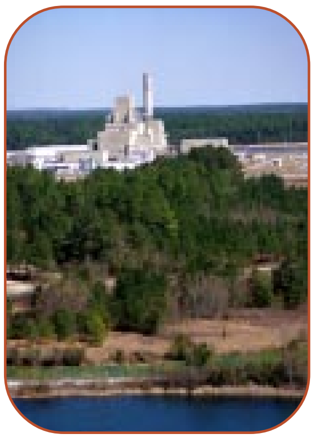
Soil Remediation Using *In Situ* Immobilization Techniques

What are the consequences of metal–contaminated soils?

Soil contamination can have dire consequences, such as loss of ecosystem and agricultural productivity, diminished food chain quality, tainted water resources, economic loss, and human and animal illness. In extensive areas of eastern and central Europe, people suffer from illnesses associated with elevated levels of lead in the air, cobalt, arsenic, mercury, and cadmium in the soil, and a food chain contaminated by metals related to heavy industry. The Savannah River Site (SRS) is one site in the U.S. that contains many polluted environments that must be remediated to levels that pose negligible human and ecological health risk.

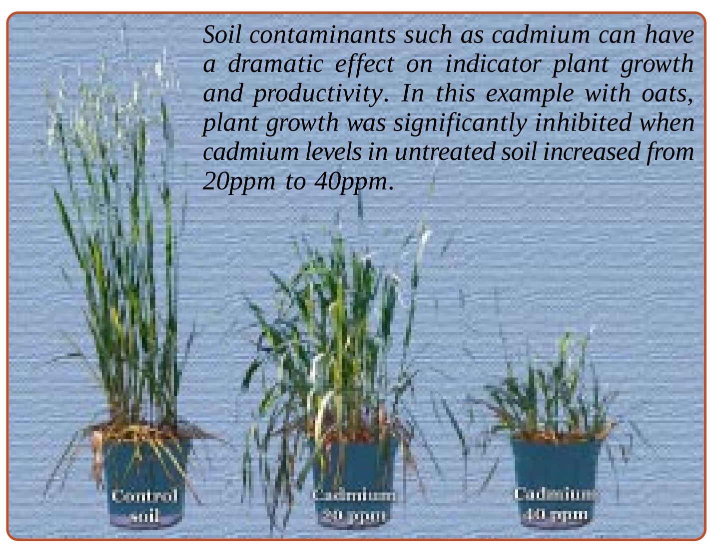


In situ immobilization techniques

In recent years, attention has focused on the development of *in situ* (in place) immobilization methods that are generally less expensive and disruptive to the natural landscape, hydrology, and ecosystems than are conventional excavation, treatment, and disposal methods. *In situ* immobilization of metals using inexpensive amendments such as minerals (apatite, zeolite, or clay minerals) or waste by-products (steel shot, beringite, iron-rich biosolids) is a promising alternative to current remediation methods. This technique relies on a fundamental understanding of the natural geochemical processes governing the speciation, migration, and bioavailability of metals in the environment. In polluted soils, metals can be dissolved in solution, held on inorganic soil particles, complexed with organic soil components, or precipitated as pure or mixed solids. Soluble contaminants are subject to migration with soil water, uptake by plants or aquatic organisms, or loss due to volatilization into the atmosphere.

Metals in soil may be associated with various phases that are reactive, semi-reactive or non-reactive. The risk to the environment from contaminated soil cannot be assessed by simply considering the total amount of potentially toxic metals within the soil because these metals are not necessarily completely mobile or bioavailable.

The main goal of *in situ* remediation techniques is to reduce the fraction of toxic elements that is potentially mobile or bioavailable. Environmental mobility is the capacity for toxic elements to move from contaminated materials to any compartment of the soil or groundwater. Bioavailability refers to the fraction of a contaminant that can be taken into any biological entity, be it plant, earthworm, or human. Depending on the chemical form in which a contaminant occurs, it may range from being totally bioavailable



Soil contaminants such as cadmium can have a dramatic effect on indicator plant growth and productivity. In this example with oats, plant growth was significantly inhibited when cadmium levels in untreated soil increased from 20ppm to 40ppm.

to virtually unavailable.

Objectives of SREL research on *in situ* immobilization of metals:

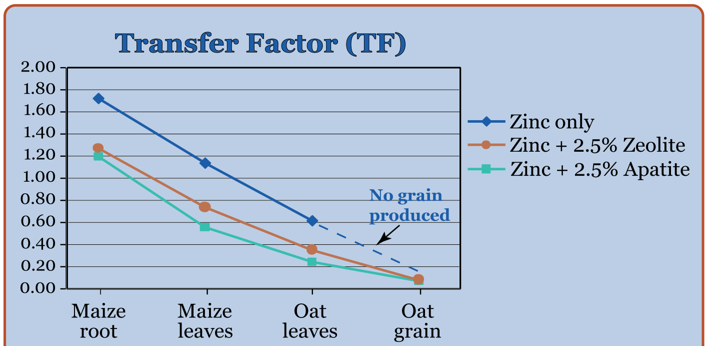
At SREL, the objectives of research on *in situ* immobilization of metals include:

- Evaluating the use of inexpensive, abundant materials as stabilizing agents in metal-contaminated soils;
- Determining the long-term efficacy of stabilizing agents;
- Determining the influence of stabilizing agents on the mobility, bioavailability, and toxicity of metals in soil;
- Developing soil quality indices as tools in evaluating the efficacy of remediation techniques and for monitoring purposes.

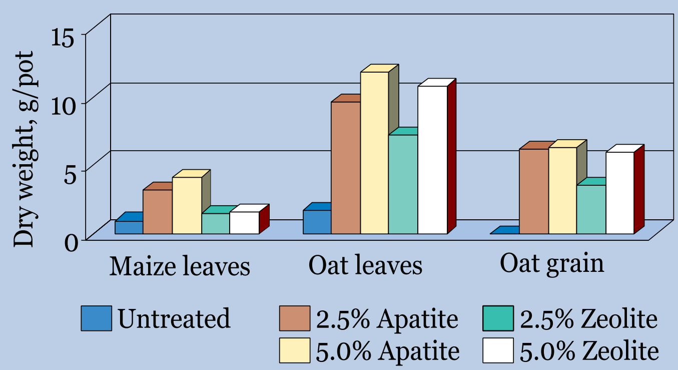
Some results of SREL research:

Soil amendments such as apatite, zeolite, clay minerals, iron oxides, and alkaline biosolids (waste by-products) were found to be suitable for remediating metal- contaminated soil. The amendments significantly reduced the mobility of metals in soil, metal uptake by plants, and metal phytotoxicity. However, the effectiveness of these amendments varied. For example, iron oxide was most effective for soils contaminated with arsenic, whereas apatite was best at reducing the mobility of lead, cadmium, and zinc. The alkaline biosolid played an important role in stabilization of copper and nickel. Zeolite stabilizes cadmium, zinc, lead, copper, and nickel in soil, especially when metal levels are not high, but its efficacy might be questionable.

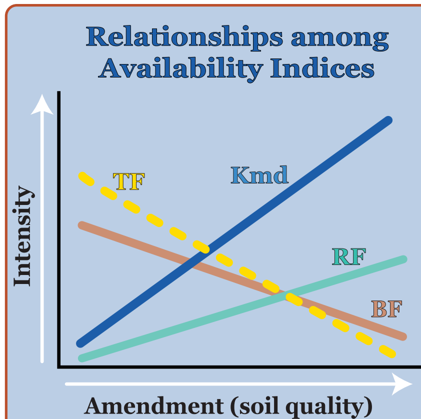
Soil amendments used with *in situ* remediation techniques decreased the mobility of metals by increasing retention of metals in the non-mobile solid phase. The influence of the stabilizing agents on the mobility, bioavailability, and toxicity of metals can be evaluated using newly developed availability indices such as the modified distribution coefficient (Kmd), bioavailablity factor (BF), recalcitrant factor (RF), and transfer factor (TF), all of which give researchers information on the amount of a metal contaminant that remains in the soil vs. the amount that moves into solution or the food chain. For example, Kmd is relatively low in heavily metal-contaminated soil, meaning that metals are fairly mobile. SREL research has shown that addition of certain amendments increased the Kmd value, reducing the mobile fraction of metals in the soil. In contrast, the bioavailability factor (BF) differs for each element, with its value being dependent upon the total concentration of the metal, the source of the metal, and the properties of the soil. While a very mobile element like cadmium can have a BF value of only 2% in uncontam-inated soils, the BF for cadmium can increase to as much as 50% in polluted soils. The RF factor typically is lower in soils with high concentrations of contaminants and low soil pH. TF values, which in-dicate metal bio-availability, are usually high in contaminated soils but decrease upon treatment.



Soil amendments such as zeolite and apatite can reduce the movement of contaminants from soils into plants, as measured in this case by the transfer factor (TF). Zinc levels in all soils were 2800ppm.



SREL experiments with maize and oats show that soil amendments such as apatite and zeolite can reduce the uptake of metals and result in increased plant growth. All plants were grown in soil containing 20ppm Cd, 1900ppm Pb, and 2800ppm Zn.



SREL studies found that the application of increasing amounts of amendments to metal-contaminated soils resulted in increased values for Kmd and RF and decreased values for BF and TF. Such changes among the soil quality indices indicate success of the remediation technique and may have relevance in risk assessment and monitoring.