Vegetation engineering structure for heavy metals absorption

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Abstract. Abstract. The treatment of contaminated water is a pressing issue. As a solution it is proposed to use a biological engineering construction with the aquatic vegetation - a bioplato. The process of water purification takes place at the expense of the natural capacity of a number of living organisms and plants to transform and absorb contaminants [1]. The phytoremediation method helps to extract heavy metals from water and makes it suitable for consumption and use. However, in order to be most effective, it is necessary to choose the planting method and optimal environmental conditions. Therefore, several types of bioplato were created and tested during the experiment: with different planting methods (bare root, container grown) and in the presence of microorganisms (Pseudomonas fluorescens and Rhodococcus erythropolis). The contaminants were water-soluble salts of lead (II) acetate and cadmium chloride. Iris pseudacorus and Typha gracilis were selected for the experiment, as the plants are capable of significant heavy metals accumulation. The sampling was carried out according to GOST R 56237-2014 «Drinking water. Sampling at water preparation stations and pipeline distribution systems» and GOST 31861-2012 «Water. General requirements for sampling». The samples were analyzed using an atomic emission spectrometer with inductively bound plasma iCAP 6300 Duo. Studies have shown that the purification rate of plants in both planting methods is quite high - more than 92 %. In bare root samples, purification is more efficient (99% in the solutions with the cadmium ions concentration 20 times above the threshold limit value (TLV). The use of microorganisms contributed to the reduction of Pb²⁺ absorption by 18% in the bioplato with bare root planting method. However, a bioplato with container grown planting method in the presence of micro-organisms is 8,7% better at purifying water from Cd²⁺ ions.

1 Introduction

One of the UN sustainable development goals is «Ensure availability and sustainable management of water and sanitation for all» [2]. However, there is the problem of heavy-
metal contaminated water bodies, which requires a solution to achieve objective [3, 4]. The presence of heavy metals in water can lead to changes in its physical properties. Contaminated water bodies become unfit for drinking and technical water supply and lose the fishing value [5-7]. Many of the inputs exhibit mutagenic and carcinogenic properties, as well as disturb the structural and functional cells systems of living organisms [8-10], which can lead to a decrease in the activity of species and populations [11]. For such purposes, the use of a biological engineering facility with the highest water vegetation, the wetland constructed, is proposed. The vegetation structures is carried out by the natural capacity of a number of living organisms and plants to absorb, decompose and process contaminants [12]. Due to the phytoremediation method, heavy metals are extracted from water, making it suitable for consumption and use [13]. Wetland constructed will improve water quality by removing heavy metals from water bodies and thereby reducing untreated water; it will help to restore aquatic ecosystems. The aim of this work was to identify the most suitable plants, how to plant them, and to use species of microorganisms to effectively remove heavy metals from the aquatic environment.

2 Methods

Standard laboratory equipment, phytolamps, and scale with an accuracy of ± 0.1 mg were used. Plastic containers of 70 l were used to place the constructed wetlands for a control group and conducting experiments. The platform mats were made of foamed polyethylene. Universal soil and vegetation pots were used for germinating seedlings. Platform mats with higher aquatic plants planted in them are placed in the container. The temperatures of air - 23 °C, water - 19 °C and pH 6 - 9 [14].

The main element of the constructed wetlands is higher aquatic plants - macrophytes [15, 16]. For experiment were selected Tipha gracilis and Iris pseudacorus [17]. Plants are not difficult to care: they prefer sunlight or partially shaded plants with high humidity. These plants provide good treatment of polluted water bodies because they are hyperaccumulators. Also plants are not pleasant in continental climate and are suitable for use in wetland areas of Central Russia [18, 19].

To test the hypothesis about the influence of the root system on the ability of plants to accumulate pollution, two methods of planting plants in the mat platform were used. In the first planting method, plants were placed directly on platform mats without soil, as a result, macrophyte roots were almost completely in contact with water. This planting method is named as “open root” system.

In the second method, plants were placed in platform mats in vegetation pots with soil. This planting method is named “closed root” system.

Additionally, during the experiments, microorganism strains were added to the water. For the experiment, immobilized lyophilized (dry form) microorganisms Pseudomonas fluoresces and Rhodococcus erytropolis were used. These microorganisms are eurybiotic and in contact with chemical substances, partially destroy them. It was suggested that the symbiosis of added microorganisms with native microorganisms on the roots of aquatic plants form a bacterial surface, which increase the heavy metal adsorption capacity of plants.

And for experiment lead acetate at concentration of 0.005 mg/l and cadmium chloride at concentration of 0.001 mg/l and 0.002 mg/l were added to the water. Sampling was carried out on the 1st, 3d, 5th, and 8th days.

3 Results and Discussion
During the observation of plants during experiments, it was noticed that despite the presence of heavy metals in water many times higher than the maximum permissible concentration, not a single plant plant has not died.

According to the results it was found that the concentration of Pb$^{2+}$ absorbed by plants in group with a closed root system after 5 days is higher than in the same plants with an open root system, which can be explained by a large injury to plants in this type of planting. Subsequently, the absorption rate in plants with open roots substantially increases almost 3 times. It may be due to the fact that the open root system of plants is in almost complete contact with water environment and the area of contact of the root hairs with water significantly more. The results of presence Pseudomonas fluorescens and Rhodococcus erytropolis microorganism strains to the system are presented in Fig. 1.

![Fig. 1. The results of an experimental assessment of the rate of absorption of Pb$^{2+}$ by plants depending on the type of planting and the addition of the microorganisms Pseudomonas fluorescens and Rhodococcus erytropolis.](image)

The addition of Pseudomonas fluorescens and Rhodococcus erytropolis to the system led to a decrease in the rate of lead accumulation in plants. The intensive development of microorganisms in the root systems of plants partially delays the entry of heavy metals into plants. This may be due to the fact that antagonistic relations arose between native microorganisms that constantly live on the roots of plants and the added ones [20] The added microorganisms suppressed the growth of the native strains. In addition to lead, a series of experiments with cadmium was conducted Fig. 2.

![Fig. 2. The results of an experimental assessment of the rate of absorption of Cd$^{2+}$ by plants depending on the type of planting](image)
Experiments on phytoextraction of cadmium in «open root» and «closed root» systems showed that the cleaning of plants in both types of planting is quite high - more than 99% in all systems. However, in samples with an «open root» system, the degree of purification is slightly higher (by 0.2%).

4 Conclusions

The results of the work carried out showed the possibility of using an effective constructive wetland with Iris pseudacorus and Tipha gracilis. Irises are more suitable plant species and the least susceptible to seasonal fluctuations. The results also confirmed the significant role of the root system in the phytoremediation process and showed that higher aquatic plants possess the greatest absorbing ability when planting with an open root system. Also Pseudomonas and Rhodococcus are not effectively for cleaning. Perhaps other strains should be selected in studies. This may be due to the fact of antagonistic attitudes between native and added strains of microorganisms.

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