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Buried Plastic Pollution and Fragmentation Dynamics in Coastal Zones: Insights from Hawaiian Beaches

Astrid E. Delorme[1,2,3], Pierre-Yves Le Gac[1], Laurent Lebreton[3,4], and Sarah-Jeanne Royer[2,3]
[1]IFREMER, Marine Structures Laboratory, Centre de Bretagne, Plouzané, France (astrid.delorme@ifremer.fr)
[2]Center for Marine Debris Research, Hawai'i Pacific University, HI, United States of America
[3]The Ocean Cleanup, Rotterdam, The Netherlands
[4]The Modelling House Limited, Raglan, New Zealand

The global transport model of marine plastics shows a disproportionate distribution of plastic pollution, estimating that approximately two-thirds of the plastic mass released from land into the ocean since the 1950s is likely to have stranded along the world's shorelines. Furthermore, plastic debris transported by ocean currents and wind can travel vast distances across the world's ocean far away from its source, eventually converging in one of the five subtropical gyres. The shores of Hawai□i are particularly impacted by plastic pollution due to its proximity to the North Pacific Subtropical Gyre, where the high concentration of floating plastic debris is known as the North Pacific Garbage Patch, NPGP. While surface surveys have documented significant concentrations of plastic pollution on Hawaiian beaches; our survey of buried plastic particles (> 0.5 mm) sampled down to 1 meter in 60 x 60 cm quadrats exposes a substantial hidden layer of pollution on the shores of Hawai□i. Our 1-meter sand column sampling from November 2022 to February 2024 reveals that 91% of the recovered plastic particles were buried below the surface layer (at 2-102 cm depth), with over 90% of these particles being small, brittle fragments primarily composed of polyethylene (PE) and polypropylene (PP). The recovered plastic particles, showed high brittleness and low molar mass (with particles having a molar mass < 10 kg mol^{-1}), signifying extensive weathering. This brittleness points to ongoing fragmentation under coastal conditions, heightening the risk of secondary microplastic formation. To better understand fragmentation behavior and rates of plastics in coastal environments, we conduct simulated swash zone tests on both weathered and unweathered PE and PP films (including the accelerated and naturally aged samples). These tests provide valuable insights into the pathways through which secondary microplastics form. High accumulation zones, such as coastal areas, could be key intervention points to prevent plastics from becoming buried or entering the marine ecosystem as secondary microplastics. Our study of buried plastics and fragmentation behaviour aims to refine models on plastic transport and accumulation, enhancing understanding of the coastal storage and re-mobilization processes of plastics between terrestrial and marine environments. Such insights into plastic fate and transformation dynamics support targeted beach cleanup prioritization in high-accumulation zones. They can inform the Legally Binding International Instrument on Plastic Pollution (LBII) and SDG 14.1 efforts, aiding global strategies to address legacy plastic pollution and refine remediation measures.