Smart polymers for purifying water from metal pollutants

Askican Hacioglu, Helsingin yliopisto/Helsingfors universitet

Impact in a nutshell

Water pollution, particularly from heavy metals like mercury and lead, is a serious global issue. Heavy metal ions are present in polluted aquatic systems and can cause severe illness or death, even at low concentrations. Almost any type of industrial plant produces wastewater contaminated with heavy metals, and removing these pollutants efficiently has crucial importance for all stakeholders, especially for protecting the environment.

I work on the synthesis of novel materials that show varying water solubility in response to temperature changes in a controllable manner. I aim to utilize this smart feature to remove metal ions from water, as these materials naturally possess a high metal-binding capacity due to their chemical structure. Achieving this goal will result in more energy-efficient water purification, enabling us to protect the environment in a more economical and sustainable way, leading to a healthier ecosystem.

Research details

Several techniques are known to reduce heavy metal content in wastewater. However, these methods can cause environmental issues themselves and may not completely eliminate metallic pollution.

Sorption techniques, which involve the adhesion of metals to the surface of another material, offer a lower-cost alternative for removing metal traces from water. Among these methods, polymer-enhanced ultrafiltration combines the sorption of metal ions on polymers with a separation step via ultrafiltration. However, the ultrafiltration step is very energy-intensive. One promising approach is using smart polymers as sorbents, which enable lower-cost separation techniques such as centrifugation, microfiltration, or sedimentation.

I work on the synthesis of novel smart polymers that show varying water solubility in response to temperature changes. These so-called "thermoresponsive" polymers have a high metal-binding capacity due to their chemical structure. At the molecular level, we are essentially replacing oxygen atoms in the polymer with sulfur atoms. This process, called thionation, allows us to tune the thermoresponsive behaviour of the polymers while also increasing their metal-binding capacity.

So far, we've optimized the reaction conditions and thionated different polymers to achieve the same molecular motifs. After filing a patent application for this process, we completed a study on tuning the thermoresponsive behaviour via thionation. We are currently evaluating the metal-binding capacity of the synthesized polymers.

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What is or will be the impact of your research?

By the end of this project, we aim to develop a highly efficient metal adsorbent system with thermoresponsive properties. This will enable the purification of polluted water by simply mixing the polymers into the solution and then increasing the temperature slightly to precipitate the polymer-metal ion complexes. This approach will be highly beneficial for water purification, as it can efficiently remove heavy metal pollutants with minimal energy consumption.

This has the potential to benefit ecosystems, communities, and industries reliant on clean water.

Industries that generate large amounts of wastewater, such as mining, oil, battery manufacturing, and chemical production, can shift towards cleaner, more efficient water treatment methods. Governments and environmental regulators may adopt stricter guidelines for wastewater treatment, knowing that a cost-effective and energy-efficient solution is available. Communities near industrial zones, particularly in regions where access to clean water is a persistent challenge, can benefit from safer, less polluted water supplies. The broader environment, including aquatic life and ecosystems, will also see reduced heavy metal contamination, leading to healthier and more sustainable biodiversity.