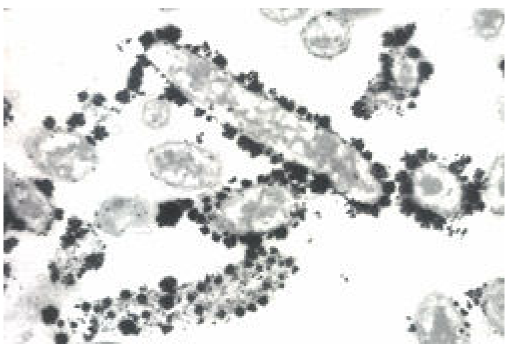
Microbes turn industrial waste into a nanocatalyst

A sustainable new technology uses microbes and industrial wastes to produce a nanocatalyst that has promise for cleaning chromium from other industrial wastewater.

Research posted today on *ES&T*'s Research ASAP website (10.1021/es0509836) describes how, in one elegant step, selected bacteria can recover precious metals from industrial waste solutions and deposit them as nanocrystal catalysts on their cell surfaces. By using the metal-covered biomass to clean up toxic chromium wastes, the researchers demonstrated the approach's potential as a sustainable technology.



Ping Yong
When exposed to waste from automotive catalytic converters, which contains palladium and platinum, cells of *Desulfovibrio desulfuricans*, shown in this transmission electron micrograph image, deposit nanocrystals of these precious metals on their surfaces.

The experiments were targeted at palladium—a precious metal used in automotive catalytic converters, circuit boards, and other electronic equipment. The metal's high cost makes its reuse desirable. In addition, the EU's 2003 Waste Electrical and Electronic Equipment directive promotes reuse, recycling, and other forms of recovery of precious metals from obsolete electronics devices such as televisions, computers, and cell phones.

The use of these waste streams as the raw material for an effective nanocatalyst is a new and exciting sustainable technology, says corresponding author Amanda Mabbett, who conducted her research as a graduate student in the group of Lynne Macaskie at the University of Birmingham's School of Biosciences (U.K.). Macaskie's group is continuing to develop new technologies that use urban waste materials as part of a project funded by the Royal Society, the U.K.'s national academy of science.

In Mabbett's experiments, microbes exposed to wastewater containing palladium from automotive catalyst or electronic scrap disposal converted the precious metal to its elemental form, Pd(0). The microbes used in the experiments, *Desulfovibrio desulfuricans* and *E. coli*, deposited this palladium as well as other metals present in the wastewater—including aluminum, platinum, and silver—as nanocrystals on the surfaces of their cells.

The researchers then harvested the nanocrystals, which incorporate the biomass from the now-dead microbes from the wastewater. They found that the bio-produced nanocrystals could be used for months as an effective and stable catalyst for the remediation of the toxic form of chromium, Cr(VI), which is frequently found in wastewater from metal plating operations. The nanocrystals converted the Cr(VI) to noncarcinogenic Cr(III), which could be easily removed by increasing the wastewater's pH.

Interestingly, Mabbett's team discovered that the cell-bound Pd(0) that they produced biologically was a more efficient catalyst than chemically produced Pd(0). This is probably due to its smaller particle size and, therefore, greater surface area, says Mabbett. In addition, the presence of other materials, such as aluminum, in the waste solution, which became part of the catalyst, promoted the process of converting chromium into its noncarcinogenic form.

"The bio-produced nanocatalyst could work as an economic alternative to the chemical [removal] of Cr(VI)," says Mabbett, who now works at the School of Molecular & Microbial Sciences and the Advanced Wastewater Management Centre at the University of Queensland (Australia). She reasons that the use of costly chemicals that are necessary for chemical reduction could be avoided. Irene Wagner-Döbler of the German Research Centre for Biotechnology, however, feels that the data are too premature to warrant such claims. "Unless I see much more data on the long-term performance and the costs compared to other methods for chromium removal, I am not convinced that this is a competitive method," Wagner-Döbler says.

Mabbett points out that an optimization of the biocatalyst production is still necessary to produce a catalyst that can perform consistently. One drawback is that the presence of other metals in the waste solution used to generate the catalyst can influence its final performance; therefore, it may be desirable to mix waste so that a more consistent composition is attained, she says. In addition, copper present in the waste streams can poison the microbial enzyme hydrogenase, which is responsible for forming Pd(0) on the cells, Mabbett explains.

"This is a really strong paper on the microbial way to make waste palladium into a material for metal remediation," says Piet Lens of the department of environmental technology at the University of Wageningen (The Netherlands). "The microbial formation of nanocatalysts may not yet be the technique for tomorrow, but it is very promising. I see a good potential for industrial applications other than chromium removal as well," Lens says. The nanocrystal biomass can indeed also be used for the remediation of PCBs, says Mabbett.

Lens points out that environmental researchers have only started to make use of bacterial abilities beyond their metabolism, such as their capacity for extracellular electron transfer. In addition to being the basis for producing the nanocatalyst in this paper, extracellular electron transfer is also used to power microbial fuel cells. “Microorganisms have evolved to do so many intricate reactions, bigger and better than anything man can do,” Mabbett summarizes. “Microbes may be able to produce better catalysts from all sorts of materials, which are just waiting to be discovered.” —ANKE SCHAEFER.

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