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Sn Isotopic Characteristics of Anthropogenic Tin Sources in Marine Surface Sediments of Busan Port, South Korea

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Tin (Sn) contamination in coastal environments, primarily resulting from the legacy of organotin-based antifouling paints such as tributyltin (TBT), continues to pose a significant threat to marine ecosystems. While TBT concentrations have been monitored for decades, identifying precise sources and understanding the long-term geochemical behavior of Sn requires more sophisticated tracers. This study investigates the application of stable Sn isotopes ($\delta^{124/120}$ Sn) in surface sediments (n=29) from Busan South Port, South Korea's largest maritime hub, to differentiate between anthropogenic and natural lithogenic inputs.

Surface sediment samples and potential terrestrial source materials were collected and processed to the <245 μm grain size fraction to minimize mineralogical bias. Following acid digestion and chemical purification via ion-exchange chromatography, Sn concentrations and isotopic compositions were measured using Multi-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICPMS; Nu Plasma II). The results reveal significant Sn enrichment in the inner port basins, with concentrations reaching as high as 27.0 ppm (e.g., station BN3), which markedly exceeds regional background levels. The $\delta^{124/120}$ Sn values exhibit a range from approximately 0.11‰ to 0.54‰, indicating a clear mixing trend between natural lithogenic Sn and anthropogenic end-members.

The correlation between Sn isotopes and the Butyltin Degradation Index (BDI) suggests that the isotopic signature is modulated by the progressive degradation of TBT into dibutyltin (DBT), monobutyltin (MBT), and eventually inorganic Sn. The distinct isotopic signatures observed in high-concentration areas allow for the forensic attribution of Sn to historical antifouling paint usage and its long-term accumulation in port sediments. This study demonstrates that Sn isotopes provide a powerful tool for environmental source tracking in complex industrial ports, offering critical insights for developing targeted remediation strategies and monitoring the recovery of regions impacted by legacy organotin contamination.