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Biological Processes for the Purification of Contaminated Wastewater

Normatov Abdurahim Eminovich[1*] and Yuldoshov Laziz Tolibovich[2]

[1]*Fergana State University, Basic Doctoral Student, Uzbekistan*
[2]*Bukhara State University, Associate Professor, Uzbekistan*

**Corresponding author*

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A B S T R A C T

Water is one of the most essential natural resources for sustaining life on Earth and plays a crucial role in maintaining ecological balance, supporting agricultural production, industrial development, and human health. However, rapid urbanization, industrial expansion, intensive agricultural activities, and population growth have significantly increased the discharge of pollutants into natural water bodies. As a result, rivers, lakes, and groundwater resources are increasingly contaminated with organic matter, heavy metals, nutrients, pesticides, pathogenic microorganisms, and various toxic chemicals. This growing pollution poses serious environmental, economic, and public health challenges, making the protection and sustainable management of water resources a global priority. This article provides comprehensive information on the efficient use of water resources, strategies for water conservation, and measures aimed at preventing water pollution. It discusses the major sources and types of water contaminants, their impact on aquatic ecosystems, biodiversity, and human health, as well as the long-term environmental consequences associated with untreated wastewater discharge. Particular attention is given to the deterioration of water quality caused by industrial effluents, municipal wastewater, and agricultural runoff, all of which contribute to the degradation of freshwater ecosystems.

Introduction

The sustainable management and conservation of natural water resources have become critical priorities for countries worldwide. Rapid industrialization has led to a significant increase in wastewater containing hazardous pollutants. In many cases, the discharge of untreated or inadequately treated industrial effluents into rivers, lakes, and other natural water bodies has resulted in severe environmental degradation.

Such pollution disrupts the ecological balance of soil and aquatic ecosystems, reduces water quality, and creates favorable conditions for the spread of waterborne and environmentally related diseases among local populations. In addition, contaminated water adversely affects agricultural productivity by degrading soil fertility and reducing crop yields. Long-term exposure to polluted water also threatens biodiversity, leading to the decline and possible disappearance of cultivated crops, medicinal plants, and wild flora. Furthermore, the deterioration of soil and water resources negatively impacts aquatic and terrestrial habitats, contributing to the reduction and extinction of numerous animal species. Therefore, effective wastewater treatment, strict environmental regulations, and the adoption of sustainable water resource management practices are essential for protecting ecosystems, safeguarding public health, and ensuring long-term environmental sustainability.

Most importantly, this contaminated wastewater is reaching the groundwater we consume, mixing with the natural water of streams and ditches, and using these waters, which contain various harmful substances, for various purposes is causing new types of diseases that pose a great threat to human health.

Clean water is necessary for all life. The negative impact of the human factor on nature is harming itself at the expense of natural cycles. All living organisms, including humanity, cannot live without water. Water is not only for drinking, but also a part of all types of products we consume. For example, fresh vegetables and fruits contain 90% water, potatoes and meat 75%, and bread up to 7%.

A person consumes from 100 ml to 3000 ml of water per day, depending on age. In particular, an average of 1200-1300 ml (48%) of water is consumed in liquid form, and 1000-1200 ml of water is consumed in food. As a result of endogenous oxidation of nutrients and breakdown of fats in the body, an average of 300 ml of water is produced per day. All water molecules in the body are renewed within 15 days in an adult, and within 35 days in children.

From a sanitation and hygiene perspective, water is essential not only for meeting basic physiological requirements but also for maintaining personal cleanliness, ensuring public health, and supporting domestic and industrial activities. Adequate access to clean water is crucial for food preparation, household sanitation, healthcare services, and production processes, thereby contributing to improved living standards and sustainable socioeconomic development.

An average person uses 370 liters of clean water per day for personal needs, 180-150 liters for hygienic showering, and 580 liters for laundry, cooking, and dishwashing. However, in addition to the above, natural water is also needed to keep residential and public buildings clean, flush waste, wash streets, and water green plants when sewage is used.

The number of people living on Earth has exceeded 8.2 billion (as of January 14, 2025). However, the amount of water has not changed, but the amount of consumption has increased. Currently, more than 3 million people in the world die from lack of clean drinking water, and 12 million people suffer from various diseases every year due to the lack of clean drinking water.

According to the analysis, in London, 170 liters of water are consumed per person per day for daily activities, in Paris - 160 liters, in Brussels - 85 liters, and in Tashkent - 370 liters.

According to calculations by scientists from the global community, the norm is set at 50 liters of water per person per day for drinking, washing, and cooking.
It is known that water is the most important mineral necessary for the survival of various organisms on Earth, and all the processes that occur in them take place only in the aquatic environment. This indicates that water is a very important and invaluable natural component. For example, during the process of photosynthesis in plant cells, an average of 4.6×10^{11} tons of oxygen are released into the atmosphere per year, and 2.25×10^{11} tons of water are consumed in this process.

Today, in the world, 2,800 km^3 of water is taken from rivers and groundwater annually to irrigate 200 million hectares of land. This is equivalent to 7% of the world's river water. Of the 2,800 km^3 of water consumed, 17% or 470 km^3 is added to rivers and groundwater in the form of return water, while the remaining 83% or 2,330 km^3 is completely consumed. On average, 92-94% of the fresh water obtained in our republic is used in agriculture, 6% in industrial enterprises, and 0.5% in municipal services as household water.

The challenge of ensuring an adequate water supply for the global population is becoming increasingly complex due to rapid urbanization, accelerated industrial and agricultural development, the expansion of irrigated agricultural areas, continuous population growth, improving living standards, and other socioeconomic and environmental factors. These trends have intensified the demand for freshwater resources, highlighting the urgent need for sustainable water management and conservation strategies.

Therefore, the protection and rational use of water resources in the world still remains one of the priority issues. In our republic, extensive scientific research is being carried out in this area and necessary measures are being taken. The development of new, economical technologies, the introduction of a closed cycle of water use, biological treatment of wastewater, and environmentally safe, economically affordable and effective methods for protecting water resources is an important requirement of the present era.

Among the sources of water pollution, the most important place is occupied by wastewater from industrial enterprises and household and communal services. These wastewaters contain various acids, phenols, alkali metals and other toxic substances, oils and petroleum products that are dangerous to living organisms. Together with wastewater used in industrial enterprises, they are the main source of pollution of natural water sources, rivers, lakes and reservoirs.

One of the key priorities in the sustainable management and conservation of water resources is the effective treatment and reuse of wastewater generated by industrial activities, agricultural operations, and domestic and municipal sectors. Among these, the purification of urban wastewater is of particular importance due to its large volume and high pollutant load. Proper wastewater treatment enables its safe reuse for various purposes, reduces environmental pollution, conserves freshwater resources, and supports sustainable economic and environmental development.

Some enterprises do not have facilities for treating wastewater contaminated with iodine substances. Even enterprises that have treatment facilities use chemical additives economically, which leads to pollution of wastewater by discharging it into open water bodies without or with insufficient treatment in accordance with the established municipal and environmental standards. In addition, preventing soil pollution in our region and cleaning contaminated soil due to its direct connection with the pollution of water sources is one of the urgent issues.

The investigation of soils contaminated by crude oil and petroleum-derived compounds, together with the evaluation of biological remediation factors, remains a significant scientific challenge. The development of effective bioremediation technologies is complicated by the complex chemical composition of petroleum hydrocarbons, variations in soil characteristics, and differences in climatic and environmental conditions. These factors considerably influence the efficiency of biological restoration processes and require site-specific remediation strategies.

In Uzbekistan, petroleum processing is carried out at major refineries, including the Bukhara, Chinaz, and Fergana oil refineries. These industrial facilities consume substantial quantities of high-quality water throughout various stages of petroleum refining and processing. Consequently, the efficient use, treatment, and recycling of industrial water are essential for reducing freshwater consumption, minimizing environmental impacts, and promoting sustainable industrial production.

According to the studied analyses, an average of 2.4 tons of clean or technical water is required to process 1 ton of petroleum products into a finished product. Among the harmful substances, oil and petroleum products occupy a special place, and insoluble derivatives of petroleum products are considered very dangerous pollutants.

The maximum permissible concentration of pollutants in industrial wastewater into municipal sewage networks, as set out in Appendix 2 of the Resolution No.820 of the Cabinet of Ministers of the Republic of Uzbekistan dated October 11, 2018, establishes that the amount of petroleum products in wastewater is 1 mg/liter, exceeding which leads to a fundamental deterioration of the natural ecological environment.

According to the calculations obtained, if the average density of oil is 0.89 g/cm^3, we can calculate how many kilograms 1 liter (1000 cm^3) of oil weighs as follows: Mass=Density×Volume, Density is 0.89 g/cm^3, and volume is 1 liter = 1000 cm3:

Mass = 0.89 g/sm^3 × 1000 sm^3 = 890 g = 0.89 kg. Therefore, 1 liter of oil is approximately equal to 0.89 kg.

If 1.1 mg/l of oil contaminates 1 liter of water, then the density of 1 liter of oil is 0.89 g/cm^3 or 0.89 kg/l. 1 liter of oil = 0.89 kg = 890 g = 890,000 mg.

If 1.1 mg of oil contaminates 1 liter of water, then 890,000 mg of oil can contaminate 809,090.91 liters of water.

1 gram of oil typically forms a film on the water surface

0.1-0.01 micrometers (µm) thick. This film thickness serves to disrupt the exchange of essential substances and gases in the water.

We use the following formula for the calculation:

$$A = \frac{m}{p \times d}$$

Here:
· *A*- distribution area.
· *m*- mass of oil (1 gram = 0.001 kg).
· *p*- oil density (approximately 0.89 g/cm^3 or 890 kg/m^3).
· *d*- film thickness (e.g. 0.1 micrometer = 1×10^{-7} meters).

$$A = \frac{0.001\,\text{кг}}{890\,\text{кг}/\text{м}^3 \times 1 \times 10^{-7}\,\text{м}} = 11.24\,\text{м}^2$$

According to calculations, 1 gram of oil or oil product can form a film on 11.24 m^2 of water. Since petroleum products have a low density compared to water and are insoluble and immiscible in water, they become a source of pollution for any water body.

To calculate the rate of spread of oil on the surface of water, with a density of 0.89 g/cm^3 per liter, a number of physical parameters affecting it can be calculated with average values. Based on the model, we calculate the rate of spread using the following data:

Information provided:

- **Density of oil (ρ_{oil})**: 0.89 g/sm^3=890 kg/m^3.
- **Density of water (ρ_{water})**: 1000 kg/m^3.
- **Gravitational acceleration (g)**: 9.81 m/s^2.
- **Oil viscosity (μ_{neft}):** Typically, the viscosity of oil averages around 0.5 Pa.
- **Spread thickness (h):** Oil typically spreads on water at a thickness of 0.1 µm (micrometer) or 1×10^{-7}m.

We calculate the diffusion rate with the following equation:

$$v = \frac{\Delta\rho \cdot g \cdot h}{\mu}$$

Бу ерда:

- $\Delta\rho = \rho_{\text{сув}} - \rho_{\text{нефть}} = 1000\,\text{кг}/\text{м}^3 - 890\,\text{кг}/\text{м}^3 = 110\,\text{кг}/\text{м}^3$,
- $g = 9.81\,\text{м}/\text{с}^2$,
- $h = 1 \times 10^{-7}\,\text{м}$,
- $\mu = 0.5\,\text{Па\textbackslash cdotpc}$.

$$v = \frac{110\,\text{кг}/\text{м}^3 \times 9.81\,\text{м}/\text{с}^2 \times 1 \times 10^{-7}\,\text{м}}{0.5\,\text{Па\textbackslash cdotpc}}$$

Calculation

$$v = \frac{110 \times 9.81 \times 10^{-7}}{0.5} = \frac{1.0791 \times 10^{-4}}{0.5} = 2.1582 \times 10^{-4}\,\text{м}/\text{с}$$

The average spreading velocity is 2.16×10^{-4} m/s, meaning that oil spreads across the water surface at a speed of approximately 0.216 mm/s.

These indicators show how negative consequences pollution of wastewater with oil and oil products can lead to.

Large manufacturing plants in our republic are large water consumers, and they have new modern wastewater treatment facilities.

Wastewater treatment in treatment facilities always requires large overall costs. The biological treatment method using modern, effective, natural and economical macrophyte plants in treatment facilities always justifies itself.

Author Contributions

Normatov Abdurahim Eminovich: Investigation, formal analysis, writing—original draft. Yuldoshov Laziz Tolibovich: Validation, methodology, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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