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Recycling and reusing ceramics and glass

Reduce, reuse, and recycle are the three Rs of sustainable practice. Of these three actions, reduce is the most straightforward, with the goal of minimizing energy use, raw material consumption, and dead-end waste production. On the other hand, recycle and reuse have multiple facets. For example, in last month's Topical Collection, "Sustainable ceramic and glass raw materials," there were several examples of materials produced for one purpose being "recycled" into raw materials for other purposes. Could this practice be considered reuse? Perhaps.

In this month's Topical Collection, "Recycling and reusing ceramics and glass," we explore some of the nuanced and various factors that must be considered when implementing the other two Rs. For example, inorganic glasses are exemplary of multiple levels of reuse and recycling. Dairies and breweries once frequently made use of glass bottles to deliver their products. After the empty bottles were returned via collection or deposit, these businesses washed and refilled the bottles until they were no longer usable. When that occurred, the business sent the bottles back to the glass company for melting and forming into new bottles.

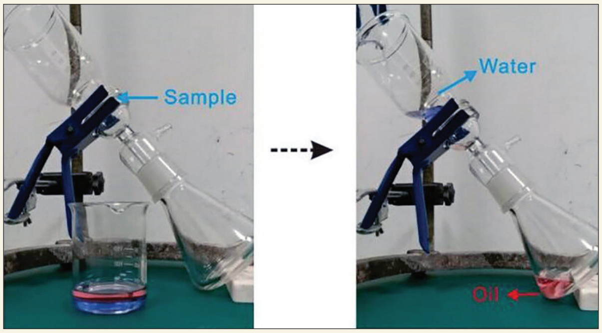
Though many companies and communities no longer make use of this business model due to increased transportation costs, these now single-use glass bottles remain highly recyclable. In the paper "Characterization of soda–lime silicate glass bottles to support recycling efforts," Gerace and Mauro showed that the mixed- colored, discarded bottles found in typical recycle streams can be reformed to create new glasses with consistent color.

Though transporting glass for recycling can be expensive, recycled glass offers the benefits of lower energy usage and carbon dioxide emissions compared to production based on carbonate raw materials. To make the most of these benefits, the reuse of ceramic and glass materials at or near the use location greatly extends the value to the user.

Being able to clean, refresh, and restore functionality via washing, calcination, or similar low-effort, low-cost methods can extend the life and utility acceptably of recycled ceramic and glass materials. Numerous papers in this month's Topical Collection explore removing simulated and real-world contaminants, including methylene blue, phosphates, and organic and pharmaceutical compounds.

Adsorption and filtration are two physical processes for removing contaminants. Adsorption is limited by the number of active physical sites to which contaminants can attach on the adsorbent's surface. Once capacity is reached, the adsorbed material must be removed to restore the adsorbent. In the paper "Pore size regulation of BN fibers and its effect on tetracycline adsorption," Liu et al. fabricated boron nitride fiber adsorbents with multiscale pores. They found the fibers adsorbed tetracycline in a nearly 1:1 removal rate. The capacity was retained at nearly 100% after five cycles of adsorption and removal via calcination.

Interestingly, in the paper "Preparation of oil–water separation network based on the novel strategies of SiO_2 ceramic micro-nano structure and PDMS modification," Liu, Zeng, and Yang developed a ceramic filter that reliably separates hydrocarbons from water. Their technology relies upon superhydrophobicity to prevent water from passing through the filter, and a simultaneous superoleophilic nature that uses surface tension to "push" the organics through the filter. They tested the filter under a wide range of real-world conditions (Figure 1) and were able to repair (recoat) the screen after eroding away the coating with sand. The refreshed screen retained more than 90% efficiency relative to the undamaged filter.



Credit: Liu et al., *International Journal of Applied Ceramic Technology*

Figure 1. Advanced ceramic filter used to separate oil (red) from water (blue).

In recent years, research into catalytic removal of organic contaminants have focused on photodegradation methods. Titanium dioxide (TiO_2) is a classic photocatalyst often used in powder forms, which can be difficult to remove from the cleaned system. In the paper "Granular titanium dioxide and silicon-doped titanium dioxide as reusable photocatalysts for dye removal," Atali et al. developed a method for granulating TiO_2. The granules exhibited activity similar to powders but were substantially easier to separate from the water.

Wang et al. took a different approach to reusability of photocatalysts in the paper "High-performance Cu_2O-based photocatalysts enabled by self-curling nanocelluloses via a freeze-drying route." They developed a copper oxide/carbon fiber aerogel fabricated by freeze-drying nanocellulose. Their material degraded 97% of the tetracycline initially, falling to 89% after 10 cycles with no regeneration required between uses.

For more information on the articles discussed above along with others in the Topical Collection "Recycling and reuse of ceramics and glass," please visit https://ceramics.org/sustainability-collections. ■