Treatment of waste and drainage water by biosorption method in Voronezh region

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Abstract. This paperwork studies a biosorption method in waste and drainage water treatment in the Don river basin under Voronezh climate conditions. The research question is: how an effective biosorption method in the Voronezh region. In this experiment Eichhornia (water hyacinth) is used as a biosorbent plant and the authors analyze the removing of some contaminants with eichhornia from wastewater. The experiment took place in the Rozhdestvenskaya Khava village of the Novousmansky district in the Voronezh region. According to experimental parameters in a period of 30 days, the effectiveness of this method is examined. An experiment is compared with similar previous experiments. Finally, at the end of this article the authors list conclusions and some recommendations according to the results of the experiment.

1. Introduction
The entry of pollutants into natural water reservoirs negatively affects to the state of water sources and its ecosystem. Every year in the Amudarya River Basin, large amount of heavy metals from wastewater of various types of industry and pesticides, fertilizers, nitrogen, phosphorus, etc. from irrigated lands through drainage canals enters to water bodies and irrigation canals [1,2]. Removing of these contaminants from water sources is possible by the phytoremediation method. In recent years, eichhornia has been widely used for treatment of polluted waters.

A large number of experiments were carried out, which yielded positive results, especially in regions with a hot climate.

The studies have studied the removing of some contaminants with eichhornia. The experiment was conducted in the Rozhdestvenskaya Khava village of Novousmansky district of Voronezh region, that locates 35 km from Voronezh. The experiment was conducted from 01.06.2018 to 30.06.2018 in the open air under natural conditions.

In recent years, adsorption is used widely among existing methods of wastewater treatment [3]. The most widely used adsorbent is activated carbon, but it is less economical because of its initial cost and
expensive regeneration [4-6]. It has been a trend for researchers to find more economical and effective alternatives like activated carbon derived from seaweed, graphite oxide and beech sawdust [6,7].

Eichhornia attracts considerable attention due to its extremely rapid spread and rapid growth, which are causes serious problems in transportation, fisheries, irrigation and hydropower (Figure 1).

Leaves of Eichhornia are wide, thick, shiny and ovate. Stems are usually long, spongy and convex. The roots are feathery, freely hanging and purple-black [7-9]. Flowers attractive, which consists six petals. It grows so fast and it can double its population in two weeks. Eichhornia reproduces by vegetative and by seeds, but vegetative reproduction predominates. Eichhornia produces large quantities of seeds that can remain viable up to thirty years [6].

Eichhornia accumulates pollution mainly on the roots, but at the same time, it can adsorb pollutants in a small amount via leaves. It is recommended to use this properties of water hyacinth, as an indicator of pollution of water reservoirs, which are locates in hot climates.

Figure 1. Eichhornias are floating on the surface of the river flow.

Studies have shown that eichhornia roots have a relatively high surface area (4.16 m²/g) and pore size (35.93 Å), and begins capture of ions into these large pores with good physical contact between biomass surface and soluble pollutant particles [8-16]. In addition, the -OH group is the main component of all types of eichhornia and acts as the main chelating center of the plant. As seen in Figure 2, the optimum adsorption of heavy metals observed in an acidic environment (pH 3.5-5.5) [8], and in an alkaline medium, adsorption practically did not occurs. This may be due to chemical and biological structure of the roots of eichhornia.

Figure 2. Effect of pH on heavy metal adsorption by Eichhornia.
2. Materials and Methods
The experiments studied the adsorption efficiency of eichhorn roots and its devouring of pollutants. Experimental studies were conducted in 500 liter container (Figure 4) in the open air (100 x 100 x 50 cm).

Eichhornia loves warm weather, that is why experiment was realized in the summer. Weather temperature according to Voronezh Hydrometeorological Center in June 2018 is presented in Figure 3 [9,16].

As seen in Figure 5, the average temperature of weather was 22-23 °C during the experiment. As shown in Table 1, the composition of test water has prepared from household wastewater and storm water. Analyzes of the composition of water were measured in a certified laboratory of the Levoberezhny sewage treatment plant of Voronezh.

Table 1. The results of experiment of wastewater treatment by Eichhornia.

| Test water Composition | At the beginning of experiment (mg/l) | At the end of experiment (mg/l) | Treatment efficiency (%) |
|------------------------|--------------------------------------|---------------------------------|--------------------------|
| Suspended solids       | 298                                  | 17,2                            | 94,2                     |
| COD                    | 533                                  | 109,7                           | 79,4                     |
| BOD₅                   | 120                                  | 35,6                            | 70,3                     |
| Calcium                | 85,16                                | 59,11                           | 30,59                    |
| Phosphates             | 5,7                                  | 0,4                             | 93                       |
| Iron                   | 3,0                                  | 1,3                             | 56,66                    |
| Alkali                 | 8,0                                  | 4,8                             | 40                       |
| Surfactant             | 1,36                                 | 0,25                            | 81,62                    |
| Sulphides              | 7,5                                  | orc.                            | 100                      |
| Oil products           | 2,6                                  | orc.                            | 100                      |
| Phenol                 | 85                                   | orc.                            | 100                      |
| Nitrate                | 3,3                                  | 1,1                             | 66,66                    |
| Nickel                 | 0,1014                               | 0,075                           | 26                       |
| Chromium               | 56                                   | 8                               | 85                       |

3. Results
The adsorption efficiency is calculated by the following formula [10]:

\[
\text{Treatment efficiency} = \frac{\text{At the beginning of experiment} - \text{At the end of experiment}}{\text{At the beginning of experiment}} \times 100\%
\]
\[ E(\%) = \frac{C_i - C_f}{C_i} \cdot 100 \]

where, \( C_i \) – initial concentration of the parameter (mg/l), \( C_f \) – final concentration of the parameter (mg/l).

As a result sulfides, phenols and oil products completely treated from the reservoir. Furthermore, observations show that phosphate removal up to 93%, surfactants up to 81%, COD decreased up to 75% and BOD\(_5\) up to 70%. From heavy metals, chromium was removed most effectively by 85%, nitrates by 66%, and the smallest indicator was fixed in nickel removal with 26%.

Figure 4 shows the breeding of eichhornia at the beginning and at the end of the experiment. It was noticeable that the treated water has become more transparent, and less smelling. The number of eichhornia increased about 8-10 times from first day of experiment. In fact, according to researchers, this number is even more in regions with hot climates [11,17].

![Figure 4. Reproduction of eichhornia at the beginning and end of the experiment.](image)

In addition, eichhornia quickly oxidizes and breaks down pollutants of wastewater into simple elements and assimilates them as food. But it is only about 20% of the total wastewater treatment. Here oxygen plays role as oxidant, which is produces in excess by eichhornia. It is well known that most of the chemical elements in wastewater are finds in compounds [11,18].

Plant transpiration raises with increasing of temperature of the wastewater and ambient air and it promotes to growth and intensity of plant reproduction, so increases the extraction of nutrients for eichhornia from treated effluent [8,19].

4. Discussion

Eichhornia was employed for wastewater treatment in many parts of the world. By planting water hyacinth in wastewater pond, part of the gaseous oxygen produced by the photosynthetic activity of the green leaves is translocated to the stems and roots and to the water body. In 1994 scientist Yahya Nor investigated the removal of phenols in the presence of copper and zinc by Eichhornia was in order to assess its ability to clean up industrial wastewaters [12,20]. Results indicated that Eichhornia has a tremendous capacity to absorb phenolic compounds as well as Cu and Zn simultaneously from test solutions containing these substances.

According to chineses scientists Tang and Xian-wen eichhornia can grow in oil-refinery wastewater after the water has undergone an initial treatment of oil-separation, flotation, and aeration [13]. They indicated that the optimum COD under which E. crassipes can be used to oxidize oil-refinery wastewater is between 65 and 131 mg/l and the highest possible COD is 262 mg/l. They reported that
Eichhornia crassipes, grown in two 3750 m² oil-refinery wastewater oxidation ponds, improved the quality and transparency of the outlet water. After 2 to 4 days retention in oxidation ponds, turbidity decreased by 32%, phenol oil decreased by 18%, COD decreased by 8-13%, nitrogen decreased by 6-18%, phosphorus decreased by 12-24%, and several heavy metals decreased by 3-54% more than the un-vegetated control. In addition, its oxygenated root zone helps to bring about flotation and flocculation of oil residue, increased aerobic degradation, and a large microbial population to stimulate decomposition [13, 21].

Low et al., reported the potential use of Biomass of non-living dried Eichhornia roots for sorption of copper from aqueous solutions. Maximum sorption was 20.90 mg Cu/g as determined for Langmuir isotherm. Several factors affecting sorption were investigated. They include the effect of pH, initial concentrations, presence of chelators and other metals. They suggested using this material in a packed-bed system for removing copper from electroplating waste [14,21].

5. Conclusion
Based on the results of experimental study, following conclusions can be listed:

- Eichhornia allows us treat the drainage water of irrigated areas and partially wastewater up to maximum permissible concentration (MPC) values.
- Wastewater treatment by using eichhornia is more economical than other methods.
- This treatment method is rather more likely to apply for small amounts of wastewater. For larger amounts it requires significant areas for artificial ponds.
- Removing of obsolete or died eichhornia requires special attention and additional costs.
- Collected eichhornia from treatment plants can be used as an animal feed or for other purposes, like a production of biogas, in the paper industry etc., but it is depends on the composition of the plant.

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