A look at the use of cement solidification/stabilization (S/S) of contaminated soil, sludge, and dredge spoils as an effective, low-cost option for industrial site remediation.
Many different technologies have been developed to reduce the impact of contaminated soils and sediments on the environment. These commonly include vapor extraction, bioremediation, desorption, and incineration, as well as a host of others, including the old fallback method of dig and haul. The old school method of placing contaminated materials in a landfill does nothing to mitigate the hazardous nature of the material. I refer to this as the “kitty litter mentality”; we cover it up and pretend it is gone.

The effectiveness and the cost of these technologies have wide ranges of value. Most technologies require the removal of the contaminated soil from the ground, treatment of some form, and often, disposal of the now treated material in a landfill. Each time the contaminated soil is touched by an excavator, auger, or any other piece of equipment, there is a per-ton cost associated with that material. If the treated soil is going to a landfill, there will also be a per-ton or per-yard cost associated with the disposal. If the material arrives at the landfill as a hazardous waste, there will be yet another charge to treat the material on some per-unit cost prior to landfilling. If the contaminated soil has been removed from the site, oftentimes, clean materials needed to backfill the excavation. More unit costs are incurred.

**Cement Solidification/Stabilization**

Cement Solidification/Stabilization (S/S) of contaminated soil, sludge, and dredge spoils offers an effective, lower cost option than most other remediation technologies. In S/S treatment, cement is blended with the contaminated soil, solidifying the soil and thereby locking up the contaminants and permanently isolating them from the environment. Stabilization of the soil via S/S also converts metal contaminants to insoluble metal hydroxides, thus preventing their leaching into the groundwater or into surface water by precipitation.

By way of example, the author conducted a study on behalf of the Ontario Ministry of the Environment (MOE) regarding the impact of truck traffic on a project at the Toronto waterfront. The Ontario MOE was initially considering dig and haul, followed by replacing the removed soil with clean backfill. The number of truck trips needed for their initial scenario required nearly 21 times the number of trucks (6,000 vs. 290) compared to cement S/S treatment.

**S/S In-Situ Treatment**

Two primary methods have been devised for remediating contaminated sites using S/S. The first method is in-situ, or in-place treatment. In this method, contaminated soil is treated directly where it lies, without first being removed from the ground. An in-situ remediation site is shown in Figure 1.

The equipment used for this method often employs an auger and excavator or a modified excavator with a rotating drum that looks very similar to a stump grinder. The equipment homogenizes the soil with dry cement or a slurry of cementitious product, injected directly into the mixing zone.

Numerous types of mechanical devices have been used successfully in this manner. Some systems are quite high-tech in that the cement product and water are metered into the mixing zone with help from an on board computer and gps controls that apply a very precise amount of cement product. Othersystems are no more precise than a back hoe mixing cement into the soil until the operator “feels” mixing is complete.

From a recycling standpoint, in-situ S/S, literally recycles the cement-treated contaminated soil into a foundation material for whatever structures may be subsequently built upon the site. Based on this author’s experience, one of the most
favorable advantages to in-situ S/S is the cost, typically half that of dig and haul to a landfill. Historically, the cost of landfilling (i.e., the kitty litter option) has been the lowest cost alternative.

**S/S Ex-Situ Treatment**

The other type of S/S technology is called ex-situ, which involves first removing contaminated soil from the ground then blending it thoroughly with cement in a mechanical mixing device such as a pug mill. The treated soil is then either placed back into the ground from where it was removed, used as a fill material at another site, or disposed in a landfill, but at a much lower cost than untreated soil. Typical ex-situ remediation operations are shown in Figures 2 and 3.

This method is more costly than in-situ owing to the ancillary equipment needed to process the soil. It also requires a larger footprint for the equipment than with in-situ. It has an advantage in that the soil and cement product can be metered together very accurately, which optimizes the amount of cement needed for effective remediation. This method can usually process a larger amount of soil than in-situ methods, depending on the size of the pug mill or other mixing device.

The ex-situ method of S/S is often used when the contamination at a site is deeper than perhaps 25 feet. As a result, the soil is treated in “lifts”. The top 20 feet or so are removed and treated in a pug mill and stockpiled. The deeper material is then excavated and treated ex-situ. At that point, the treated soil is placed back in the ground, reused in some other fashion, or disposed off-site.

**Proven Technology**

Both in-situ and ex-situ cement S/S technologies have proven to be very effective in the remediation of contaminated soils. According to the U.S. Environmental Protection Agency (EPA) publication, *Treatment Technologies for Site Cleanup: Annual Status, Twelfth Edition* (https://www.epa.gov/sites/production/files/2015-08/documents/asr12_full_document.pdf), 126 source control treatment projects were conducted from 2002 to 2005; more than 22 percent of these projects used either in-situ or ex-situ cement S/S treatments.

Cement S/S is quite effective for remediating both metals and organic contaminants. Cement products of all types have a high pH in solution. For those of us who may not have dusted off our college chemistry text indecades, a high pH means cement is a fairly strong base, when wet. Specifically, wetted cement products have a high concentration of hydroxide. That old chemistry text will also have a section on the “Solubility Rules”. These rules define for us what ions will form insoluble precipitates in aqueous solutions. The metals found on the periodic table form insoluble metal hydroxides with the exception of all the column 1 metals and three of the metals in column 2. In short, this means that cement S/S will convert characteristically hazardous metals to non-hazardous, non-leachable, insoluble metal hydroxides. Based on testing for contaminant mobility using a leaching extraction test method (TCLP test), the reduction in the concentration of metals between untreated and S/S-treated soil is often four to five orders of magnitude. Based on testing for contaminant mobility using another leaching extraction test method (SPLP test) on a sample that has been first made into a Structural Integrity Test (SIT- EPA method 1310B) monolith, the reduction is even greater; typically the leachable metals are not detectable at that point.

**Example Applications**

Two brief examples of successful cement S/S remediation projects follow. The first site was located in Lansing, MI. It had been used in the 1970s and 1980s as an industrial barrel recycling facility, but had been abandoned for at least 25 years. At that time, little, if any, quality control was implemented.

---

**Figure 2.** Site using ex-situ cement stabilization of contaminated soils. Source: Photo courtesy of LafargeHolcim.

**Figure 3.** Ex-Situ mixing of cement with contaminated soils. Source: Photo courtesy of LafargeHolcim.
The Use of Cement in Site Remediation
by Paul Ruehl

The results were remarkable. The leachable lead was reduced to .0035-3.8 mg/L based on TCLP testing, below levels that suggest a hazardous waste. The cost for remediation was about half the cost of the original proposal. Furthermore, the original proposal would not have reduced the lead leachability, but rather, would have only contained any leachable lead within the hazardous waste landfill.

The second example S/S project involves a large Brownfield redevelopment project in Nova Scotia, called the Sydney Tar Ponds, successfully completed between 2007 and 2013. The site of an old steel mill, this was a massive site of 100 hectares (250 acres) with approximately 800,000 metric tons of contaminated soil. It had a virtual potpourri of contaminants, including PCBs, raw sewage, benzene, cooling pond sludge from a coke oven, and a wide variety of metals. When organics are the primary contaminants of concern, Portland cement is the best option. It forms more bonds in three dimensions and is most effective at encapsulating the organic molecules.

The site was remediated by means of in-situ S/S, and the site was then redeveloped into soccer fields, running paths, and other recreational uses. Before and after images of the remediated site are shown on the opening page of this article.

Summary
Cement S/S has proven to be a very effective soil remediation option for both metals and organic contamination. EPA has approved and used both in-situ and ex-situ cement S/S at numerous sites since at least 1982, when this author became actively involved with the technology. This technology dramatically reduces the leachability of contaminants of concern and is typically the lowest cost option.

Paul Ruehl is with LafargeHolcim in Detroit, MI. E-mail: Paul.Ruehl@LafargeHolcim.com.