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Polymer-Specific Ecological Risks in Estuarine Sedimentary Archives: a case study from the Santos–Cubatão Estuarine System (Brazil)

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Microplastic (<5 mm) pollution has emerged as a pervasive contaminant in estuarine systems under intense anthropogenic pressure. We evaluate polymer-specific ecological risks in a sediment core from the Santos–Cubatão Estuarine System (Brazil), a long-standing industrial pollution hotspot, using the Polymer Hazard Index (PHI)[1] and the Potential Ecological Risk Index (PERI)[2], both classified from low to dangerous (Table 1). Microplastics were density-separated using NaCl solution and identified by micro-Fourier transform infrared spectroscopy (μ-FTIR; Agilent Cary 630). Quality assurance included procedural blanks, positive and negative controls. The Morrão River core (0–200 cm) contains 200–4,200 items kg^{-1}, with higher concentrations in the uppermost layers. Microplastics are dominated by secondary fragments and fibers, mainly polyethylene (PE, 36%), polystyrene (PS, 30%), polypropylene (PP, 20%), polyvinyl chloride (PVC, 7%), polyurethane (PU, 4%), and polyethylene terephthalate (PET, 3%). The upper 100 cm exhibits “Dangerous” ecological risk (PERI >600) and “Very High” hazard potential (PHI up to 1,496) (Figure 1). Elevated risk is mainly driven by PVC and PU, which, despite lower abundance, exhibit extremely high hazard scores (10,001 and 7,384, respectively) due to the potential release of toxic additives and monomers (e.g., phthalates, heavy metals, isocyanates) during environmental degradation[1]. These compounds are associated with endocrine disruption and microbial toxicity[3]. In contrast, the most abundant polymers, PE/PP/PS, show low intrinsic hazard scores (1–30) but high environmental persistence. Their accumulation in sedimentary archives increases long-term ecological exposure and enhances physical stress mechanisms such as ingestion and obstruction in benthic organisms[3]. FTIR spectra reveal features consistent with oxidative weathering signatures, including enhanced carbonyl bands, consistent with polymer aging in sedimentary environments. Such degradation increases surface heterogeneity and may enhance interactions with coexisting contaminants, supporting the view of microplastics as evolving geochemical phases rather than inert particles. By integrating polymer-specific chemical hazards with sedimentary accumulation patterns, this study frames estuarine sediments as reactive geochemical archives where chemical toxicity and physical durability jointly control the long-term environmental footprint of plastic pollution.

[1]Lithner, D. *et. al*. (2011) Sci. Total Environ. 3309–3324.
[2]Ranjani, M., *et. al.,* (2021) Mar. Pollut. Bull. 163, 111-969.
[3]Campisi, L. *et al.* (2025) Sci. Total Environ. 960, 178-276.

Equations	Variables	Classification risks
$PHI = \sum(S_n \, x \, P_n)$	• S_n = hazard score (PE = 11; PP = 1; PVC = 10,001; PU = 7384; PET = 4); • P_n = relative polymer	• $PHI < 10$: Low • $10 \leq PHI < 100$: Moderate • $100 \leq PHI < 1{,}000$: High • $1{,}000 \leq PHI < 10{,}000$: Very High • $PHI > 10{,}000$: Dangerous
$CF_i = C_i / C_{oi}$ $T_r^i = \sum_{n=1}^{n}(P_n \, x \, S_n)$ $PERI = T_r^i \, x \, C_f^i$	• C_i: Microplastics concentration at depth i; • C_{oi}: Lowest microplastics concentration of the sediment core; • T_r^i: toxicity coefficient; • C_f^i: contamination factor at the same depth.	• $PERI < 150$: Low • $150 \leq PERI < 300$: Moderate • $300 \leq PERI < 600$: High • $600 \leq PERI < 1{,}200$: Very High • $PERI > 1{,}200$: Dangerous

