Proceedings of the 17th Biennial Waste Processing Conference
ASME 1996

THE WES-PHix® ASH STABILIZATION PROCESS

Mark R. Lyons
Wheelabrator Environmental Systems Inc.
Hampton, New Hampshire

ABSTRACT

This paper discusses a patented process developed by Wheelabrator Environmental Systems Inc. for chemically stabilizing ash from municipal solid waste combustion facilities. This technology, marketed commercially as the WES-PHix® Process, reduces the solubility of certain heavy metals in ash through the addition of soluble phosphate, lime and water. The addition of these reagents to ash promotes the formation of geochemically stable metal phosphate compounds which are resistant to leaching. The WES-PHix® Process produces stabilized ash which consistently passes the U.S. Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure and other regulatory leaching tests.

The chemical reactions caused by the application of soluble phosphate and lime to ash are discussed. The solubility of metal phosphate compounds is examined, and stabilized ash leaching test data are presented.

The advantages and performance record of the WES-PHix® Process, including cost, are also presented.

INTRODUCTION

The combustion of municipal waste in modern trash-to-energy facilities is one component of an integrated and environmentally sound approach to solid waste management. The combustion of municipal waste produces ash residue which can be safely managed in a variety of ways. In the United States, most municipal waste combustion (MWC) ash is disposed in lined sanitary landfills or ash monofills. Some ash is also beneficially used as a sanitary landfill cover material or as an aggregate in road construction.

The stabilization of ash from a specific MWC facility is often necessary to comply with regulatory leaching test requirements or to minimize metals solubility in a beneficial ash use application.

The chemical stabilization of MWC ash through the addition of soluble phosphate and lime is a highly effective method for decreasing the solubility of certain trace heavy metals. This stabilization technology, marketed commercially as the WES-PHix® Process, has been successfully used by Wheelabrator Environmental Systems since 1987. WES-PHix® is now the most widely used proprietary ash stabilization process in the world.

DISCUSSION OF WES-PHix® PROCESS CHEMISTRY

Dissolution and Precipitation Reactions

The heavy metals in untreated MWC ash which are available for leaching are present as soluble solid phases located on the surfaces of the ash particles, and as metal cations or aqueous complexes dissolved in the interstitial pore water. Research on combined MWC ash (bottom ash, fly ash and scrubber residue) indicates that for lead, less than 30% of the element is available for leaching. The majority of the trace metals in ash are present as insoluble lattice-substituted compounds, or are bound in a glassy matrix (Eighmy, 1994).

Lead, cadmium and certain other metals in ash are immobilized by the WES-PHix® Process through dissolution and precipitation reactions. Water is mixed with the ash to dissolve the soluble solid phase metals. The phosphate and lime, when added to the ash/water mixture, react with the metals in solution to form metal phosphate and metal carbonate compounds which precipitate out of solution (Eighmy et al., 1990). Some metal hydroxide compounds may also form, but they are not believed to be the solid phases which control lead and cadmium solubility in WES-PHix® treated MWC ash.

Solid Phases Controlling Metals Solubility

Substantial research has been conducted to determine the solid phases controlling lead and cadmium solubility in WES-PHix® treated MWC ash. Theoretical analyses have been performed using p{Pb^{2+}}-pH solubility diagrams, Eh-pH stability fields, and p{PO_4^{3-}}-pH predominance diagrams. The techniques of x-ray powder diffraction analysis and geochemical modeling of ash leachates have also been used to study WES-PHix® treated ash. The research conducted to date suggests that chloropyromorphite [$Pb_5(PO_4)_3Cl$] and lead hydroxypyromorphite [$Pb_5(PO_4)_3OH$] the predominant lead phosphate minerals formed by the WES-PHix®

Process (Eighmy, 1995). Other lead phosphate minerals likely formed by the addition of soluble phosphate and lime to ash include hinsdalite [$PbAl_3(PO_4)(OH)_6SO_4$].

One of the solid phases controlling cadmium solubility in WES-PHix® treated ash appears to be cadmium carbonate ($CdCO_3$) (Eighmy et al., 1990). Research by Wheelabrator also suggests that phosphate minerals such as cadmium hydroxypyromorphite [$Cd_5(PO_4)_3OH$] play a role in reducing cadmium solubility. Although WES-PHix® has been shown to reduce the leachability of copper and zinc in MWC ash, the solid phases controlling the solubility of these two metals have not been identified. Additional research will be conducted in 1996 by the University of New Hampshire (UNH) to conclusively identify the insoluble metal phosphate phases formed in MWC ash by the WES-PHix® Process.

Metal Phosphate Mineral Characteristics

The metal phosphate minerals likely formed in MWC ash by the WES-PHix® Process are included in Table 1 (Eighmy, 1995). These minerals are found in nature, and some are mined as ores. Phosphate minerals are geochemically stable and highly insoluble over a wide pH, pE and temperature range (Eighmy, 1995). Table 1 also lists the log of the solubility product for each phosphate mineral. A very small value (e.g. log = -84.4 or $10^{-84.4}$)means the corresponding mineral is highly insoluble. An inspection of the solubility products for the listed phosphate minerals indicates that these compounds are very insoluble. The stability and low solubility of phosphate minerals make them extremely effective at immobilizing lead and cadmium in ash.

STABILIZED ASH LEACHING BEHAVIOR

The formation of phosphate minerals and other compounds in ash by the WES-PHix® Process significantly reduces the leachability of lead and cadmium under both ash monofill and laboratory leaching test conditions.

Monofill Leaching

The leachates from two ash monofills in New Hampshire containing only WES-PHix® stabilized combined ash are analyzed on a monthly basis for the presence of lead and cadmium. The ash monofill in Newport, NH receives WES-PHix® treated ash from the Wheelabrator Claremont MWC facility, and the monofill in Franklin, NH receives treated ash from the Wheelabrator Concord MWC facility. The Newport monofill has been receiving treated ash since 1988, and the Franklin monofill has been receiving treated ash since 1989.

A review of the monthly leachate analytical results for both monofills reveals that the lead and cadmium concentrations in the leachates are often below laboratory detection limits. Lead and cadmium have been detected in the leachate from the Newport monofill more frequently than in the leachate from the Franklin monofill. However, all the laboratory analytical results for the New-port leachate confirm that lead and cadmium are leaching from the treated ash at very low levels. Table 2 presents the leach-ate analytical data for the Franklin monofill through November 1995.

The University of New Hampshire is conducting ongoing research on the long term leaching behavior of untreated ash and WES-PHix® treated ash. Two lysimeters have been established outdoors on the UNH campus in Durham, New Hampshire. One lysimeter contains untreated combined ash with scrubber residue (CASR) from the Wheelabrator Claremont facility, and the other lysimeter contains WES-PHix® treated CASR from the same facility. The ash was placed in both lysimeters in September 1988. Both lysimeters have been exposed to precipitation/infiltration, repeated freeze/thaw cycles, and wetting/drying phenomena for over seven years. Leachate has been collected from the lysimeters and analyzed every 1-3 months, depending on the level of infiltration, since 1988. The leachate analytical results indicate that WES-PHix® treatment reduces lead leaching from combined ash by approximately one order of magnitude. In fact, lead is typically below laboratory detection limits in the treated ash leachate. Cadmium concentrations are also below laboratory detection limits in the ash leachates.

This UNH research project confirms that the WES-PHix® Process is effective at controlling the long term leaching of lead and cadmium from combined ash.

Laboratory Leaching Test Data

Thousands of laboratory leaching tests have been performed on WES-PHix® treated ash since 1986. Ash treated with WES-PHix® Process consistently leaches very low concentrations of metals as measured by the Extraction Procedure (E.P.) Toxicity Test, the Toxicity Characteristic Leaching Procedure (TCLP), and the California Waste Extraction Test (WET).

These three leaching tests have historically been used by regulatory agencies in the United States to predict the potential for metals to leach from landfilled MWC ash and contaminate ground-water. Despite a large body of scientific evidence that these three leaching tests grossly exaggerate the actual leaching behavior of MWC ash in a landfill, EPA is now requiring every MWC facility owner or operator to use the TCLP test to determine if ash from their facility exhibits hazardous characteristics. Unstabilized combined ash from a MWC facility, when subjected to the TCLP test, may leach lead and cadmium in concentrations which exceed regulatory limits. The treatment of combined MWC ash with the WES-PHix® Process will ensure that TCLP results will consistently be below regulatory limits for lead and cadmium.

Figure 1 describes the behavior of untreated CASR when the material is subjected to the TCLP test. As shown by the graph, CASR can leach lead in excess of the regulatory limit of 5 milligrams per liter (mg/l) if the pH during the TCLP test is less than about 6 or greater than about 10. CASR can also leach cadmium in excess of the regulatory limit of 1 mg/l if the pH during the TCLP test is less than about 8. Experience has shown that the pH will be below 8 or above 10 when untreated CASR from some MWC facilities is subjected to the TCLP test.

Recent TCLP data for WES-PHix® treated ash are presented in Table 3. TCLP data for untreated ash from three large mass-burn MWC facilities are compared to data for WES-PHix® treated ash from the same facilities. The ash from Facility A and B is combined ash with scrubber residue. The ash from Facility C is fly ash only, with no scrubber residue.

A review of the data indicates that the TCLP results for the untreated ash samples from all three facilities exceeded the regulatory limits for lead and/or cadmium. The samples of WES-PHix® treated ash from all three facilities produced TCLP results which were well below the regulatory limits for lead and cadmium.

It is important to note that the treated ash samples were immobilized by full scale WES-PHix® systems located at the three MWC facilities. Therefore, the TCLP results for the treated ash samples confirm the real world effectiveness of the WES-PHix® Process, and are not simply experimental results produced under ideal laboratory or pilot test conditions.

TABLE I METAL PHOSPHATE MINERALS AND THEIR SOLUBILITY PRODUCTS		
Element	Mineral	log K_{sp}[a]
Lead		
$Pb(H_2PO_4)_2$	primary lead orthophosphate	-9.84
$PbHPO_4$	secondary lead orthophosphate	-11.40 to -11.43
$Pb_3(PO_4)_2$	tertiary lead phosphate	-44.30 to -44.60
$Pb_4O(PO_4)_2$	tetraplumbite phosphate	-65.17
$Pb_5(PO_4)_3OH$	lead hydroxypyromorphite	-76.80
$Pb_5(PO_4)_3Cl$	lead chloropyromorphite	-84.40
$PbAl_3PO_4(OH)_6SO_4$	hinsdalite	-99.10
$PbAL_3(PO_4)_2(OH)_5 \cdot H_2O$	plumbogummite	-99.30
$PbFe_3PO_4(OH)_6SO_4$	corkite	-112.60
Cadmium		
$Cd_3(PO_4)_2$	tertiary cadmium phosphate	-32.6 to -38.1
$Cd_5(PO_4)_3OH$	cadmium hydroxypyromorphite	?
Copper		
$Cu_3(PO_4)_2$	tertiary copper phosphate	-36.85
$Cu_3PO_4(OH)_3$	cornetite	-48.00
$Cu_5(PO_4)_3OH$	copper hydroxypyromorphite	-65.00
$Cu_5(PO_4)_2(OH)_4 \cdot H_2O$	psuedomalachite	-75.80
Zinc		
$Zn_3(PO_4)_2$	tertiary zinc phosphate	-32.04
$Zn_4(PO_4)_2(OH)_2 3H_2O$	spencerite	-52.80
$Zn_5(PO_4)_3OH$	zinc hydroxypyromorphite	-63.10
$ZnFe_4(PO_4)_3(OH)_5$	zinc rockbridgeite	-138.60
Calcium		
$Ca_3(PO_4)_2$	β -whitlockite	-31.08
$Ca_5(PO_4)_3OH$	hydroxyapatite	-44.20
$Ca_5(PO_4)_3Cl$	chloroapatite	?

[a]Nriagu and Moore, 1984

TABLE 2
LEAD AND CADMIUM CONCENTRATIONS IN LEACHATE (MG/L)
FRANKLIN, NH ASH MONOFILL

Sample	Metal	
Date	**Lead**	**Cadmium**
5/89	BDL	BDL
7/89	0.058	0.018
10/89	BDL	BDL
1/90	BDL	BDL
4/90	BDL	BDL
7/90	BDL	BDL
8/90	BDL	BDL
10/90	BDL	BDL
1/91	BDL	BDL
3/91	BDL	BDL
6/91	BDL	BDL
9/91	BDL	BDL
12/91	0.60	0.16
1/92	BDL	BDL
2/92	BDL	BDL
5/92	BDL	BDL
8/92	BDL	BDL
10/92	0.13	BDL
2/93	BDL	BDL
5/93	BDL	BDL
8/93	BDL	BDL
11/93	BDL	BDL
2/94	BDL	BDL
6/94	BDL	BDL
7/94	BDL	0.008
11/94	BDL	BDL
2/95	BDL	BDL
5/95	BDL	0.008
8/95	BDL	BDL
11/95	BDL	BDL

BDL = Below Detection Limit
Cadmium Detection Limit = <0.005 mg/l
Lead Detection Limit = <0.05 mg/l

Figure 1
TCLP Behavior of Unimmobilized CASR

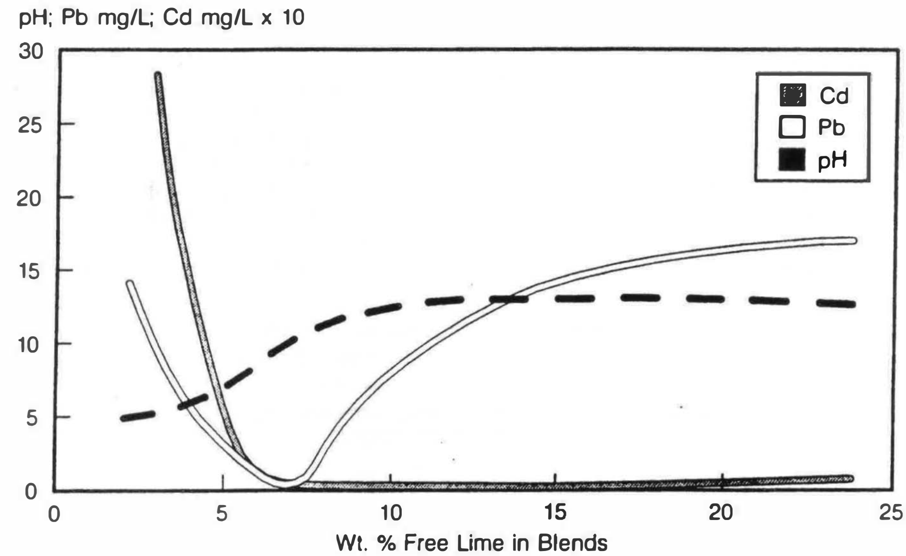


Figure 2 depicts the TCLP behavior of CASR after treatment with the WES-PHix® Process. The solubility of lead and cadmium in WES-PHix® treated CASR is significantly reduced as measured by the TCLP test. The graph shows that lead and cadmium are insoluble across an extremely wide pH range. The curves for lead and cadmium indicate that the use of WES-PHix® will prevent dramatic fluctuations in TCLP test data for combined ash with scrubber residue.

Figure 2
TCLP Behavior of Immobilized CASR

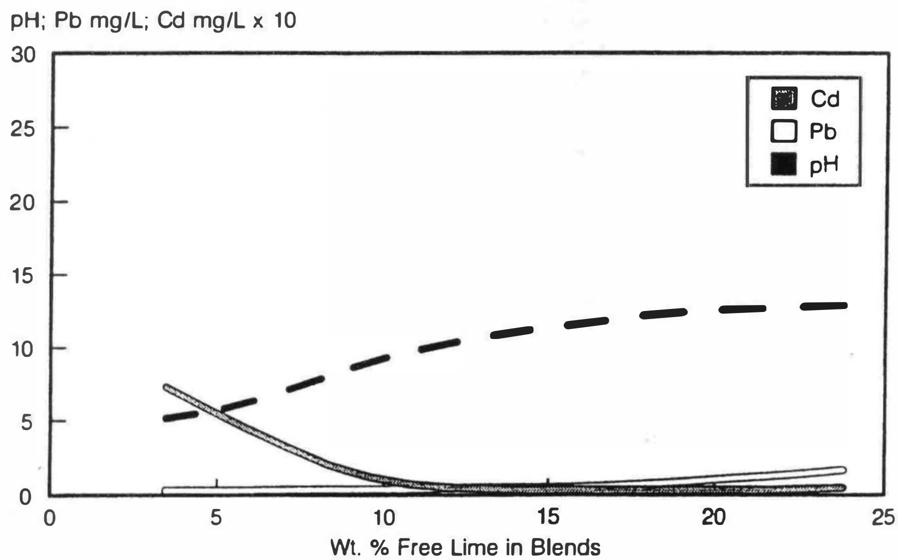


Table 3
Untreated vs. WES-PHix® Treated Ash
TCLP Results (mg/l)

		Facility A		Facility B		Facility C	
	Reg. Limit	Untreated[1]	Treated[2]	Untreated[3]	Treated[2]	Untreated[1]	Treated[2]
Lead	5.0	2.3	<0.5	5.4	2.2	46	0.41
Cadmium	1.0	1.3	0.078	0.4	0.13	18	0.48

Notes:
1. These data are from a WES-PHix® treatability study performed on composite samples.
2. These data are the averages of TCLP results for 14 eight hour composite samples collected over 7 consecutive days.
3. These data are the averages of monthly TCLP results from a 3 year period.
4. All data for Facility C are TCLP results for fly ash only with no scrubber residue.

WES-PHix® PROCESS OPERATING HISTORY

The WES-PHix® Process was invented by M. O'Hara and M. R. Surgi under a Wheelabrator research contract in 1986. The Process was patented by Wheelabrator in 1988. WES-PHix® was first used on a full scale, commercial basis in 1987 at Wheelabrator's 200 ton per day MWC facility in Claremont, New Hampshire. The Process has been used successfully at the Claremont facility for seven years and at the 500 ton per day Wheelabrator Concord facility for five years. The treated combined ash from these facilities is tested monthly and has never exhibited the characteristic of toxicity as defined by the EPA.

Two other MWC facilities also have long-term WES-PHix® system operating histories. The 575 ton per day Wheelabrator facility in Gloucester County, New Jersey has been using WES-PHix® to treat combined ash since January 1990, and the 2500 ton per day American Ref-Fuel facility in Essex County, New Jersey has been using the Process to treat combined ash since 1991. The combined ash streams from these two facilities have never exhibited hazardous characteristics under the monthly TCLP testing regimen required by the state of New Jersey.

At this writing, 23 MWC facilities are using the WES-PHix® Process to stabilize either combined ash or fly ash alone. The WES-PHix® treated ash streams from these facilities are routinely characterized according to either the current U.S. EPA guidance for TCLP testing or more stringent state testing requirements. None of the stabilized ash streams have ever exhibited toxicity.

Also, over 40 MWC facilities in Japan are now using WES-PHix® to stabilize fly ash only. Approximately 10,000 tons per day of MWC ash are now being treated by the WES-PHix® Process in the United States and Japan. Wheelabrator estimates that approximately 5 million tons of MWC ash have been successfully stabilized by WES-PHix® since 1987, which is a performance record unmatched by any other proprietary ash treatment process currently used in the United States.

DISCUSSION OF OTHER ASH TREATMENT METHODS

Lime Stabilization

One commonly practiced form of MWC ash treatment in the United States is the addition of lime to ash. Many MWC facilities are already using lime for acid gas scrubbing, but the free lime in scrubber residues is often insufficient to immobilize lead and cadmium in ash. Therefore, some MWC facilities add additional lime to their scrubber systems to increase the free or unspent lime in the ash. The objective of this approach is to influence the pH when a TCLP test is performed on the lime stabilized ash. As previously shown in Figure 1, combined ash with scrubber residue will usually leach lead and cadmium below regulatory limits if the pH during the TCLP test is maintained between about 8 and 10. The graph in Figure 1 also shows that between 5 percent and 8 percent free lime by weight is needed in the combined ash to maintain the pH during the TCLP test within this narrow range. Unfortunately, it can be difficult to control the amount of free lime in combined ash through the operation of an acid gas scrubber. The routine operation of a scrubber to meet acid gas emission limits may result in more than eight percent free lime in the combined ash. Therefore, a MWC facility operator attempting to stabilize ash with an acid gas scrubber cannot be certain of acceptable TCLP results. If too little or too much free lime is present in the ash, lead and/or cadmium will leach in excess of the TCLP limits.

In summary, the use of lime to stabilize ash does not reduce the leachability of both lead and cadmium across a wide pH range. In fact, the addition of lime to combined ash (or fly ash) with scrubber residue may actually increase lead leaching. Lime stabilization is not a reliable method of immobilizing both lead and cadmium in MWC ash.

Solidification with Portland Cement

Another ash stabilization method practiced in the United States by at least one MWC facility is physical solidification of combined ash with portland cement. Cement and water are mixed with ash and allowed to cure into a monolith. Portland cement solidification usually requires a curing period of 3 to 28 days to achieve acceptable TCLP results for lead and cadmium.

The leaching of lead and cadmium can be reduced by solidification with cement through several mechanisms. The monolith, at least initially, will have a low permeability and a small surface area to volume ratio compared to the unsolidified ash. The low permeability will restrict the flow of a leaching fluid through the monolith and the small surface area to volume ratio will reduce the number of sites where the leaching fluid can dissolve metals present on the ash particle surfaces.

The addition of water to an ash/portland cement mixture will also hydrate the calcium silicates present in the cement. As hydration occurs, calcium and hydroxide ions will go into solution and react with metal cations in the ash, such as cadmium, forming new compounds that are sparingly soluble under alkaline conditions (Chesner, 1994).

Solidification of ash with portland cement nevertheless has some significant disadvantages. A 1993 U.S. EPA study of several different ash stabilization/solidification technologies showed that cement stabilization was 7 to 30 times less effective than WES-PHix® at controlling the leaching of lead from combined MWC ash. Cement stabilization of combined ash is expensive, with costs reportedly ranging from about $25 to $50 per ash ton (Chesner, 1994). The monoliths formed by solidification of ash with cement require a curing period and are expensive to transport and landfill. In the landfill, the monoliths may crumble over time, and newly exposed ash particle surfaces may leach some unimmobilized metal species.

Most importantly, samples of the monolith must be crushed prior to performing a TCLP test on the cement stabilized ash. The crushing process may expose unimmobilized lead compounds on ash surfaces, and, combined with the high pH environment caused by the cement, may allow lead to leach above the TCLP limit.

Sulfide Stabilization

The chemical stabilization of MWC ash with sulfide reagents has been researched by Wheelabrator and others and found to be less effective than the WES-PHix® Process. For example, research on the use of calcium sulfide and sodium sulfide as immobilizing agents was funded by Wheelabrator in the mid-1980's. The research showed that sodium sulfide by itself was not effective at reducing the solubility of lead and cadmium in fly ash. However, calcium sulfide was an effective immobilizing agent for lead and cadmium as measured by the E.P. Toxicity Test. A combination of sodium sulfide and calcium oxide was also tested and found to be about one-half as effective as calcium sulfide alone (O'Hara et al., 1986).

Fly ash treated with sodium sulfide and calcium oxide was also placed in columns and leached with a synthetic acid rain (pH of 3.93). The leaching results for the sulfide treated ash were compared to identical column leaching studies performed on WES-PHix® treated fly ash. The concentrations of lead in the aliquots collected from the sulfide treated fly ash columns were about 5 to 7 times higher than the concentrations in the aliquots collected from the WES-PHix® treated ash columns. Treatment of the fly ash with sulfide maintained the pH of the aliquots above 12.5. Therefore, the ability of the sulfide to precipitate lead as lead sulfide (PbS) could not overcome the amphoteric behavior of lead hydroxide [$Pb(OH)_4^{-2}$] at these high pH values (Surgi, 1986).

During this research, the formation of potentially toxic hydrogen sulfide (H_2S) gas was also observed. The sulfide reagents apparently absorbed water during the experiments, liberating H_2S.

Work by others has further indicated that metal sulfide precipitates do not exhibit long term stability in oxidizing environments (IAWG, 1994).

A patent for the treatment of MWC ash with calcium sulfide and/or sodium sulfide was allowed as a result of this research (O'Hara et al., 1986). Nonetheless, Wheelabrator does not use sulfides to stabilize ash because of their relatively high cost, their questionable effectiveness at immobilizing lead, the potential for H_2S gas formation, and the instability of metal sulfides under oxidizing conditions.

Vitrification

Vitrification is a process for melting MWC ash and then cooling the material to form a vitreous or glassy product. Metals in the ash are apparently bound in the glassy matrix and are unavailable for leaching. Because the melting point of MWC ash is around 2600°F, a tremendous amount of energy is required to vitrify ash. Ash vitrification is estimated to cost upwards of $100 per ash ton, and the management of contaminated off-gases from the process is also a potential problem (Chesner, 1994). The recycling of the vitrified ash may generate a revenue source which could offset the processing costs of vitrification. Nonetheless, the high cost of vitrification remains a major obstacle to the widespread use of this technology to stabilize ash.

WES-PHix® PROCESS ADVANTAGES

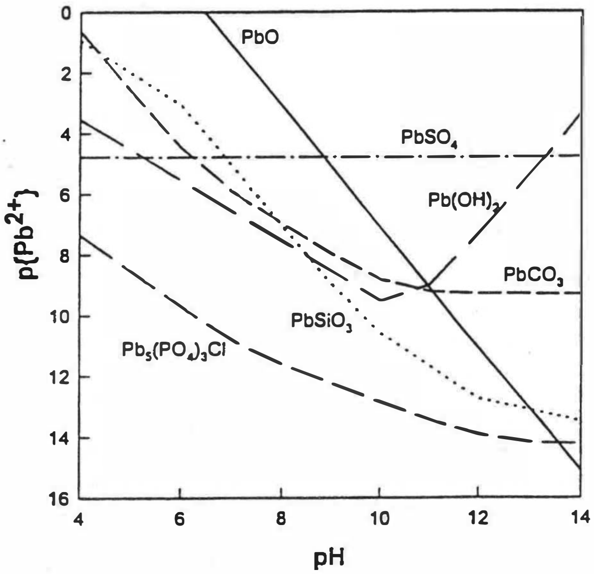
The WES-PHix® Process has many important advantages over the other ash stabilization/ solidification technologies discussed. These advantages are presented below in some detail.

Effectiveness

The stabilization of MWC ash with soluble phosphate and lime forms highly stable and insoluble metal phosphate minerals. These phosphate compounds are much less soluble than the metal compounds formed by other treatment methods. As stated previously, the predominant lead phosphate mineral formed by the WES-PHix® Process in MWC ash is believed to be chloropyromorphite [$Pb_5(PO_4)_3Cl$]. The stabilization of ash with lime alone or portland cement will form, under certain conditions, lead hydroxide [$Pb(OH)_2$], lead carbonate ($PbCO_3$) and lead silicate ($PbSiO_3$). Figure 3 are solubility diagrams which describe the activity (or solubility in an ideal solution) of some lead compounds at different pH values (Eighmy, 1995). The diagrams are plots of the negative log of lead activity versus pH. Although the solubility diagrams present a simplified picture of actual combined ash leaching behavior, they do illustrate general solubility trends for lead in ash.

Figure 3 shows that chloropyromorphite is one of the most insoluble lead minerals that can form in ash. Lead hydroxide, lead carbonate, and lead silicate are several orders of magnitude more soluble than chloropyromorphite. The solubility diagram indicates that treatment of MWC ash with soluble phosphate is a much more effective method of stabilization than lime or portland cement.

Figure 3
Solubility Diagrams for Simple Mineral Phases Containing Lead



Cost

Experience has shown that the capital and operating costs of the WES-PHix® Process are lower than other commercially proven ash treatment methods. The capital cost of a full-scale WES-PHix® ash treatment system at a MWC facility will typically range from $250,000 to $750,000. WES-PHix® capital costs will vary from plant to plant depending on existing facility ash handling/conditioning equipment, the equipment redundancy requirements of the MWC operator, and other factors. WES-PHix® system operating costs will also vary from facility to facility. Factors affecting operating costs include bottom ash to fly ash ratio, ash chemistry, including the amount of free lime present in the scrubber residue, and ash quantities. WES-PHix® system operating expenses for MWC facilities are usually between $4 and $7 per combined ash ton, with an average cost of about $5 per ton. This cost includes royalties, reagents, and electricity. WES-PHix® systems are typically designed to be fully automated, so a full time operator is not required. Existing facility personnel can be easily trained to operate, monitor, and maintain a WES-PHix® system.

WES-PHix® ash treatment costs compare favorably with those of lime based stabilization systems. However, as shown previously, lime based ash treatment systems are not always effective. WES-PHix® treatment costs are considerably lower than those of portland cement solidification systems.

Physical Characteristics of Treated Ash

One of the major advantages of the WES-PHix® Process over portland cement solidification is that phosphate treated ash remains free flowing. The retention of the free flowing particulate nature of ash after WES-PHix® treatment provides for ease of handling, transportation, disposal, or beneficial use of the material. Solidification of ash with portland cement not only presents handling difficulties, but also limits beneficial use options.

Treatment of MWC ash with the WES-PHix® Process also provides superior dust control for fly ash. Most MWC facilities add water to fly ash for dust control, and phosphates are well known surfactants which enhance the dust suppression properties of water. WES-PHix® treatment only slightly increases the weight of MWC ash. This advantage is important for MWC facilities that pay tip fees for ash disposal.

Process Reaction Time

The kinetics of the WES-PHix® Process chemical reactions are quite rapid. This rapid reaction time means that ash samples can be collected for TCLP analysis immediately after WES-PHix® treatment. The conversion of soluble metal compounds in ash to insoluble phases will occur well before the TCLP test can be completed. The WES-PHix® chemical reaction kinetics compare very favorably with the 3 to 28 day curing time required for portland cement solidification. The short WES-PHix® chemical reaction time means that treated ash does not need to be stored for days at the MWC facility before it is transported off-site for disposal or recycling.

Ash Recycling Opportunities

The stabilization of MWC ash with the WES-PHix® Process to eliminate metal leaching concerns can facilitate the beneficial use of combined ash or bottom ash in construction projects. WES-PHix® treated combined ash is being used as daily cover and road construction material at landfills in Florida and California. Two other states have approved the use of WES-PHix® treated MWC ash in road construction applications. One facility in Nashville, Tennessee is manufacturing a construction aggregate from combined MWC ash and treating the material with the WES-PHix® Process. The manufactured aggregate is then sold to local contractors for use in road construction projects.

WES-PHix® Performance Record

The WES-PHix® Process is now used at 23 MWC facilities in the United States to immobilize trace metals in ash. WES-PHix® is now also used at over 40 MWC facilities in Japan to stabilize fly ash alone. The technology is treating over 10,000 tons of MWC ash per day, and over 5 million tons of ash have been successfully stabilized since 1987. Four MWC facilities have been operating WES-PHix® systems for at least 6 years. Most importantly, no WES-PHix® treated ash stream has ever exhibited the characteristic of toxicity as defined by the U.S. EPA. Wheelabrator believes the performance record of WES-PHix® is unequaled by any other ash stabilization technology used in the United States.

CONCLUSION

The WES-PHix® Process is an effective, commercially proven, and inexpensive ash stabilization technology. The Process is patented in the United States, Canada, Japan and Europe.

WES-PHix® is more effective and reliable than stabilization of ash using lime, sodium/calcium sulfide, or portland cement. For example, test data shows that lime stabilized ash will produce highly variable TCLP results over time at the same MWC facility. U.S. EPA data further shows that WES-PHix® stabilization is far more effective at controlling the leaching of lead from MWC than solidification/stabilization with portland cement. Finally, while vitrification of MWC can be effective at reducing the solubility of metals in ash, the technology is currently cost-prohibitive.

Wheelabrator is presently licensing the WES-PHix® Process to MWC facility owners and operators worldwide. The successful operating history of WES-PHix® will provide MWC facility owners/operators with a high degree of confidence that their ash will satisfy TCLP or other regulatory leaching test requirements. The WES-PHix® Process may also provide beneficial use alternatives to monofill or co-disposal methods of ash management.

REFERENCES

Chesner, W. H., (1994) "Treating Ash to Reduce Metal Leaching", p. 36-43. Solid Waste Technologies, Vol. VIII, No. 6.

Eighmy, T. T.; Bobowski, S.F.; Ballestero, T.P.; Collins, M.R. (1990) "Theoretical and Applied Methods of Lead and Cadmium Stabilization in Combined Ash and Scrubber Residues", p. 275-314. Proceedings of the Second International Conference on Municipal Solid Waste Combustor Ash Utilization, UNH Press, Durham, NH.

Eighmy, T. T. (1994) personal communication.

Eighmy, T. T. (1995)" The Use of Soluble Phosphate for Lead Stabilization in Incineration Residues", submitted for publication to the Japanese Journal of Waste Research.

International Ash Working Group (IAWG)(1994) "An International Perspective on the Characterization and Management of Residues from Municipal Solid Waste Incineration - Summary Report", Netherlands Energy Research Foundation, Petten, The Netherlands.

Kosson, D.S.; Kosson, T.T.; Van de Sloot, H. (1993) "Evaluation of Solidification/Stabilization Treatment Processes for Municipal Waste Combustion Residues", Risk Reducgion Engineering Laboratory, U.S. Environmental Protection Agency.

Lyons, M. R. (1995) "The WES-PHix® Ash Immobilization Process", p. 156-168. Proceedings of the 7th International Conference on Municipal Solid Waste Combustor Ash Utilization published by Resource Recovery Report.

O'Hara, M. J., Urban, P. (1986) "Immobilization of Lead and Cadmium in Fly Ash", U.S. Patent 4,629,509.

O'Hara, M. J., Surgi, M. R.; (1988) "Immobilization of Lead and Cadmium in Solid Residues from the Combustion of Refuse Using Lime and Phosphate", U.S. Patent 4,737,356.

Surgi, M. R.; Withrow, K. L. (1986) "Results of Preliminary Column Leaching Experiments Using Westchester Fly Ash", unpublished report.