Impedance spectroscopy quantifies microplastics waste in waterways

Microbeads used in cosmetics such as in facial scrubs can traverse from shower drains through sewage into the oceans. Once there, they have the potential to inflict serious injury to marine animals that ingest them. These small particles are a small subset of the cumulative microplastics waste in oceans that stems from numerous sources: bulk plastic parts disintegrate and contribute to this grave pollution problem. Viable methods to detect or filter out these waste microplastics must first overcome the complex diversity of shapes, chemistries, and sizes of these particles. Existing standard spectroscopy approaches are generally slow, labor-intensive, and simply cannot identify and track the immense numbers of these microplastics. These pollutants strongly resemble background natural materials, such as sand or algae, and a conventional screening tool is incapable of addressing the enormity of this problem.

Recent efforts have increasingly relied on impedance spectroscopy to conduct high-throughput analysis of flowing particles. The technique finds

use in medical imaging and relies on electrical properties between different cells to discern tumor cells from blood or bacteria in water. Electrodes immersed in flowing liquid monitor frequency-dependent resistance to derive impedance. Since particle dimensions (at low frequencies) and chemistries (at higher frequencies) influence the resistance and impede electric current (forcing it out of phase with the fluctuating voltage), a carefully calibrated measurement can readily pick up the presence, quantity, identity, and key properties of microplastic beads in flowing tap water.

Anna Michel and Beckett Colson of the Woods Hole Oceanographic Institution (WHOI) recently fine-tuned an impedance measurement device to carry out this work. They detected over 90% of plastics with a 300–1000 μm size range out of a continuous flow of over six liters per hour. They published their experimental design and findings in a recent issue of *ACS Sensors* (<https://doi.org/10.1021/acssensors.0c02223>).

Michel, the principal investigator of the work, told *MRS Bulletin* that for us to understand the fate and effects of microplastics in aqueous environments, we need to first be able to determine how many plastics are present. We really do not know the impact of microplastics on the environment and

therefore we need robust approaches for measuring them, she says. Colson, a graduate student in the Massachusetts Institute of Technology-WHOI Joint Program, adds, “This technique has significant promise for future *in situ* instrumentation. The dream is to refine the technique for real-time microplastic monitoring.”

To test their approach, the researchers constructed a flow cell that directed particle-containing water between two parallel-plate electrodes. They used a lock-in amplifier to record the impedance changes as particles passed through the sensor at six frequencies between 10 kHz and 3 MHz. The researchers used MATLAB software to build a machine-learning model to interpret impedance data as a given material: microplastic, biology, or air bubbles. The measurement also derived the particle size of the microplastics in the fluid medium. For verification, a downstream filter collected the particles and allowed visual quantification with an optical microscope. The results were highly accurate: 99% of the particles were correctly classified as their respective material types. The high-throughput nature of this approach allows much faster screening of wastewater than manual counting of microplastics in liquid samples.

Although many cosmetic products are adopting more environmentally friendly formulations that eschew nonbiodegradable plastic beads, numerous other pollutants contribute to this issue. Tires, which rub off small rubber bits during driving, and clothes, which shed small fragments during each wash, persistently add to waste streams. To avoid harming marine life and having plastics enter the food web, advanced filtration systems need to remove these microplastics from wastewater. The innovative approach by Michel and Colson suggests that a method may one day be available that can keep up with the immense volume of sewage and rainwater runoff and direct their flow to appropriate filters and treatment facilities.

Boris Dyatkin

Microscope image showing the microplastics (colorful beads) and organisms (top row, from left to right: Daphnia, Moina, Copepod) and seeds used for testing a new microplastic quantification technique. Credit: Anna Michel and Beckett Colson.