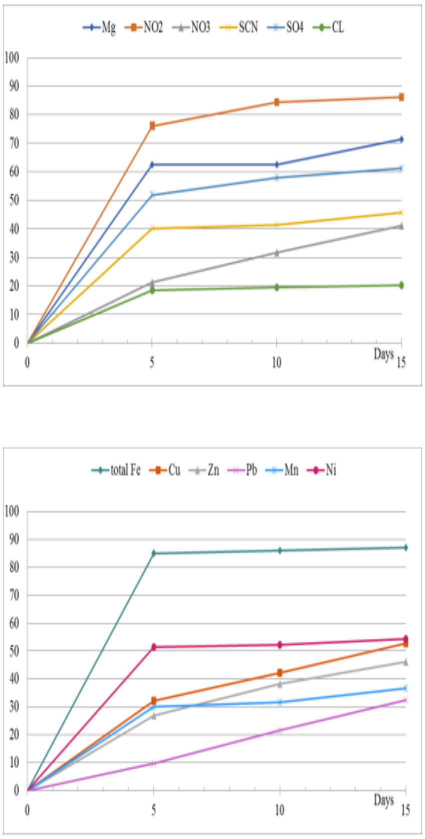

Fig. 3. Dynamics of accumulation of wastewater components by pistia, 200 mg/m^2

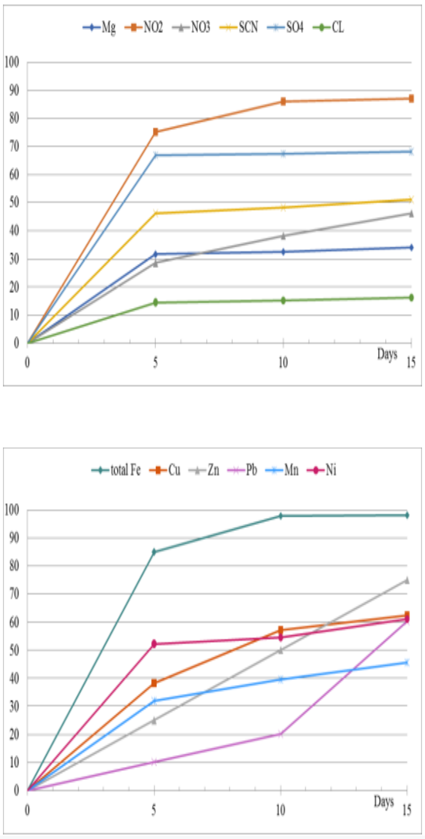

Fig. 4. Dynamics of accumulation of wastewater components by duckweed, 200 mg/m2

As follows from the above data, the degree of cure of wastewater components depends on the compound and the plant under study. The maximum accumulation of metals is observed in the first 3 days for the studied cations and anions. The highest assimilating ability was found in echornia

The highest level of power generation in RTME was observed in installations with pistia with a graphite electrode, the maximum voltage was recorded at the level of 412 mV, at cultivation duration 60 days, current 1.61 mA

The table shows the results for determining the phytoremediation potential for the studied substances and the stress recorded in the RTME.

Table 2. Calculated total phytoremediation potential for the studied substances and electrogenation

Phytoremediation potential by pollutants, mg/g wet weight	Meaning
Eichornia	25
Pistia	21
Duckweed	10

RMTE with pistia, voltage, mV, every other day 1 10 15 60	25,03 274,33 183,33 328,16
RMTE sludge current, μA through, days 1 10	77,18 155,25

15 60	500,75 289,91

We propose to use submerged aquatic plants in the form of bio-plateau in combination with plant microbial elements.

The bio-plateau consists of two blocks: a phyto-garden with aquatic plants fixed in peat or straw with sludge applied to them and a plant-microbial fuel cell. The frame of the bio-plateau is made of hollow retaining frame structures made of sealed plastic pipes, inside which a cage made of non-woven material is installed. Biological loading will be placed in the cage - aquatic plants, peat with applied strains of destructor microorganisms. The second unit is a plant-based microbial fuel cell with pistia plantings.

Conclusion

In conclusion, we managed to create a two-chamber plant of the bio-plateau type, combining the functions of cleaning from pollutants and power generation of plant-microbial fuels elements and make a selection of effective electrode materials.

Of the plants, pistia, rice and eichornia turned out to be more effective, the lowest rates of current generation were noted when using duckweed.

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