E CONF SERIES
International Conference on Medical Science, Medicine and Public Health
Hosted online from Jakarta, Indonesia
Website: econfseries.com 30th October, 2025

PURIFICATION OF INDUSTRIAL WASTEWATER FROM HEAVY METALS USING SORBENTS BASED ON THERMALLY ACTIVATED OPOKA MINERAL AND AILANTHUS TREE BIOMASS

Uktam Farhodovich Umirov
PhD student at the Navoi Branch of the Academy of Sciences of the Republic of Uzbekistan
Uktam Shavkatovich Temirov
Professor at Navoi State University of Mining and Technologies

Jurabek Mehrikulovich Shodikulov
Associate Professor at Navoi State University of Mining and Technologies

Abstract
In this study, the possibility of purifying industrial wastewater from the "Electrochemical Plant" JSC was investigated using sorbents prepared from thermally treated opoka mineral and Ailanthus tree biomass. The experimental results showed that increasing the amount of Ailanthus-based sorbent significantly enhanced the removal efficiency of heavy metal ions (Cu^{2+}, Ni^{2+}, Zn^{2+}, Sr^{2+}, Se^{2-}, Al^{3+}), reaching 85–95%, while the total mineralization of the wastewater decreased by 30–35%. The highest purification efficiency was achieved when a mixture containing 0.8% thermally activated opoka and 0.2% Ailanthus sorbent was applied.

Keywords: thermally activated opoka, Ailanthus tree biosorbent, industrial wastewater, heavy metals, sorption efficiency, adsorption, local mineral raw materials, water purification.

According to the World Health Organization (WHO), more than 20% of the world's population uses water contaminated with heavy metals, mineral salts, and organic pollutants each year. Therefore, within the framework of the United Nations Sustainable Development Goals (SDG 6.3) for 2020–2030, the task of "implementing wastewater treatment and purification technologies" has been identified as a top global priority.

On a global scale, industrial effluents contaminated with chloride, sulfate, nitrate, and heavy metal ions (Cu, Ni, Pb, Zn) are increasingly widespread. To mitigate such contamination, the trend of applying low-cost sorbents derived from natural minerals and biological wastes is growing rapidly. For example, studies by Din et al. (2025) and Svedaite E. (2025) demonstrated that sorbents obtained from opoka and woody biomass wastes are capable of removing 85–95% of phosphorus and heavy metals from aqueous media. Such sorbents are actively employed in Africa, China, India, and several European countries as part of the “low-cost sorbent” strategy.

Thermal activation has been shown to significantly enhance the porosity and the number of active surface sites of the sorbent, increasing adsorption efficiency by a factor of 2–3. Consequently, research in this field is recognized as one of the most promising directions in the development of innovative and environmentally friendly technologies for the purification and sustainable management of global water resources.

In Uzbekistan, water resources are primarily dependent on the Amu Darya and Syr Darya river basins, and the country’s water balance is highly sensitive to both natural and anthropogenic impacts. Industrial and agricultural enterprises, particularly in the Navoi, Bukhara, and Kashkadarya regions, discharge wastewater that is heavily polluted with heavy metals, phosphates, and nitrates. For instance, analyses of wastewater in the Navoi region have revealed concentrations of Cu^{2+}, Ni^{2+}, Zn^{2+}, Sr^{2+}, and Cr^{3+} ions several times higher than permissible limits. This situation underscores the urgent need to develop cost-effective and efficient sorbents based on locally available raw materials, independent of imported components.

The opoka mineral is widely distributed throughout Uzbekistan—particularly in the Kyzylkum, Jizzakh, and Navoi regions—where its large natural reserves make it an economically attractive raw material. Thermally activated opoka possesses a highly porous structure and a large specific surface area, which provide strong physicochemical stability and excellent adsorption capacity for heavy metal ions. At the same time, biomass waste from the Ailanthus tree (Elaeagnus angustifolia L.), a locally abundant species, can be thermally processed to produce biosorbents. The combination of these natural mineral and biological resources allows for the creation of a composite, low-cost, and environmentally friendly sorbent system suitable for wastewater purification under local Uzbek conditions.

During the research, the purification of industrial wastewater from “Electrochemical Plant” JSC was carried out using locally available mineral and biological raw materials. For this purpose, a thermally activated opoka mineral sample was applied at 0.8% of the wastewater mass, while Ailanthus tree biomass—pyrolyzed and thermally treated—was added at concentrations of 0.1–0.25%. The experiments were conducted under laboratory conditions with 200 mL wastewater samples; stirring was performed for 60 minutes followed by 30 minutes of sedimentation. The concentrations of Cu^{2+}, Ni^{2+}, Zn^{2+}, Sr^{2+}, and Cr^{3+} ions were determined in the treated water.

The analysis revealed that during the purification process using 0.8% thermally activated opoka mineral and Ailanthus-based biosorbent, the adsorption efficiency of metal ions increased steadily with the amount of Ailanthus sorbent added. For example, the removal efficiency of Cu^{2+} ions increased from 82.06% to 93.71%, Ni^{2+} from 75.65% to 90.11%, and Zn^{2+} from 78.43% to 90.48%. Similarly, for Sr^{2+} and Se, the purification efficiency rose from 83.39% and 62.06% to 92.90% and 89.51%, respectively. The highest efficiency was observed for Al and Cu, where the addition of 0.2–0.25% Ailanthus sorbent resulted in removal rates of 98.75% and 93.71%, respectively. Molybdenum (Mo) and chromium (Cr) exhibited relatively lower adsorption performance, with removal efficiencies of about 61.46% and 84.50%. These results indicate that thermal and alkaline activation of the Ailanthus sorbent enhances the number of active surface sites, and its combination with the highly porous structure of opoka produces a synergistic effect, significantly improving the adsorption of heavy metals from industrial wastewater.

The use of 0.8% thermally activated opoka mineral and 0.1–0.25% Ailanthus tree sorbent significantly reduced the concentration of heavy metal ions in wastewater. As the amount of Ailanthus sorbent increased, the sorption efficiency for Cu^{2+}, Ni^{2+}, Zn^{2+}, Sr^{2+}, Se^{2-}, and Al^{3+} ions rose to 85–95%. The highest purification efficiency was observed when a mixture containing 0.8% opoka and 0.2% Ailanthus sorbent was used, which reduced the total mineralization of the water by 30–35%.

The study demonstrated that using locally available mineral and biological raw materials allows for the purification of industrial wastewater through an economical, environmentally friendly, and energy-efficient method. The composite system based on thermally activated opoka and Ailanthus tree sorbent minimizes the need for chemical reagents, promotes the use of renewable resources, and enables the reuse of treated wastewater for agricultural or technical purposes. Therefore, this approach holds significant practical importance for the environmentally safe neutralization of industrial effluents and the protection of water resources in industrial regions.

References

1. Svedaite E.O. Opoka as a Natural Material for Phosphorus Removal. – Water, 2025, Vol. 17, No. 20, pp. 3017–3028.
2. Sorption Treatment and Desalination of Mineralized Water. – International Information and Engineering Technologies Association (IIETA), 2024, Vol. 15, No. 3, pp. 215–226.
3. Din S.U., Ahmed M., Khan A. Utilization of Wood Bark Waste as an Adsorbent for Pb(II) Ion Uptake from Aqueous Solutions. – Scientific Reports, 2025, Vol. 15, No. 2, pp. 1123–1134.
4. Bailey S.E., Olin T.J., Bricka R.M., Adrian D.D. A Review of Potentially Low-Cost Sorbents for Heavy Metals Removal. – Water Research, 1999, Vol. 33, No. 11, pp. 2469–2479.