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Experimental Insights into Acute and Sub-Chronic Toxicity of Emerging Environmental Contaminants

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Abstract

Environmental contaminants of emerging concern—including pharmaceutical residues, industrial by-products, and synthetic organic chemicals—are increasingly detected in soil, water, and biological systems. Despite their rising prevalence, toxicological information remains limited for several of these compounds. This study investigates the acute and sub-chronic toxicity patterns of a representative emerging contaminant using in vivo and in vitro assay models. Dose-dependent physiological alterations, oxidative stress responses, and organ-specific biochemical changes were evaluated over a 90-day exposure period. Results indicate significant hepatotoxic and nephrotoxic effects at concentrations previously considered environmentally safe, along with perturbations in antioxidant defense mechanisms. These findings underscore the necessity of re-evaluating environmental exposure thresholds and highlight the importance of continuous risk assessment strategies for unregulated contaminants.

***Keywords:** Toxicology; Emerging contaminants; Sub-chronic exposure; Oxidative stress; Environmental health; Risk assessment*

Introduction

The global rise in industrialization, intensive agriculture, and large-scale pharmaceutical consumption has led to the continuous release of a wide range of chemicals into the environment. Among these, substances categorized as emerging contaminants have become a growing concern due to their persistent nature, bioaccumulative potential, and unknown toxicological profiles. Unlike traditionally regulated pollutants such as heavy metals or volatile organic compounds, these new-age contaminants include synthetic musks, personal care product residues, flame retardants, microplastics, and metabolites of pharmaceuticals. Their widespread detection in water bodies and terrestrial ecosystems has raised questions regarding their long-term effects on human health and ecological stability.

Toxicological studies serve as essential tools for understanding the biological impact and risk associated with such contaminants. Acute toxicity assessments help determine immediate physiological and

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biochemical responses following short-term exposure, whereas sub-chronic studies offer a more comprehensive understanding of cumulative effects on organ systems, cellular metabolism, and regulatory pathways. The need for rigorous evaluation is heightened by the fact that many emerging contaminants enter the environment continuously at low concentrations, often below detectable thresholds, yet may still exert biological effects through chronic exposure mechanisms.

Moreover, oxidative stress has been increasingly recognized as a central mechanism underlying the toxicity of numerous environmental pollutants. Disruption of antioxidant defense systems, including catalase, superoxide dismutase, and glutathione-related enzymes, may lead to cellular damage, inflammation, and organ dysfunction. Several contaminants can also interact with endocrine pathways, modulate gene expression, and impair detoxification enzymes, thereby amplifying their potential health risks.

Given these concerns, the present study investigates the acute and sub-chronic toxicity of a representative emerging contaminant using standardized toxicological approaches. The research aims to evaluate dose-response relationships, characterize biochemical and oxidative stress biomarkers, and explore organ-specific toxicity. By establishing evidence-based toxicity thresholds, the study contributes to the broader understanding required for environmental risk assessment and regulatory decision-making. Ultimately, addressing the toxicological uncertainties surrounding emerging contaminants is essential for safeguarding public health and ensuring sustainable environmental management practices.

Conclusion

The toxicological assessment presented in this study highlights that emerging contaminants, even at environmentally relevant concentrations, can exert significant biological effects during prolonged exposure. Sub-chronic exposure induced measurable alterations in oxidative stress biomarkers, biochemical parameters, and organ histology, indicating potential risks that are not reflected in current environmental guidelines. These findings emphasize the urgency of updating regulatory frameworks, establishing comprehensive monitoring programs, and conducting species-specific risk assessments. Continued research is essential to fully elucidate the mechanisms of toxicity and support evidence-based environmental policies that protect both human and ecological health.

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