Center for Particulate and Surfactant Systems (CPaSS)

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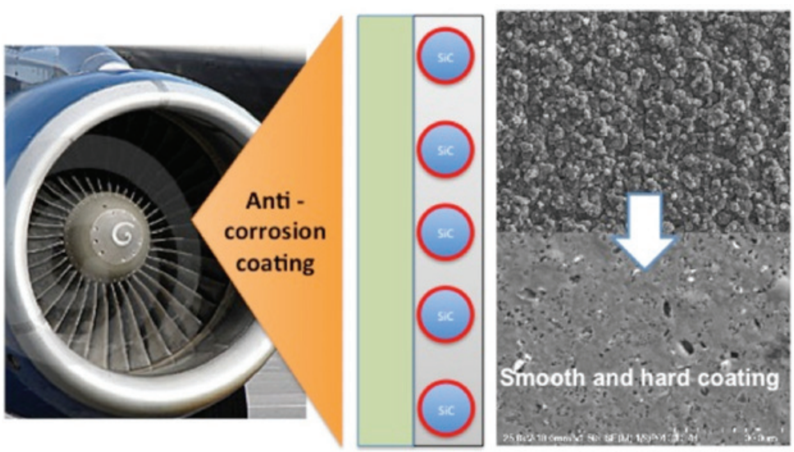
Wear-Resistant Metal-Ceramic Composite Coatings

The cost of corrosion within the North American aircraft industry was estimated to be over $13 billion per year, with an additional few billions added on for the US military's aircraft. A significant portion of the costs of such corrosion, as well as that of erosion and abrasion of landing gear and other critical parts can be eliminated with the application of high-wear resistant coatings.

Incorporation of hard ceramic micro or nanoparticles into metal coatings is a very promising approach to improve the wear and corrosion resistance of the surfaces that must perform under harsh conditions. To be evenly incorporated, these nanoparticles must be well dispersed in very hostile plating solutions. This is challenging because of the need for dispersing reagents to function under extremely high electrolyte and pH conditions without impacting electroplating efficiency. CPaSS researchers, supported jointly by the I/UCRC and the Boeing Company, have used cationic polymers to develop a novel method for preparing stable dispersions by precoating the particles, thus avoiding any decrease in the efficiency of the plating process caused by dissolved polymers.



Harder and smoother coatings reduce the friction and eventual wear and corrosion of high impact surfaces of aircrafts

Economic Impact: This innovation is leading to new high performance composite coatings and increased revenues because of the improved lifetimes of surfaces when used under harsh conditions. Electro-co-deposited films offer exceptional hardness, durability and wear resistance for applications in numerous industries. These films enhance the product lifetime, reduce maintenance costs and promote new product developments. The breakthrough CPaSS process lowers reagent and energy use during electroplating, while improving the coating properties. The resulting final products are more sustainable with a reduced carbon footprint and extended lifetimes. Because of lower maintenance, repair and overhaul costs the electroplating industry can potentially generate higher revenues (5-10% increase from $6.2 billion) by introducing more durable products for end users that are primarily in the aviation and automotive industries.

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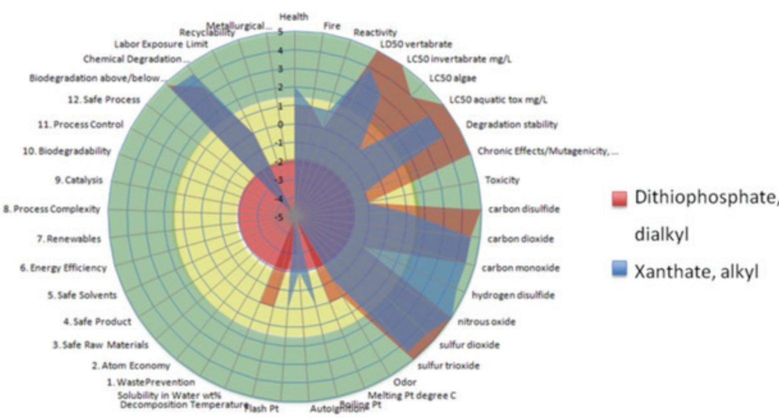
A Multi-Dimensional Greenness Index to Evaluate Chemicals Used in Processing

A problem that underpins many technologies critical to modern industries is how to selectively and effectively separate valuable minerals from undesirable ones in ores or to control dispersion in personal and health care products. Large volumes of different types of chemicals are used in mineral processing industries. Many of these have the potential to produce negative impacts on safety, health, and the environment (SHE). Consequently, they must be either well-managed or replaced with more benign alternatives.

Various separate regulations exist to constrain the manufacture, transport, implementation, or consequences of the use of the chemicals in particular applications. For example, flotation is one typical mineral processing operation in which high-value minerals are separated from low-value minerals through the use of chemicals that selectively change the surface of finely divided high-value minerals so that they adhere to rising air bubbles and become concentrated in the resulting froth. This process of flotation has been successfully used for over a century and forms a principle means of value-mineral concentration.



An example that shows the comparison of two typical mining chemicals (dithiophosphate and xanthate) used as collectors in the mineral processing industry. The format of presenting the greenness is a spider-diagram, on which the larger the overall area, the greener the chemical.

A full assessment of the SHE consequences of chemicals used for this purpose should include aspects along the entire chain of events from manufacture, to transport, to deployment in the application, and to final fate, disposal, or waste treatment. However, current assessments are too often done in piecemeal. For example, the chemical manufacturer designs and optimizes a safe and economical process for the production and transport of the chemical to the mineral processing front gate; the mineral processing operator chooses and optimizes the use of a chemical within the plant to boost production and quality in a safe manner; and finally the waste management operator deals with the residuals. Compartmentalizing assessments along this chain of events can lead to myopic evaluations.

A more holistic scheme would be desirable - i.e., a means by which one could decide between alternative chemicals for a specific application with the intent to minimize negative SHE consequences across the entire chain of events. CPaSS researchers approached this by developing a Greenness Index, using the example of assessing flotation chemicals through their manufacture, use, and final fate.

The strategy behind the design of this tool was to include consideration of physical, chemical, environmental (e.g., biodegradability, human toxicity, water quality), economic, and social attributes. The mathematical algorithms that form the working machinery of this tool have been designed to be flexible and adaptable enough to allow the individual user to incorporate the particulars of their own mineral processing operations (e.g., operational specifics, economic model, and risk analysis methods). This tool establishes a framework for the evaluation of chemicals throughout their life and use cycles, and enables a more holistic comparison that can be a better basis for sustainable choices in mineral processing operations.

Economic Impact: By 2015, the annual international mining chemicals market is expected to exceed $10.5 billion (http://www.mining-technology.com/features/feature117826/). Selection of greener chemicals to replace problematic ones currently used in the mineral processing industry is driven by external pressure from increasingly strict regulations, as well as by demands from various quarters for sustainable development. Our Greenness Index, an advance on the other available tools for evaluating chemicals in this manner, can be used to assess chemicals throughout their life and use cycles. One of the most outstanding features of this tool is its ability to incorporate a variety of information, including the fate of chemicals in a process and a wide selection of data from laboratory experiments, simulations, and models. This tool has been well received by several major mining companies (Barrick, Newmont, Vale and Freeport McMoRan), and has been used to evaluate several flotation chemicals in their operations. Personal care companies are beginning to explore use of the Greenness Index. The economic impacts on the mining industry will likely be substantial.

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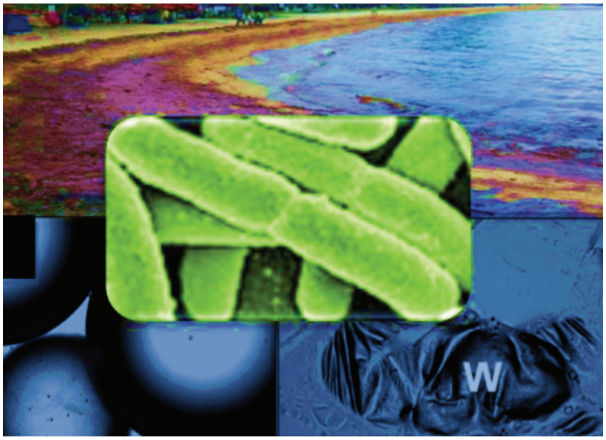
Environmentally Benign Biosurfactants for Oil Spill Remediation



Environmentally benign bio-reagents for oil cleaning.

Surfactants are molecules that possess the ability to disperse oil in water. For that reason, they can be used to mitigate the effects of oil spills. There are concerns as to how reliably they can be used without they themselves causing toxicity to marine ecology. CPaSS researchers have used bio-reagents derived from *Bacillus Subtilis* bacteria because they are benign and exhibit similarities to oil dispersion surfactants. These bio-reagents have special viscoelastic properties that enable them to form robust films at the oil/water interface. Such films have long term durability to encapsulate oil droplets so that they can remain dispersed in water where microbes are able to degrade them.

Surfactants form self-assembled structures (micelles) where the core of such structures are hydrophobic and have the ability to entrap oil. The bioreagents tend to aggregate and form a film at the oil/water interface. Because such films are sustainable for long durations, they enable oil to be dispersed in water for long periods. These reagents are environmentally benign. Furthermore, the droplet sizes are significantly large (a few microns) as compared to micelles which are of sizes of nanometers.

Knowledge on the chemical structural, the nature of the bio-reagents, and the mechanism by which they function to disperse oil has been broadcasted on National Geographic Channel and in the Discovery Channel TV series of Brave New World by Stephen Hawking. Thus, such information is available to the industries that are seeking environmentally benign technologies for oil spill remediation.

Economic Impact: Because this research makes it possible for smaller amounts of the bioreagents to be required to effectively disperse oil, the work should have a number of difficult-to-quantify economic impacts, as well as environmental impacts with long-term benefits. Because it is also reasonable to assume that this breakthrough will be used within the personal care and pharmaceutical industries to develop novel technologies for encapsulation of target material such as fragrance or of drugs, economical benefits should accrue there as well.

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Prototype Greenness Index for Mineral Resource Development

A new Greenness Index based on an integration of the Twelve Principles of Green Chemistry and ICMM's ten principles for Sustainable Mining Development is in the prototype stage. This tool will bridge the existing gap between focused efforts in the chemical and mineral processing industries. The Greenness Index will allow mining companies to evaluate the multifarious aspects of sustainability in mineral processing operations. Supported by several major mining companies, this collaborative and comprehensive effort is the first of its kind. Over the next twelve months the algorithm will be tested and refined for chemically assisted flotation operations. This will ultimately allow the economic and environmental impact of sustainable processes to be engineered.

Mining companies can evaluate sustainbility in processing operations.

Economic Impact: This new initiative and the progress made in the past year has already spurred great interest in the mining and the chemical industry in terms of providing a framework and tools to evaluate and account for chemicals in the mining life cycle. The work is designed to provide the necessary metrics to evaluate current industry standards. With iterative refinements to the prototype, we plan to develop a robust tool that can suggest greener alternatives to old industry standards. Nationally it promotes awareness of the use and impact of chemicals and open accountability. The integration of the Twelve Principles of Green Chemistry and ICMM's ten principles for Sustainable Mining Development philosophy into the prototype is essential to promote greener mineral processing.

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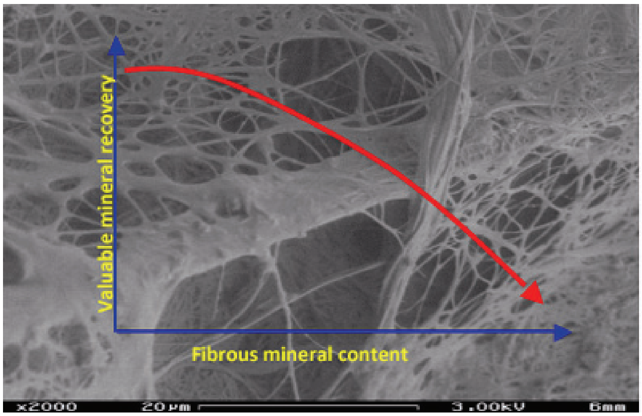
Sustainable Mineral Resource Recovery



Network formation by fibrous minerals leading to poor mineral recovery and process efficiency.

One of the major sustainability challenges facing the mineral industry today is the selective and efficient recovery of strategically important valuable minerals and metals from low quality complex ores. Processing of ores is characterized by poor mineral recovery and high water and energy consumption. Flotation separation, which is still the most widely used method, is severely hampered because of the presence in ores of waste minerals, notably silicates. While the adverse effects of waste minerals are well recognized, the root causes for these effects remained elusive, thereby impeding development of robust solutions to the problem.

In collaboration with Vale and Cytec Industries, CPaSS researchers have uncovered important root causes. The pioneering work has demonstrated that the shape and morphology of the waste silicates have large negative impacts on processing efficiency; in some cases far greater than that resulting from the chemistry of such silicates. Most notably, strong evidence was found for complex fibrous networks in suspensions of the ground ores. These networks dramatically increase slurry viscosity and reduce the efficiency of gas dispersion and bubble-particle attachment; all of which lead to poor separation and process efficiency.

The prevailing belief in the scientific community was that the detrimental effect of waste silicates was due to hetero-coagulation between the silicates and the valuable minerals, generally referred to as slime coating. CPaSS research has demonstrated that platy, acicular, or fibrous particles interact and entangle in ore suspensions to form micro and macro networks, which result in dramatic changes in slurry rheology, gas dispersion, and bubble-particle attachment. Such network formation leads to several undesirable consequences: transport of large amounts of non-value silicates to the value mineral concentrate by bubble flux, reduction in valuable mineral recovery, and high water and energy consumption. Our initial discoveries were made in Ni ores.

Economic Impact: This novel research will have a significant scientific and technological impact, allowing us to devise ways to enhance selective separation of valuable minerals from complex and poor quality ores while consuming less water and energy, thereby addressing the sustainability challenges facing the US industry for the foreseeable future. Plant operators will benefit by implementing our recommendations and solutions, particularly in diagnosing the problem before processing, and making better decisions related to selection of reagents and conditions.

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