

Supporting Information

Text S1. Analysis of Density Separation Experimental Data

To investigate the suspension behavior of microplastics, 100 microplastic particles (5 mm in size) of five distinct materials were individually immersed in ultrapure water, saturated sodium chloride (NaCl) solution, and saturated sodium iodide (NaI) solution. Recovery efficiencies of microplastics in the three systems followed the order: NaI > NaCl > ultrapure water (Fig.S1). Saturated NaCl solution effectively floated low-density microplastics but exhibited poor performance for higher-density microplastics (e.g., polyvinyl chloride [PVC] and polyethylene terephthalate [PET]), yielding recovery rates of only ~10%. This limitation renders it unsuitable for microplastic separation in environmental samples. In contrast, saturated NaI solution achieved complete flotation of all five microplastic types, confirming that high-density solutions enable efficient microplastic separation.

Text S2. Analysis of Density Separation Experimental Data with Sediment Addition

Saturated NaCl solution is widely used for microplastic flotation due to its cost-effectiveness compared to alternatives like NaI or zinc chloride (ZnCl_2). To evaluate sediment-induced effects on separation efficiency, two sets of experiments were conducted:

1. 100 microplastic particles (sizes: 500 μm , 3 mm, 5 mm; five materials) were introduced into saturated NaCl solution, stirred with a glass rod for 5 minutes, and visually counted for recovery.
2. The same microplastic-sediment mixture (100 particles + 5 g sand) was homogenized, added to saturated NaCl solution, stirred for 5 minutes, and recovery was quantified visually.

Saturated NaCl solution showed inadequate separation of high-density microplastics (Fig.S2). Notably, sediment addition significantly reduced microplastic recovery, attributed to adsorption of sediment components onto microplastics, which perturbed density-based separation. Larger microplastics (e.g., 5 mm) exhibited more pronounced recovery reduction, likely due to their greater surface area and consequent higher adsorption capacity. While saturated NaCl may be viable for low-density microplastic extraction in laboratory settings, its inefficiency in complex matrices limits large-scale applications. Given the 5 mm size class was most susceptible to sediment interference, subsequent experiments focused on 5 mm microplastics.

Text S3. Analysis of Oil-Assisted Separation and Optimization Experimental Data

To enhance separation, sediment samples containing 5 mm microplastics were mixed with saturated NaCl solution, overlaid with a 1 mm oil layer, stirred for 15 minutes, and remain undisturbed for 30 minutes. Oil-water separation was then performed to calculate recovery. The oil-NaCl hybrid method improved recovery compared to NaCl alone (Fig.S3) but was deemed suitable only for microplastic abundance surveys, not qualitative environmental analysis.

An optimized oil-air flotation approach was further developed: sediment samples were placed in a flotation column with 500 mL water and a 1 mm oil layer, followed by aeration (200 mL/min). Air bubbles carried microplastics to the surface, where they adsorbed onto

the oil layer; subsequent oil-water separation enabled recovery quantification. This method eliminated density dependence, achieving ~100% recovery even for high-density microplastics, outperforming both NaCl alone and oil-NaCl methods. However, like the oil-NaCl approach, it remained limited to abundance studies due to qualitative analysis constraints (Fig.S4).

Text S4. Analysis of Froth Flotation Experimental Data

Froth flotation was optimized using alkyl polyglucoside (APG), a biodegradable surfactant. Sediment samples with 5 mm microplastics were added to a flotation column containing 500 mL of 0.05 g/L APG solution, followed by aeration (200 mL/min). Air bubbles adsorbed microplastics and rose to form a froth layer, which was separated via a 200 μ m sieve for recovery quantification.

Similar to oil-air flotation, APG-assisted froth flotation eliminated density dependence, achieving ~100% recovery for high-density microplastics. The entire process was completed within 2 minutes. Mechanistically, APG reduced solution surface tension, facilitating froth formation during aeration; microplastics adsorbed onto rising bubbles, forming a froth-microplastic aggregate that overflowed and was collected. Notably, APG's eco-friendly, fully biodegradable nature ensured zero pollution, high efficiency, and reliable recovery, making it suitable for both quantitative and qualitative microplastic analysis.

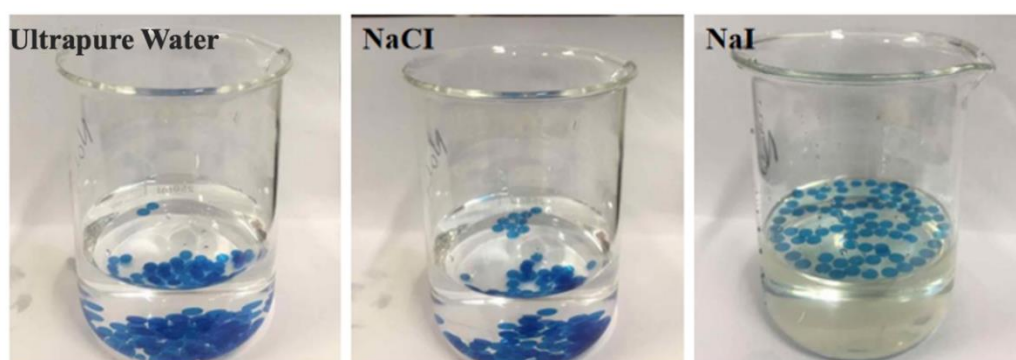


Figure S1: Suspension characteristics of PVC in ultrapure water, saturated sodium chloride solution and saturated sodium iodide solution.

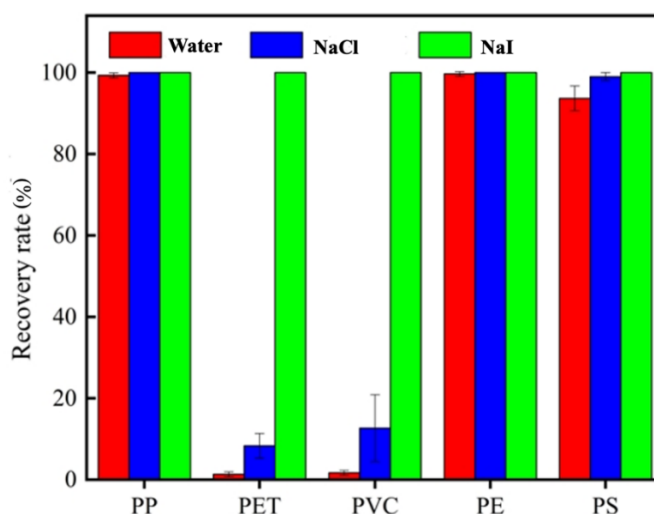


Figure S2: Recovery rates of various types of microplastics in ultrapure water, saturated sodium chloride solution and iodide solution respectively.

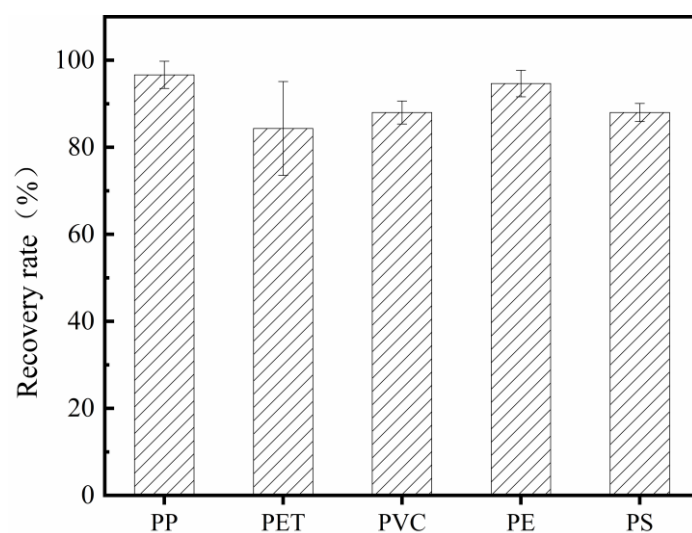


Figure S3: Recovery rate of Oil +NaCl separation mode.

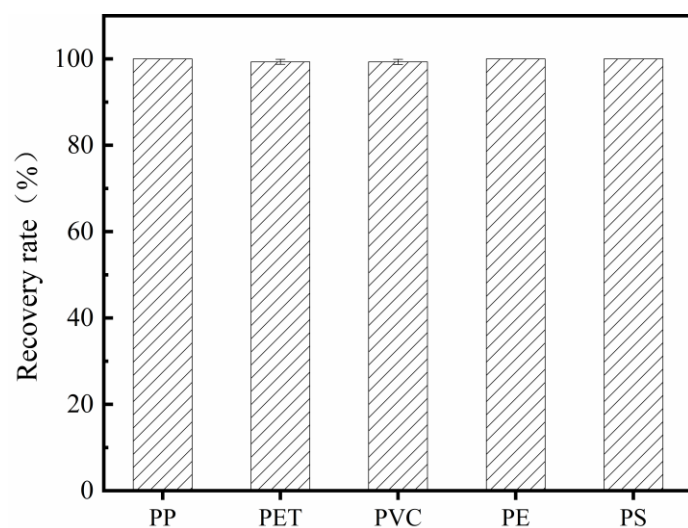


Figure S4: Recovery Rate of Oil+Air Flotation Separation Mode.

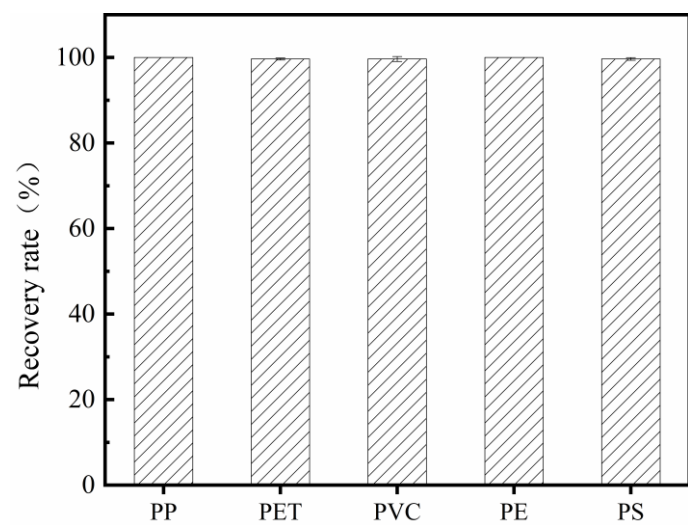


Figure S5: Recovery Rate of Foam Flotation Separation Mode.

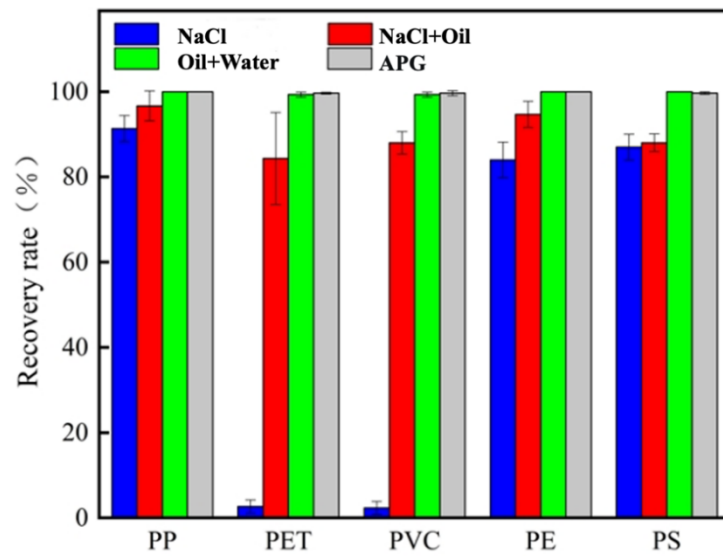


Figure S6: Recovery rate of microplastics in sand sediments under different separation methods.