Sustainable use of precious metals through biotechnological recycling

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1. Introduction - Many post-consumer products, such as electronics goods and catalytic converters in cars, are important sources of precious metals, such as platinum group metals (PGMs) and gold. Conventional thermal and chemical recycling techniques remain the best methods for recycling precious metals, so these domestic resources of precious metals have yet to be fully utilized. We believe that more research and development is needed to recycle precious metals from secondary sources. Biological technologies now provide an attractive and eco-friendly alternative strategy. Therefore, we propose using new biotechnologies to recycle precious metals from post-consumer products, which will lead to the sustainable use of precious metals.

2. Results and Discussion - Our research focuses on using *Shewanella* bacteria (*Shewanella algae*) to recycle precious metals. The *Shewanella* bacteria are microorganisms that can reduce ferric iron to ferrous iron by electron transfer under anaerobic conditions. The electrons are obtained from the oxidation of lactate or formate. We recognized that the reduction potential of ferric iron is almost equal to the reduction potential of aqueous precious metal ions (Pd(II), Pt(IV), Rh(III) and Au(III)). Therefore, we investigated using *Shewanella* bacteria to reduce and deposit the PGMs ions into metal nanoparticles at room temperature and neutral pH within 60 min, using lactate as the electron donor. We attempted to use our microbial recovery system to extract PGMs from spent automotive catalysts. The *Shewanella* bacteria were able to achieve rapid and efficient recovery of PGMs ions (Pd(II), Pt(IV) and Rh(III)) from the spent catalyst leachate at pH 6 and room temperature.

Shewanella bacteria can also be applied as a biomaterial for adsorbing soluble precious metals from aqueous acidic solutions. This is possible because *Shewanella* bacteria lose their microbial ability to reduce precious metal ions under acidic pH conditions. Alternatively, *Shewanella* bacteria have a cell surface consisting of biological materials containing functional groups that are responsible for the adsorption of precious metal ions. We attempted to recover gold from electronic waste. When processing leachate of spent electronic components, *Shewanella* bacteria were able to rapidly and effectively collect Au(III) ions from a strongly acidic solution at pH 1. Importantly, *Shewanella* bacteria did not react with other metal ions, such as copper and iron. The microbial ability to selectively and rapidly recover only Au(III) ions demonstrates the potential for commercialization of biotechnological recycling of gold from electronic waste.

Our proposed bio-technologies (Figure 1) are good examples of using room-temperature microbial reactions for low-energy and low-cost recycling processes, resulting in decreased CO_2 emissions. Our highly efficient process fits into a small unit and could be introduced at local collection points for post-consumer products and operate as a regionally distributed technology for recycling precious metals.