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Impacts, Chemistry, and Mechanisms of Contaminants and Pollutants on Surface and Groundwater Around Polluted Sites

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Abstract: The contamination of surface and groundwater by chemical pollutants poses a major global challenge, threatening ecological balance, human health, and sustainable water resources. Pollutants, including heavy metals, organic compounds, nutrients, pharmaceuticals, per- and polyfluoroalkyl substances (PFAS), and microplastics, infiltrate aquatic systems through industrial discharges, mining, agriculture, and urban runoff. Their persistence, transformation, and mobility are governed by complex chemical and biological mechanisms, such as adsorption, precipitation, complexation, redox reactions, and microbial biodegradation. For instance, arsenic undergoes redox cycling between As(III) and As(V), mercury is transformed into toxic methylmercury, while lead forms insoluble hydroxides or carbonates depending on pH and carbonate concentrations. Similarly, organic pollutants undergo hydrolysis, photolysis, and microbial degradation, though many yield toxic intermediates. Emerging contaminants like PFAS resist degradation due to strong C–F bonds, while microplastics act as carriers for hydrophobic organics and metals. Mechanistic insights are vital for understanding toxicity, such as cadmium-induced oxidative stress, lead interference with neurotransmission, and endocrine disruption by

organics. This review synthesizes recent advances in the chemistry and mechanisms governing contaminant behavior in surface and groundwater. It highlights the mechanistic underpinnings of pollutant fate, health effects, and remediation technologies, emphasizing the need for integrated, interdisciplinary approaches to safeguard water quality and ecosystem health.

Keywords: Surface water; Groundwater contamination; Heavy metals; Emerging pollutants; Mechanisms.

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