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Development of Biotechnologies for Cleaning of Water Bodies on the Absheron Peninsula from Organic and Inorganic Pollutants

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Abstract

This article addresses the issues of lake pollution in the area of the Absheron Peninsula and introduces new approaches to enhancing their self-purification capacity. For the purification of organic and inorganic contaminants of lakes on the Absheron Peninsula, the prospects for using activated sludge microorganisms and the Fermi Start preparation, consisting of an association of microorganisms, were studied.

The research found that the use of activated sludge microorganisms can reduce the amount of phenol in the waters of Lake Boyukshor by 99%. Furthermore, it was determined that the Fermi Start preparation is more effective in purifying water contaminated with heavy metals. For example, during one hour of experimentation, the degree of copper removal reached 78%, reducing the metal concentration in water to near the maximum allowable concentration (MAC) of 1.0 mg/L.

Keywords: Absheron Peninsula, oil-containing pollutants, heavy metals, activated sludge

Introduction

The shortage of water and the pollution of water bodies are among the most pressing global challenges of our time. Although natural and climatic factors contribute to the worsening of this issue, the role of anthropogenic impact in the pollution of aquatic ecosystems should be especially emphasized. For instance, the discharge of industrial and domestic waters into water bodies without appropriate treatment leads to the pollution of water bodies. These pollutants not only alter the physical and chemical characteristics of water but also disrupts its biological properties.

Similar problems are also observed in the water bodies of the Absheron Peninsula. In this industrial region, one of the key concerns is the presence of more than 200 reservoirs covering a total area of 3,325 hectares, the majority of which are of anthropogenic origin [7]. The history of their formation is directly related to the development of the oil industry in the Absheron region, with household and industrial waste accumulating in these bodies of water [5].

The concentration of pollutants in these water bodies significantly exceeds the permissible limits, with the majority consisting of oil-based pollutants and heavy metals HMB [4].

The natural process of self-purification of water in bodies, as well as in soil, is slow [8]. In modern industrial age, due to a sharp increase in waste, reservoirs are no longer available to manage such significant pollution. This created the need to neutralize, purify water from both organic and inorganic pollutants, and treat the waste accordingly [2].

The well-known ability of microorganisms to degrade organic matter, extract and accumulate metals from aqueous solutions makes them potentially promising for option for us in the process of bio-purification of water bodies [1, 3, 11, 12, 13].

We have conducted research to identify approaches and principles of biotechnological methods for cleaning water bodies in the Absheron industrial region. The goal of our research is to develop modern technologies for purification of lakes from organic and inorganic contaminants, which constitutes one of the most critical environmental challenges in the country's industrial regions.

Materials and methods

The object of the study was water samples taken from Lake Boyuk-Shor. Water samples were collected using conventional methods using bathometers [9].

The study investigated the potential for cleaning water bodies from organic (C_6H_6O – phenol) and inorganic (Cu – copper) contaminants using activated sludge microorganisms and the Fermi-start biopreparation. Activated sludge was collected from the Gousany aeration station, which treats wastewater from Baku. To obtain dry biomass, activated sludge was dried at 105^0C, and the resulting dry biomass was used in the experiments. Various amounts (1 ml, 5 ml, 10 ml) of growing cells were used to obtain dry biomass.

Wood sawdust with a particle size of 0.1-0.3 mm was used as adsorbent fillers. All experiments were carried out in triplicate.

Result and Discussion

The degradation of phenol in a medium was studied using biopreparations based on activated sludge, the association of effective microorganisms "Fermi Start", and a natural adsorbent - sawdust. The experiments were conducted in two versions: with the addition of sawdust and without sawdust.

For this purpose, activated sludge was grown in flasks on shakers in the presence of phenol. The experiment utilizes the mineral medium formulated by Dianova and Voroshilova, with the following composition (mg /l): K2HPO4 - 1.0; KH2PO4 - 1.0; NH_4NO_3 - 1.0; $MgSO_4$ - 0.2; $CaCl_2{\cdot}6H_2O$ - 0.01; $FeCl_3{\cdot}6H_2O$ - 3 drops of saturated solution [9].

Phenol was added as a carbon source at a concentration of 50 mg. Cultivation was carried out at a constant temperature of 28^{0}C for 5 days. Every 24 hours, samples were taken from the flasks to determine phenol content (Fig. 1).

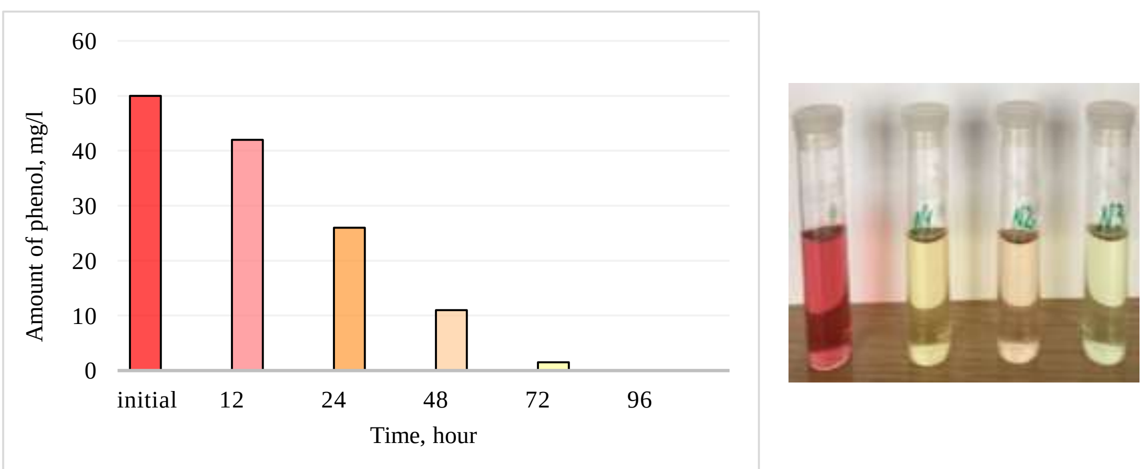

Fig. 1. Decomposition of phenol by microorganisms of activated sludge + sawdust

As shown in Fig. 1, biopreparations based on activated sludge have a high degradation capability with respect to phenol. After 5 days, the biomass was separated from the liquid phase by centrifugation, and the phenol content in the culture medium was determined using a Palintest Photometr device at a wavelength of 520 nm.

The data presented in Table 1. indicate that the amount of phenol in the medium after 5 days of cultivation decreased in all variants of the experiment. However, the best result was obtained when using the biopreparation together with sawdust. In this variant, the content of phenol in the medium after 5 days of cultivation decreased significantly - 99%.

Table 1. Destruction of phenol in the environment using biopreparations based on activated sludge and natural adsorbent – sawdust

Experimental variant	Phenol concentration (C_6H_5OH) mg/l		Degree of sorption and decomposition, %
	At the beginning	In 5 days	
Phenol solution + sawdust	50	35,5	29
Phenol solution + activated sludge	50	11,5	77
Phenol solution + activated sludge + sawdust	50	0,25	99,5

Similar experiments were conducted to investigate the purification the aquatic environment from heavy metals. To study the potential of removing inorganic contaminants from water bodies using microorganisms, copper chloride ($CuCl_2$) was used as the source of copper in model experiments. The salt was selected due to its high solubility in the aquatic environment. The ability of microorganisms to bioaccumulate Cu^{2+} was judged by the degree of disappearance of copper ions from the culture liquid. Copper adsorption was studied in 250 ml Erlenmeyer flasks under dynamic conditions.

Biomass of IAI and probiotic microorganisms was added to flasks containing metal solutions, and the flasks were then placed in a thermostat on a shaker (130 rpm, 25^0C). Flasks containing only the copper solution, without microbial biomass, were used as a control. After 20-60 minutes, the microbial mass was passed through a membrane filter to separate it from the liquid medium where the residual concentration of metals was analyzed. Copper content, as well as phenol content, were determined using a Palintest Photometr device at a wavelength of 520 nm (Fig. 2, p. 79).

The results show that the association of probiotic microorganisms when introduced into water with an initial copper content of 5.0 mg/l (more than 5 MAC) reduces the metal content in water by 1.1 mg/l, i.e., almost to the MAC level (1.0 mg/l). The degree of copper purification in an hour of the experiment was 78%.

The obtained results show that the adsorption capacity of probiotic microorganisms is significantly high (Table 2). This is consistent with the findings of other researchers studying the accumulation of heavy metals by probiotic microorganisms. [10, 14].

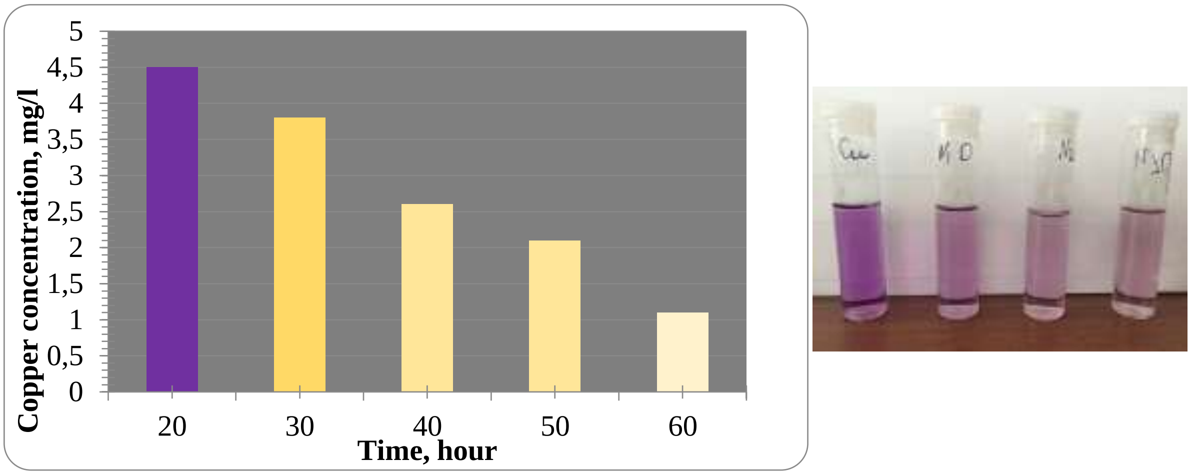

Fig.2. Sorption of copper ions by probiotic microorganisms

The results of the study indicate that the copper saturation of the microbiocenosis with is achieved after 40 minutes, and the amount of absorbed copper primarily depends on the initial concentration of the metal in the solution. As the metal concentration increases, the degree of its absorption by the microorganisms' cells increases over the same period.

Table 2. Degree of purification of Boyuk-Shor water from copper after passing through biofilters

№	Option	Degree of purification, %			Total purification degree
		1st filtration	2nd filtration	3rd filtration	
1	Dried biomass of «Fermi-start»	57	14	9	80
2	Dried biomass of "fermi-start" + sawdust	58	18	13	89
3	Dried biomass of activated sludge6	35	11	5	51
4	Dried biomass of activated sludge + sawdust	38	18	6	62

The data presented in Table 2 shows that the adsorption capacity of IAI was significantly lower compared to probiotic microorganisms.

At the same time, the system analysis revealed that in the environment with probiotics, the reduction in Cu content in the water was significantly higher compared to the IAI microbiocenosis. This is likely because the IAI used in our laboratory experiments had already been saturated with TM contained in the wastewater treated in the Baku aeration station, i.e., the active adsorption surface of this microbiocenosis was reduced. This is supported by data from which showed that the copper content in the dry activated sludge from the Gousani aeration station was 4.5 mg/kg. [6]. Dried biomass and the active suspension of the "Fermi-start" biopreparation are characterized by a higher adsorption effect with respect to TM compared to activated sludge.

Thus, both the IAI and the Fermi-start association of probiotic microorganisms demonstrate a high potential for the adsorption of heavy metals. As an integrated biosystem, they can effectively develop biotechnologies for cleaning water bodies in the Absheron industrial region from hydrocarbons and heavy metal pollution.

The conducted research allowed for the development a biobon design for cleaning water systems of lakes on the Apsheron Peninsula from oil, oil products and heavy metals. The developed biopreparations based on the most active cultures of oil-oxidizing microorganisms isolated from samples of Boyuk-Shor waters, as well as the biocenosis of activated sludge and the biopreparation "Fermi-start" are used as a biologically active component of biobons.

Waste of plant origin can be used as adsorbents, for example, cotton husk, rice husk, sawdust, i.e., depending on regional resources - these substances of plant origin are distinguished by a high adsorbing capacity for oil.

Fillers are completely natural, non-toxic and environmentally friendly absorbents on an organic basis.

The size of biobons can be different depending on the task. The technology of using different types of biobons is offered - stationary, dynamic, and cascade (Fig. 3).

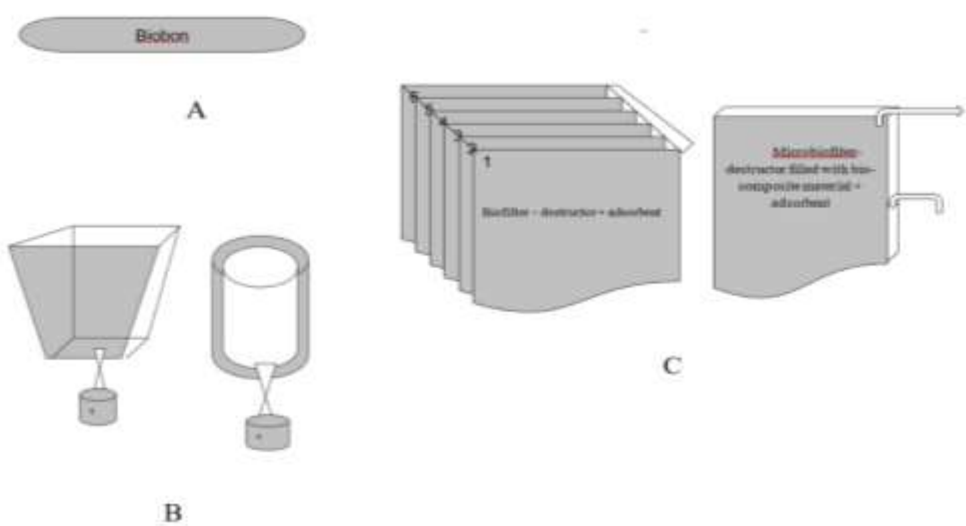

Fig. 3. Schematic view of a biobon
A - stationary, B - dynamic and B - cascade type of biobons

They can be very effective and they will perform two functions at the same time:

- Absorb petroleum hydrocarbons and heavy metals contained in water bodies;
- Organic contaminants (hydrocarbons, phenols, surfactants, etc.) absorbed in them will gradually decompose by microorganisms

Biobons can be used to protect lake waters from pollution by phenols, oil and oil products, to draw in and absorb small oil spills. It is assumed that they can effectively localize possible spill zones in water bodies. The number of microbiofilters, their size and residence time are determined by the degree of pollution of the water environment of the water body and the type of pollutant

Conclusion

Thus, the proposed models of mobile biofilters in water systems will have multifunctional properties - polluted water will pass through a "biological filter" that has two functions: collecting and decomposing.

Cleaning lakes from organic and inorganic substances opens up ways to improve their sanitary and hygienic properties, restore their bio-ecological functions, and make it possible to use their waters for industrial fish farming.

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