

Environmental remediation uses chemical principles to remove pollutants and restore contaminated ecosystems

Ilya Morozov*

Department of Environmental and Applied Chemistry, Eurasia University of Chemical Sciences, Kazakhstan.

*Corresponding author: Ilya Morozov. Department of Environmental and Applied Chemistry, Eurasia University of Chemical Sciences, Kazakhstan.

Email: ilya.morozov.envchem@eurasiaedu.org

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Abstract

Environmental remediation applies chemical and material science principles to remove, neutralize, or transform pollutants present in soil, water, and air. Industrialization and urbanization have introduced hazardous substances such as heavy metals, organic toxins, and persistent pollutants into ecosystems, necessitating effective remediation strategies. Techniques including adsorption, chemical oxidation, bioremediation, photocatalysis, and membrane filtration are widely used to restore environmental quality. This article discusses the mechanisms, materials, and applications of environmental remediation in modern chemical science.

Keywords: Environmental remediation, Pollutant removal, Adsorption, Bioremediation, Chemical oxidation, Heavy metals, Wastewater treatment, Photocatalysis, Membrane filtration, Ecological restoration.

Introduction

Environmental remediation is a critical application of chemistry aimed at addressing the accumulation of pollutants in natural ecosystems caused by industrial discharge, agricultural runoff, and urban waste [1]. Contaminants such as heavy metals, pesticides, hydrocarbons, and synthetic dyes persist in soil and water, posing risks to human health and biodiversity. Chemical science provides tools to transform, immobilize, or remove these harmful substances through carefully designed remediation processes. Adsorption is one of the most widely used techniques, where pollutants adhere to the surface of materials such as activated carbon, metal oxides, and nanocomposites. The effectiveness of adsorption depends on surface area, porosity, and chemical affinity between the adsorbent and pollutant [2]. Chemical oxidation methods, using agents such as ozone or hydrogen peroxide, break down complex organic pollutants into less harmful products. Bioremediation integrates biological and chemical principles by employing microorganisms to degrade pollutants into harmless substances. This approach is especially useful for treating oil spills and organic waste in contaminated soils [3]. Photocatalysis, driven by light-activated catalysts, further enhances pollutant degradation by generating reactive species capable of breaking down persistent

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compounds. Membrane filtration technologies provide physical separation of contaminants from water, offering high efficiency in wastewater treatment. Advances in nanomaterials and polymer membranes have improved selectivity and durability in such systems [4]. Combined remediation approaches often yield better results by addressing multiple types of pollutants simultaneously. Heavy metal contamination is a significant concern due to the non-biodegradable nature of metals like lead, mercury, and cadmium. Chemical precipitation, chelation, and adsorption are commonly used to remove these ions from water and soil. Surface-modified materials and green adsorbents derived from natural sources have gained attention for sustainable remediation practices [5].

Conclusion

Environmental remediation applies chemical techniques to remove pollutants and restore contaminated ecosystems. Through adsorption, oxidation, bioremediation, and membrane technologies, chemistry provides effective solutions for environmental protection. Ongoing research into sustainable and efficient remediation methods will play a vital role in preserving environmental quality for future generations.

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