Smart Hydrogel Beads for Selective Removal of Pollutants from Water

Hui Yang, Jadranka Travas-Sejdic

Water pollution is a growing sustainability challenge, especially in laboratory and industrial settings where wastewater can contain a complex mixture of chemicals. This project aimed to develop a simple and efficient material system for selectively removing and degrading pollutants from water. The work was supported by the Faculty of Science Sustainability Network Research Award and aligns with the University of Auckland's sustainability goals in clean water management and environmental protection.

In this project, I developed smart hydrogel beads with a core–shell structure. Hydrogels are soft, water-rich materials, and the core–shell design means that each bead contains two different regions: an inner core and an outer shell. These two regions have different chemical properties, allowing the beads to control how pollutants move through the material. A key feature of the system is that it responds to pH, meaning that changes in acidity can influence which pollutants enter the bead and where they are located.

The beads were designed to combine two functions in one material. First, they can selectively capture pollutants from water, acting like a smart filter. Depending on the pH, the beads can attract or block different charged molecules, allowing pollutants to be separated into different regions of the bead. Second, the beads contain a catalyst in the outer shell that can activate an oxidant and generate reactive species to break down pollutants. By keeping the catalyst in a specific region, the reaction can occur in a more controlled way rather than throughout the whole material.

The results showed that the core–shell hydrogel beads could regulate pollutant transport and degradation through their structure and pH-responsive behaviour. Under some conditions, the beads acted mainly as a selective adsorption material, while under other conditions they supported catalytic degradation. Importantly, the spatial confinement of the catalyst helped shift the best degradation performance toward near-neutral pH, which is more practical for real water treatment compared with strongly acidic conditions.

This research demonstrates how smart soft materials can be used to improve pollutant removal from water. The system reduces the need for multiple separate treatment steps by combining selective capture and degradation in one bead. It also uses a metal-free carbon-based catalyst, which helps avoid secondary contamination from metal leaching. In the future, this approach could be further developed for treating laboratory wastewater, industrial wastewater, or other complex water systems. More broadly, the project shows how careful material design can support more sustainable and adaptable water treatment technologies.

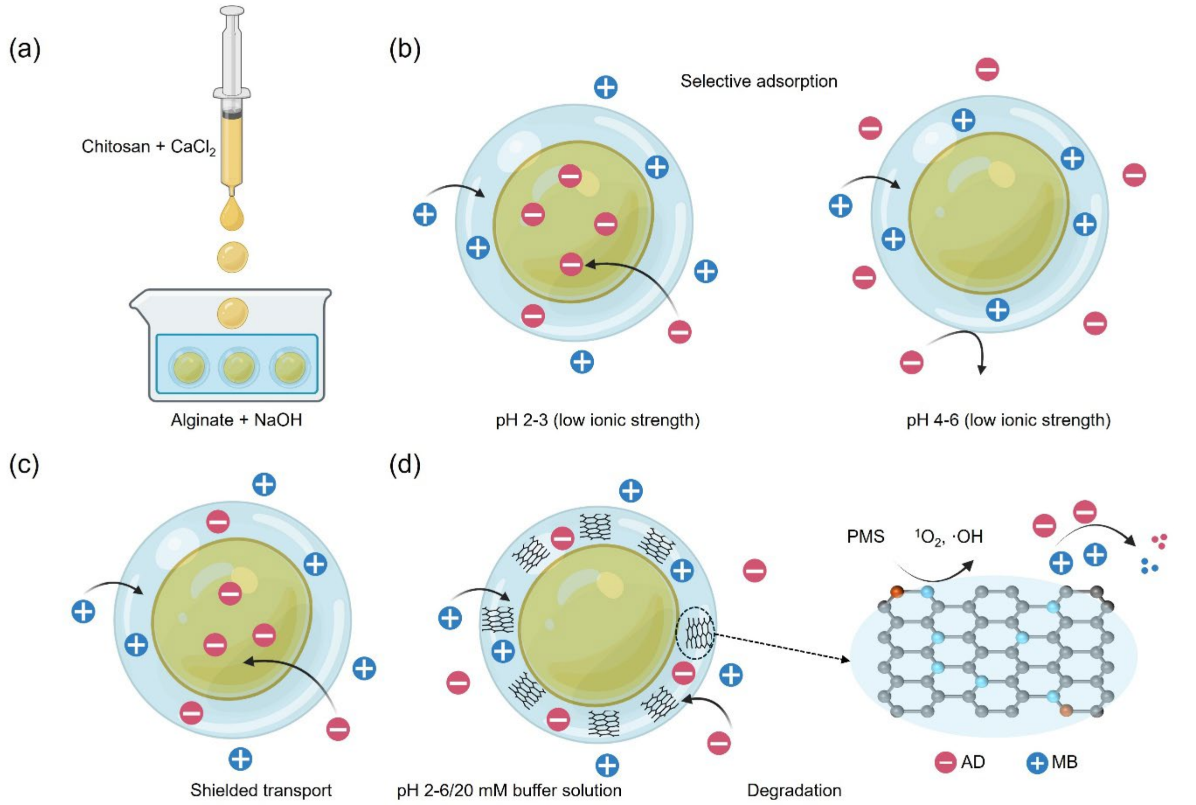

Figure 1. Schematic illustration of the hydrogel bead system. The beads have a core–shell structure, where different regions perform different functions. By changing the pH, the beads can control how pollutants move through the system and where reactions occur.

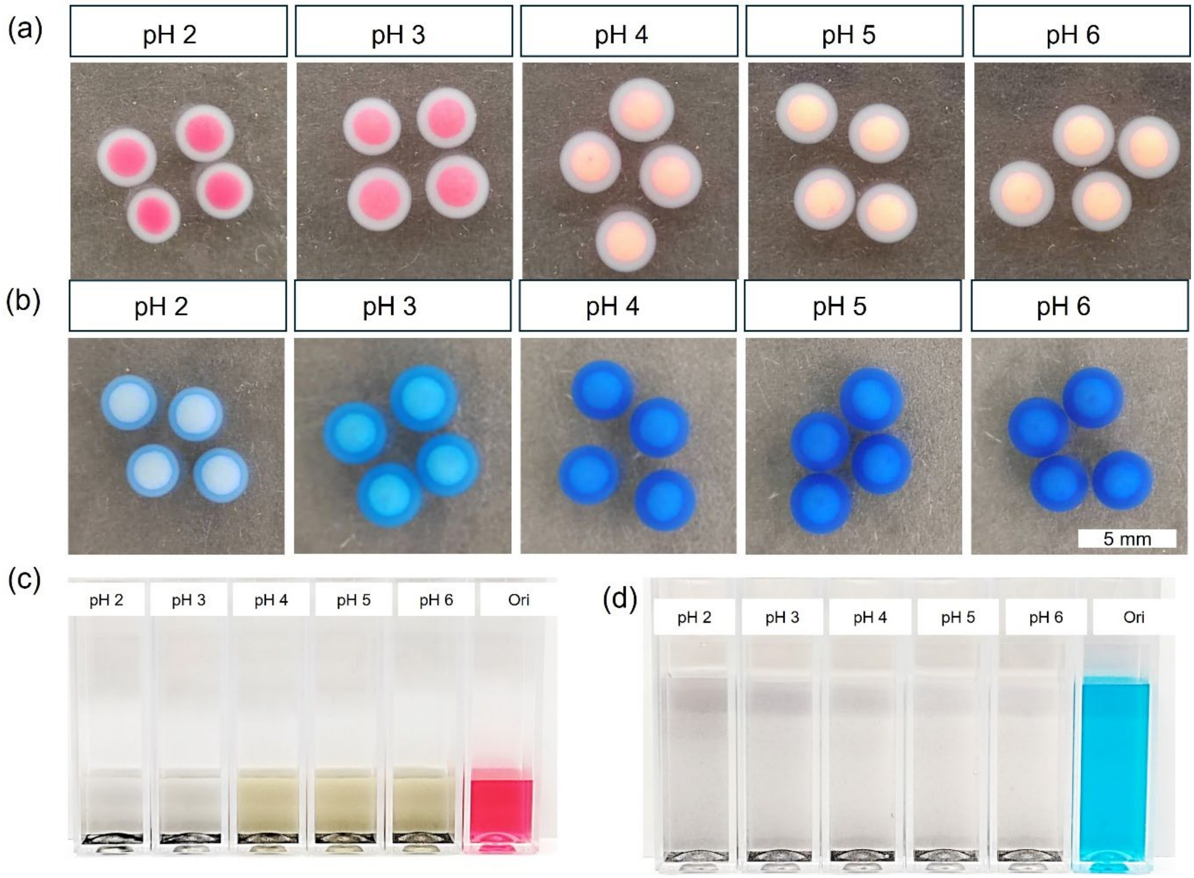

Figure 2. pH-dependent selective capture and removal of pollutants using hydrogel beads.