ELSEVIER Journal of Hazardous Materials 52 (1997) xi–xiii

JOURNAL OF HAZARDOUS MATERIALS

# Preface

Solidification/stabilization (S/S) continues to be a widely practiced technology for the treatment of liquids, sludges, ashes and contaminated soils. In this special issue we have attempted to bring together a broad variety of articles illustrating the current state of our knowledge about the technology. Various parts of the community involved in S/S research are well represented in the issue: we have articles from academia, industry and government laboratories. The work reported here also shows the importance of bringing to bear the perspectives of different technical backgrounds when dealing with complex problems such as those which an evaluation of S/S represent.

Ideally, chemical modeling of a waste form can allow us to predict its long-term behavior in different chemical environments. Such an endeavor will require identification of the relevant chemical species in the system, their activity, Eh, pH, etc. The thermodynamic parameters that are necessary for modeling are scarce. Fortunately, such a thermodynamic database is gradually being built (Glasser, this issue).

Cementitious wasteforms have very complex chemistry. Glasser's review of background information is an excellent introduction to this subject. A consequence of the complexity is that any single analytical technique is inadequate to characterize the system chemically. Many of the techniques now used on wasteforms have been used before to characterize portland cement hydration; for instance, powder X-ray diffractometry to identify chemical species of the waste and the binder matrix. However, since the major hydration product of portland cement, calcium silicate hydrate, is practically amorphous, X-ray diffractometry is not sufficient to understand the effect of the wastes on the cement matrix. Magic angle spinning nuclear resonance spectroscopy is a tool which can be used to study the polymerization of silicates and it has been used extensively to study the effect of wastes on cement (e.g. Akhter et al., this issue). Thermal analysis has been used on portland cement to quantify the amounts of hydrated and carbonated phases, and since many of the precipitated waste phases in wasteforms are hydroxides, the technique can identify and quantify these phases. Decrease in conductivity can be correlated with the precipitation and subsequent removal of phases from the pore solution. Olson et al. have used conductivity measurements to see changes in wasteforms with simulated radioactive materials. Rinehart et al. have used a comparatively new technique, X-ray absorption near-edge structure (XANES), for the measurement of hexavalent chromium in a soil and its solidified/stabilized product. By this method, the hexavalent form can be directly analyzed without any laborious and time-intensive chemical extraction procedure. Such an extraction procedure will cer-

0304-3894/97/$17.00 Published by Elsevier Science B.V.
*PII* S0304-3894(96)01804-3

tainly destroy the phase containing the chromium. XANES can be used to analyze solids, liquids and gases with practically no sample preparation and can identify different oxidation states of many elements of environmental interest, such as sulfur, iron, selenium, lead, etc. X-ray absorption spectroscopy is very promising in the environmental field as it can be used to detect very low levels of a contaminant and also the chemical environment of such contaminants.

The work reported in this volume covers a range of specific waste materials. Arsenic and chromium are wastes that are often difficult to stabilize by portland cement alone, and there are contributions here dealing with both systems: Akhter et al. and Rinehart et al., respectively. Roy and Cartledge treat the effects of copper wastes on cementitous wasteforms. Olson et al. report on the suitability of a portland cement-Class F fly ash–attapulgite binder as the matrix for solidifying/stabilizing a simulated radioactive waste. The article by Malone et al. deals with a problem that can occur when radioactive wastes are treated with portland cement. Temperature cycling can lead to crystallization of certain salts with high expansion which can produce complete failure of the wasteform.

The research community may not have been successful in communicating research results to the practitioners using the technology. Hill and Pollard, through an extensive review of work done in their laboratory and elsewhere, show that there are many processes which interfere with S/S of wastes. For example, many wastes themselves, as well as atmospheric carbon dioxide, may alter the S/S process, sometimes with detrimental results. Nevertheless, vendors often use the same recipe for commercial work at sites containing dissimilar wastes. One of the regulatory tests for successful S/S is that a certain minimum unconfined strength is achieved (50 psi for US EPA). This strength can be easily achieved by adding the necessary amount of cement. The added cement may not, however, immobilize the contaminants better.

The consensus in the cement/concrete research community is that carbonation of structural concrete should be avoided. Lange et al. find that carbonation is not necessarily harmful for wasteforms, since for certain cement types it can enhance strength and reduce leaching. Incorporation of the toxic ions in the carbonate phase is probably responsible for the reduced leaching. Changes due to carbonation can be slow in occurring, and several other contributions in this volume deal with long-term effects. Regulatory tests for wasteforms are usually conducted after short curing times. As pointed out by Glasser and also found in the articles by Akhter et al. and Roy and Cartledge, some of the changes in the cementitious matrix can take months, and even years. The concentration dependence of waste effects is also emphasized in the contribution from Roy and Cartledge.

Most leaching models for wasteforms consider bulk diffusion of the waste under the gradient created by waste and the leachant as the principal mechanism of leaching. Real world leaching, however, does not follow such a pattern. Leaching usually starts from the exterior exposed surface and moves inward. The zone not exposed to acid attack maintains its integrity and chemistry, whereas the region exposed to the acid becomes more porous, more silicic and loses all its calcium hydroxide. These two regions are separated by a very narrow zone several tens of micrometers thick. Baker and Bishop have used the shrinking unreacted core (SUC) model to mimic this process. They applied the SUC model to commercial wasteforms and found good correspondence between prediction and leaching results. In a second contribution dealing mainly with leaching phenomena, Barna et al. consider experimental data on leaching of sodium and lead, two species with very different chemical behaviors. They develop a new model combining solubilization of species present in the solid phase of the porous matrix saturated with water and diffusional transport.

Research on S/S has progressed beyond the laboratory. With our present level of understanding of the process, we can devise formulations which should work quite well in the laboratory. Scaling up that process for field application is, however, a different matter. Stegemann et al. report testing of the performance of an electric arc furnace dust stabilized with an activated blastfurnace slag system in the field. By comparing field and laboratory samples, they show that field performance of the wasteform was quite satisfactory, though slightly different and variable from the laboratory samples. The differences observed can be explained from our understanding of the chemistry of the system.

This volume illustrates very well that researchers are beginning to bring together a very wide variety of techniques to produce a fundamental understanding of S/S. The work is far from complete, however. We require, for instance, more collaboration between researchers conducting leaching studies and phase characterization studies to develop an integrated model of the leaching process. The work reported here also deals with a number of specific problems, like long-term matrix changes, that have often been suggested to be important, but are seldom investigated in practice. Clearly, S/S can work. But it can only work consistently and effectively if we generate (and also thereafter consult) a fundamental understanding of the process as well as an extensive database of practical applications.

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