Cleaning Up Environmental Contaminants with Quantum Dot Technology

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The 2023 Nobel Prize in Chemistry was focused on quantum dots — objects so tiny, they're controlled by the strange and complex rules of quantum physics. Many quantum dots used in electronics are made from toxic substances, but their nontoxic counterparts are now being developed and explored for uses in medicine and in the environment. One team of researchers is focusing on carbon- and sulfur-based quantum dots, using them to create safer invisible inks and to help decontaminate water supplies.

The researchers will present their results today at the spring meeting of the American Chemical Society (ACS). ACS Spring 2024 is a hybrid meeting being held virtually and in person March 17-21; it features nearly 12,000 presentations on a range of science topics.

Quantum dots are synthetic nanometer-scale semiconductor crystals that emit light. They are used in applications such as electronics displays and solar cells. “Many conventional quantum dots are toxic, because they're derived from heavy metals,” explains Md Palashuddin Sk, an assistant professor of chemistry at Aligarh Muslim University in India. “So, we're working on nonmetallic quantum dots because they're environmentally friendly and can be used in biological applications.”

Quantum dots are tiny — usually only tens of atoms in diameter. Because they're so small, their properties are controlled by quantum effects, which makes them act a little strangely compared to larger objects. Namely, they emit light differently than one might expect; for example, gold materials appear blue on this scale. Nonmetallic quantum dots exhibit the same effect and have been explored by other researchers as a tool for bioimaging. Palashuddin has focused on designing carbon- and sulfur-based quantum dots (Cdots and Sdots, respectively) for a variety of other applications.

“Carbon and sulfur are very abundant, cost-effective materials, and they can easily be synthesized into quantum dots,” he says. “You can make carbon dots from waste materials, then use them for removing pollutants — they’re a way to make the process come full circle.”

Palashuddin has already put Cdots and Sdots to work in a variety of ways, though both are relatively recent discoveries. Though small, the dots have a large surface area, which can easily be functionalized to adapt the dots for different applications. Previously, the team designed dots that shined different colors, depending on which contaminants they encountered. That meant they could help identify contaminants — such as lead, cobalt and chromium — in a water sample without leaching any new metals from the dots themselves.

In addition to identifying contaminants, Cdots can help break down pollutants such as pesticides and dyes in water. In one project, Palashuddin and collaborator Amaresh Kumar Sahoo, an assistant professor who studies nanobiotechnology at the Indian Institute of Information Technology, formed Cdots from potato peels and then mounted them on microscopic robots designed to target and degrade toxic dyes in samples simulating polluted water.

The team has also developed methods to remove contaminants from water entirely, rather than just identifying or degrading them. They’ve specially designed Cdots to sop up automotive oil and are currently exploring a Cdot-based filter system to help treat oil spills.

Next, the researchers plan to put their laboratory findings to work in the field, possibly in a project focused on the Yamuna River. This river runs directly through New Delhi and is famously contaminated, especially in more populated areas. Palashuddin hopes to use his team’s nonmetallic dots to identify and separate the various pollutants in the river, including pesticides, surfactants, metal ions, antibiotics and dyes. Ideally, the dots will be functionalized to grab as many of these different contaminants on their surfaces as possible, so they can then be easily removed.

The potential uses for nonmetallic dots don’t just end with water treatment, though. Palashuddin and colleagues are currently investigating uses that could align more closely with traditional, metal-based dots, but without the toxicity concerns. As an example, some light-emitting quantum dots developed by the team could be included in invisible inks to help prevent counterfeiting, or incorporated into light-emitting devices, including television screens.

The team hopes that their work can help broaden the uses for nonmetallic quantum dots and put their unique properties to work in the environment.

Read the original article on American Chemical Society (ACS).