Research Brief 153: Novel High-Strength Iron Cement Sequesters Pollutants

Superfund Basic Research Program

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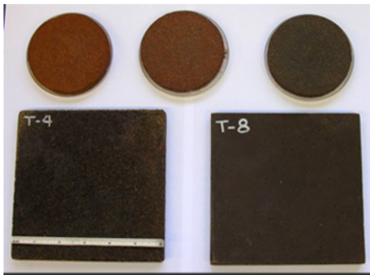
Background:

Traditional industrial processes are being updated to consume less material, generate less waste, and use less energy. In addition, researchers and engineers are developing new methods to complement established processes. These secondary systems transform waste streams into feed stocks for new products that can break down or safely sequester toxic materials. These "industrial ecology" approaches seek to eliminate pollution by integrating recycling at all stages of a product's life cycle - from acquisition of raw materials to reuse of parts/materials when the product no longer functions.



Examples of iron carbonate cement. Compositional differences produce slight variations in color. The 6-inch scale bar on the lower left sample indicates the dimensions of the tiles and disks.

Mr. David Stone, a graduate student working with University of Arizona SBRP researchers Joan Curry and Janick Artiola, is using solid waste materials from sources such as open pit copper mines, coal-fired power plants, steel foundries, cement plants, and shot blasting facilities to create hard aggregate materials for use in industrial and environmental applications.

Advances:

Guided by processes in nature, Mr. Stone has developed a bench-top method to create an iron-based cement, which incorporates carbon dioxide during the curing process. The basic solid material components are zero-valent iron and silica. Mr. Stone uses fly ash as the predominant silica source because of its wide availability, and small, consistent particle size.


UA SBRP Investigator Joan Curry and David Stone at the 2007 University of Arizona Technology Innovation Award Luncheon

The largest and most widespread source of cheap iron is scrap steel, which must be reduced to powder - a process that requires energy input. The researchers use an electrochemical cell to dissolve the steel at the anode in an acid bath, which results in the deposition of zero-valent iron at the cathode. The brittle deposit is broken off of the cathode and crushed into granules. This process can be made both economically feasible and environmentally benign by using solar cells as the DC power source.

Preliminary studies indicate that iron prepared in this way forms very strong aggregate materials. The researchers mix the iron, silica, and other materials (promoters, catalysts, and stabilizers) and add water to form a paste that can be deposited in a mold or placed directly and troweled smooth, just like Portland cement products. The aggregate material hardens upon exposure to carbon dioxide, which is absorbed and permanently trapped within the mineral matrix. A 5/8" thick, 12"x12" tile, which weighs 5 kg, can sequester about 1 kg of CO_2. The iron carbonate composite falls into the category of "super-strong" cements. The material can have greater strength than Portland cement, and functions more effectively under certain extreme conditions such as those found in seawater and other corrosive environments. On-going work is focused on improving the process, investigating the material micro-structure and the chemistry of the curing process.

The University of Arizona has filed a patent application to protect this discovery.

Significance:

Metallic iron is a common filtrate for a variety of environmental contaminants including the dense non-aqueous phase liquids trichloroethylene and perchloroethylene; metals such as arsenic, cadmium, chromium, copper, lead, and zinc; and radioactive materials. The iron-based cement production process developed at the University of Arizona could be used to bind these toxic materials in a cement matrix. The SBRP researchers have plans to test the material's ability to permanently sequester metals as well as organics. As such, this research effort has great potential to protect human and environmental health.

The researchers believe that their process is particularly intriguing because it not only consumes waste materials, but also consumes a primary green house gas. This is of great interest to the Portland cement industry because carbon dioxide is a major and unavoidable by-product of cement production. It is possible that carbon dioxide emissions from Portland cement plants could be used as an input stream for the production of an iron-carbonate waste-based cement material. This could lead to savings (or profits) as it could: reduce costs of processing industrial waste materials; yield carbon credits for sequestering CO_2 during the manufacturing process; and produce a marketable product that could be used as building panels, tiles, block, pavers, etc.

For his discovery of this material, Mr. Stone received the 2007 University of Arizona Student Technology Innovation Award.

* Update (October 01, 2007):

David Stone, Joan Curry and Janick Artiola have been awarded a $50,000 supplemental grant from the SBRP to continue testing the iron-based composite material for the stabilization of industrial wastes, and potentially, arsenic bearing residuals. This supplemental grant will allow for ongoing work to improve the process, investigate the material s micro-structure and the chemistry of the curing process.

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