Affordable Manufacturing of High Surface Area Iron Powder for Remediation

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Environmental Problem

Toxic chemicals contaminate soil and groundwater in numerous locations worldwide. These compounds, including chlorinated hydrocarbons and transition metal compounds, are now affecting aquifers that supply drinking water. Adverse health effects associated with exposure to these chemical compounds include damage to the nervous system, liver dysfunction, and an increased cancer risk.

Traditional remediation protocols often are prohibitively expensive, leave behind toxic byproducts, and are difficult to implement, particularly when addressing a deeply embedded contaminant phase. Alternative remediation techniques involve treating the contaminant phase in the subsurface. These *in situ* methods include the injection of zero-valent metal particles, typically iron, into the ground. The metal sustains an electrochemical reaction that converts the toxic materials into innocuous products. Commercially available iron particles typically are coarse, with dimensions of a few micrometers to a millimeter or larger. When injected underground, these large metal particles are held back by soil particles before they reach the contaminant phase.

SBIR Technology Solution

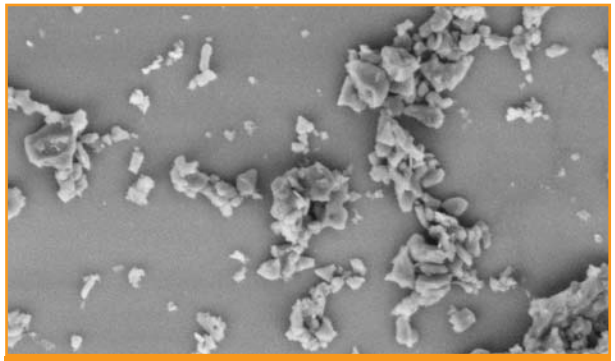
With support from EPA's SBIR Program, OnMaterials, LLC, developed a scalable manufacturing process to produce affordable, submicrometer and nanocrystalline zero-valent metal powders. This work led to the development of Z-Loy™, a nonaqueous zero-valent metal suspension. The discrete particle size is advantageous because other nanocrystalline zero-valent iron (NZVI) particles, prepared by chemical precipitation or thermal reduction, typically are aggregated into larger particles that hinder underground mobility.

Engineered and manufactured in the United States, Z-Loy™ provides the remediation community a zero-valent metal with small, discrete particles that enable underground mobility to remediate deeply embedded substances. Z-Loy™ particles have highly reactive surfaces that enable the rapid elimination of toxic substances without producing toxic daughter products. Z-Loy™ offers a metallic surface area of approximately 15 m^2/g; this provides exceptional reactivity because reaction kinetics scale with surface area. A first-order measure of reactivity is obtained by making a 10 g/L aqueous suspension (10 g particulate matter in 1 L of water) and measuring the oxygen reduction potential (ORP). ORP quantifies the ability of the metal particles to accomplish electrochemical reduction; a large negative value is indicative of a reactive material. Due to its high metallic surface area, Z-Loy™ exhibits values between -800 and -900 mV as compared to approximately -200 mV for conventional iron powders. These values provide a nonincremental improvement in reduction potential.

Laboratory microcosm studies using gas chromatography show the rapid and near-complete elimination of aqueous-phase chlorinated hydrocarbons from very concentrated solutions. Additionally, the resulting reaction products consist primarily of innocuous, nonchlorinated gaseous hydrocarbons with little or no toxic chlorinated byproducts formed.

Commercialization Information

The exceptional reactivity of Z-Loy™ has been independently corroborated by prospective customers in laboratory experiments. This has led to subsurface injections, the largest of which occurred



Scanning electron microscope micrograph showing the discrete, submicrometer and nanocrystalline particles of Z-Loy™ zero-valent iron powder.

at a 1,1,1-trichloroethane-contaminated facility in Edison, New Jersey. This pilot injection used pneumatic fracturing in fractured bedrock and pressurized injection in overburden material to emplace 1,400 lb of Z-Loy™ in the subsurface. Underground mobility was verified by the visual observation of iron at monitoring wells 15 feet away from the injection site at two vertical intervals. This far exceeded the 8-10 feet expectations, and thus diluted the 2-3 g/L targeted Z-Loy™ loading. Even so, electrochemical activity was verified by the reduction of ORP from slightly positive values to nearly -400 mV at a monitoring well approximately 35 feet from the injection point. A second phase injection of 8,000 lb at the Edison site is scheduled. This will be one of the largest injections of NZVI to date.

OnMaterials has tailored the Z-Loy™ product line to meet particular remediation requirements. Three different categories of zero-valent iron materials currently are available with properties engineered to address site-specific needs: Z-Loy™, Z-Loy™ Flake, and Z-Loy™ LA. Presently, synthesis capacity is about 1 ton per day and will increase as demand requires.

Company History

OnMaterials, LLC, a privately held company, specializes in the synthesis and processing of technical powders, including ceramic and metal nanopowders. The company was formed in 2000 and offers technical support services designed to minimize risk and reduce costs associated with the development and implementation of custom applications, products, and processes. OnMaterials' research and development operations are located in San Diego, California, and its Z-Loy™ manufacturing operation is located in Longmont, Colorado.

SBIR Impact

- Toxic chemical substances, including chlorinated hydrocarbons and transition metal compounds, contaminate soil and aquifers that supply drinking water.
- OnMaterials developed Z-Loy™, a nonaqueous zero-valent metal suspension that enables underground remediation of toxic substances.
- Current synthesis capacity is are approximately 1 ton per day.
- OnMaterials has successfully emplaced 1,400 lb of Z-loy™ at a contaminated site in New Jersey. A second phase injection of 8,000 lb at this site is scheduled.