

Bunker Hill Sediment Characterization Study

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December 2009



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EXECUTIVE SUMMARY

The INL was contacted by the Coeur d'Alene Basin Commission in the summer of 2008 and asked to conduct a series of extraction procedures and leach tests on soil from the area of the Central Impoundment Area (CIA) and in the Osborn Flats area. Exposed minerals from historic mining activities have contributed to contamination in the South Fork Coeur d'Alene River and its tributaries. Due to the challenge of cleanup, a preliminary study of metal availability and release from sediments from the area was performed to help understand the factors that affect metal mobility. Three groups of experiments were conducted:

- Sequential extraction tests to determine the operational speciation of the metals in the sediment
- Leaching tests to determine the effect of pH on metal leached and,
- Leaching tests to provide insight into the effect of aerobic and anoxic conditions on the metal leached.

Core samples were collected in August 2008 from four locations, three from just outside of the CIA and one from the Osborn Flats area. Core samples were collected from various depths down to 9 feet. The samples were stored in liquid nitrogen until the extraction tests were conducted. The core samples from each depth underwent a modified sequential extraction procedure which separated the metals into 4 fractions: extractable, carbonate bound or acid soluble, organic/oxide/sulfide-bound, and residual.

Metal-bearing minerals were mined from subsurface sulfide deposits, with the principal ore minerals being galena (PbS), sphalerite (ZnS), and argentiferous tetrahedrite $[(\text{Cu,Fe})_{12}\text{Sb}_4\text{S}_{13}]$ with lesser amounts of chalcopyrite (CuFeS_2). Pyrite (FeS_2) is common but amounts vary from site to site. Once the ores were disturbed or extracted by mining, contaminant metals were distributed along the tributaries, lake and rivers of the region. Contaminant metals continue to be redistributed between a wide range of chemical and physical states depending on exposure to oxidizing or reducing conditions (which can vary seasonally). Chemical processes that contribute to this redistribution include complexation with solutes such as carbonate, variations in pH, sorption by other mineral phases such as iron oxides and by organic matter, and co-precipitation with iron and manganese oxides. Microbial processes also affect the oxidation and reduction of various metals depending on other environmental factors.

The primary metals of concern were zinc, cadmium, and lead. In addition, calcium, iron, magnesium, manganese, sulfur, and selenium were also measured. The sediment samples were subjected to a sequential extraction protocol that segregates the metals into four operationally defined fractions: ion-exchangable fraction (Phase 1), acid-soluble fraction (Phase 2), organic/oxide/sulfide-bound fraction (Phase 3), and the residual fraction (Phase 4). Cadmium tended to be the most mobile metal, although it was present in the lowest concentrations. Iron was the least mobile, suggesting that most of the iron existed as stable iron oxides or mineral iron. Lead was generally more easily extracted than the zinc and both were present in concentrations higher than was observed for cadmium.

Leaching tests were conducted to determine how pH and the presence or absence of oxygen affect the concentration of leached metals. The pH of the leach solution naturally had a significant effect on the leachability of all of the metals. Cadmium and zinc leached at greater rates as the pH of the leach solution was reduced. At a pH of 2, the concentration of Cd and Zn was roughly ten times higher in the leach solution than what was observed at pH 6 or 7. A similar pattern was observed with Pb, although the differences were less dramatic, being about 5 times higher Pb concentration at pH 2 than 6-7.

Leaching tests were also conducted to determine how the presence or absence of oxygen affected metal concentrations in leach solutions. The tests were conducted following a two week wetting/drying cycle conducted at atmospheric conditions. The most notable observation was that each location reacted very differently from the other locations. However, at each location, cadmium and zinc reacted in the same manner.

Metal concentrations were highest in the sediments collected at SF-BH-E-PZ-12 near the CIA. The metal concentrations in locations SF-OB-PZ-13 (Osborn Flats area), BH-E-PZ-16 and BH-E-PZ-24 (both from around the CIA) for cadmium, lead and zinc were relatively similar. In general lead and zinc tend to not be as easily mobilized or extracted for any of the locations, but cadmium was the most easily extracted, particularly in sediments from BH-E-PZ-16 and BH-E-PZ-24.

In experiments conducted at pH 7, many of the elements (Al, Cd, Cu, Fe, Mg, Pb, and Zn) show little or no change with time. The rates of leaching in pH 2 solutions, in contrast to the pH 7 solutions, appear to increase with time for most of the elements. Leached concentrations were also greater at low pH except for S. Leached Ca, Mg, and K concentrations increased over time but appeared to approach a steady state near the end of the experiment.

CONTENTS

EXECUTIVE SUMMARY	v
ACRONYMS.....	xii
1. INTRODUCTION	1
1.1 Methods and Materials.....	2
1.1.1 Study Area and Sample Locations	2
1.1.2 Sample Collection	3
1.1.3 Sequential Extractions.....	3
1.1.4 Extraction Procedures	4
1.1.5 Leach Tests	5
2. RESULTS.....	7
2.1 Sequential Extractions.....	7
2.1.1 Sample Location SF-OB-PZ-13	7
2.1.2 Bunker Hill Sample SF-BH-E-PZ-12	12
2.1.3 Bunker Hill Sample SF-BH-E-PZ-16	18
2.1.4 Bunker Hill Sample SF-BH-E-PZ-24	23
2.1.5 Extraction of Iron from the soil cores	28
2.2 Leach Tests	30
2.2.1 pH Effect on Leaching.....	30
2.2.2 Effect of Aerobic or Anoxic Conditions on Metal Leaching	41
3. SUMMARY AND CONCLUSIONS.....	53
3.1 Sample Location SF-OB-PZ-13	53
3.2 Sample Location SF-BH-E-PZ-12	55
3.3 Sample Location SF-BH-E-PZ-16	57
3.4 Sample Location SF-BH-E-PZ-24	58
4. REFERENCES.....	60

FIGURES

Figure 1. Soil core locations.	2
Figure 2. Truck-mounted roto sonic drill rig.	3
Figure 3. Sample core location near Osborn, Idaho.....	8
Figure 4. Core sample from location SF-OB-PZ-13, 1.0–1.8-foot depth.	8
Figure 5. Core sample from location SF-OB-PZ-13, 3.0–4.0-foot depth.	9
Figure 6. Core sample from location SF-OB-PZ-13, 5.0–5.6-foot depth.	9
Figure 7. Cadmium percentages present in the Osborn Flats soil core.....	10
Figure 8. Lead percentages present in Osborn Flats soil cores.	11
Figure 9. Zinc percentages present in Osborn Flats soil core.	12

Figure 10. Sample core location SF-BH-E-PZ-12.	13
Figure 11. Core sample from location SF-BH-E-PZ-12, 1.0–2.0-foot depth.....	13
Figure 12. Core sample from location SF-BH-E-PZ-12, 3.0–4.0-foot depth.....	14
Figure 13. Core sample from location SF-BH-E-PZ-12, 5.0–6.0-foot depth.....	14
Figure 14. Core sample from location SF-BH-E-PZ-12, 7.0–8.0-foot depth.....	15
Figure 15. Core sample from location SF-BH-E-PZ-12, 8.0–9.0-foot depth.....	15
Figure 16. Cadmium percentages present at sample location BH-E-PZ-12.	16
Figure 17. Lead percentages present at sample location BH-E-PZ-12.	17
Figure 18. Zinc percentages present at sample location BH-E-PZ-12.....	18
Figure 19. Photo of drill rig at sample location SF-BH-E-PZ-16.	18
Figure 20. Core sample from location SF-BH-E-PZ-16, 1.0–2.0-foot depth.....	19
Figure 21. Core sample from location SF-BH-E-PZ-16, 3.0–4.0-foot depth.....	19
Figure 22. Core sample from location SF-BH-E-PZ-16, 5.0–6.0-foot depth.....	20
Figure 23. Core sample from location SF-BH-E-PZ-16, 7.0–8.0-foot depth.....	20
Figure 24. Cadmium percentages present at sample location BH-E-PZ-16.	21
Figure 25. Lead percentages present at sample location BH-E-PZ-16.	22
Figure 26. Zinc percentages present at sample location BH-E-PZ-16.....	23
Figure 27. Collecting the core samples for SF-BH-E-PZ-24 core location.	23
Figure 28. Core sample from location SF-BH-E-PZ-24, 1.0–2.0-foot depth.....	24
Figure 29. Core sample from location SF-BH-E-PZ-24, 3.0–4.0-foot depth.....	24
Figure 30. Core sample from location SF-BH-E-PZ-24, 5.0–6.0-foot depth.....	25
Figure 31. Core sample from location SF-BH-E-PZ-24, 7.0–8.0-foot depth.....	25
Figure 32. Cadmium percentages present at sample location BH-E-PZ-24.	26
Figure 33. Lead percentages present at sample location BH-E-PZ-24.	27
Figure 34. Zinc percentages present at sample location BH-E-PZ-24.....	28
Figure 35. Iron released from the four locations during the sequential extraction.	29
Figure 36. Effect of different pH on leaching of cadmium from sediment samples over a 90 day time interval.	31
Figure 37. Effect of different pH on leaching of lead from sediment samples over a 90 day time interval.	31
Figure 38. Effect of different pH on leaching of zinc from sediment samples over a 90 day time interval.	32
Figure 39. Effect of different pH on leaching of iron from sediment samples over a 90 day time interval.	32
Figure 40. Effect of different pH on leaching of sulfur from sediment samples over a 90 day time interval.	33

Figure 41. Effect of pH on cadmium concentration over time.	33
Figure 42. Effect of pH on lead concentration over time.	34
Figure 43. Effect of pH on zinc concentration over time.	34
Figure 44. Effect of pH on iron concentration over time.	35
Figure 45. Effect of pH on sulfur concentration over time.	35
Figure 46. Effect of pH on cadmium concentration over time.	36
Figure 47. Effect of pH on lead concentration over time.	36
Figure 48. Effect of pH on zinc concentration over time.	37
Figure 49. Effect of pH on iron concentration over time.	37
Figure 50. Effect of pH on sulfur concentration over time.	38
Figure 51. Effect of pH on cadmium concentration over time.	39
Figure 52. Effect of pH on lead concentration over time.	39
Figure 53. Effect of pH on zinc concentration over time.	40
Figure 54. Effect of pH on iron concentration over time.	40
Figure 55. Effect of pH on sulfur concentration over time.	41
Figure 56. Effect of aerobic and anoxic conditions on cadmium concentration over time.	42
Figure 57. Effect of aerobic and anoxic conditions on lead concentration over time.	42
Figure 58. Effect of aerobic and anoxic conditions on zinc concentration over time.	43
Figure 59. Effect of aerobic and anoxic conditions on iron concentration over time.	43
Figure 60. Effect of aerobic and anoxic conditions on sulfur concentration over time.	44
Figure 61. Effect of aerobic and anoxic conditions on cadmium concentration over time.	45
Figure 62. Effect of aerobic and anoxic conditions on lead concentration over time.	45
Figure 63. Effect of aerobic and anoxic conditions on zinc concentration over time.	46
Figure 64. Effect of aerobic and anoxic conditions on iron concentration over time.	46
Figure 65. Effect of aerobic and anoxic conditions on sulfur concentration over time.	47
Figure 66. Effect of aerobic and anoxic conditions on cadmium concentration over time.	47
Figure 67. Effect of aerobic and anoxic conditions on lead concentration over time.	48
Figure 68. Effect of aerobic and anoxic conditions on zinc concentration over time.	49
Figure 69. Effect of aerobic and anoxic conditions on iron concentration over time.	49
Figure 70. Effect of aerobic and anoxic conditions on sulfur concentration over time.	50
Figure 71. Effect of aerobic and anoxic conditions on cadmium concentration over time.	50
Figure 72. Effect of aerobic and anoxic conditions on lead concentration over time.	51
Figure 73. Effect of aerobic and anoxic conditions on zinc concentration over time.	51
Figure 74. Effect of aerobic and anoxic conditions on iron concentration over time.	52
Figure 75. Effect of aerobic and anoxic conditions on sulfur concentration over time.	52

Figure 76. Cadmium, lead, and zinc concentrations in the sediment cores at SF-OB-PZ-13 from the > 2mm fraction.	53
Figure 77. Cadmium, lead, and zinc concentrations in the soil used in the leach tests from the > 2 mm fraction.....	54
Figure 78. Metal concentrations at each core depth for sample location SF-BH-E-PZ-12 from the >2 mm fraction.	55
Figure 80. Cadmium, lead, and zinc concentrations at SF-BH-E-PZ-24 from the > 2mm fraction.	58
Figure A-1. Cadmium pH equilibrium diagram at 25°C.....	84
Figure A-2. Lead pH equilibrium diagram at 25°C.	85
Figure A-3. Zinc pH equilibrium diagram at 25°C.	86
Figure A-4. Iron pH Equalibrium Diagram at 25°C.....	87
Figure A-5. Leach solution pH for Location SF-OB-PZ-13.	88
Figure A-6. Leach solution pH for Location SF-BH-E-PZ-12.	88
Figure A-7. Leach solution pH for Location SF-BH-E-PZ-16.	89
Figure A-8. Leach solution pH for Location SF-BH-E-PZ-24.	90

TABLES

Table 1. Core identification numbers and depth of samples collected.....	2
Table 2. Simulated groundwater makeup.	5
Table 3. Total metal concentrations in sediments used in leach study.	30
Table A-1. Phase I of sequential extraction – laboratory data.	64
Table A-2. Phase II of Sequential Extraction – Laboratory Data. Note U indicates that the ion was analyzed for but not detected above the sample quantification limit or detection limit.	66
Table A-3. Phase III of Sequential Extraction – Laboratory Data. Note U indicates that the ion was analyzed for but not detected above the sample quantification limit or detection limit.....	68
Table A-4. Total Concentration in Treated and Untreated Sediments used in Sequential Extractions.	70
Table A-5. Concentrations from pH leach test from 0–90 days.	72
Table A-6. Concentrations for leach tests in the presence and absence of oxygen from 0–90 days.....	80
Table A-7. Groundwater constituents measured previously.....	83
Table A-8. Partial data for Percent soil less than 2mm.....	90

ACRONYMS

EPA	Environmental Protection Agency
INL	Idaho National Laboratory
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
CIA	Central Impoundment Area

Bunker Hill Sediment Characterization Study

1. INTRODUCTION

The long history of mineral extraction in the Coeur d'Alene Basin has left a legacy of heavy-metal-laden mine tailings that have accumulated along the Coeur d'Alene River and its tributaries (U.S. Environmental Protection Agency [EPA], 2001). Silver, lead, and zinc were the primary metals of economic interest in the area, but the ores contained other elements that have become environmental hazards including zinc, cadmium, lead, arsenic, nickel, and copper. The metals have contaminated the water and sediments of Lake Coeur d'Alene, and continue to be transported downstream to Spokane, Washington, via the Spokane River. In 1983, the EPA listed the Bunker Hill Mining and Metallurgical Complex on the National Priorities List. Since that time, many of the most contaminated areas have been stabilized or isolated; however, metal contaminants continue to migrate through the basin.

Identification of primary sources of contamination can help set priorities for cleanup and cleanup options, which can include source removal, water treatment, or no action depending on knowledge about the mobility of contaminants relative to water flow. The mobility of the contaminants under natural or engineered conditions depends on multiple factors including the physical and chemical state (or speciation) of metals and the range of processes, some of which can be seasonal, that cause mobilization of metals.

Metal-bearing minerals were mined from subsurface sulfide deposits, with the principal ore minerals being galena (PbS), sphalerite (ZnS), and argentiferous tetrahedrite $[(\text{Cu},\text{Fe})_{12}\text{Sb}_4\text{S}_{13}]$ with lesser amounts of chalcopyrite (CuFeS_2). Pyrite (FeS_2) is common but amounts vary from site to site. Once the ores were disturbed or extracted by mining, contaminant metals were distributed along the river tributaries and lake sediments and continue to be redistributed between a wide range of chemical and physical states depending on exposure to oxidizing or reducing conditions (which can vary seasonally). Chemical processes that contribute to this redistribution include complexation with solutes such as carbonate, variations in pH, sorption by other mineral phases such as iron oxides or organic material, and co-precipitation with iron and manganese oxides.

Sediments from Canyon Creek were analyzed previously in May of 2007 by Karen Wright, George Redden, and Carl Palmer (Wright et al., 2007) of the INL. In that study approximately 40% of the Zn, Cd, and Pb was removed as exchangeable and acid soluble, and are considered easily leached. Approximately 20% of the Pb, Cd, and Zn removed during the sequential extractions came from the residual fraction, and is considered very difficult to leach. The remaining 40% that was removed as Fe/Mn/Al hydrous oxide bound and oxidizable organic bound. The ease of leaching from these fractions will depend on the pH and Eh of the system. There were no apparent trends in extracted metals with depth that were consistent for all of the locations.

As a follow on to the work completed by Wright et al., 2007, the INL was asked to collect and analyze sediments from the area near the CIA and Osborn Flats area in 2008 in an effort to help understand the factors that affect metal mobility around the CIA and in the Osborn Flats area. Three groups of experiments were conducted:

- Sequential extraction tests to determine the operational speciation of the metals in the sediment
- Leaching tests to determine the effect of pH on metal leached and,
- Leaching tests to provide insight into the effect of the presence or absence of oxygen on the metal leached.

The following sections explain the methodology and results from the tests conducted on the core samples collected for this study.

1.1 Methods and Materials

1.1.1 Study Area and Sample Locations

Soil cores samples were collected from three locations near the CIA. The general locations of three of the cores are shown in Figure 1 below. Soil core number SF-OB-PZ-13 was collected from a different location in the Osborn Flats area. Samples from the cores were collected at various depths in the soil profile. Table 1 lists the core locations along with the associated sample depths that were collected.



Figure 1. Soil core locations.

Table 1. Core identification numbers and depth of samples collected.

Core ID	Sample Depth				
	1–2 feet	3–4 feet	5–6 feet	7–8 feet	8–9 feet
SF-OB-PZ-13	x	x	x	No Sample	No Sample
SF-BH-E-PZ-12	x	x	x	x	x
SF-BH-E-PZ-16	x	x	x	x	No Sample
SF-BH-E-PZ-24	x	x	x	x	No Sample

1.1.2 Sample Collection

A truck-mounted vibrating coring device known as a roto sonic drill was used to collect the core samples at each location (Figure 2).



Figure 2. Truck-mounted roto sonic drill rig.

The coring device used a sectioned steel pipe with a 2-in. diameter polycarbonate liner. The pipe was driven into the sediments and cores were retrieved in the polycarbonate liner. The liner was withdrawn from the steel pipe and cut into sections approximately 12 in. long. Primary sub-samples were taken from the top, bottom, and intermediate intervals from each of the three cores. The core sections, still surrounded by the polycarbonate liner, were immediately capped, taped, labeled, placed in liquid nitrogen for storage, and transported to INL for analysis. The cores were held at liquid nitrogen temperatures until testing began. Prior to testing, the sediments were thawed, dried, and sieved in an oxygen free anaerobic chamber, with the <2 mm fraction being retained and used in the subsequent extraction and leach tests.

1.1.3 Sequential Extractions

The sequential extraction procedure was adapted from the method reported by Tessier (Tessier et al., 1979). There are recognized limitations to using sequential extraction methods for determining metal speciation and many variations to the Tessier standard procedure have been proposed (Gleyzes et al., 2002). Given that the previous study of the Canyon Creek area used this method, the same procedure was used to facilitate comparison of results (Wright et al., 2007). The Tessier method (Tessier, 1979) was followed with the exceptions of eliminating Step 3 (Fe/Mn/Al hydrous oxide bound) to reduce cost. The residue sediment remaining after the extractions were complete was sent to an EPA contract laboratory

for the final total digestion and analysis step (Phase 4 below). Briefly, the extraction procedure subjects the sample to conditions that should preferentially remove metals associated with different environments: ion-exchangable, acid-soluble, oxides/organic-bound/sulfides, and the residual. Extractant solutions from each step were adjusted to pH 2 with HNO_3 and stored in labeled polypropylene centrifuge tubes in a refrigerator at 4°C until shipped to the EPA-specified contract laboratories for analysis. The first two steps of the sequential extraction, ion-exchangable and acid-soluble were conducted in an anaerobic chamber with low to now oxygen present.

The water used in the following extraction procedures was 18-Mohm deionized water, and was prepared by reverse osmosis using a Barnstead deionization unit. All reagents used were reagent grade.

Phase 1 (ion-exchangable): 1M MgCl_2 : 203.33g $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ was dissolved in deionized water and diluted to 1 L with deionized water. The solution pH was adjusted to pH 7 with NaOH or HNO_3 as needed.

Phase 2 (acid-soluble): 82.03g Na-acetate was dissolved in ~800ml water. The pH was adjusted to 5 using acetic acid and diluted to 1 L with deionized water.

Phase 3 (oxidizable, organic-bound, and some sulfides): A mixture of 9 mL 0.02M HNO_3 and 15 mL 30% H_2O_2 were adjusted to pH 2 with HNO_3 , 3.2M ammonium acetate was prepared by dissolving 246.7 g of reagent grade $\text{CH}_3\text{COONH}_4$ in 20% HNO_3 and diluting to 1 L with 20% HNO_3 .

Phase 4 (residual): For the residual phase, the remaining sediment was collected and shipped to an EPA contract laboratory for analysis.

1.1.4 Extraction Procedures

- **Phase 1:** Approximately 3 g dry sediment was placed in a 50-ml polypropylene centrifuge tube. Twenty four mL 1M MgCl_2 at pH = 7 was added and the mixture was agitated for 1 hour. The suspension was centrifuged at 12,000 rpm for 30 minutes and the supernatant was decanted and saved for analysis. Twenty-four mL water was added to the suspension and the contents mixed, and centrifuged again at 12,000 rpm for 30 minutes. The liquid rinse was decanted and discarded.
- **Phase 2:** Twenty-four mL 1M sodium acetate at pH 5 was added to the sediment from Phase 1 and agitated for 5 hours. The pH was monitored and adjusted to pH 5 if necessary with additional measured volumes of acetic acid. The suspension was centrifuged and the supernatant saved for analysis. The residue was mixed with 24 mL water, centrifuged as before and the supernatant discarded.
- **Phase 3:** To the sediment from Phase 2 was added 9 mL 0.02M HNO_3 and 15ml 30% H_2O_2 (adjusted to pH 2 with HNO_3). The mixture was loosely capped, weighed, and heated to 85°C for 2 hours with occasional agitation. After 2 hours the sample was brought back to the original weight with a 3:5 mixture of 0.02M HNO_3 and 30% H_2O_2 . Fifteen mL of 30% H_2O_2 (adjusted to pH 2 with HNO_3) were added and the sample was weighed and heated to 85°C with occasional agitation. After 3 hours the samples were cooled to room temperature and the original weight was regained with the addition of more 30% H_2O_2 . Fifteen mLs of 3.2M $\text{CH}_3\text{COONH}_4$ in 20% v/v HNO_3 was added with water to dilute the sample to 60 mL total volume. The mixture was agitated for 30 minutes, and then centrifuged and washed as in the previous steps.
- **Phase 4:** The remaining sediment after the above extractions were collected was shipped to an EPA contract laboratory for analysis.

The collected phases and residue from each test were analyzed for the following elements: Ca, Cd, Fe, Mg, Mn, Pb, S and Zn.

1.1.5 Leach Tests

Two types of leach tests were carried out. The first series of leach tests were conducted under anoxic conditions at 6 different pH levels (2, 3, 4, 5, 6, and 7) to observe the effect of pH on the leachability of the elements. This test was conducted on the sediments samples under anaerobic conditions to simulate sediments that are held under saturated anoxic conditions. The second series of leach tests were performed on sediments which had been exposed to air and several wet/dry cycles in order to simulate microbial sulfide oxidation that would exist above the saturated zone. The tests were completed using composites of all of the cores from each location. The leach tests were carried out as described in the next two sections.

1.1.5.1 Leach test to indicate the sensitivity to a lower pH

Composites of all the cores (2 mm sieved samples) from each location were made. This was accomplished by combining all of the remaining material from the core location and tumbling the container for 2 minutes. Fifty gram sub-samples of sediment were added to a 500 ml bottle in an anaerobic chamber to which 500 ml of simulated groundwater was added (Table 2). Simulated groundwater was formulated from groundwater data collected on 9/25/08 for SF-OB-PZ-13, and data collected on 10/09/08 for SF-BH-E-PZ-12, SF-BH-E-PZ-16, SF-BH-E-PZ-24 (Table 2). Six different pH experiments were performed on the sediment samples at pH 2, 3, 4, 5, 6, and 7. One molar sulfuric acid was used to adjust pH down and 200 mM sodium hydroxide was used to adjust pH up as necessary.

Simulated groundwater (Table 2.) was autoclaved to decrease the oxygen concentration in the water. The simulated groundwater was then placed in an anaerobic chamber for 3 days for further removal of O₂. The sediment samples were handled in a sealed chamber with nitrogen (90%), carbon dioxide (5%), and hydrogen (5%) gasses and a palladium catalyst to scavenge oxygen from the air in the glovebox. The sediment samples were placed into bottles, the leaching solution was added, and the bottles were sealed inside the anaerobic chamber. The sealed bottles were placed on a shaker at ~120 rpm. Leaching was done for 3 months, with a 10 ml solution sample pulled at time zero, 8 hours, 16 hours, 24 hours, 3 days, 7 days, 1 month, 2 months, and 3 months. All aliquot samples were diluted to 20 mL with pH 2 HNO₃ and sent to an EPA approved laboratory for analysis. The pH was adjusted with 1 M H₂SO₄ or 0.2 M NaOH to bring each experiment back to the original pH when sampling or at least once per week.

Table 2. Simulated groundwater makeup.

g/L	SF-OB-PZ-13	SF-BH-E-PZ-12	SF-BH-E-PZ-16	SF-BH-E-PZ-24
Mg ₂ SO ₄ ·7H ₂ O	0.05	0.207	0.93	0.99
KCl	0.002	0.0056	0.0075	0.013
CaCO ₃	0.056	0.08	0.01	0.23
NaCl	0.01	0.0027	0	0
NaNO ₂	0.0001	0.00001	0.00001	0.0001
NaNO ₃	0.0001	0.00001	0.00001	0
K ₂ HPO ₄	0.0002	0	0.004	0.0042
Na ₂ SO ₄	0.014	0.035	0.014	0.0327
(NH ₄) ₂ SO ₄	0.00002	0	0	0
FeSO ₄	0	0.02	0.0001	0.111

1.1.5.2 Leach Test to compare the effects of wet/dry cycling followed by aerobic or anoxic conditions

Two sets of leaching experiments were conducted to compare different conditions that may result from sulfide oxidation. The first leaching experiment used soil samples that were fully exposed to air for two weeks of wet/dry cycles followed by leaching with simulated infiltrating surface water (deionized

water) under aerobic conditions. The second leaching test used soil samples that were fully exposed to air for two weeks of wet/dry cycles followed by leaching with simulated groundwater under low/no oxygen conditions.

The first leaching experiment (aerobic) was conducted using composites of all the cores (<2 mm sieved samples) from each location. Fifty grams of soil was taken from each location and placed in aluminum trays. These were left at room temperature with full air exposure for 2 weeks. Samples were sprayed 1-3 times per day, until the sediment was saturated with deionized water to stimulate a wet/dry cycle (rain water) resulting from precipitation events. After the two week time interval, five hundred ml of deionized water was added to the four 50g soil samples and these were shaken aerobically at ~120 rpm for the duration of the test. Leaching was done for 3 months, with 10 ml samples pulled from each soil sample. Liquid samples were taken at time zero, 8 hours, 16 hours, 24 hours, 3 days, 7 days, 1 month, 2 months, and 3 months. Samples were diluted to 20 mL with pH 2 HNO₃ and sent to an EPA approved laboratory for analysis. The pH of the samples was measured but not adjusted during the testing interval.

The second leaching experiment (anoxic) was conducted using composites of all the cores (<2 mm sieved samples) from each location. Fifty grams of soil was taken from each location and placed in aluminum trays. These were left at room temperature with full air exposure for 2 weeks. Samples were sprayed 1-3 times per day, until the sediment was saturated with deionized water to stimulate a wet/dry cycle (rain water) resulting from precipitation events. Groundwater data collected on 9/25/08 for SF-OB-PZ-13, and groundwater data collected on 10/09/08 for SF-BH-E-PZ-12, SF-BH-E-PZ-16, SF-BH-E-PZ-24 was used to formulate the simulated groundwater (see Table 2). Oxygen was removed from the simulated groundwater as above and 500 ml was added to each 50 g sample of soil in the anaerobic chamber. The anoxic soil samples were then sealed and placed on a shaker at ~120 rpm. Leaching was done for 3 months, with 10 ml samples pulled in the anaerobic chamber for anoxic soil samples. Liquid samples were taken at time zero, 8 hours, 16 hours, 24 hours, 3 days, 7 days, 1 month, 2 months, and 3 months. Samples were diluted to 20 mL with pH 2 HNO₃ and sent to an EPA approved laboratory for analysis. The pH of the samples was measured but not adjusted during the testing interval.

2. RESULTS

The results of this project are separated into two sections: Sequential Extractions and Leach Tests. The data for each is presented in section 2.1 and 2.2 respectively. Prior to conducting the tests, samples were maintained in an anoxic frozen condition to prevent oxidation and reaction (biological and chemical) from occurring.

2.1 Sequential Extractions

The first step in the sequential extraction (shown as phase I in the Figures below) represents the most easily extractable or exchangeable portion of the elements present in the sediment. It is extracted by leaching the soil with 1M MgCl_2 (pH=7) for 1 hour. This step of the sequential extraction was conducted under anoxic conditions to minimize the effect of oxidation prior to or during the extraction procedure.

The second step of the extraction is designed to liberate the specifically sorbed or carbonate bound elements. This phase is extracted by leaching the soil with 1M sodium acetate adjusted to pH 5 with acetic acid for 5 hours. This step of the sequential extraction was also conducted in a low- to no-oxygen environment, again to remove outside influences of oxidation on the samples. In the figures below, the second fraction is presented as Phase II.

The third extraction step represents a combination of the organic bound fraction, and some of the Fe/Mn/Al hydrous oxide bound fraction (that would have been released in the 0.04 M hydroxylamine-HCL in 25% v/v acetic acid step) and some sulfides of the elements present in the soil. These elements are frequently bound to various forms of organic matter, however, because the step that selectively removes the oxide fraction was skipped, this third extraction will also remove some metal oxides resulting from exposure to air and pyrometallurgical ore processing. In addition, some portion of the residual metal sulfides that are present will be extracted. Under strong oxidizing conditions organic matter, Fe/Mn/Al hydrous oxide bound and some sulfides can be degraded to release the soluble elements. This fraction is extracted by leaching with 0.02M HNO_3 and 30% H_2O_2 (adjusted to pH 2 with HNO_3) for five hours at 85° C, and then add 3.2 M $\text{CH}_3\text{COONH}_4$ in 20% v/v HNO_3 for 30 minutes. In the figures below, the third extraction is presented as Phase III. The remaining sediment was sent to an EPA laboratory where it underwent a total digestion and analysis for remaining elements. This fraction is referred to as the residual or total fraction of metal.

The fractions shown in the following graphs represent the concentrations of elements present only in the soil that was in the > 2mm fraction. In general there were no consistent trends in the first three phases of the extraction. But there was a general trend in the residual metal concentrations in the soil. Typically, the concentrations of elements remaining in the residual fraction, was highest near the surface. Assuming that the material is generally consistent with depth with respect to the origination of the material, the material at the surface contains material that is typically harder to extract with the 3 extraction methods used in this study. This is consistent with years of oxidation occurring near the surface of the material.

2.1.1 Sample Location SF-OB-PZ-13

This site was located near Osborn, Idaho. Figure 3 shows the location where the core samples were collected. Figures 4–6 show the core samples collected from this location as they were opened in an oxygen free glovebox.



Figure 3. Sample core location near Osborn, Idaho.



Figure 4. Core sample from location SF-OB-PZ-13, 1.0–1.8-foot depth.



Figure 5. Core sample from location SF-OB-PZ-13, 3.0–4.0-foot depth.



Figure 6. Core sample from location SF-OB-PZ-13, 5.0–5.6-foot depth.

The following series of graphs shows the relative amounts of elements leached from the sediment samples. Figure 7 shows the relative amount of cadmium found at the three soil depths tested. Cadmium concentrations in these sediment samples vary from 72.4 mg/kg at the surface to 6.3 mg/kg at 3–4 feet

and 21.9 mg/kg at 5–6 feet below the surface. Comparing Figure 7 with Figures 8 and 9 shows that while the exchangeable cadmium (Phase I) is much higher than the exchangeable lead and zinc, the total concentration of cadmium is much lower than the lead and zinc. For instance the total cadmium concentration in the 3-4 foot depth was measured to be 6.3 mg/kg. The exchangeable cadmium extracted resulted in over 40% of the cadmium present at this depth, but this represents only 2.5 mg/kg of Cd. Cadmium is by nature more mobile than most other metals. The amount of cadmium present in the carbonate extractable fraction (Phase II) appears to represent an additional 5-15% of the total cadmium, and another 10-20% is found in the organic/oxide/sulfide bound phase (Phase III). Over time, the exchangeable cadmium will be released first. If conditions become more acidic, the carbonate bound cadmium will be released and over time, the cadmium bound to organic matter or as oxides or sulfides will release even slower.

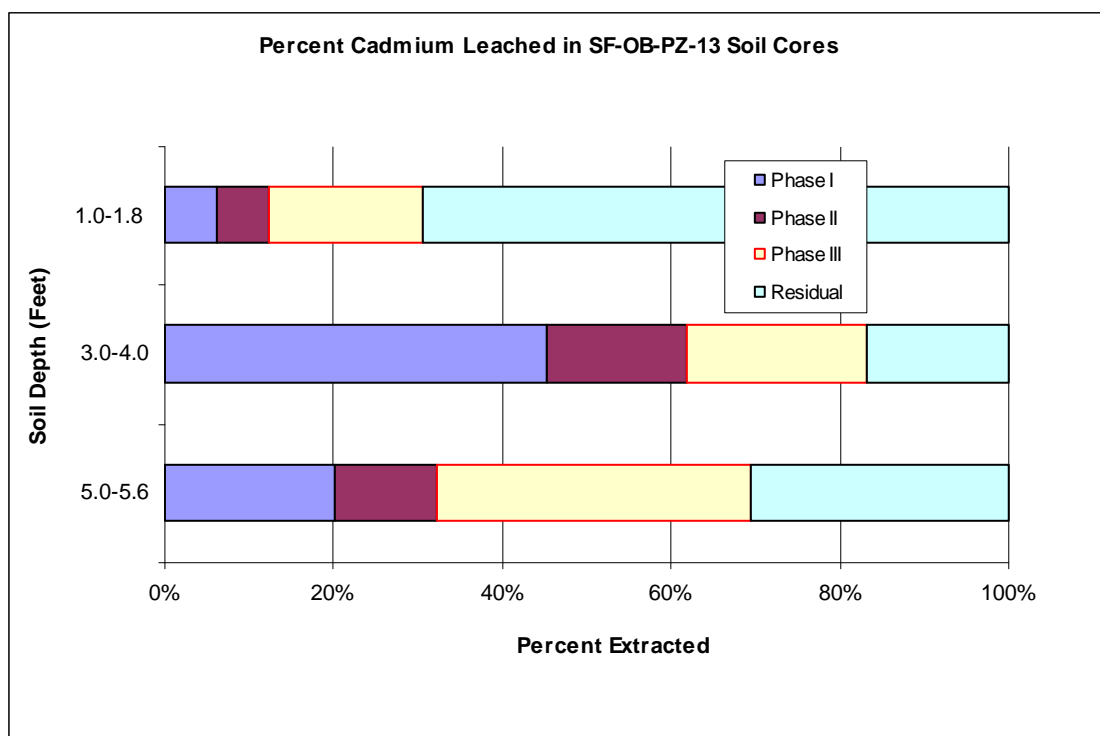


Figure 7. Cadmium percentages present in the Osborn Flats soil core.

The concentration of lead in this soil was measured and ranged from 11,300 mg/kg at the surface to 1,920 mg/kg at 3-4 feet, and 3,730 mg/kg at 5-6 feet. While the concentration of lead at the surface was quite high, the percent of exchangeable lead in the surface soil was less than 1% and below 5% for the 3-4 foot and the 5-6 foot range as shown in Figure 8. However, the carbonate bound lead accounted for 20-40% and the organic/oxide/sulfide bound lead accounted for 30-40 % of the total lead in the soil. The amount of lead released from the third extraction step or as an organic bound, oxide, or sulfide was uniform with depth.

The results show that under normal (non acidic) conditions, the lead in the sediments will tend to remain immobile. However, under increasingly acidic condition, the release of lead will increase and under highly acidic conditions, organic/oxide/ sulfide bound lead will also be released.

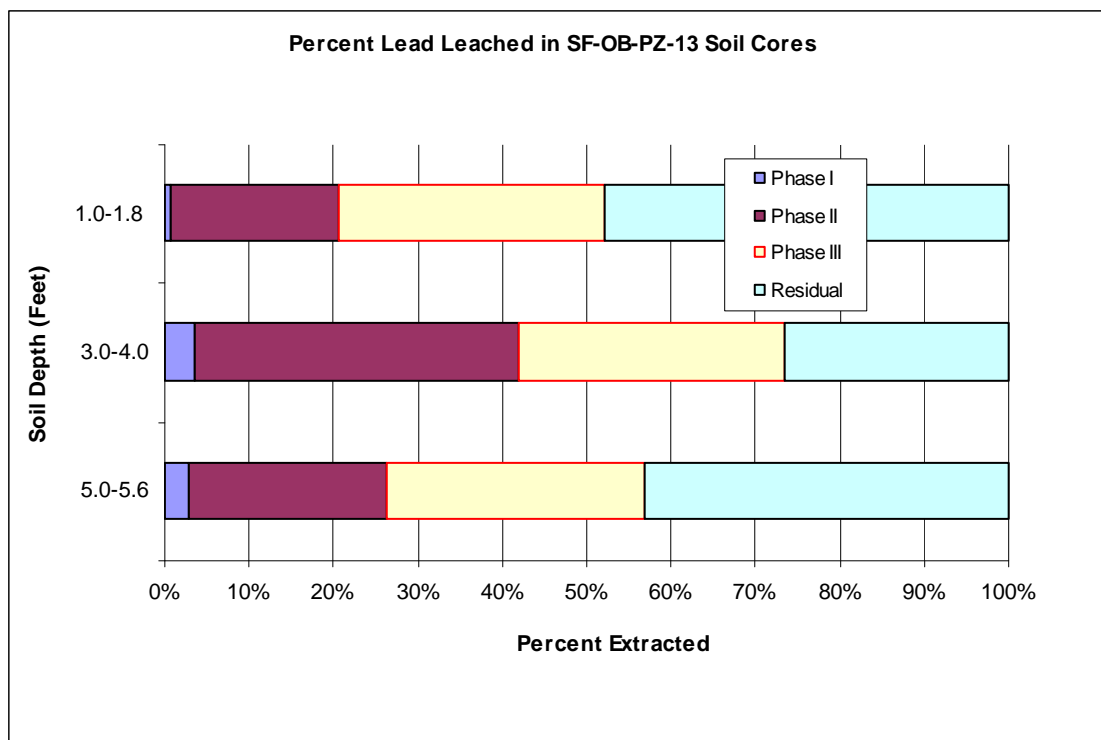


Figure 8. Lead percentages present in Osborn Flats soil cores.

Soil from the Osborn Flats area was analyzed for total zinc, which ranged from 8,560 mg/kg at the surface to 886 mg/kg at a depth of 3-4 feet and 3040 mg/kg at a depth of 5-6 feet. The results in Figure 9 show that only a small amount of the zinc in the soil is present in an exchangeable form (Phase I extraction). In addition, the results from the Phase II and Phase III extractions also show that not more than about 43% of the zinc is extracted at any depth. Taken together, these results would indicate that the major portion of zinc present in the soil is in some form of refractory mineral, perhaps as a zinc silicate or bound up in another silicate mineral. However, without further analysis of the minerals present in the soil (perhaps by X-ray diffraction) this premise cannot be confirmed.

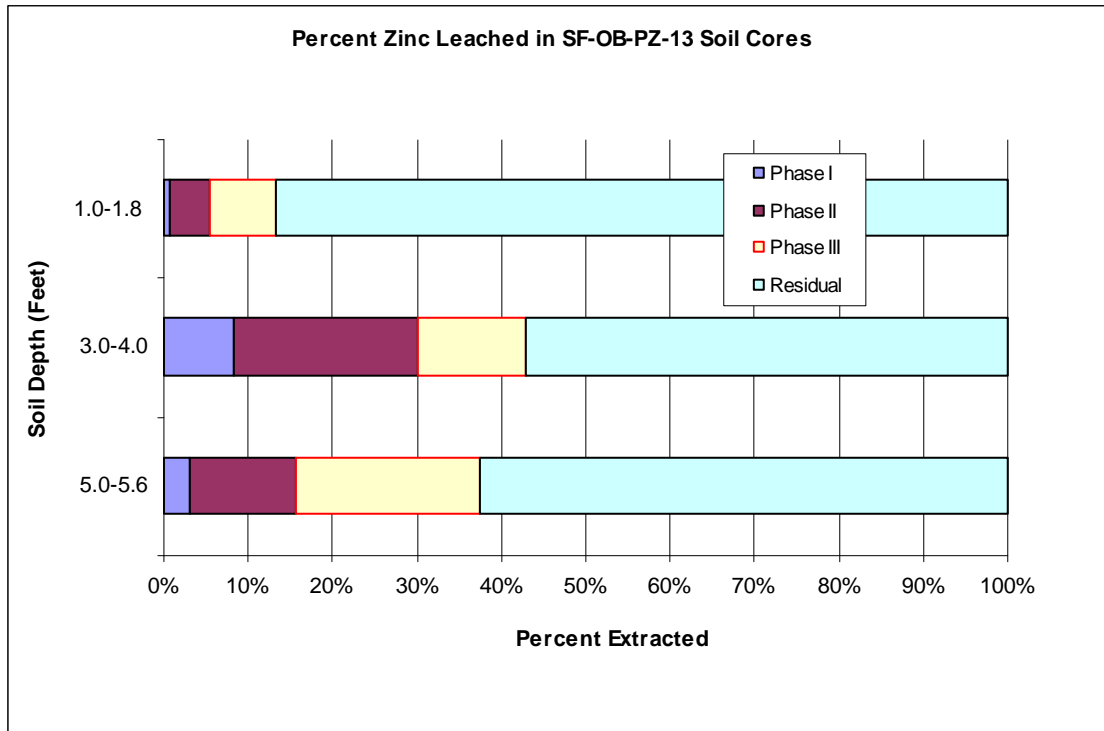


Figure 9. Zinc percentages present in Osborn Flats soil core.

2.1.2 Bunker Hill Sample SF-BH-E-PZ-12

Three locations were sampled near the CIA. The first location, near the south east side of the repository, labeled SF-BH-E-PZ-12 on the map above in Figure 1 had cadmium concentrations that ranged from 37.9 mg/kg at 1–2 feet, 14.7 mg/kg at 3–4 feet, 2.9 mg/kg at 5–6 feet, 123 mg/kg at 7–8 feet, and 254 mg/kg at 8–9 feet. Figure 10 shows the location of this core sample. Figures 11–15 show the core samples as they were opened in the glovebox. Note that in the 8–9 foot section, there was noticeable moisture and the color was a blue grey, much different than the cores taken at other locations.



Figure 10. Sample core location SF-BH-E-PZ-12.

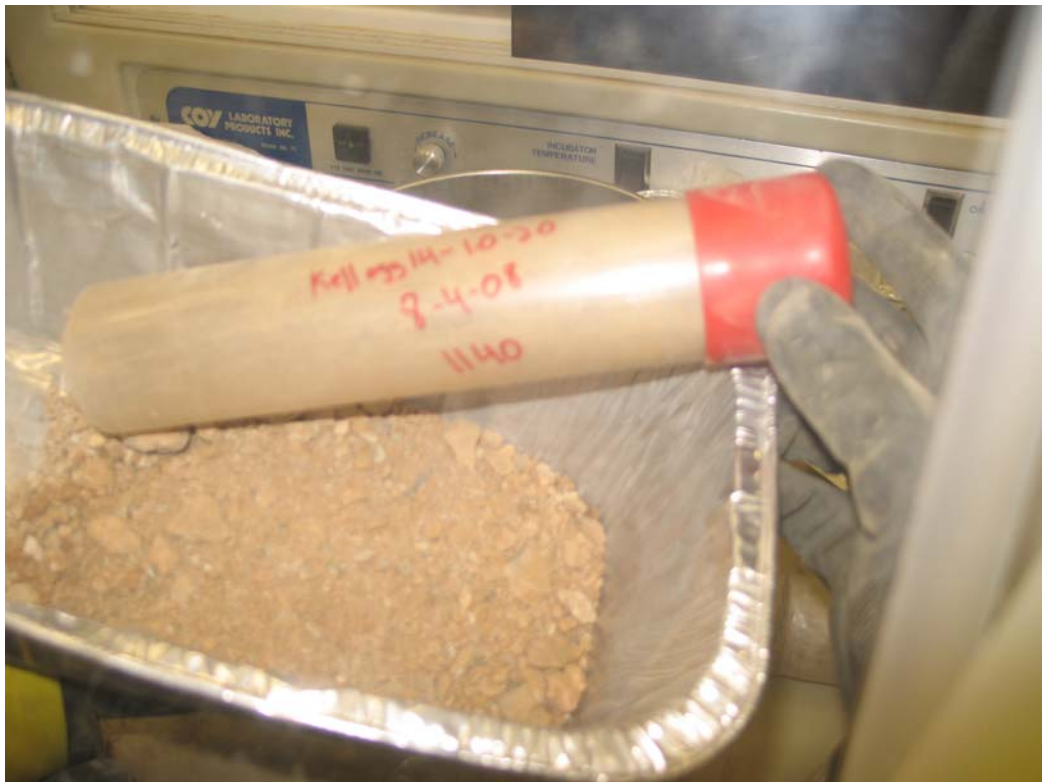


Figure 11. Core sample from location SF-BH-E-PZ-12, 1.0–2.0-foot depth.



Figure 12. Core sample from location SF-BH-E-PZ-12, 3.0–4.0-foot depth.



Figure 13. Core sample from location SF-BH-E-PZ-12, 5.0–6.0-foot depth.



Figure 14. Core sample from location SF-BH-E-PZ-12, 7.0–8.0-foot depth.



Figure 15. Core sample from location SF-BH-E-PZ-12, 8.0–9.0-foot depth.

Similar to the Osborn Flats location, the amount of exchangeable cadmium represents a higher percentage than the exchangeable lead or zinc (Phase I, Figure 16-18). At the surface, the carbonate bound cadmium represents a higher percentage, but that percentage decreases with depth. However, at lower depths, the organic/oxide/sulfide bound cadmium accounts for the highest percentage. The results from the 5-6 foot depth would indicate that the cadmium is present in a refractory form at this depth and is difficult to leach (only 17% of the cadmium was removed). This location is the only one that showed significant trends with depth, with the cadmium being more available near the surface.

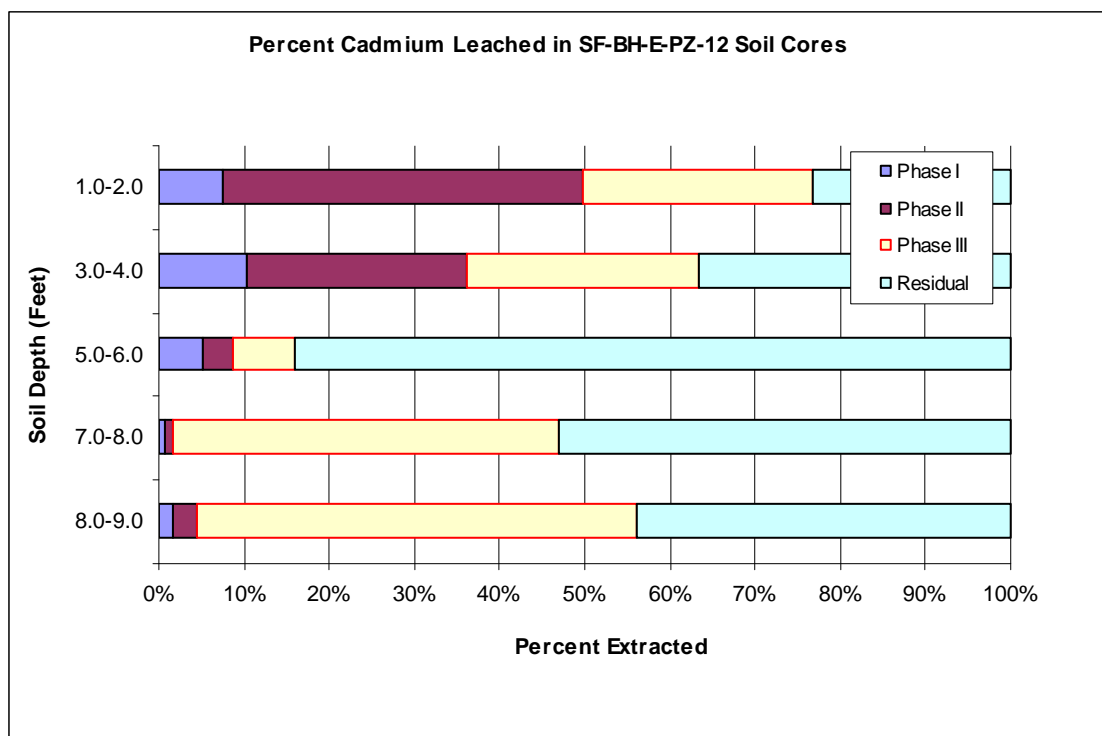


Figure 16. Cadmium percentages present at sample location BH-E-PZ-12.

Lead concentrations measured in the soil at this location ranged from 12,100 mg/kg at 1-2 feet, 6,890 mg/kg at 3-4 feet, 7,190 mg/kg at 5-6 feet, 116,000 mg/kg at 7-8 feet, and 17,300 mg/kg at 8-9 feet. As shown in Figure 17, the exchangeable lead accounted for less than 5% of the total at any depth, but because the total concentration of lead in the soil is high, the exchangeable phase is significant. The carbonate bound phase (Phase II) also represented a significant amount of the total lead, ranging from 30-50% of the total lead (Figure 17). The organic/oxide/sulfide bound lead varied from less than 5% to as much as 35% of the total lead. The most notable observation is the high concentrations of carbonate bound lead near the surface. Changes in pH could impact this fraction of lead more easily than at the 5 foot and lower sections. The lead bound to the organic matter/oxide/sulfide, which represents a significant amount in this soil is fairly stable and will be release slowly over a long period of time.

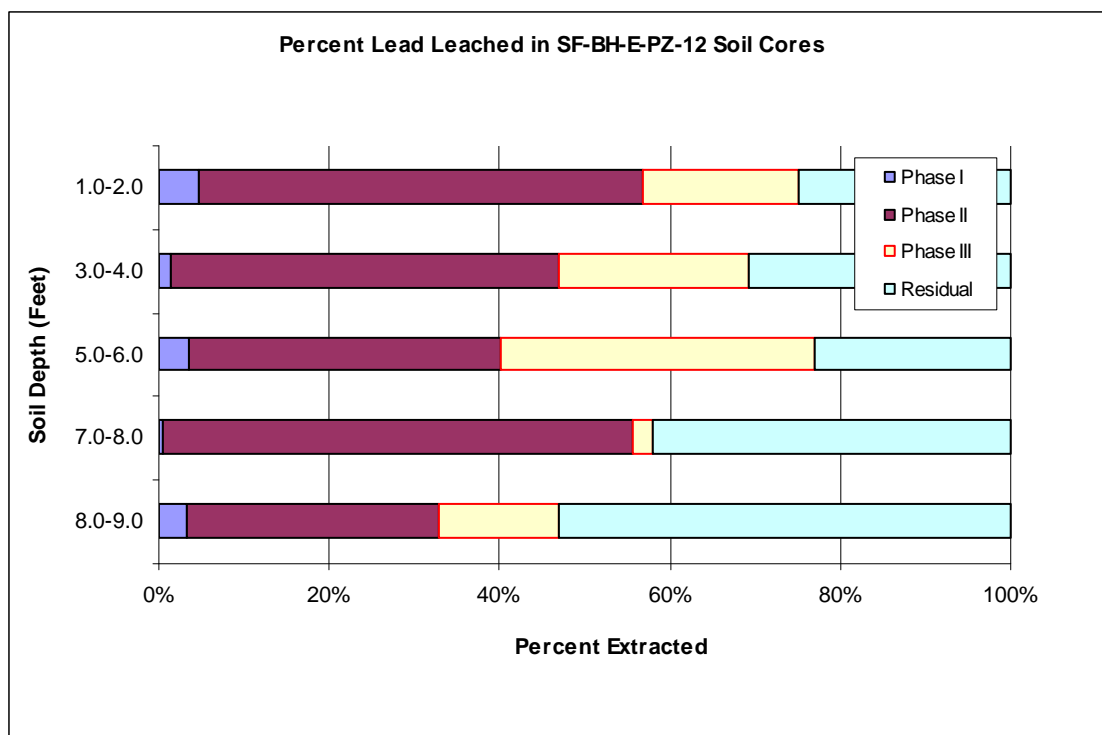


Figure 17. Lead percentages present at sample location BH-E-PZ-12.

This location had zinc concentrations that ranged from 4,820 mg/kg at 1-2 feet, 2,870 mg/kg at 3-4 feet, 1,110 mg/kg at 5-6 feet, 11,800 mg/kg at 7-8 feet, and 24,300 mg/kg at 8-9 feet. These concentrations were as much as an order of magnitude higher than those measured at Osborn Flats. Similar to the Osborn Flats results, the exchangeable zinc (Phase I) at this location accounted for much less than the cadmium or lead measured in this location (Figure 18). The exchangeable zinc was less than 5-10% of the total zinc concentration at all depths. The carbonate bound zinc represented nearly 20% of the total zinc in the top 3-4 feet, but generally less than 10% beyond that. The organic bound/oxide/sulfide zinc accounted for 20-40%, except for the 5-6 foot depth which had less than 5%. Similar to the cadmium results at the 5 to 6 foot depth (Figure 15), the zinc is apparently present at this depth as some form of refractory mineral which is resistant to leaching.

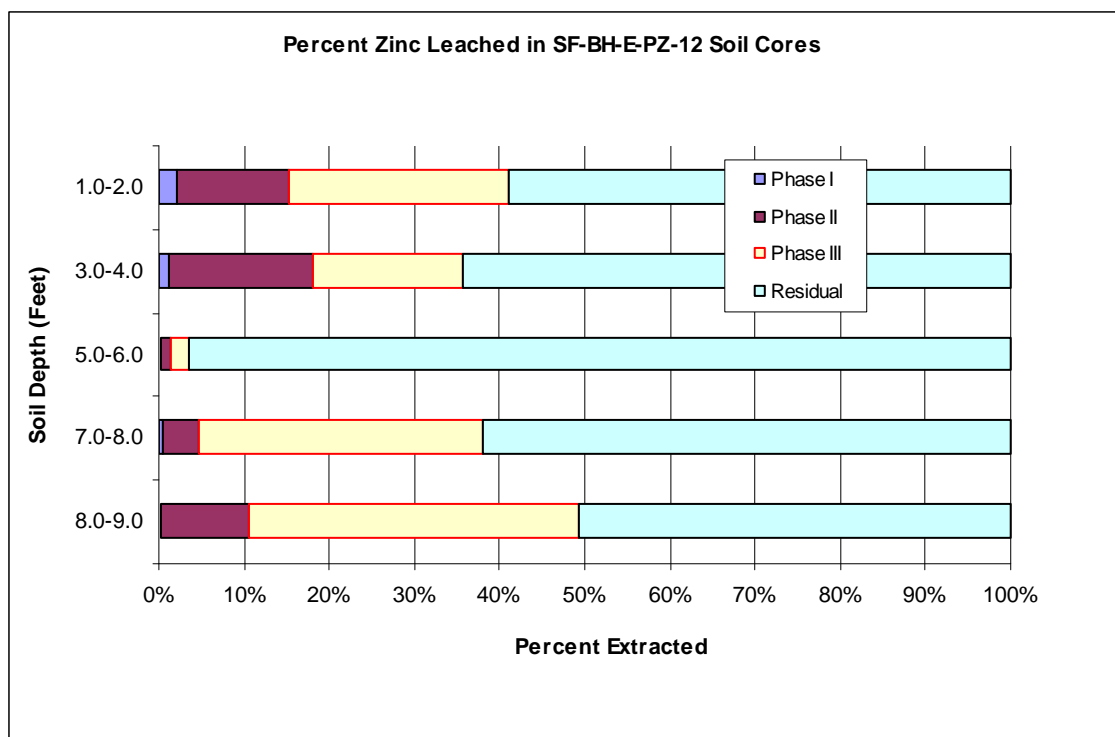


Figure 18. Zinc percentages present at sample location BH-E-PZ-12.

2.1.3 Bunker Hill Sample SF-BH-E-PZ-16

The core from this location was also taken near the CIA. Figure 19 shows the location of this core sample. Figures 20–23 show the core samples from each depth sampled at this location. Note that the core samples in this location are reddish brown, particularly in the 5–6 foot section, indicating the presence of oxidized iron in the sediments.



Figure 19. Photo of drill rig at sample location SF-BH-E-PZ-16.



Figure 20. Core sample from location SF-BH-E-PZ-16, 1.0–2.0-foot depth.



Figure 21. Core sample from location SF-BH-E-PZ-16, 3.0–4.0-foot depth.



Figure 22. Core sample from location SF-BH-E-PZ-16, 5.0–6.0-foot depth.



Figure 23. Core sample from location SF-BH-E-PZ-16, 7.0–8.0-foot depth.

The amount of cadmium present at this location varied from 19.2 mg/kg at 1-2 feet, 43.8 mg/kg at the 3-4 foot depth, 72.8 mg/kg at the 5-6 foot depth, and 13.8 mg/kg at the 7-8 foot depth. These concentrations are roughly comparable to the previous location, but the percent of exchangeable cadmium is much higher at this location as was the case for zinc and lead (Figures 24-26). This location is less stable than the other locations. Oxidation reduction potential (ORP) values were an order of magnitude higher from groundwater taken at this location in September and October 2008 than any of the other locations (Table A-7). Iron values in the water were low indicating that the iron may have oxidized and precipitated as ferric oxyhydroxides. This result would then lead to a higher percentage of cadmium, lead, and zinc in the exchangeable phase. Alternatively, the soil may have experienced a lower pH condition at various times of the year, which could have resulted in the breakdown of carbonates minerals – thus liberating the carbonate bound cadmium, which would then likely show up in the exchangeable phase. Either way, the exchangeable fraction of metal at this location is higher than other locations.

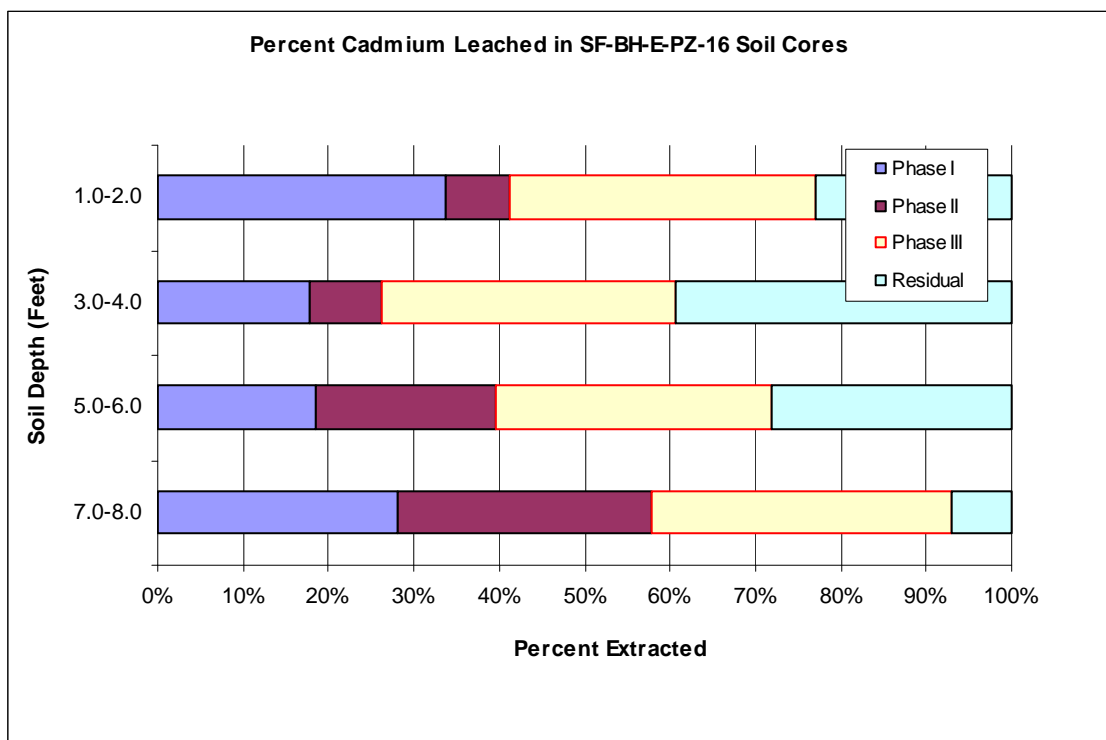


Figure 24. Cadmium percentages present at sample location BH-E-PZ-16.

The amount of lead present in the soil at this location was measured to be 8,130 mg/kg in the 1-2 foot range, 5,290 mg/kg at the 3-4 foot range, 5,970 at the 5-6 foot range and 1,110 at the 7-8 foot range. While these concentrations are lower than the E-12 location, the exchangeable lead is higher. At 3-4 feet the exchangeable lead exceeds 20% (Figure 25). That is to say, of the 5,970 mg/kg lead present in the soil, roughly 1,200 mg/kg lead is more easily exchangeable. The amount of carbonate bound lead is similar, but the lead bound to organic matter/oxides/sulfides is less.

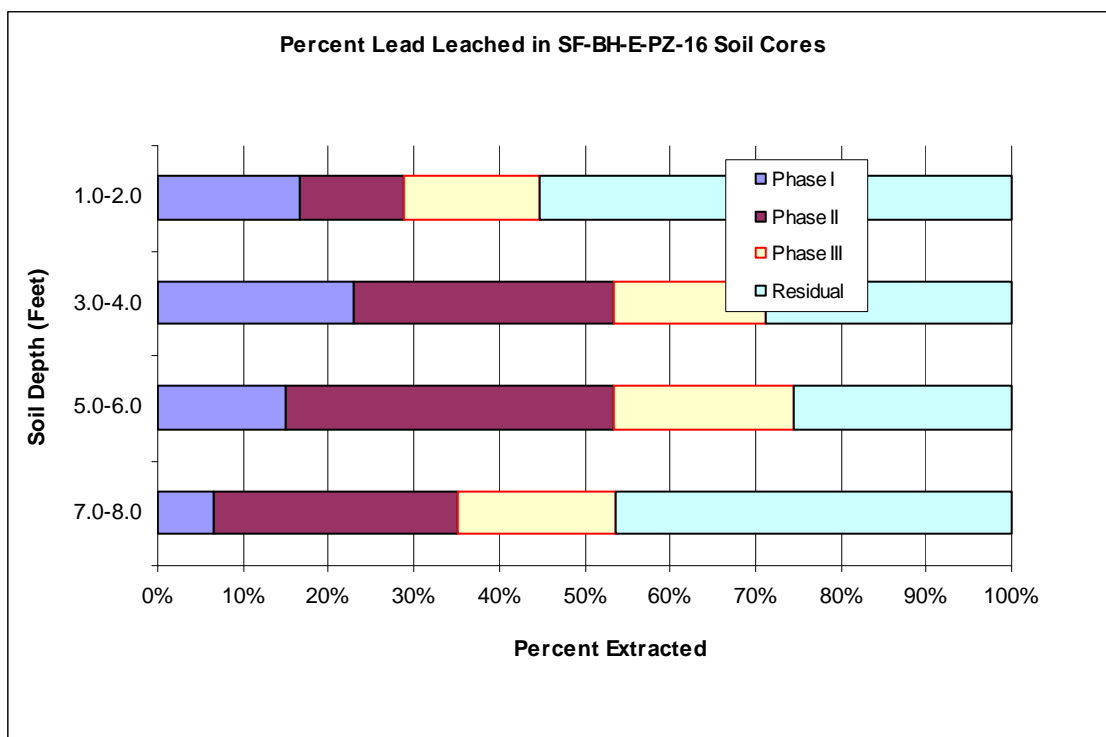


Figure 25. Lead percentages present at sample location BH-E-PZ-16.

The concentrations of zinc at this location were 3,730 mg/kg in the 1-2 foot range, 6,800 mg/kg at the 3-4 foot range, 11,700 mg/kg at the 5-6 foot range, and 1,690 mg/kg at the 7-8 foot range. At this location, there was a slightly higher percentage of exchangeable zinc than at the previous two locations (Figure 26). The exchangeable zinc is highest near the surface. However, the carbonate bound zinc is greater at 5-6 and 7-8 feet than it is above those levels. The amount of zinc bound in the organic/oxide/sulfide phase is similar to the previous described location.

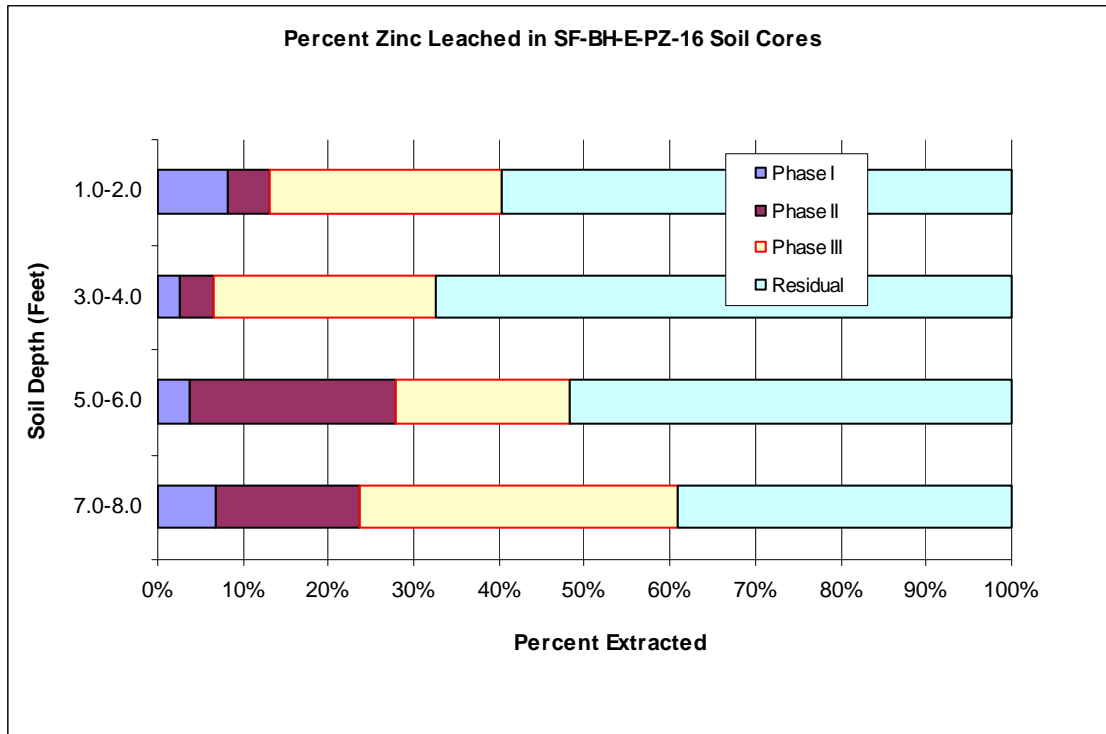


Figure 26. Zinc percentages present at sample location BH-E-PZ-16.

2.1.4 Bunker Hill Sample SF-BH-E-PZ-24

The core samples for this section were also collected near the CIA. Figure 27 shows the location where the drill rig collected the cores in the field. Figures 28–31 show the cores from each depth.



Figure 27. Collecting the core samples for SF-BH-E-PZ-24 core location.

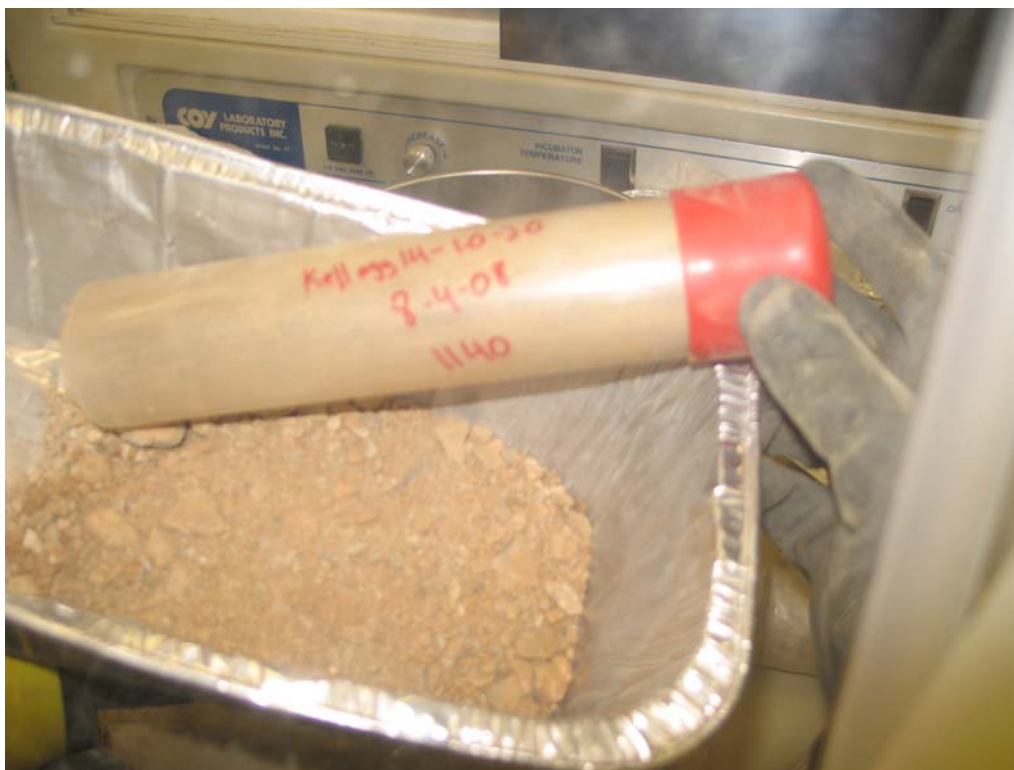


Figure 28. Core sample from location SF-BH-E-PZ-24, 1.0–2.0-foot depth.



Figure 29. Core sample from location SF-BH-E-PZ-24, 3.0–4.0-foot depth.



Figure 30. Core sample from location SF-BH-E-PZ-24, 5.0–6.0-foot depth.



Figure 31. Core sample from location SF-BH-E-PZ-24, 7.0–8.0-foot depth.

Cadmium concentrations in the soil range from 26.7 mg/kg at 1–2 feet, 13.5 mg/kg at 3–4 feet, 54.6 mg/kg at 5–6 feet, to 9.2 mg/kg at 7–8 feet. Cadmium is the most mobile of the metals of concern. Nearly 45% of the cadmium is readily exchangeable in the 7–8 foot region (Figure 32), and nearly a third is exchangeable at the 5–6 foot depth. At the lower depths, more than 90% of the cadmium is found as exchangeable, carbonate bound, and organic matter/oxide/sulfide bound cadmium combined. Under wet, slightly acidic environmental conditions, it would be possible to remove over 50% of the cadmium from the 5–6 foot and 7–8 foot sections soil in a short amount of time.

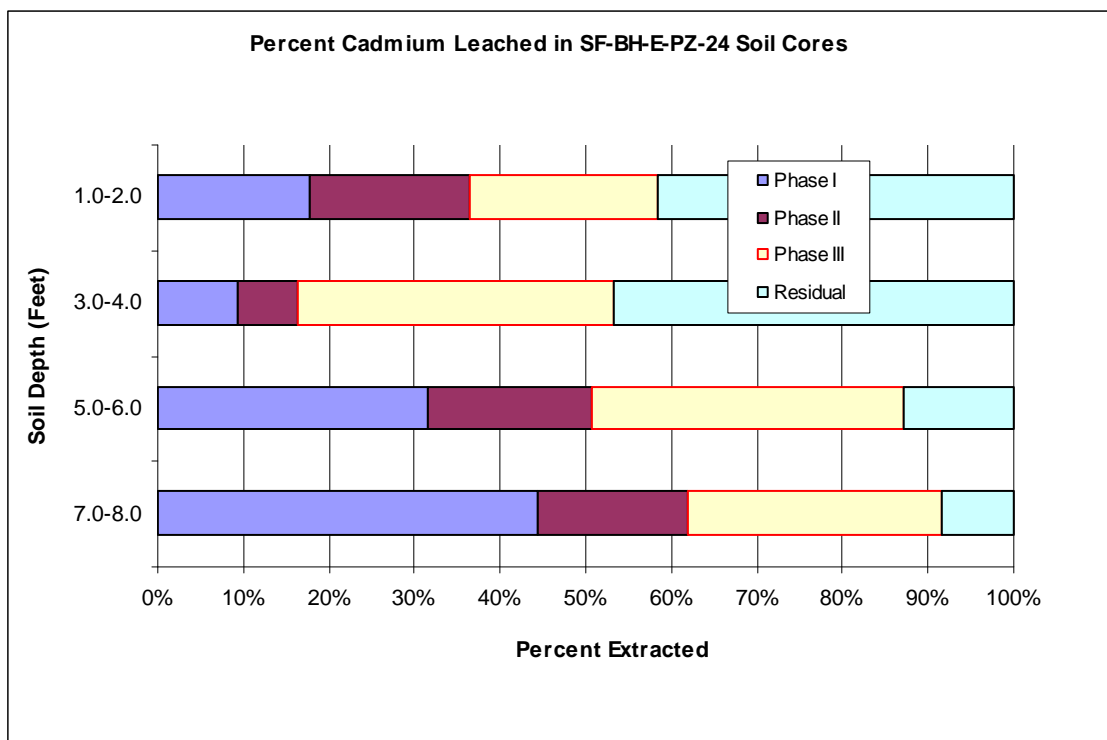


Figure 32. Cadmium percentages present at sample location BH-E-PZ-24.

The concentration of lead at this location ranges from 6,130 mg/kg at the 1–2 foot range; 3,490 mg/kg at the 3–4 foot range; 5,900 mg/kg at the 5–6 foot range, and 258 mg/kg at 7–8 feet. Similar to previous Osborn Flats and BH-E-PZ-12 samples, only a small percent of the lead is present as exchangeable lead (Figure 33). The carbonate bound lead was higher (Phase II), and the organic matter bound/oxide/sulfide bound lead (Phase III) contained approximately 10-20 % of the total lead. In general the lead in the soil at this location would not be extracted at neutral pH, but a downward shift (more acidic) in pH could release more than 60% of the lead in the 5-6 foot soil depth.

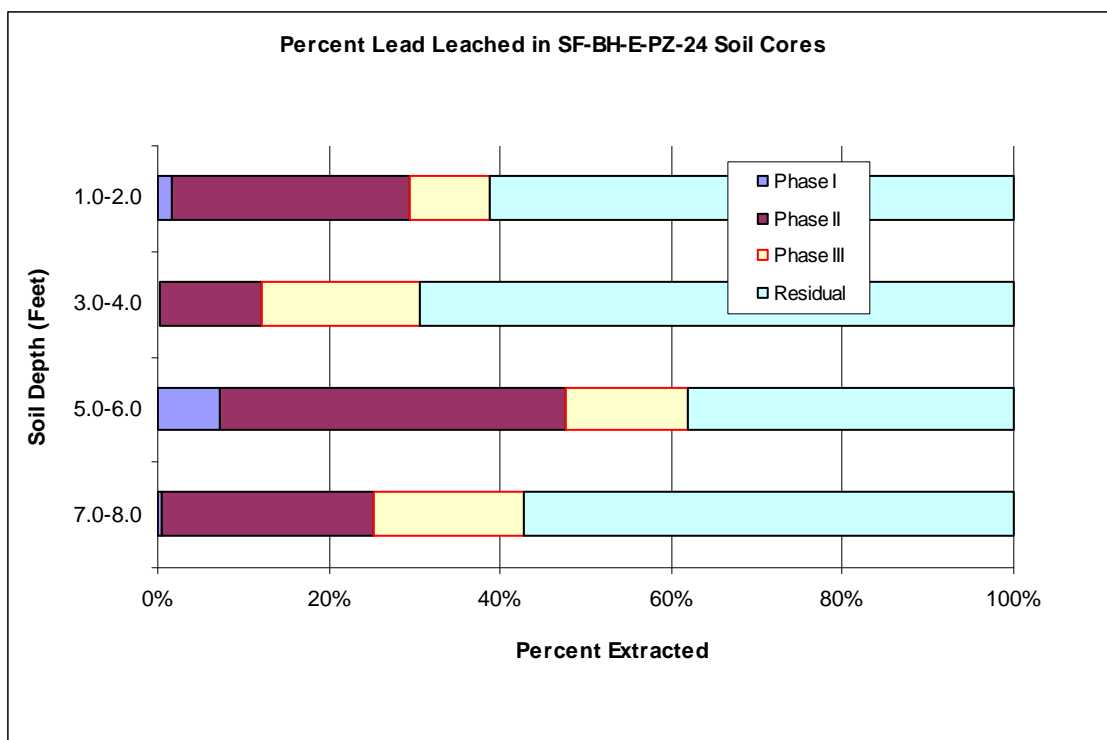


Figure 33. Lead percentages present at sample location BH-E-PZ-24.

The zinc concentrations at this location were higher in the top two elevations than at lower depths. The concentration of zinc ranges from 11,000 mg/kg at 1–2 feet; 11,900 mg/kg at the 3–4-foot range; 3,300 mg/kg at the 5–6-foot range; and 1,080 mg/kg at 7–8 feet. Although the concentrations of zinc were much higher in the top two cores, the exchangeable zinc was much lower (Figure 34). The same is true of the carbonate bound zinc and the percentage of zinc bound to organic matter/oxide/sulfide. This suggests that although the zinc concentrations are fairly high in the top 4 feet of soil, it is in a fairly stable form.

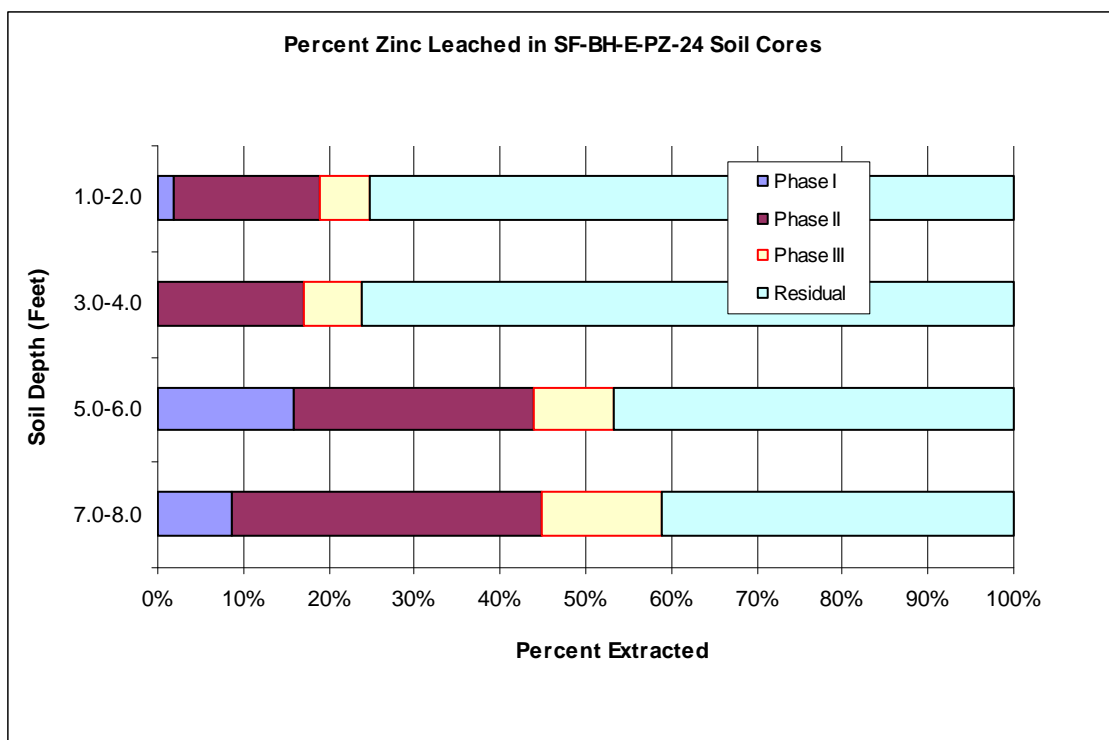


Figure 34. Zinc percentages present at sample location BH-E-PZ-24.

2.1.5 Extraction of Iron from the soil cores

Very little iron was extracted at all locations, except at BH-E-PZ-24 (E-24 in figure below) where approximately 10 to 12% was released as exchangeable (See Figure 35 below). These results suggest that most of the iron in the cores is present in a form only extractable by hydrofluoric acid digestion (residual fraction). Under low pH high oxidizing conditions (nitric acid and hydrogen peroxide) most iron will remain insoluble and will show up in the residual fraction. In the Canyon Creek Study (Wright et al., 2007), where the 3rd step of Tessier (1979) sequential extraction procedure was done; only 5-10% of the iron was present in the oxide form. The exception is at BH-E-PZ-24 where, since the iron is more available (Phase II extractable), possibly in the form of a reduced iron carbonate or sulfate.

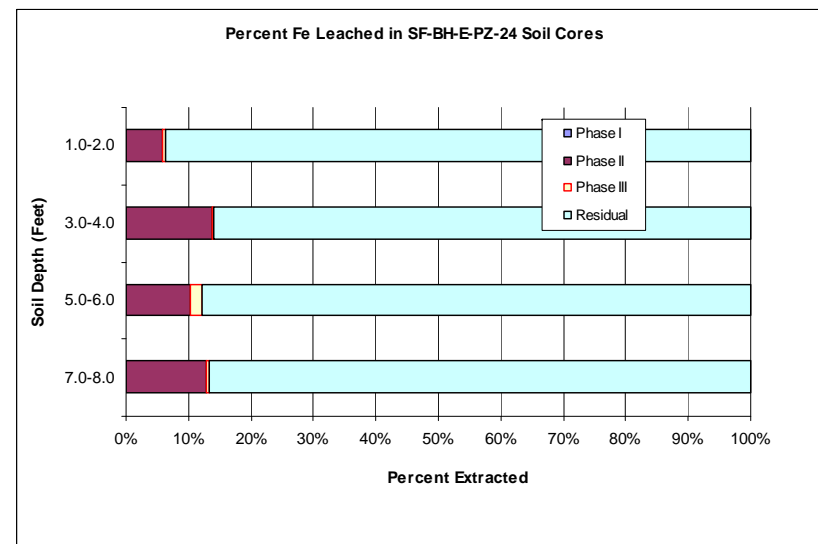
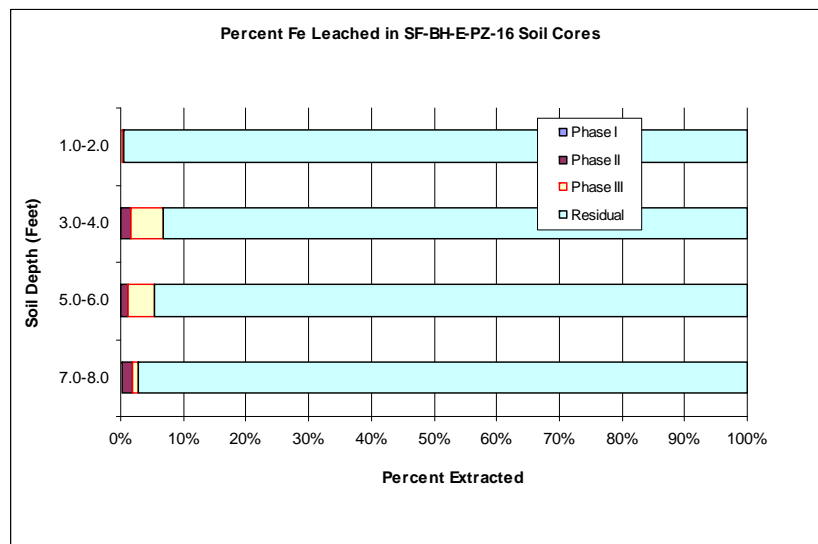
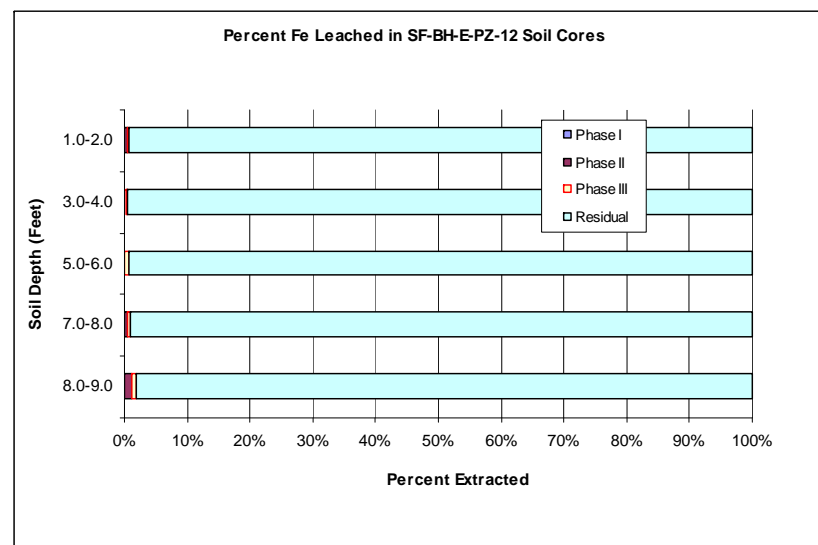
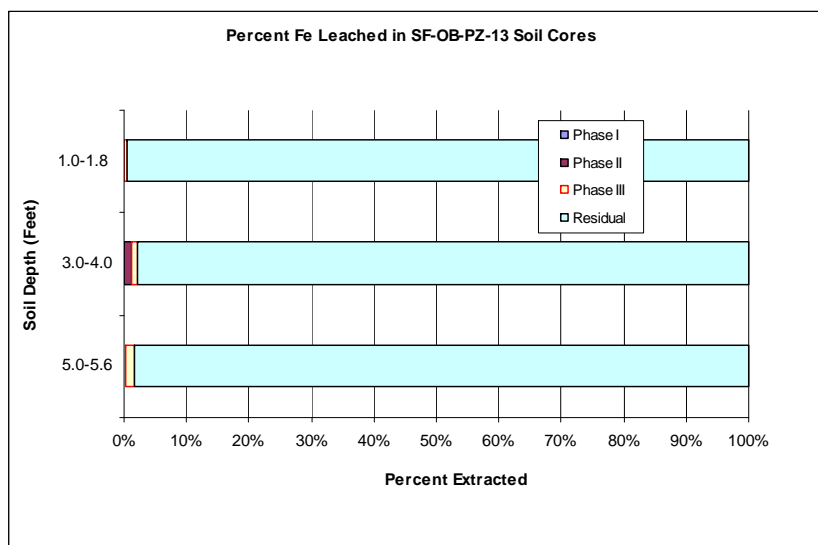


Figure 35. Iron released from the four locations during the sequential extraction.

2.2 Leach Tests

A series of leaching tests were conducted for each coring location to determine the effects of pH and redox potential on metal leachability. Core samples (only the <2 mm fraction) from each depth at each location were combined to form a single sample for that location. The different depth samples from each location were mixed to achieve a homogeneous soil sample for the set of leach studies conducted.

The leach studies were divided into two tests. The first leach test looked at the effect of pH on metal leaching. The second test compared leaching between soils exposed to oxygen atmosphere with wet/dry cycle then either leached with distilled water to represent rainwater under normal atmospheric conditions or simulated groundwater and no oxygen, simulating saturated subsurface conditions. Prior to beginning the tests, sediment from each location was sent to the EPA laboratory and the total metal concentrations were measured. Table 3 shows the concentrations of the elements of interest for the composited samples of each location. The following sections will present the results of these two tests.

Table 3. Total metal concentrations in sediments used in leach study.

Concentrations for Elements of Interest (mg/kg)									
Location	Cd	Ca	Fe	Pb	Mg	Mn	Se	Zn	S
SF-OB-PZ-13	31.4	939	57,800	7,550	1,110	5,860	3.5	5,310	2,630
SF-BH-E-PZ-12	103	2,630	117,000	82,400	4,080	12,000	3.5	21,100	19,000
SF-BH-E-PZ-16	34.0	2,350	95,300	5,240	2,950	7,430	3.4	7,710	12,600
SF-BH-E-PZ-24	13.7	34,600	98,300	3,070	3,900	10,600	3.5	9,960	4,510

2.2.1 pH Effect on Leaching

Homogenized soil from each of the four locations (SF-OB-PZ-13, SF-BH-E-PZ-12, SF-BH-E-PZ-16, SF-BH-E-PZ-24) was divided into 6 subsamples. Each subsample was exposed to simulated groundwater adjusted to one of 6 pH levels (pH 2, 3, 4, 5, 6, and 7) for a duration of 90 days. For each test, 50 grams of soil was mixed with 500 mL of the pH adjusted, simulated groundwater from each site (Table 2). The samples were sealed in an oxygen free environment and placed on a shaker at 120 rpm. For the first 30 days, the pH of each solution was monitored twice weekly and adjusted to maintain the required pH. After 30 days the samples were checked weekly to maintain pH levels (see Figures A-5, A-6, A-7 and A-8). Ten ml solute aliquots were collected at time 0, 8 hours, 16 hours, 24 hours, 3 days, 7 days, 1 month, 2 months, and 3 months. The samples were diluted to 20 mL with deionized water, acidified to less than pH 2 with concentrated nitric acid and shipped to an offsite laboratory for analysis. The following sections discuss the results for the conditions tested.

2.2.1.1 Core Location SF-OB-PZ-13

Figure 36 shows the effect of pH on cadmium leaching over time. The results show that as the pH is reduced, cadmium extraction and concentration in the solution increases. Figure 37 shows the effect of pH on lead leachability. There was an initial release of lead followed by a decrease over time in lead concentration due to precipitation of the lead with sulfates in the simulated groundwater except for the result at pH 7 (Pourbaix, 1974). Lead sulfides could also be formed if sulfate reducing bacteria are active. At day 60, the concentration was measured at 48,400 ug/L lead. The scale on the graph was held at a maximum of 30,000 ug/L to allow the reader greater detail in viewing the lower concentrations. For unknown reasons, the concentration of lead was highest at pH 7 at this location. One possible explanation is that the sediment at this location is not homogeneous and there was a higher lead concentration than in the other samples. Below pH 7, the concentrations behaved more as would be expected, with concentrations at pH 2 being higher than the remaining 4 pH levels and lead concentrations at pH 5 and 6

were lower than the other pH values. Zinc removal followed a pattern similar to cadmium, with lower pH resulting in higher concentrations of zinc in solution (Figure 38).

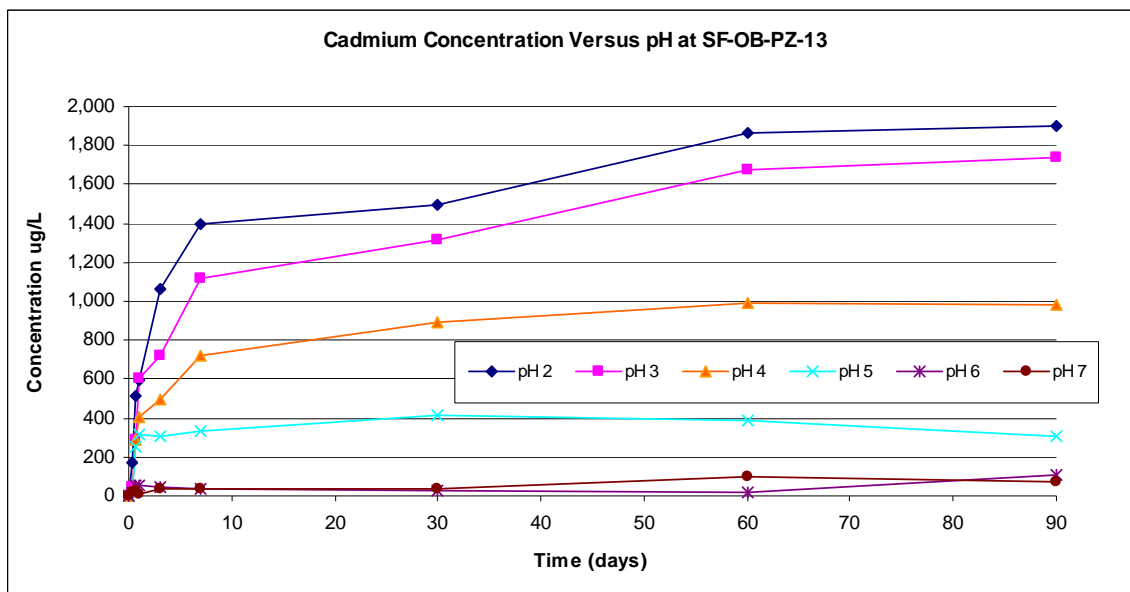


Figure 36. Effect of different pH on leaching of cadmium from sediment samples over a 90 day time interval.

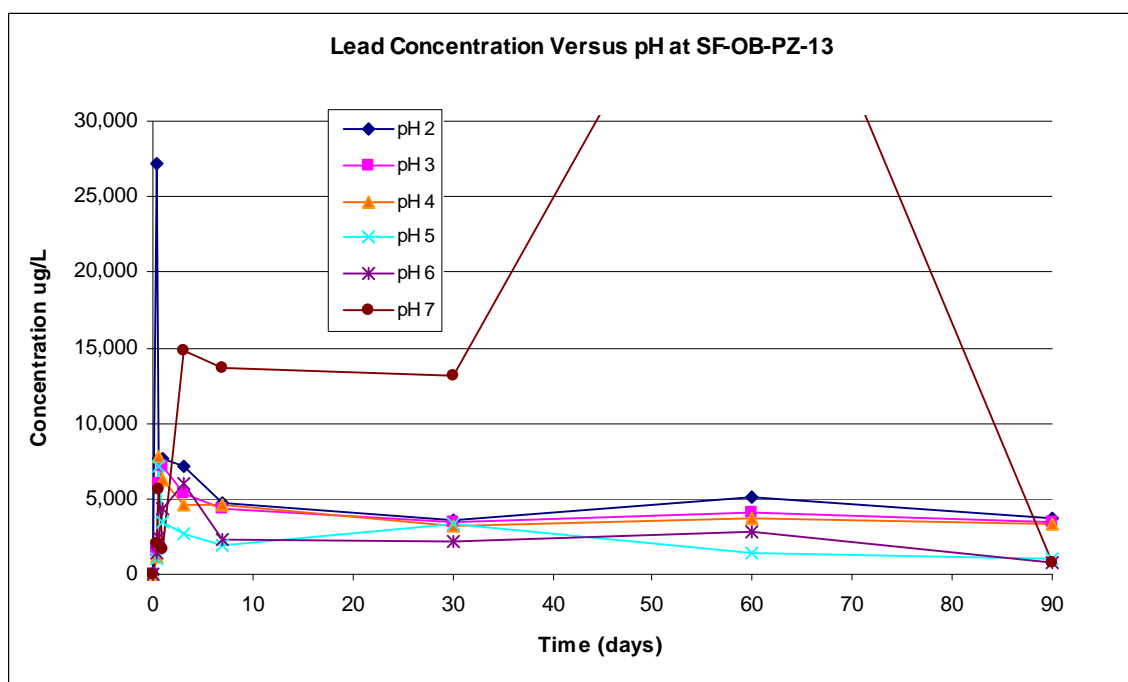


Figure 37. Effect of different pH on leaching of lead from sediment samples over a 90 day time interval.

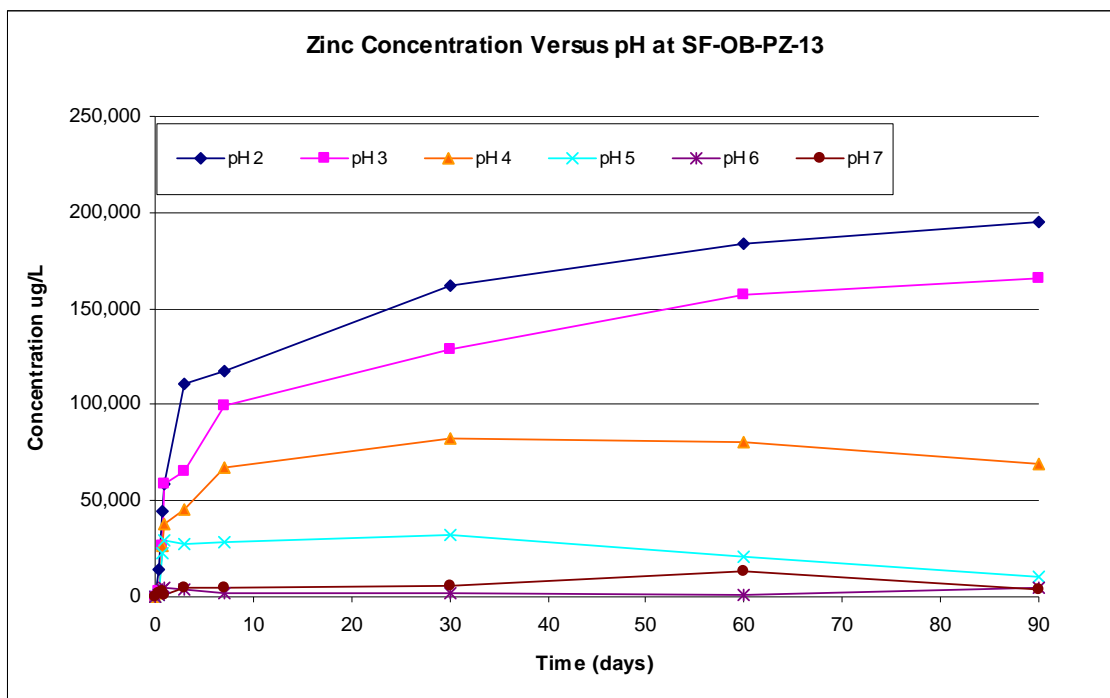


Figure 38. Effect of different pH on leaching of zinc from sediment samples over a 90 day time interval.

Iron remained fairly insoluble except at pH 2, and a slightly elevated extraction at pH 3 (Figure 39). The iron concentration at pH 2 continued to increase over time, which is typical of the release of iron from oxides/hydroxides under low Eh and low pH conditions. From Figure 40, it can be seen that sulfur removal also increases as the pH is reduced. The sulfur in the soil at this location may be in the form of an iron oxy/hydroxy sulfate or pyritic minerals, which, as conditions become more acidic, releases more sulfur (as sulfate) and iron into solution, which is supported by the data presented in Figures 39 and 40..

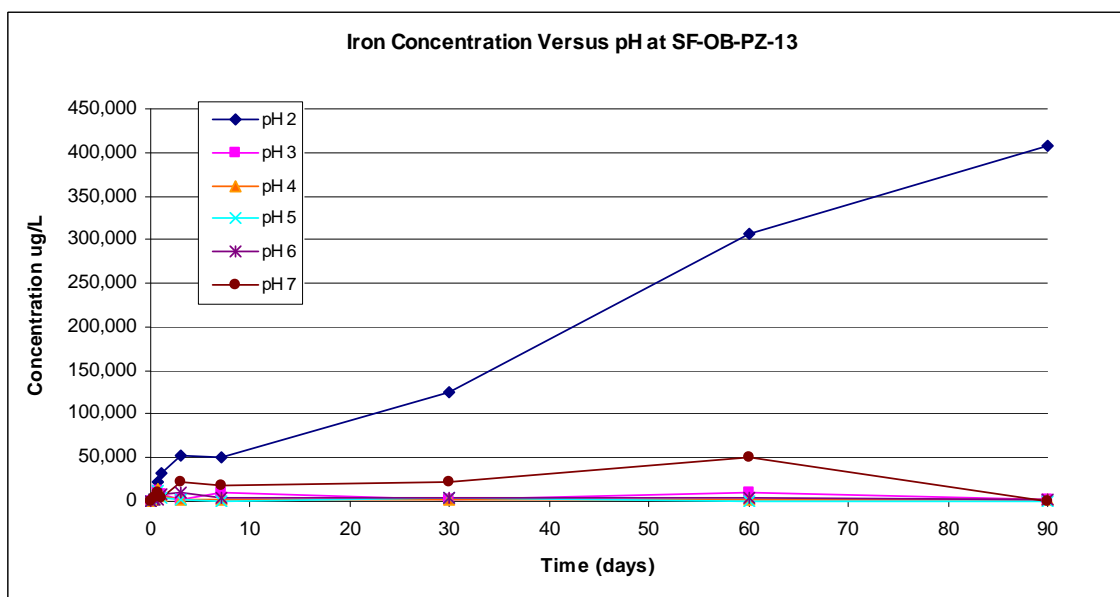


Figure 39. Effect of different pH on leaching of iron from sediment samples over a 90 day time interval.

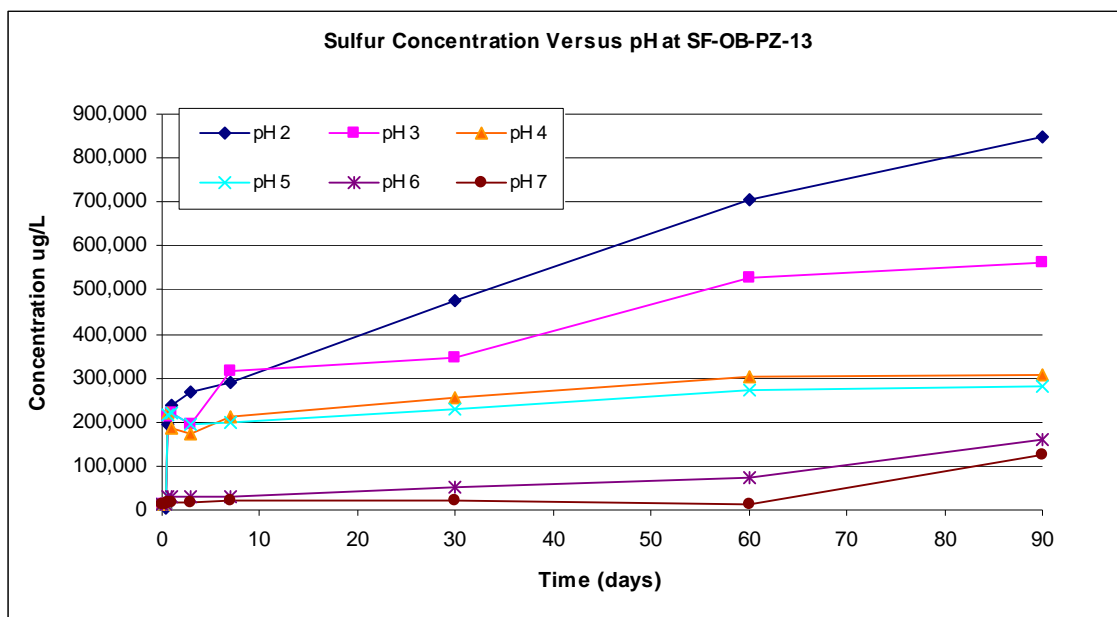


Figure 40. Effect of different pH on leaching of sulfur from sediment samples over a 90 day time interval.

2.2.1.2 Core Location SF-BH-E-PZ-12

The second location where core samples were collected was from the Southeast side of the CIA (Figure 1). Figures 41–45 show the concentrations of Cd, Pb, Zn, Fe, and S as a function of time and pH. All of these data show a similar trend: A decrease in pH results in an increase in ion release with time. As with the Osborn Flats sample, lead concentration in solution decreases over time, most likely due to precipitation lead with sulfate which is sparingly soluble (Pourbaix, 1974) present in the simulated groundwater. Iron and sulfur responded similarly to the Osborn Flats sediments.

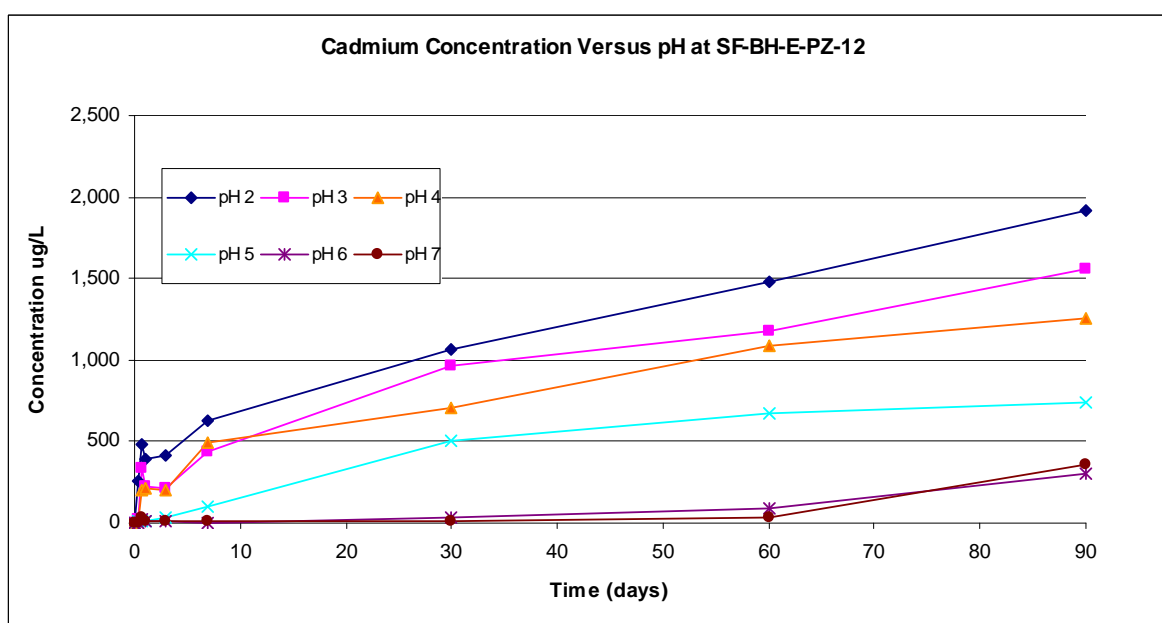


Figure 41. Effect of pH on cadmium concentration over time.

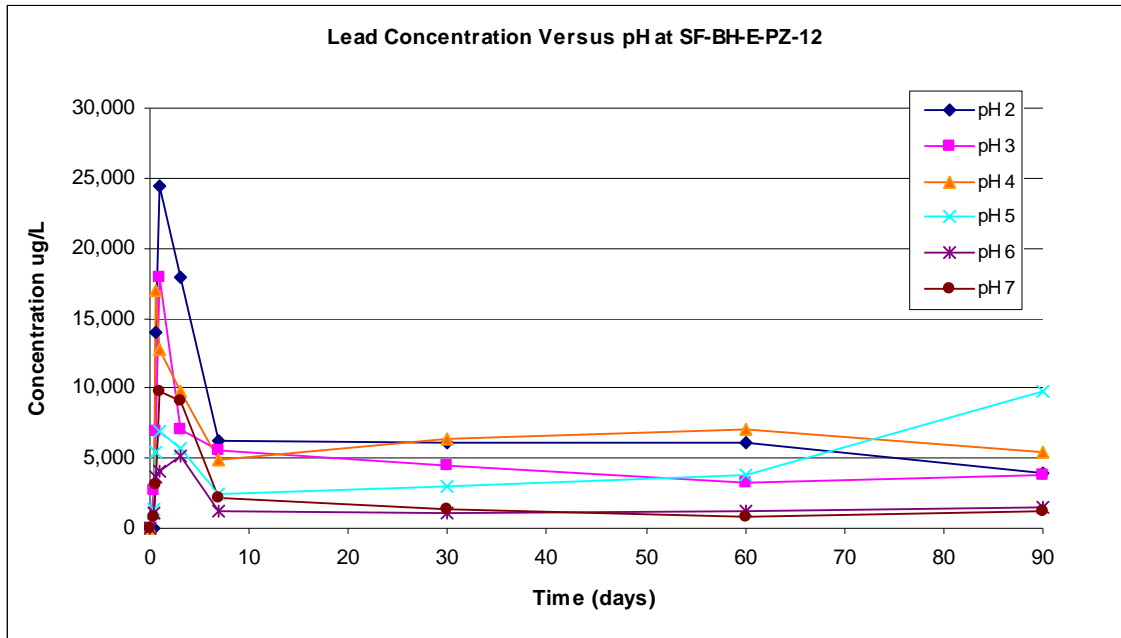


Figure 42. Effect of pH on lead concentration over time.

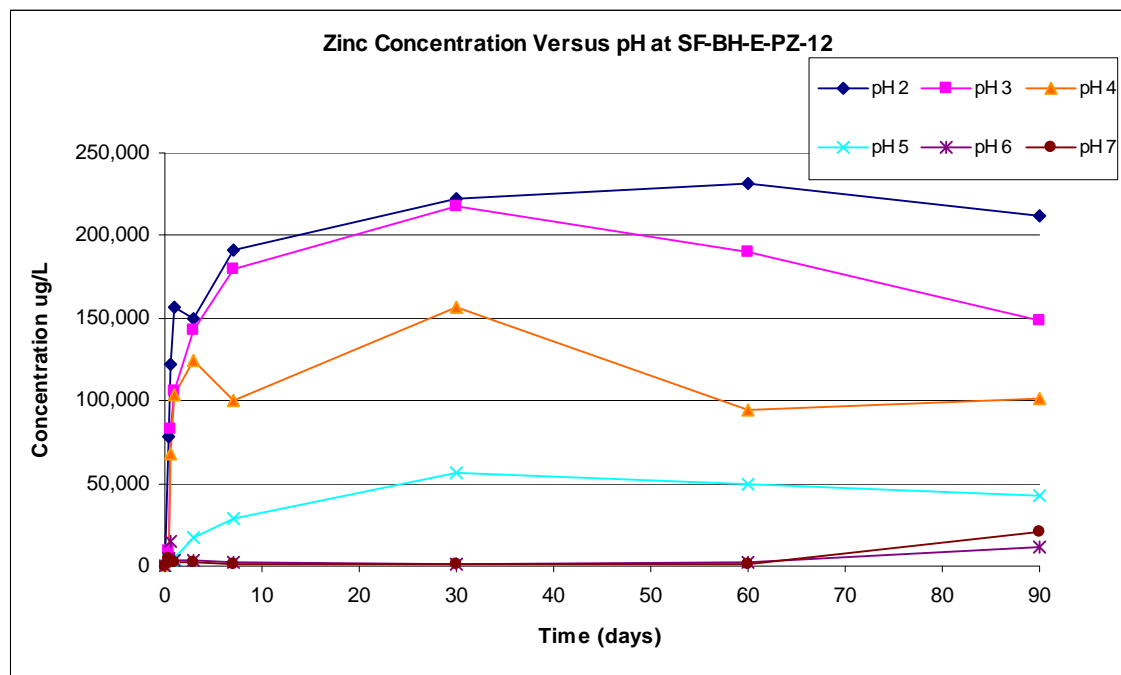


Figure 43. Effect of pH on zinc concentration over time.

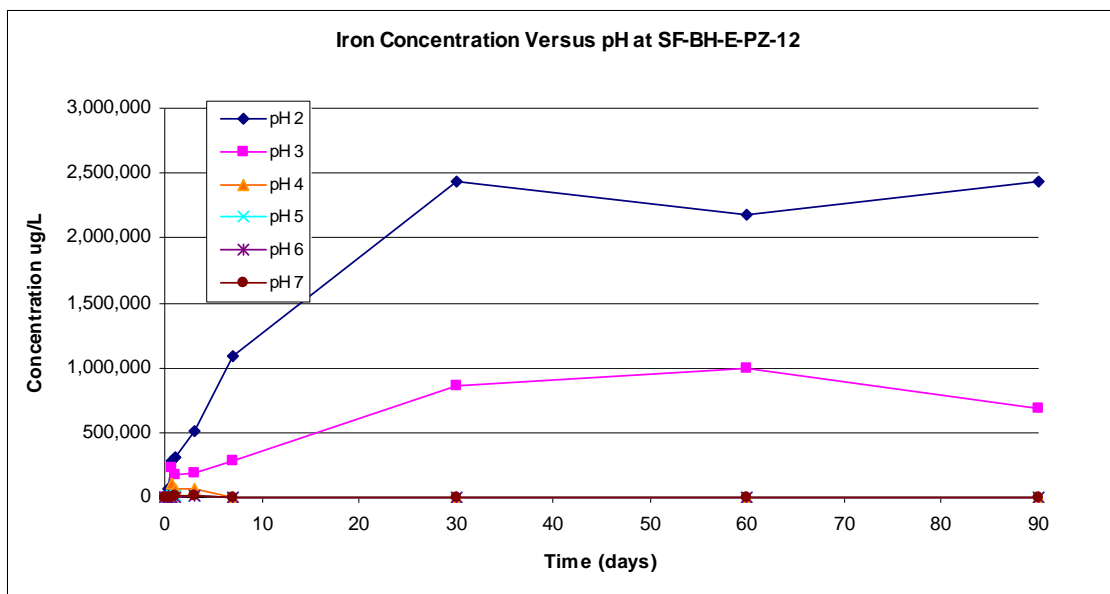


Figure 44. Effect of pH on iron concentration over time.

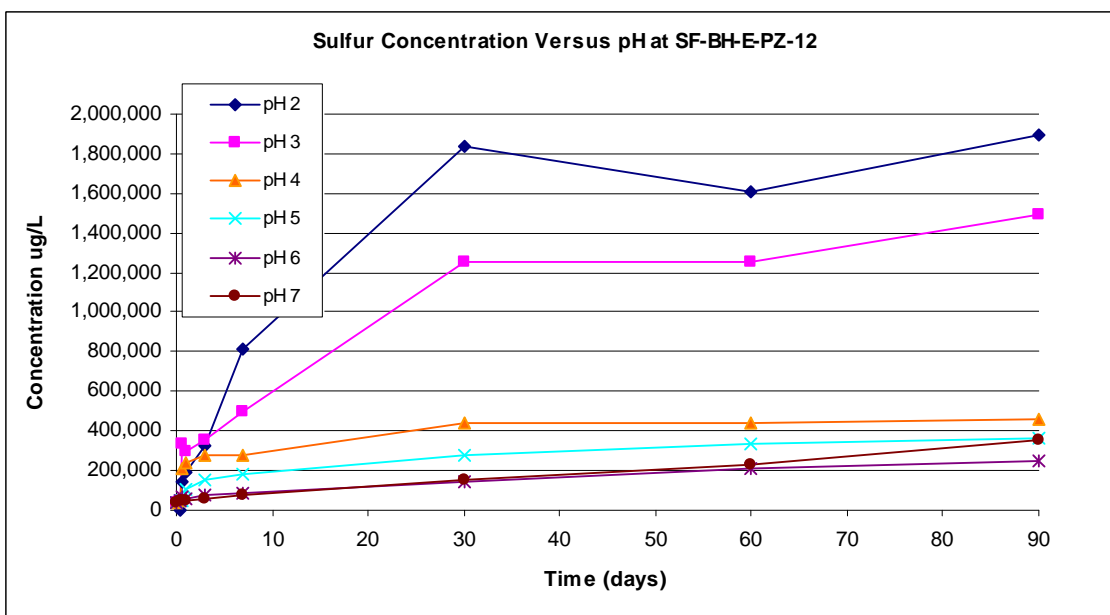


Figure 45. Effect of pH on sulfur concentration over time.

2.2.1.3 Core Location SF-BH-E-PZ-16

The third location where core samples were collected was from directly south of the CIA -- see Figure 1. Figures 46–50 show the concentrations of Cd, Pb, Zn, Fe, and S over time as a function of pH. The pattern of metal and sulfur extraction (and subsequent lead precipitation) follows a similar trend as the previous location (SF-BH-E-PZ-12), that is reducing the pH results in an increase in ion concentration in solution.

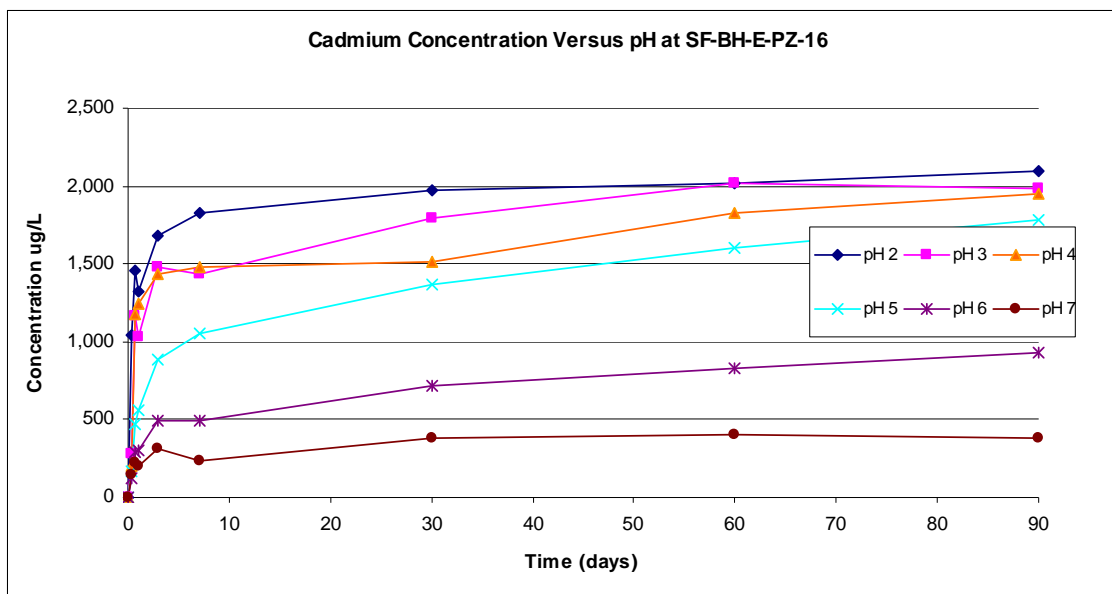


Figure 46. Effect of pH on cadmium concentration over time.

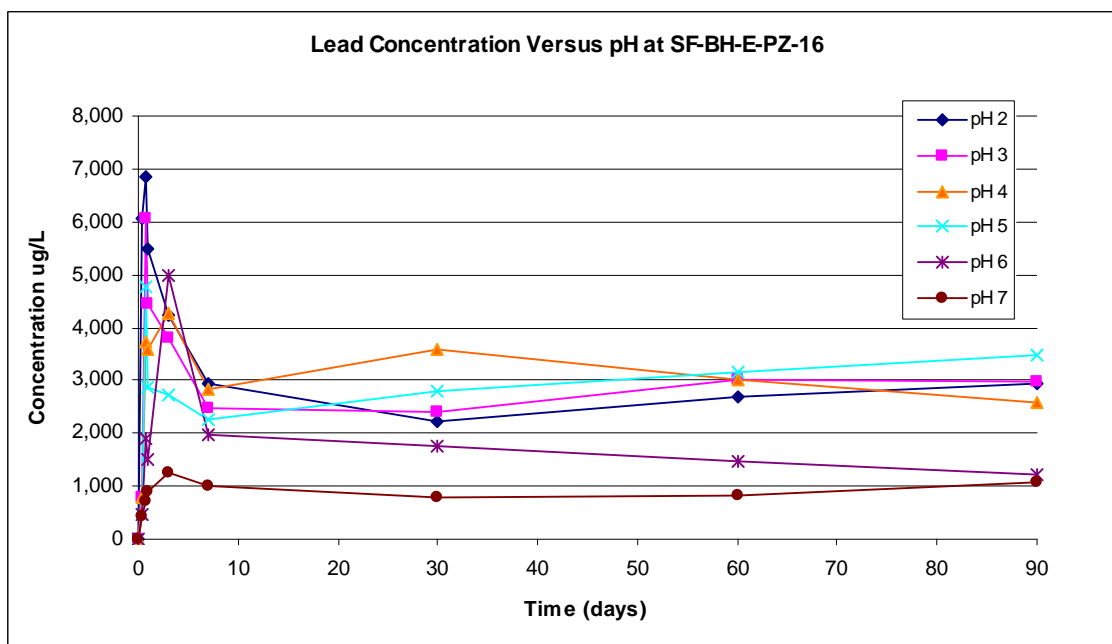


Figure 47. Effect of pH on lead concentration over time.

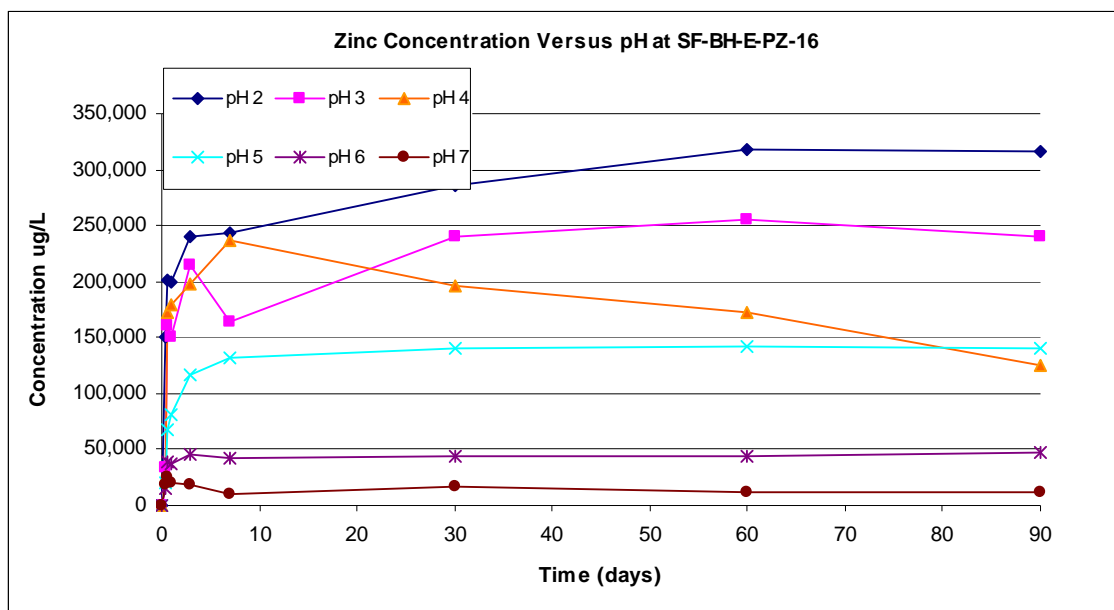


Figure 48. Effect of pH on zinc concentration over time.

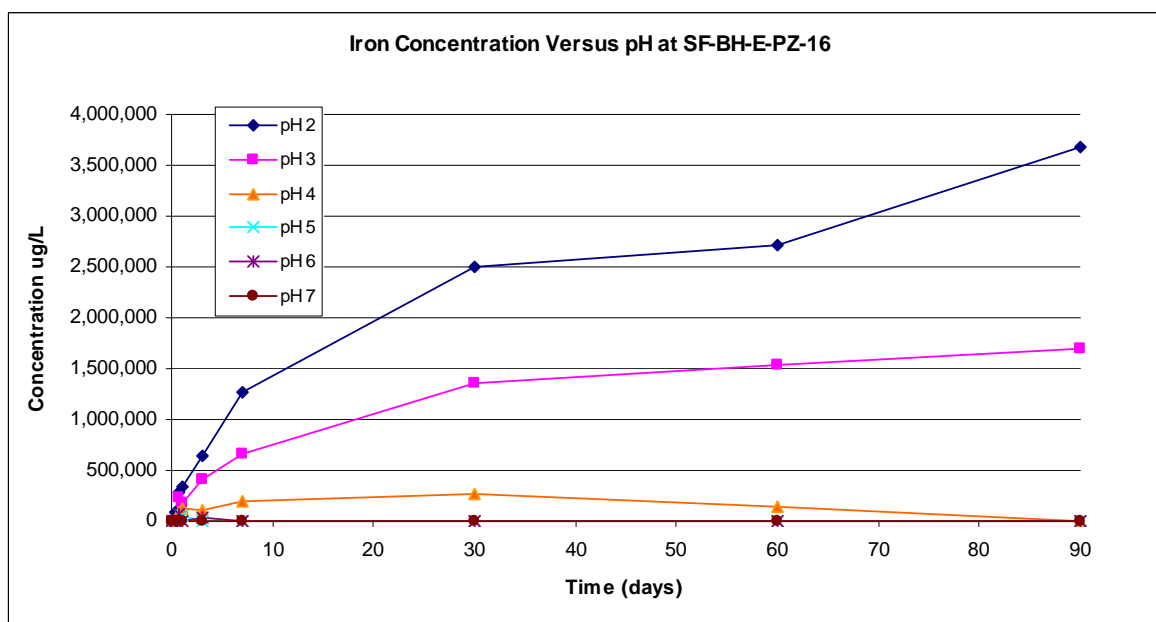


Figure 49. Effect of pH on iron concentration over time.

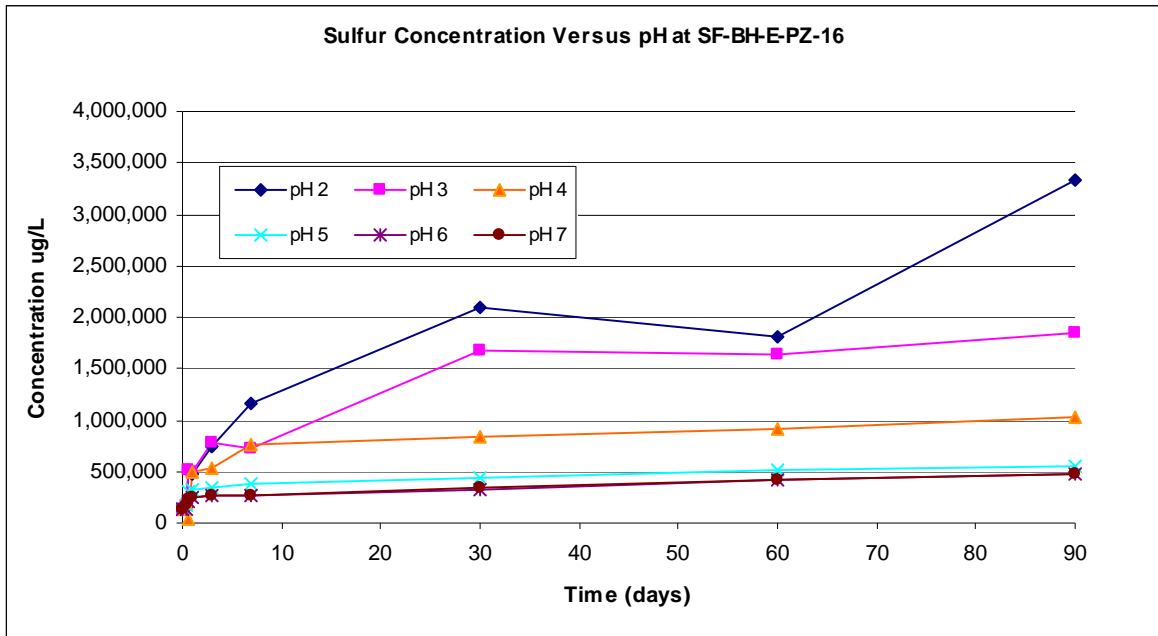


Figure 50. Effect of pH on sulfur concentration over time.

2.2.1.4 Core Location SF-BH-E-PZ-24

The final location where core samples were collected was from the west side of the CIA—see Figure 1. Figures 51–55 show the concentrations of Cd, Pb, Zn, Fe, and S as a function of time and pH. The leaching trends of these elements from this location also are similar to the previous CIA locations. Based on the trends from previous locations, it appears that the pH 2 and 3 samples on day 60 mislabeled prior to analysis. On the figures presented below, the data points for pH 2 and pH 3 for day 60 were swapped on each graph to represent what was believed to be the correct values, as it appeared that they were switched before the analysis of the samples. Also the value for the pH 2 day 90 was 2500 ug/L. The scale for the graph was kept at 1500 ug/L to give more detail to the lower concentrations. Like the other leach tests, as the pH is reduced the concentration of the ions of interest increases. The metals of interest at this location were more stable at pH values 5 and higher. The concentrations of the cadmium and zinc showed little change until the pH dropped to 4 or less. Iron concentrations changed very little until the pH dropped to 2.

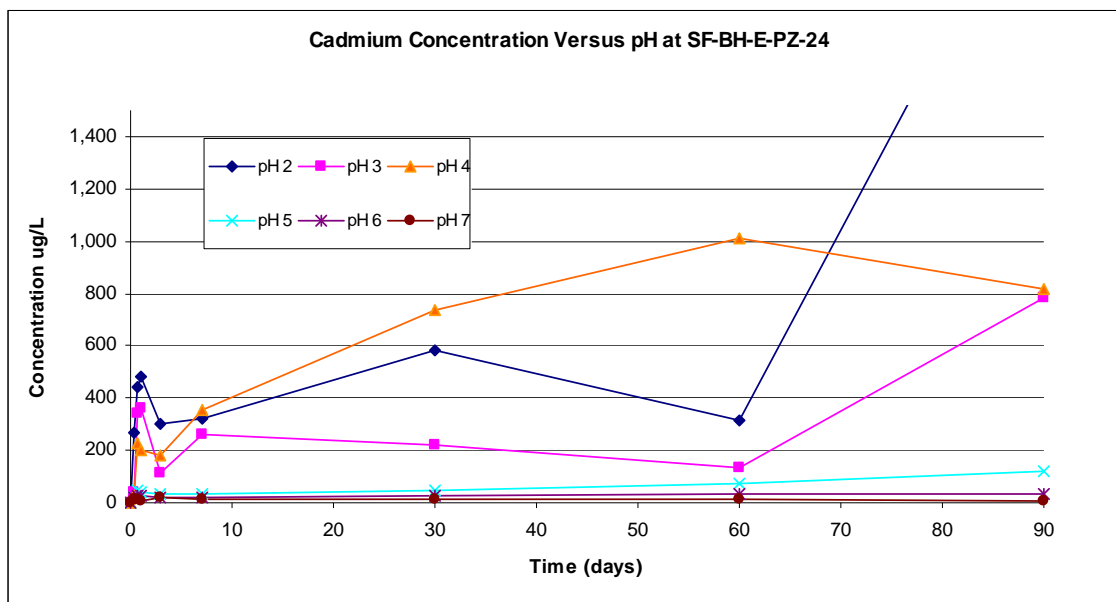


Figure 51. Effect of pH on cadmium concentration over time.

* Day 60 for pH 2 and pH 3 were switched.

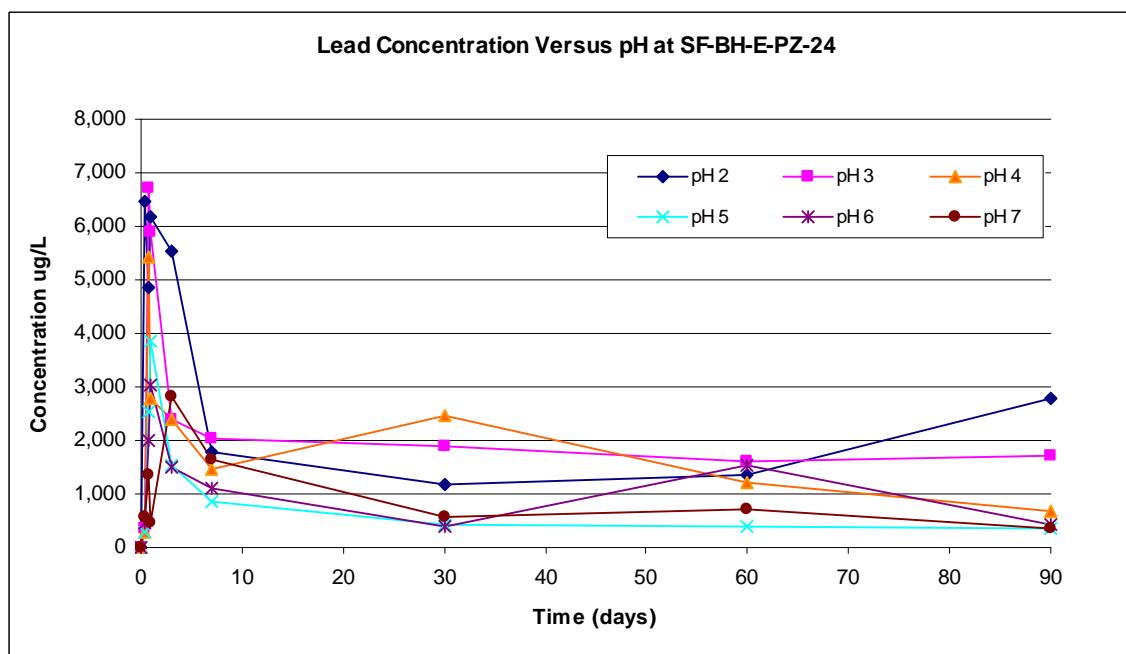


Figure 52. Effect of pH on lead concentration over time.

* Day 60 for pH 2 and pH 3 were switched.

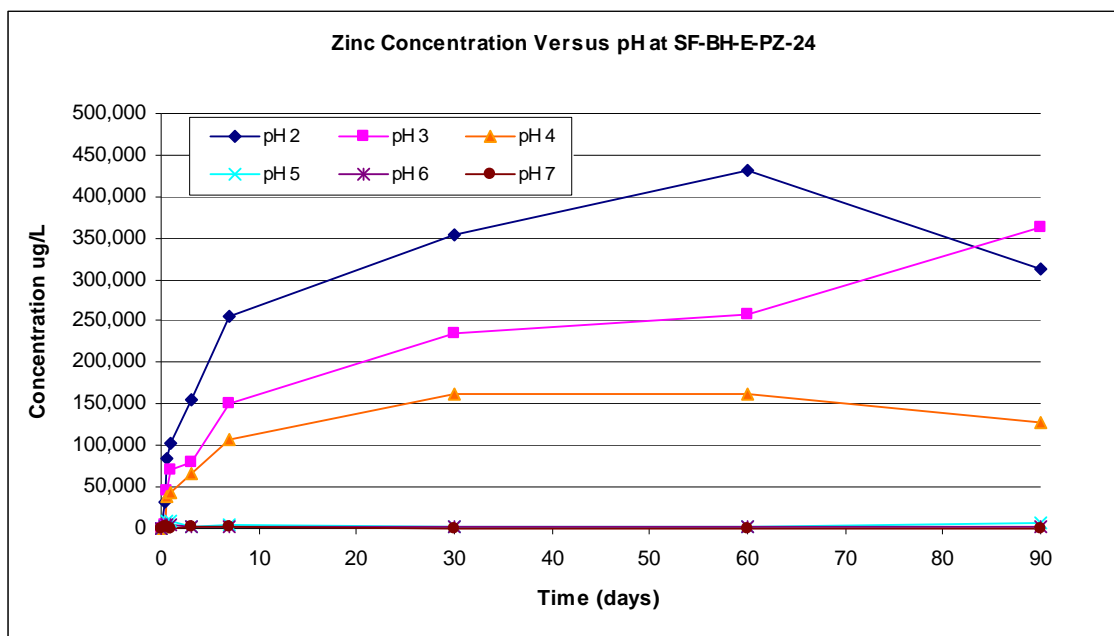


Figure 53. Effect of pH on zinc concentration over time.

* Day 60 for pH 2 and pH 3 were switched.

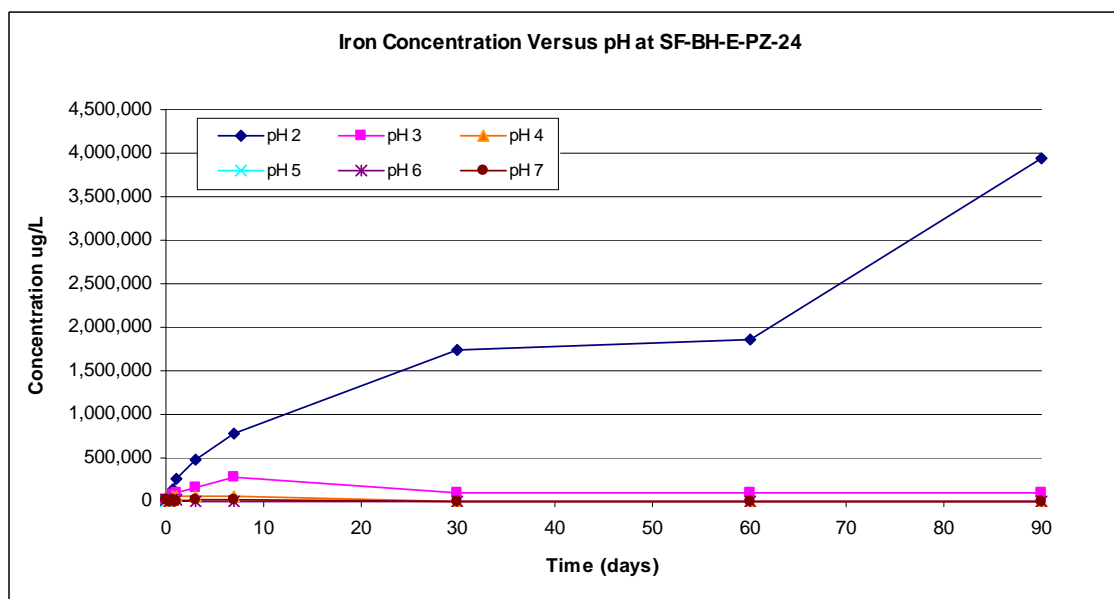


Figure 54. Effect of pH on iron concentration over time.

* Day 60 for pH 2 and pH 3 were switched.

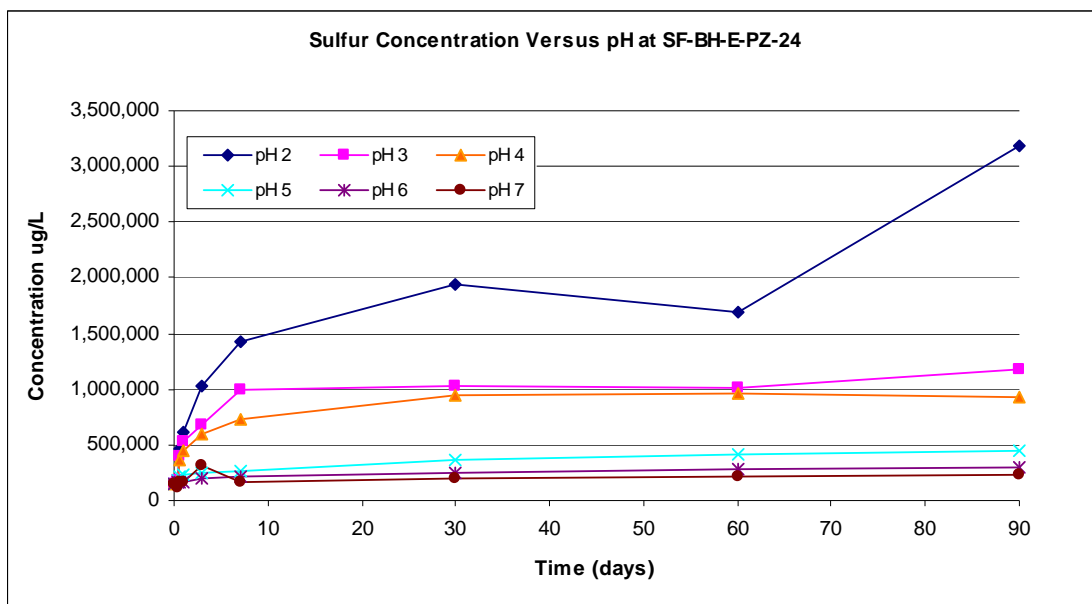


Figure 55. Effect of pH on sulfur concentration over time.

* Day 60 for pH 2 and pH 3 were switched.

2.2.2 Effect of Aerobic or Anoxic Conditions on Metal Leaching

This test consisted of two treatments. Both treatments received a two week wet/dry cycle under aerobic conditions. In the first treatment, 50 grams of soil was mixed with 500 mL of the simulated rainwater (deionized water) and mixed for the duration of the study. The soil and solution was exposed to the atmosphere during the 90 day test. Under the second treatment, 50 grams of soil was mixed with 500 mL of the simulated groundwater and mixed for the duration of the study, but in this case the samples were maintained in oxygen free environment. Leachate samples were collected at time 0, 8 hours, 16 hours, 24 hours, 3 days, 7 days, 1 month, 2 months, and 3 months. The pH was monitored, but not altered. The sample size collected was 10 mL. The 10 mL samples was diluted to 20 mL with deionized water, acidified to less than pH 2 with concentrated nitric acid and shipped to an offsite laboratory for analysis. The following graphs show the metal concentrations for the conditions tested. To compare the effect of the wet/dry cycles (oxygenated soils) with leaching under anoxic conditions, data from the leaching tests from the previous section where pH effect was studied under anoxic conditions was added. For each graph below a third line was added that shows the metal concentration under anoxic conditions for the pH that this soil stabilized at in this leach test. The pH was selected based on the steady state pH of the sediments being tested in this leach test (Figure A-5). For the location SF-OB-PZ-13 below, the pH tended to be closest to pH 5. So the cadmium concentration from the previous leach study versus pH (at pH 5) for this location was added onto the graph. The same procedure was done for each of the other consecutive graphs.

2.2.2.1 Sample Location SF-OB-PZ-13

The cadmium concentrations at this location did not show significant differences between the sample exposed to oxygen continuously and those maintained in an oxygen-free environment (Figure 56). There was an initial small spike of cadmium released, which was then followed by steady concentration for the remainder of the test. While other factors certainly impact this as well, the effect of the two-week wetting/drying cycle significantly reduced the amount of cadmium released when compared to the release of cadmium from the soil that was not exposed to the wet/dry cycles or oxygen.

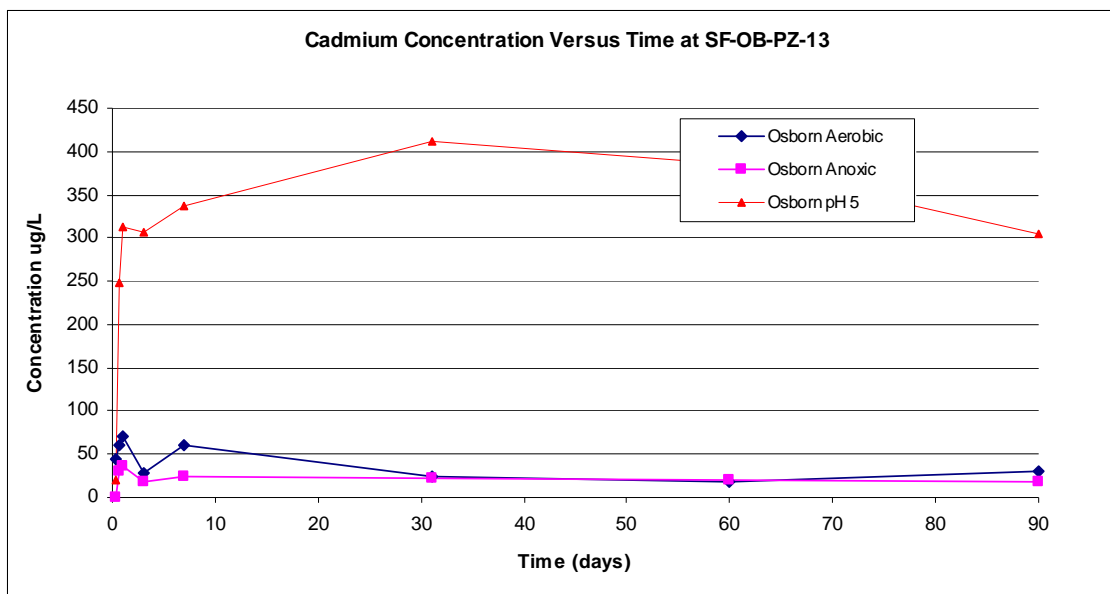


Figure 56. Effect of aerobic and anoxic conditions on cadmium concentration over time.

The concentration of lead in the pH leach test at pH 5 was similar to the lead concentrations from this redox leach test; however, the oxygen free sample resulted in slightly lower lead concentrations over time and the distilled water oxygenated sample release more lead than both (Figure 57). As with the cadmium, there was an initial release of lead from the wet/dry cycle which then precipitated out of solution over time. The zinc concentrations leached from the two samples were similar to the pattern seen for cadmium (Figure 56 and 58). Again, there was not a significant difference between zinc released from the aerobic sample versus the anaerobic sample. But the amount of zinc released from the pH 5 study showed higher release rates than the two tests conducted following the wet dry cycle.

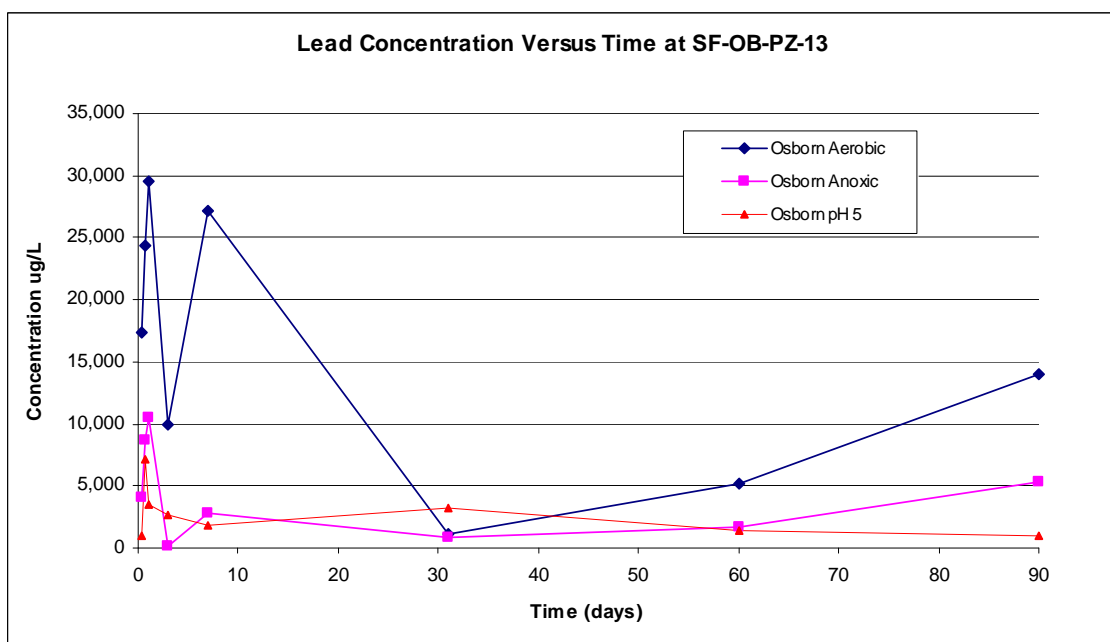


Figure 57. Effect of aerobic and anoxic conditions on lead concentration over time.

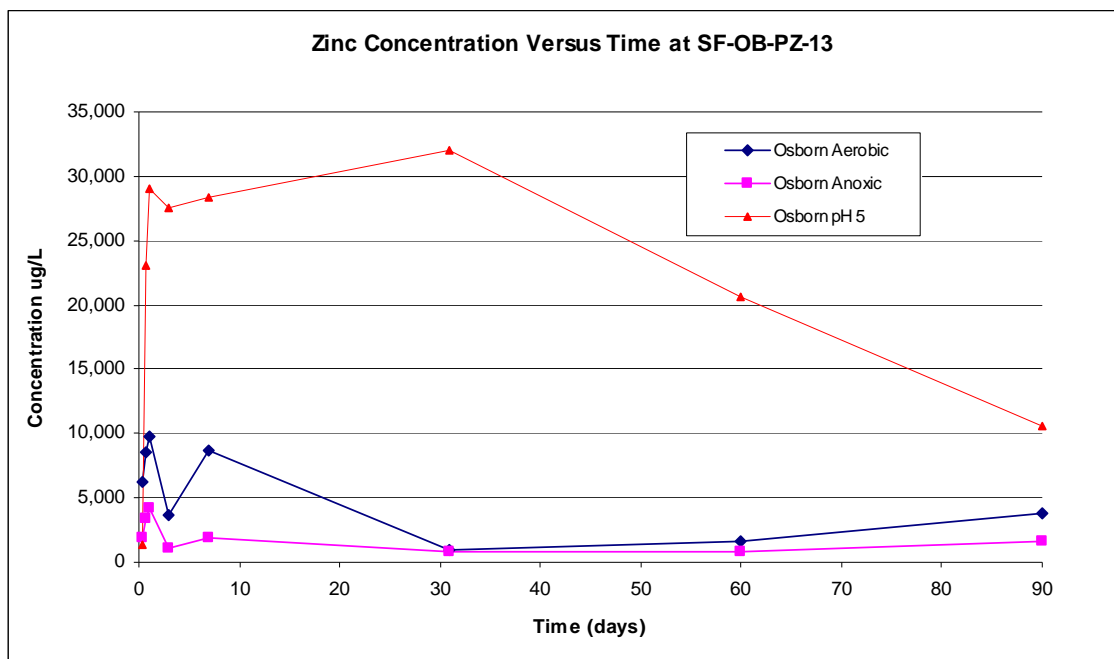


Figure 58. Effect of aerobic and anoxic conditions on zinc concentration over time.

The iron concentration spiked early due to the wet/dry cycling, but quickly fell to concentrations below 5000 ug/L (Figure 59). As the iron precipitated out, it would likely take with it the other metals also. This would also explain the drops in concentration of the other elements. Sulfur concentrations for this aerobic versus anoxic leach test reacted similarly to each other. The increased concentration in the subsurface sample was due to the presence of trace amounts of sulfur in the simulated groundwater (Figure 60). The sulfur concentration in the pH 5 leach test was much higher, but did not undergo a 2 week wet/dry cycle and was maintained in an oxygen free environment throughout the test.

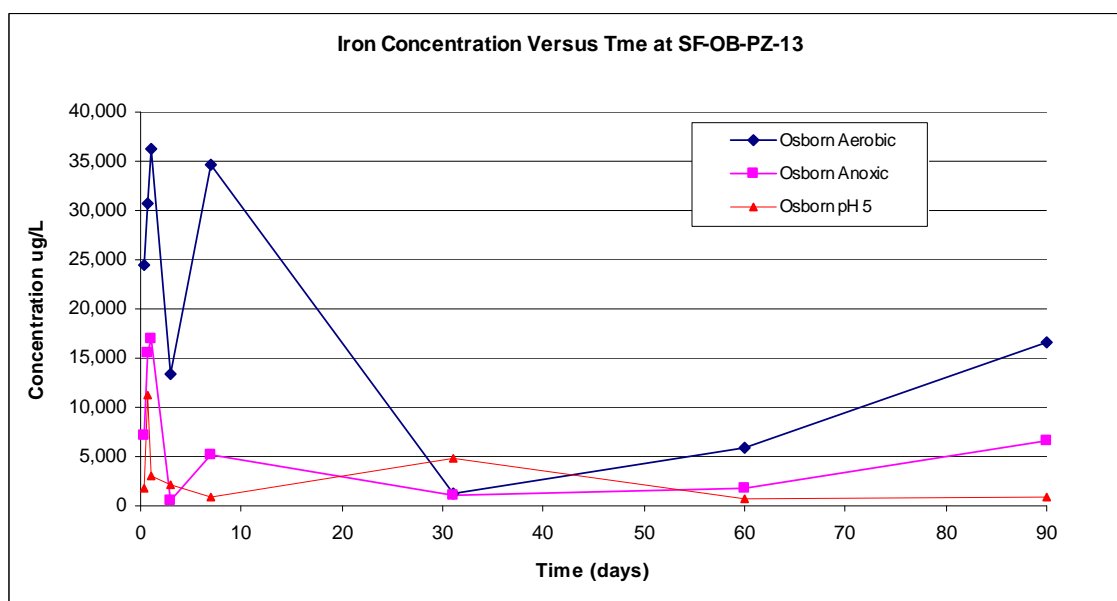


Figure 59. Effect of aerobic and anoxic conditions on iron concentration over time.

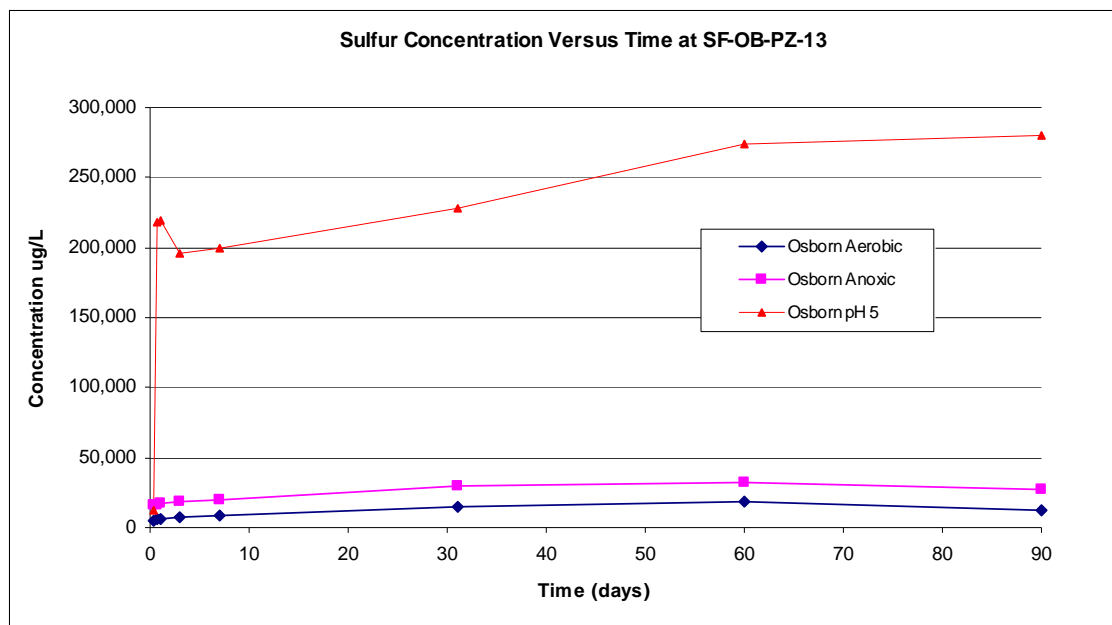


Figure 60. Effect of aerobic and anoxic conditions on sulfur concentration over time.

2.2.2.2 Sample Location SF-BH-E-PZ-12

This core location was located on the South East side of the CIA (Figure 1). Figures 61–65 show the concentrations of Cd, Pb, Zn, Fe, and S as a function of time. The samples were exposed to a two week wet/dry cycling followed by a 90 day leach test using deionized water for one treatment and simulated groundwater for a second treatment. For this location, the cadmium concentration increased significantly over time for the anaerobic sample, but to a much lower extent with the aerobic sample (Figure 61). At this location the pH of the solution stabilized near a pH of 5 (Figure A-6). The cadmium concentration from the anaerobic sample was also similar to the concentration of cadmium from the pH5 leach test. Under aerobic conditions, oxidized iron compounds will precipitate and also adsorb other elements, which could be the reason for the low concentration of cadmium in solution under aerobic conditions. Lead concentrations from both samples showed a similar pattern to the Osborn Flats samples (Figure 62), again most likely due to precipitation of lead over time as an insoluble oxides or sulfides. Like the other locations, there was an initial spike associated with the release of metals from the wet/dry cycle. This was followed by a sharp drop in concentration, then a slight increase over time.

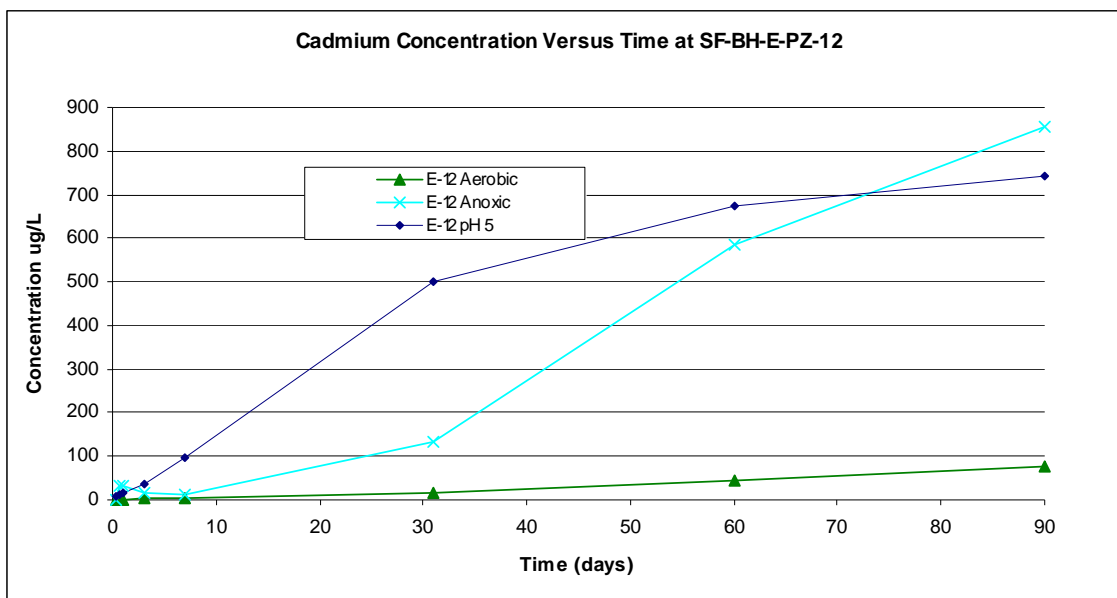


Figure 61. Effect of aerobic and anoxic conditions on cadmium concentration over time.

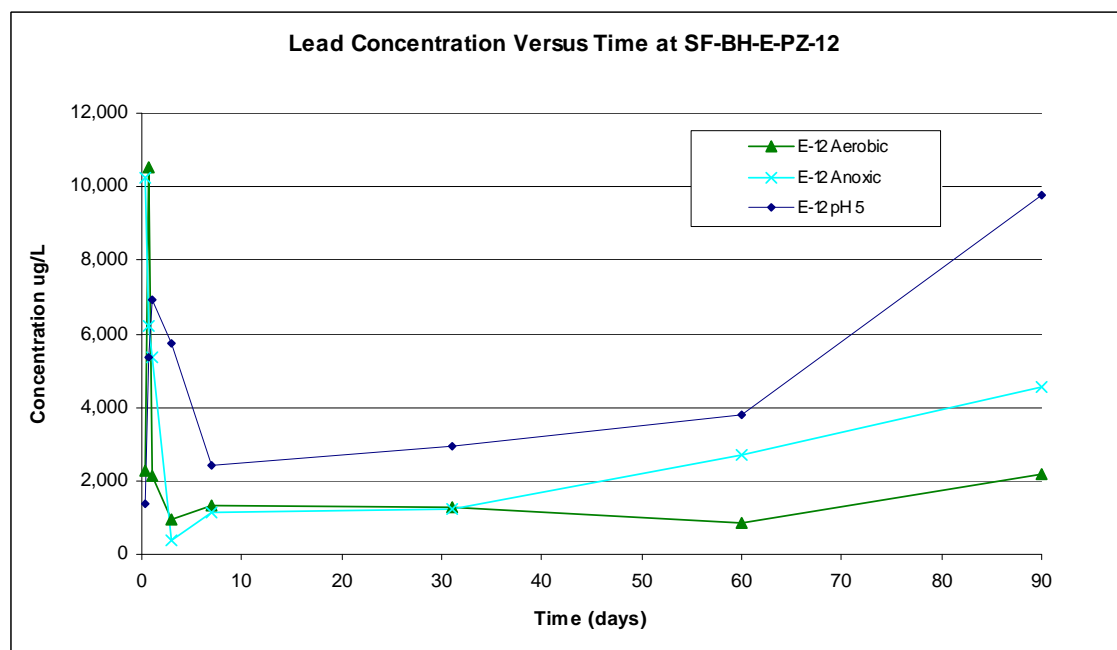


Figure 62. Effect of aerobic and anoxic conditions on lead concentration over time.

Zinc reacted similarly to cadmium at this location. For SF-OB-BZ-13 anaerobic pH 5 is high and wet/dry sample both show a small spike followed by a flat steady concentration in the leach solution. For SF-BH-E-PZ-12, the anaerobic pH 5 test steadily climbs, the groundwater test starts low and climbs, but is lower than pH 5 and the surface test is low and stays that way. The zinc concentration in the oxygen free samples continued to increase over time, while in the samples containing oxygen, the zinc concentration remained relatively constant. In the pH 5 treatment, the concentration of zinc increased more rapidly, but still achieved about the same overall concentration as the sample maintained in the oxygen free groundwater. In the pH 5 treatment, the sediments did not undergo the 2 week wet/dry cycle.

The iron did not react much differently regardless of whether oxygen was present during the leaching or not, but there was a spike during the first start of the leaching, primarily resulting from the wet/dry cycling.

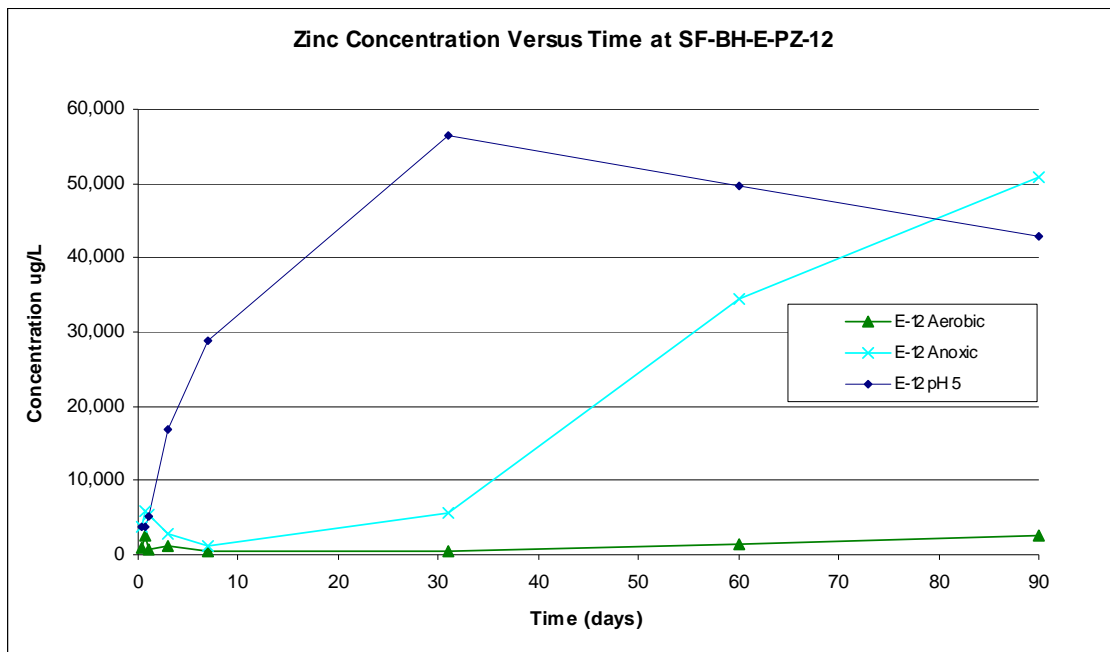


Figure 63. Effect of aerobic and anoxic conditions on zinc concentration over time.

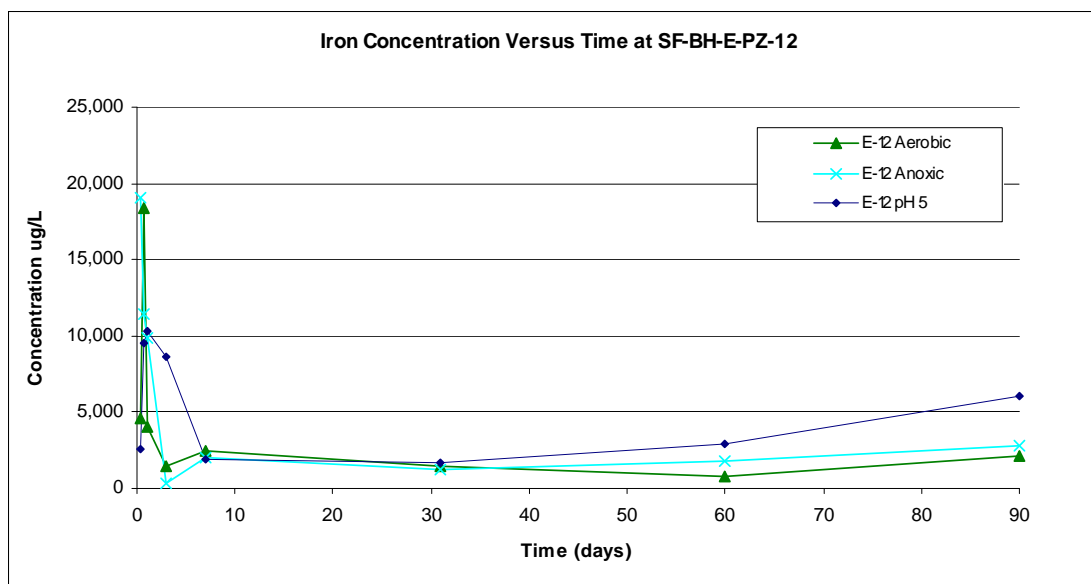


Figure 64. Effect of aerobic and anoxic conditions on iron concentration over time.

Sulfur concentrations reacted similarly to the previous location (Figure 65). The surface or oxygenated samples had the lowest release concentrations, and the pH 5 treatment and the oxygen-free

treatment had higher measured concentrations. Again it should be noted that sulfur was present in the simulated groundwater, but not in the simulated rainwater, which would account for the difference in concentrations.

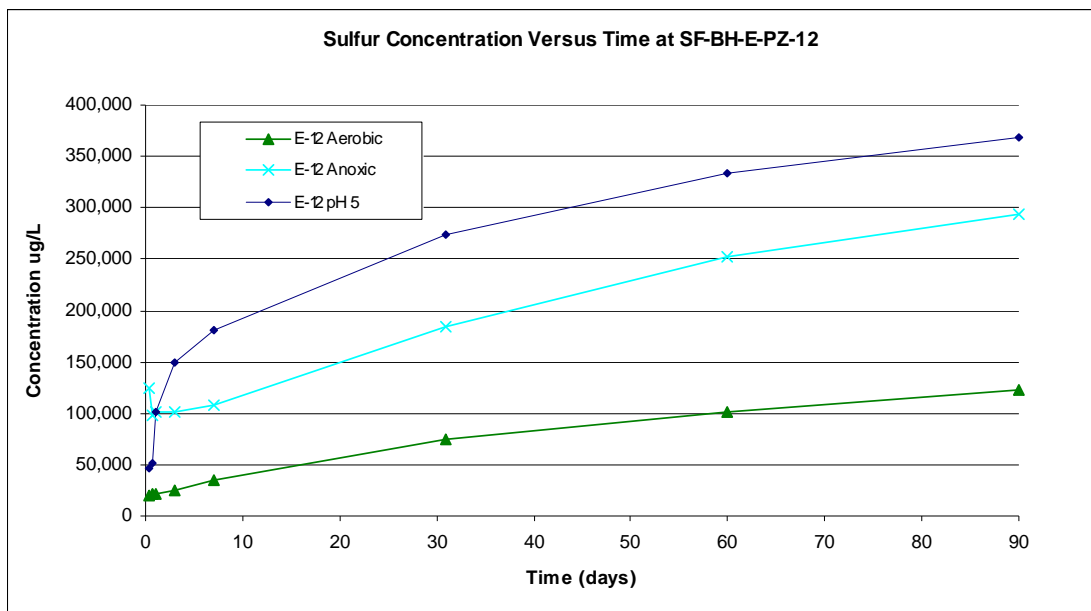


Figure 65. Effect of aerobic and anoxic conditions on sulfur concentration over time.

2.2.2.3 Sample Location SF-BH-E-PZ-16

There were no differences in cadmium concentrations at this location between the surface (oxygen present) sample and the subsurface (oxygen-free) sample. The pH 5 treatment increased more initially, but then continued to increase at the same rate as the other two treatments.

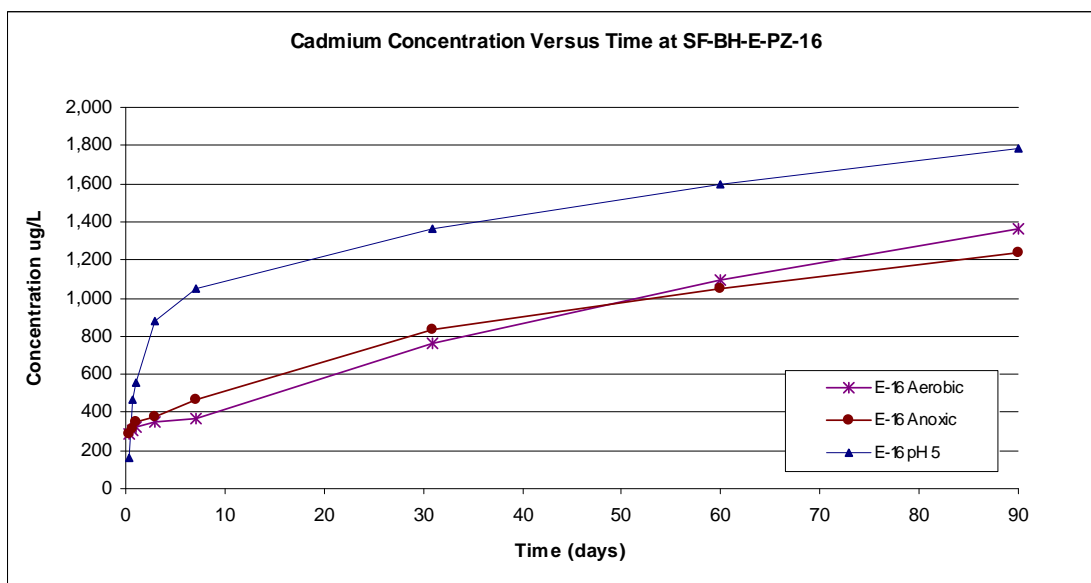


Figure 66. Effect of aerobic and anoxic conditions on cadmium concentration over time.

Lead responded similarly to the other locations, with an initial spike in concentration followed by a quick reduction in concentration. Very little difference was observed between the simulated surface and simulated subsurface treatments. The pH 5 treatment experienced the same types of lead concentration increase, although the overall concentration was higher than the surface and subsurface treatment (Figure 67).

Zinc also responded like the other metals at this location. The concentration continued to increase throughout the duration of the leach test. There were no differences in zinc concentrations at this location between the surface (oxygen present) sample and the subsurface (oxygen-free) sample. The pH 5 treatment increased more initially, but then continued to increase at the same rate as the other two treatments as with cadmium. There was more exchangeable lead and zinc at this location compared to the previous two locations measured during the sequential extractions. This would support the leach data here where more lead and zinc were leached than the other locations.

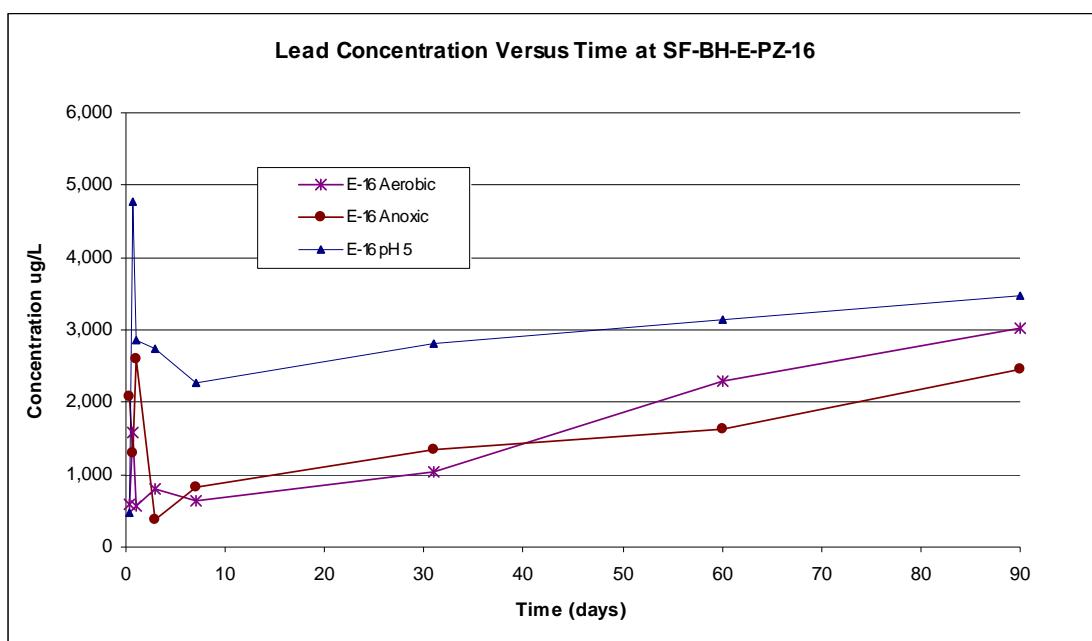


Figure 67. Effect of aerobic and anoxic conditions on lead concentration over time.

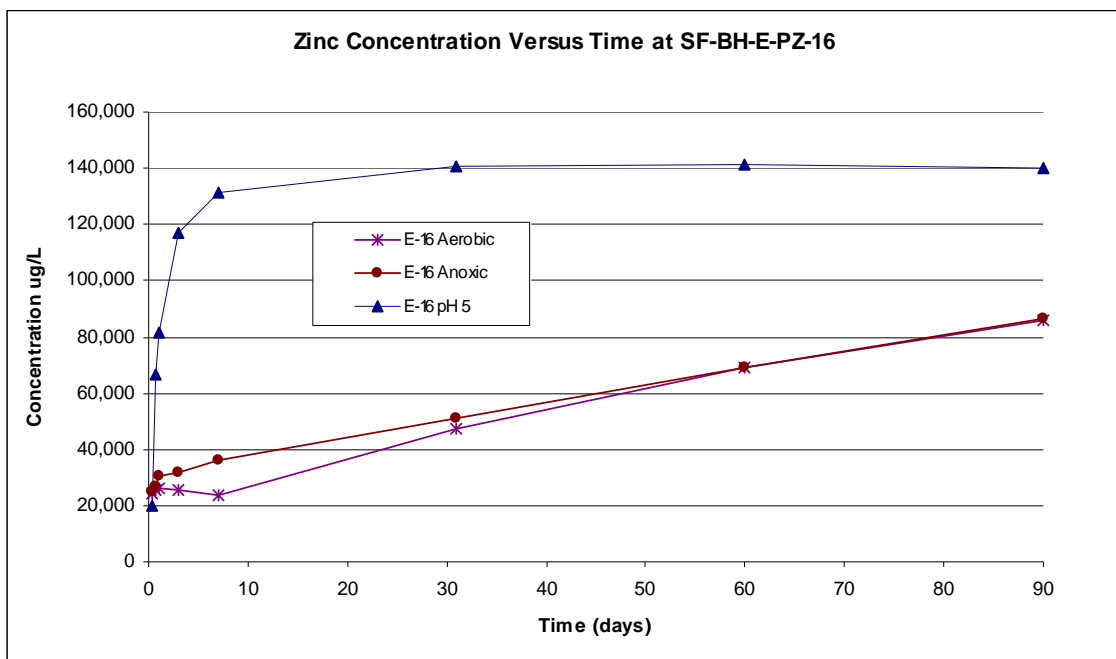


Figure 68. Effect of aerobic and anoxic conditions on zinc concentration over time.

Iron concentrations spiked initially, but dropped quickly and remained constant, which was consistent all locations, probably due to the higher pH. Any iron that is released is oxidized to ferric and is not stable above pH 2 (Figure 69). Sulfur concentrations responded in similar manner as the previous two locations also (Figure 70).

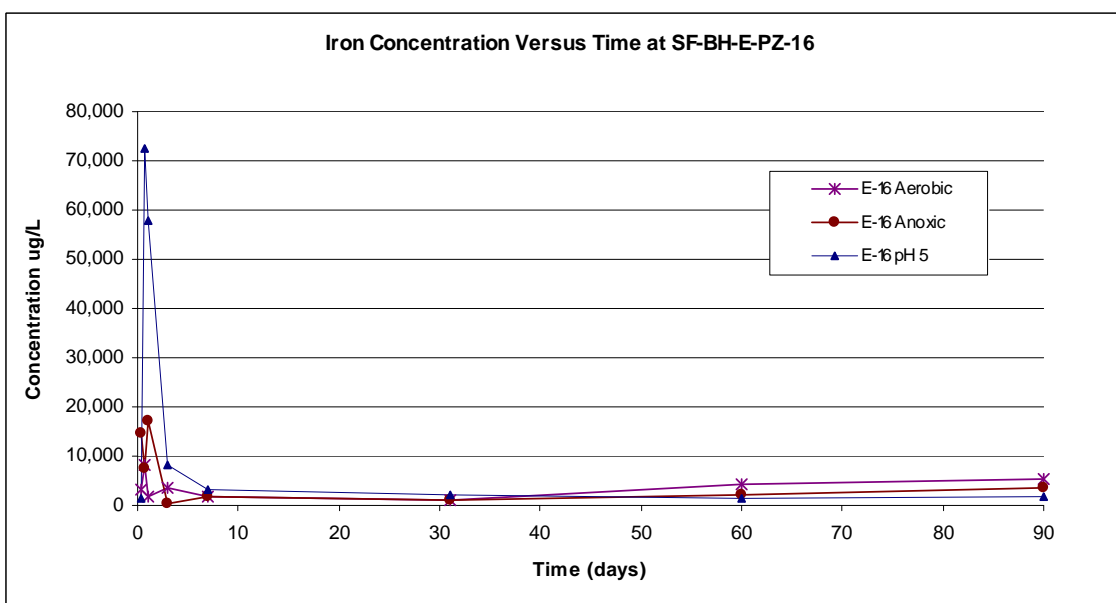


Figure 69. Effect of aerobic and anoxic conditions on iron concentration over time.

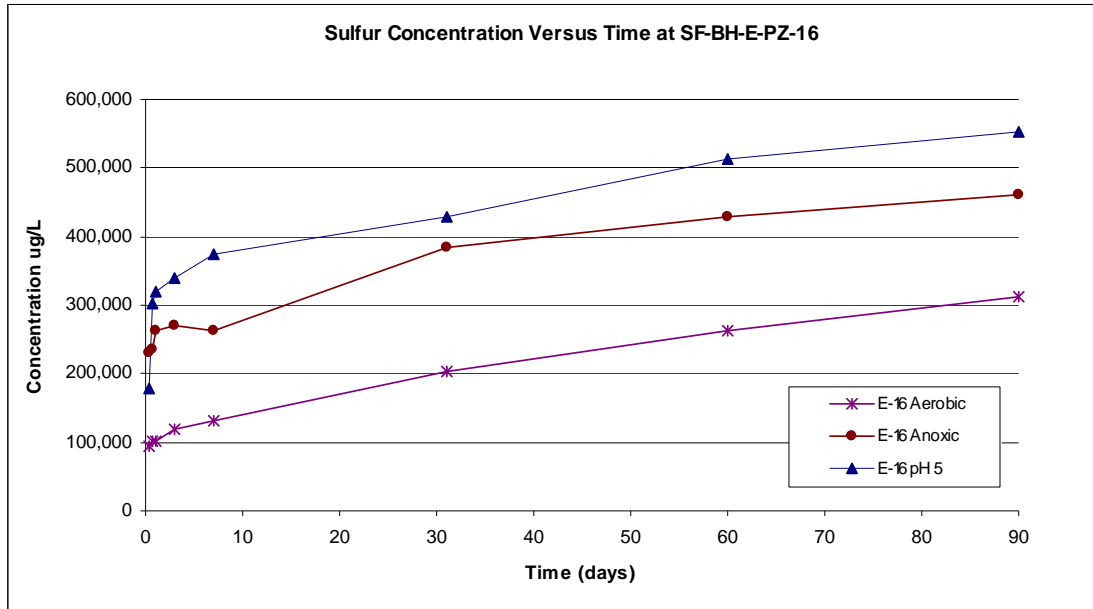


Figure 70. Effect of aerobic and anoxic conditions on sulfur concentration over time.

2.2.2.4 Sample Location SF-BH-E-PZ-24

Cadmium concentration at this last location did not increase over time like the cadmium concentrations at the previous CIA locations. A noticeable initial spike in cadmium concentration resulted from the wet/dry cycling prior to starting the leach test (Figure 71). The concentration of lead responded similarly to the cadmium concentration at this location (Figure 72).

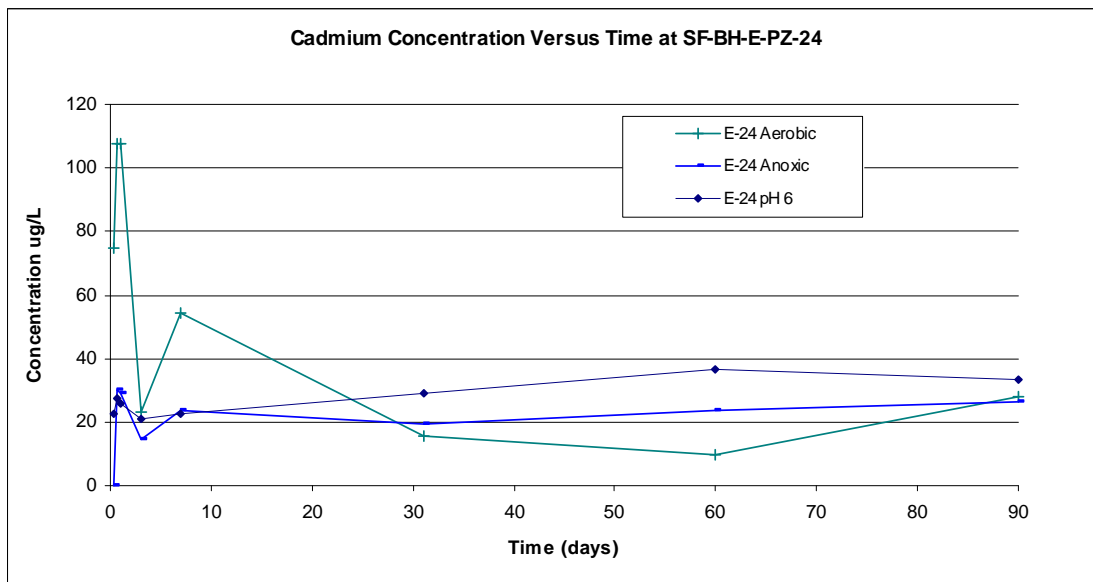


Figure 71. Effect of aerobic and anoxic conditions on cadmium concentration over time.

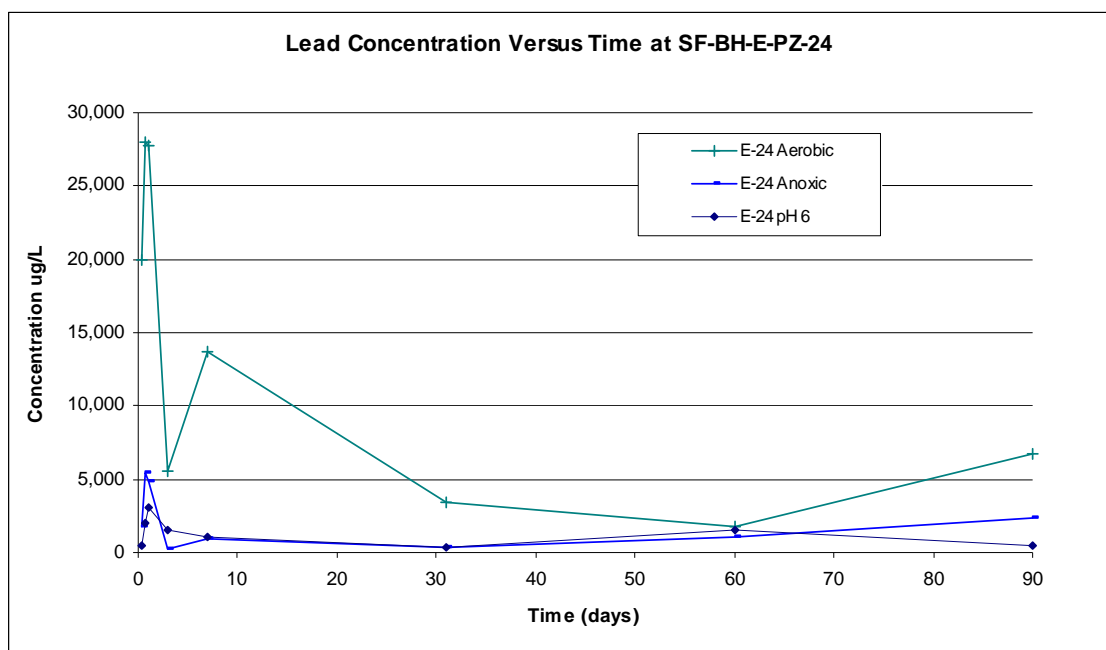


Figure 72. Effect of aerobic and anoxic conditions on lead concentration over time.

Zinc concentrations followed the same trend as cadmium and lead at this location. The initial concentration of zinc spiked early following the wet dry cycle then quickly precipitated out of solution and remained at a much lower concentration. This is likely due to a combination of the reaction of the elements with the constituents in the leach solution (simulated groundwater), the presence of high concentrations of other ions that were leached from solution, and the interaction with the iron in solution. Iron and sulfur reacted similarly to other locations.

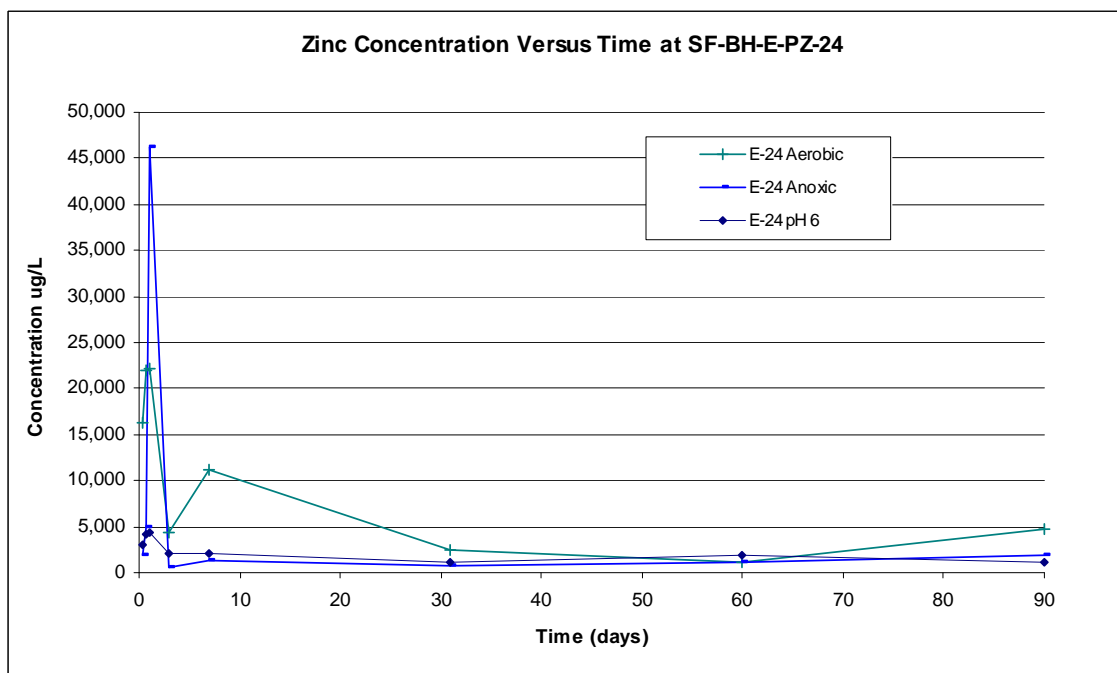


Figure 73. Effect of aerobic and anoxic conditions on zinc concentration over time.

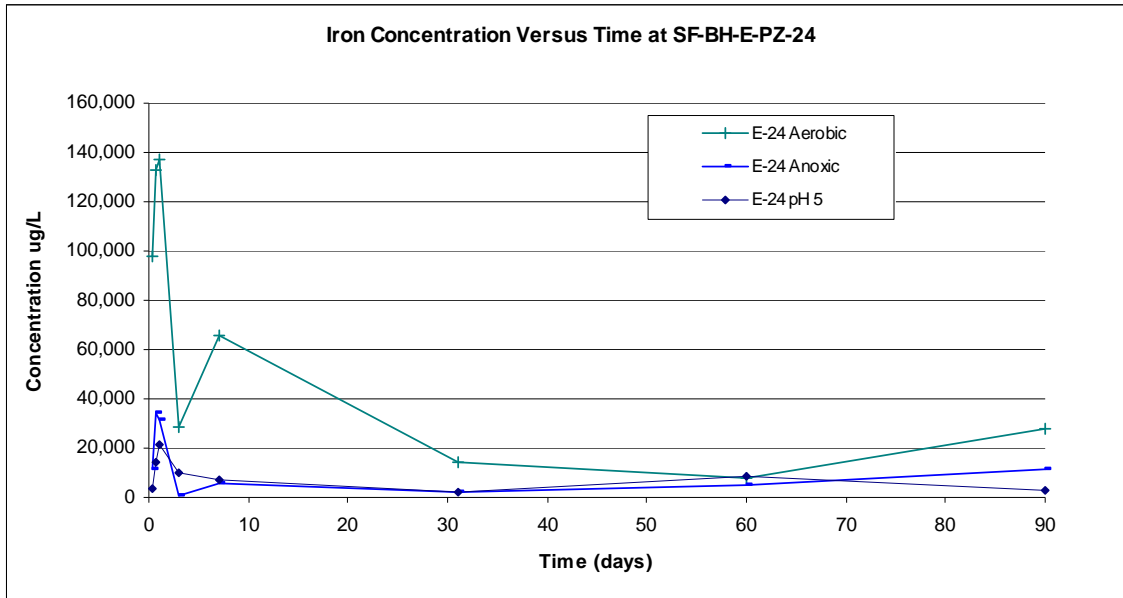


Figure 74. Effect of aerobic and anoxic conditions on iron concentration over time.

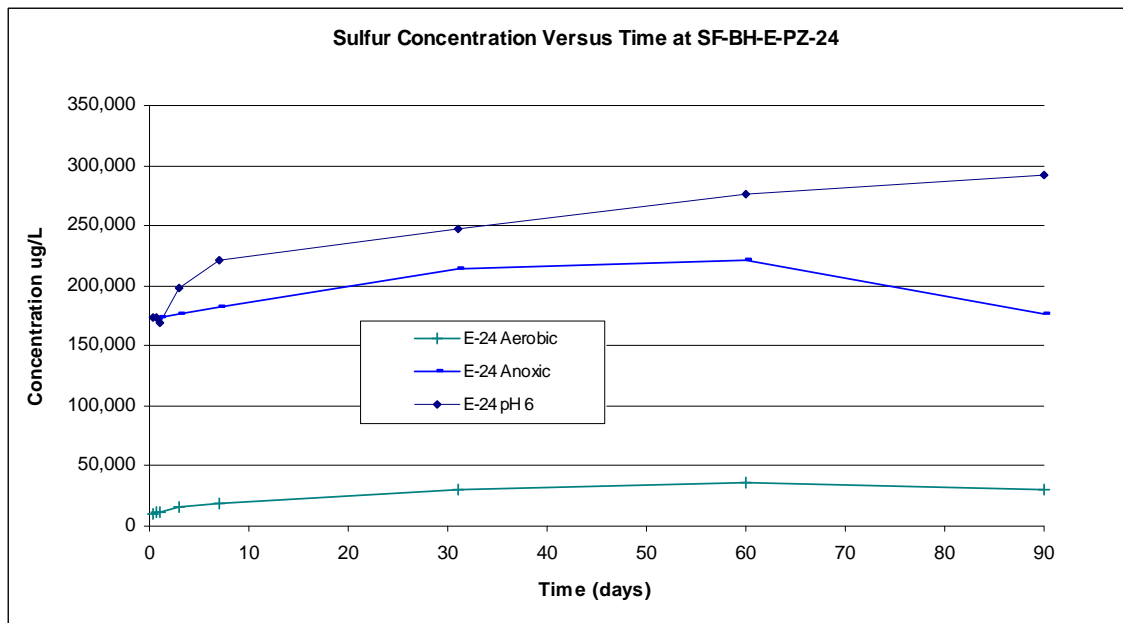


Figure 75. Effect of aerobic and anoxic conditions on sulfur concentration over time.

3. SUMMARY AND CONCLUSIONS

The results of the sequential extractions, pH leach study, and aerobic vs anoxic leach study have been presented above. This section summarizes the data collected at each location and provides additional interpretation where noteworthy conditions or results were found.

3.1 Sample Location SF-OB-PZ-13

The core for sample SF-OB-PZ-13 was taken in the Osborn Flats area. This section summarizes the data generated from the sequential extractions, pH leach studies, and aerobic/anoxic leach studies. Figure 76 shows the total cadmium, lead, and zinc concentrations at this location. Note that the total concentrations were only measured in the soil fraction less than 2 mm. The cadmium, lead, and zinc concentrations were highest at the surface and lowest in the 3-4 foot depth. All three metals presented followed a similar trend, although the total concentrations for the lead and zinc were 100 times greater than the cadmium.

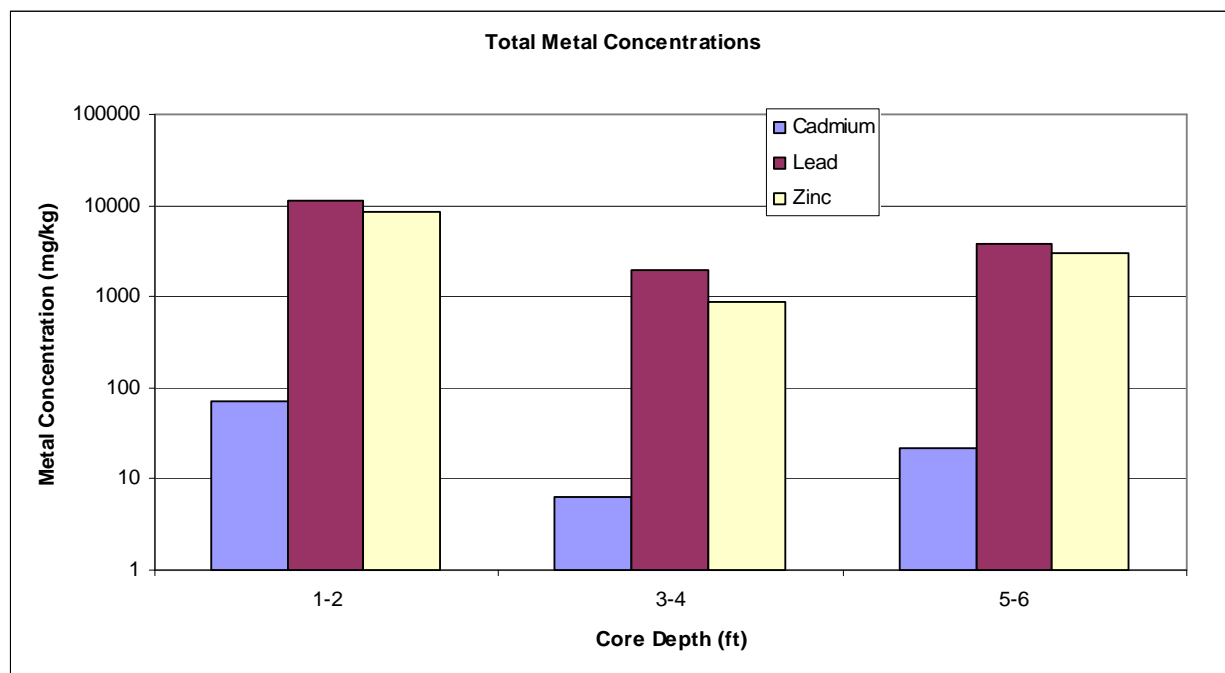


Figure 76. Cadmium, lead, and zinc concentrations in the sediment cores at SF-OB-PZ-13 from the > 2mm fraction.

While the total cadmium concentrations were highest at the surface, the cadmium was more stable, or more difficult to extract, at the surface than at the 3–4 foot depth or the 5–6 foot depth (see Figure 7). The cadmium concentration was least stable, or more easily extracted, in the 3–4 foot depth, however, the cadmium concentration was also lowest at this depth. The cadmium in the 1-2 foot depth was most likely associated with stable oxide complexes, while the metals at lower depths were released in the exchangeable phase making them more mobile. There was less variability in the lead mobility as shown in the sequential extraction data in Figure 8, but the same trend was observed, that is, the lead was more stable at the surface and less stable at depth, with the 3–4 foot depth having the highest concentrations of lead in the leach solution. Zinc also followed the same trend, with the surface having the least available

zinc and the 3–4 foot depth having the most easily extractable zinc. There was a general trend for the residual or total remaining metals to represent the higher proportions at or near the surface. This suggests that years of oxidation have resulted in higher concentrations of refractory metals at or near the surface.

For the leach tests, the cores from each depth were combined from each location in order to have enough material to complete the leach tests. A subsample was sent to the EPA laboratory for analysis and the results are presented below in Figure 77. The cadmium concentrations were, again, much lower than the lead and zinc.

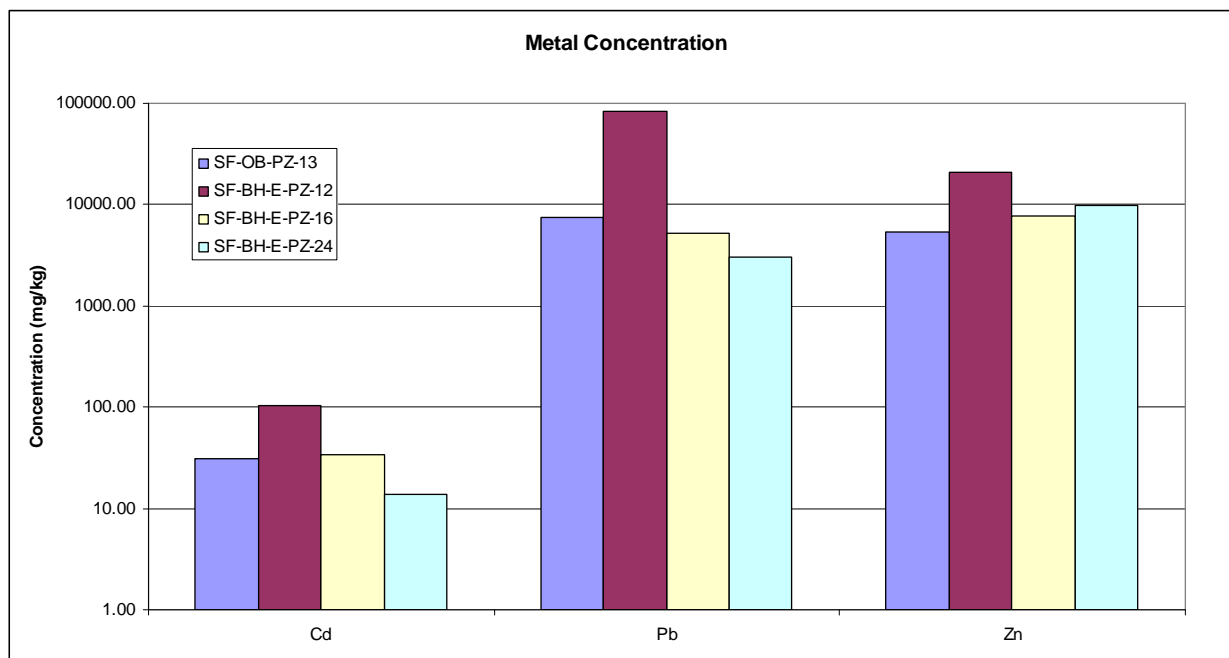


Figure 77. Cadmium, lead, and zinc concentrations in the soil used in the leach tests from the > 2 mm fraction.

The cadmium concentrations during the leach test were significantly affected by pH. As pH increased, cadmium concentrations in the leachate decreased. At pH values less than 6.5 and Eh levels above -0.4, cadmium tends to remain in the Cd 2+ state (see Figure A-1 in the Appendix). Cd 2+ is generally more mobile than it is in other speciations, but can be easily absorbed to hydrous oxides such as iron oxy-hydroxide or organic matter. The data did show that at pH 2–3 (Figure 36), the concentrations of cadmium in the leachate were 100 times higher than at pH 6–7, and 2–3 times the concentration found at pH 4–5 which is more consistent with what would be expected naturally. Most of the cadmium extraction had occurred by Day 30, the concentration had become fairly stable for pH values 4 or higher but continued to increase until Day 60 for pH 2 and 3.

The lead concentrations were generally not as sensitive to pH except for pH 7 (Figure 37), which had an abnormally high leach rate for lead, until day 90. The concentrations at day 90 were significantly lower than the previous pH 7 values. Other than that exception, the lead concentrations did not change much relative to pH.

The zinc concentrations followed a much more expected leach pattern than the lead. At lower pH, more zinc was removed. The greatest increase in zinc concentration in the leachate occurred in the first 7 days and began to plateau after that, although, it did continue to increase slightly throughout the duration of the test for pH 2 and 3 (Figure 38).

The metals will remain stable at this location as long as the pH remains 5 or greater. Cadmium, lead, and zinc are all fairly insoluble while the pH of the soil solution remains greater than 5. When the sediment was exposed to a wet/dry oxidizing cycle, the cadmium concentration over time tended to stabilize at about the same concentration regardless of the presence or absences of oxygen, or simulated rainwater or simulated groundwater. There was a trend for high leach rates for cadmium initially from the sediments exposed to oxygen in the first 7 days, but after that the concentrations were about the same regardless of the presence or absence of oxygen. For this location, the simulated groundwater contained very little magnesium, potassium, and calcium compared to the other locations (Table 2). These ions can mobilize the cadmium, lead and zinc from the exchangeable sites where they are bound. The simulated groundwater from the other locations had higher concentrations of these exchangeable ions and thus resulted in higher leach rates. However, 5 to 10 times as much cadmium was released from the sediment with no exposure to oxygen and leaching with simulated groundwater at the same pH. The same trend was seen for zinc as cadmium. For lead, slightly higher concentrations were observed in the leachate from the sediments exposed to air, and leached with distilled water relative to the ones that were maintained in an anoxic condition and leached with simulated groundwater. This may be due to anions in the simulated groundwater that will precipitate lead. In addition, sediments containing iron or other metal-absorbing oxides and exposed to oxygen will tend to adsorb and precipitate most cationic metals more rapidly than under reducing conditions.

3.2 Sample Location SF-BH-E-PZ-12

The data from the sequential extractions and leach test for sample location SF-BH-E-PZ-12 is summarized in this section. Five depths were collected from this sample site. The zinc, cadmium and lead concentrations were highest at this location relative to the other three locations tested. At this location cadmium, lead, and zinc concentrations were greater at the 7–8 and 8–9-foot cores than at the surface. The concentrations of these three metals were lowest in the 5–6-foot cores.

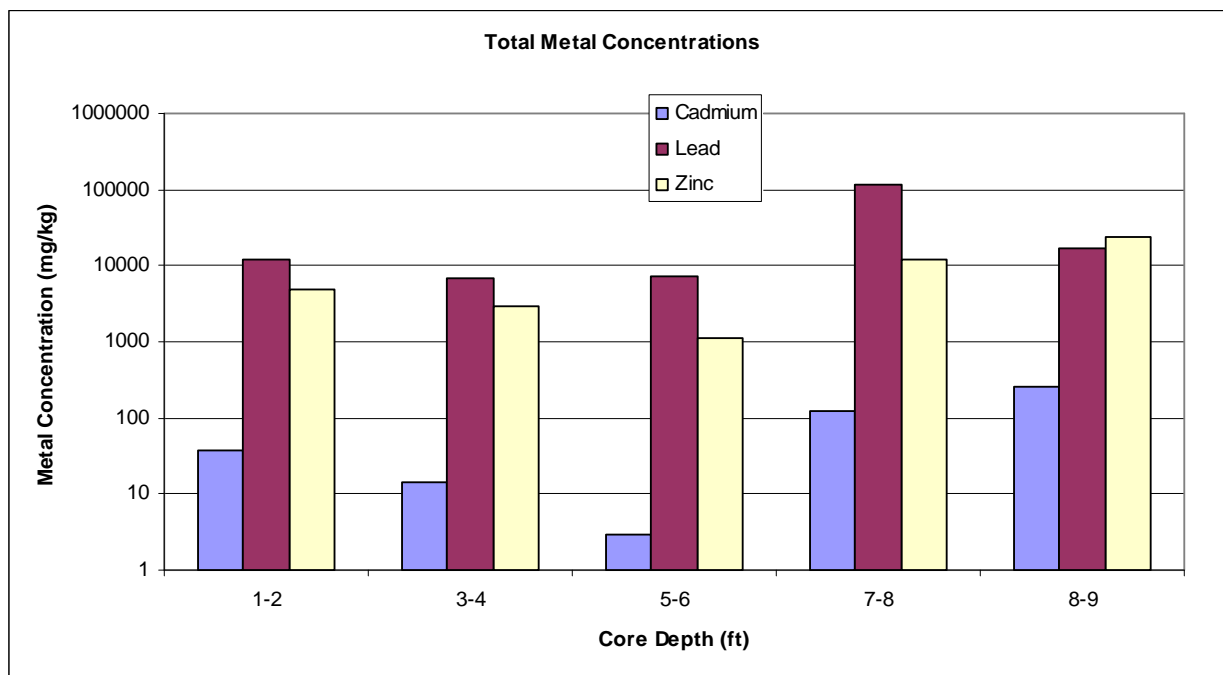


Figure 78. Metal concentrations at each core depth for sample location SF-BH-E-PZ-12 from the >2 mm fraction.

At this location, 40–50% of the cadmium could be extracted with the first two extraction steps at the 1–2 and 3–4-foot depths, while less than 10% could be extracted below that. Hence, cadmium was less stable in the top 1–4 feet and more stable at depths below 4 feet (Figure 16). Lead tended to have less variability in extraction characteristics regardless of depth. The first step in the extraction process removed less than 10% of the lead. The second step was able to remove an additional 30–50% (Figure 17). Zinc was more stable than either of the other two metals discussed. Less than 5% was readily exchangeable, and less than 20% was released in the second stage of the sequential extraction procedure (Figure 18). In the previous location, SF-OB-PZ-13, there was a general trend for the residual or total remaining metals to represent the higher proportions at or near the surface. This was not the case in this location. Residual Cd, Pb, and Zn concentrations were not consistently patterned with depth.

For the leach tests, the cores from each depth were combined for each location in order to have enough material to complete the leach tests. For this location the cores from the 1-2, 3-4, 5-6, 7-8, and 8-9 foot depths were combined, forming a single sample. A subsample was sent to the EPA laboratory for total metal analysis and the results are presented above in Figure 77. The cadmium concentrations were again, much lower than the lead and zinc. During the leach tests where pH was compared between treatments, the cadmium concentration continued to increase during the 90 day test. It never reached a state of equilibrium. Of course the concentration was highest in the low pH and decreased as pH was increased (Figure 41). Lead tended to be less sensitive to pH changes (Figure 42). There was, however, a large release of lead initially which then decreased by day 7 and remained fairly constant for the remainder of the study. For SF-BH-E-PZ-12 more lead is released at lower pH's but since it precipitates out at all pH's you don't see the pH difference over time that was observed in cadmium and zinc. Zinc leachability tended to react more classically as did the cadmium release. At lower pH, more zinc was released than at high pH. The pH has a significant impact on zinc release. At pH 6 and 7 very little release was observed. At pH 5, the concentration stabilized at about 50,000 ug/L, at pH 4 it doubled to 100,000 ug/L, and at pH 2-3, the concentration ranged from 150,000 – over 200,000 ug/L (Figure 43). At pH 2-3 iron became very mobile, but at pH 4 and greater, any iron released would oxidize to ferric iron and precipitate out and was not observed in solution (Figure 44). Sulfur also exhibited increases in leach values at lower pH (Figure 45).

This location reacted uniquely to the presence or absence of oxygen during the 90 day leach test. Cadmium and zinc concentrations continued to rise for the duration of the study after initial exposure to oxygen then leaching with simulated groundwater under anoxic conditions, but under the presence of oxygen and leaching with distilled water, the cadmium concentrations increased only slightly (see Figure 61). One possible reason for this is the higher concentrations of magnesium, potassium, and calcium in the simulated groundwater, which could displace the zinc and cadmium from exchange sites in the soil in the anoxic leach test. Also, based on the sequential extraction results, the percent of residual (metals bound to oxides/hydroxides) cadmium and zinc is highest in this soil. Under low oxygen, the oxides/hydroxides could be less stable and could release more of the bound cadmium and zinc.

Lead concentrations were high during the start of the leach test (over 10,000 ug/L), probably due to the two week wetting and drying cycle. By day 3, the concentrations had dropped off significantly (about 1,000 ug/L) probably due to precipitation and increased only slightly through the remainder of the test (Figure 62). Zinc reacted similarly to cadmium in sediment with initial exposure to oxygen then leaching with simulated groundwater which increased continuously for the duration of the 90 day test, while in the oxygenated sample leached with distilled water, the zinc only increased slightly during the 90 day test (Figure 63). Iron remained fairly constant throughout the tests, following an initial spike regardless of the test treatment. At pH 5 any release of iron would likely be ferric and would precipitate out. Sulfur concentrations increased continuously over the 90 days, with the concentrations in the anoxic samples increasing at a higher rate.

The cadmium, lead and zinc concentrations were highest at this location, although a lower percentage of cadmium, lead, zinc leached from the soil compared to the other 3 locations.

3.3 Sample Location SF-BH-E-PZ-16

At this location there tended to be less variation in cadmium, lead and zinc concentrations between the 4 core depths sampled (Figure 79). The concentrations at this site are similar to sample location SF-OB-PZ-13 and SF-BH-E-PZ-24, but less than SF-BH-E-PZ-12. The core samples showed more oxidized iron at this location than the other three locations based on visual observations (see Figures 20-23). In addition, the oxidation reduction potential from the groundwater collect in September and October of 2008 at this location was 5 to 10 times higher than the other locations (see Table A-7).

The exchangeable cadmium ranged from 18 to 35 % which was consistent with most of the other locations. 30 to 35% of the cadmium was extracted in the 3rd step or the organic/oxide/sulfide bound phase. The lead was more easily extracted from this location, ranging from 7 to 23% exchangeable. Exchangeable zinc tended to follow the same patterns as the other sample locations, with most of the zinc being tightly bound and only able to be liberated by total digestion of the sample. Like SF-OB-PZ-13, there was a general trend for the residual or total remaining elements to represent the higher proportions at or near the surface. This suggests that years of oxidation have resulted in higher concentrations of refractory metals at or near the surface.

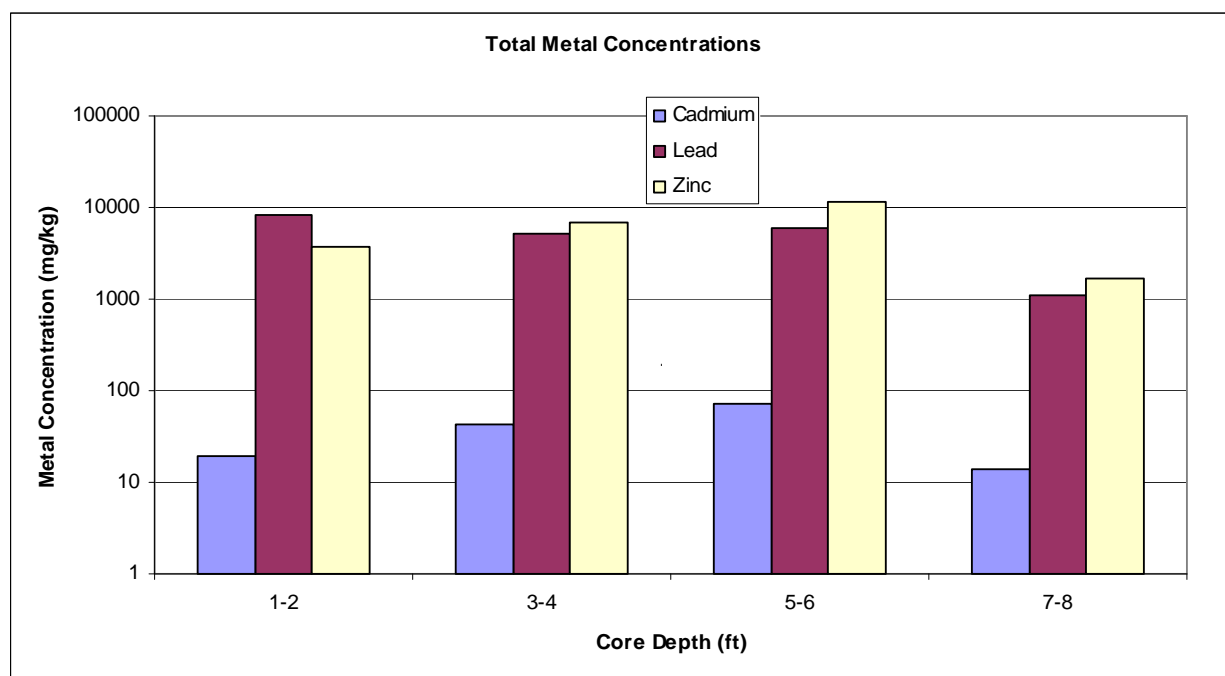


Figure 79. Metal concentrations at each core depth for sample location SF-BH-E-PZ-16 from the > 2mm fraction.

The leach tests reacted consistently with the expected outcomes, with more cadmium and zinc being released at lower pH, and less at higher pH. Typically, by the end of the first month, the concentration had begun to plateau. Lead concentrations had a spike early in the leach test consistent with leaching of the surface oxidized material. This same pattern was observed in Canyon Creek on the leach study conducted there (Wright et al., 2007). The concentration then stabilized at a lower concentration

probably due to precipitation with sulfates. At pH values between 2 and 5 there was only slight differences in lead concentration and at pH 6 and 7 less lead was leached.

There were very little differences observed in the cadmium, lead and zinc concentrations exposed to oxygen and then leached with distilled water, or exposed to oxygen then leached with simulated groundwater under anoxic conditions. For all three metals (cadmium, lead and zinc), the concentration of released metal was higher in the sample not exposed to oxygen and leached with simulated groundwater. The concentration continued to increase over the 3 month test in both treatments. The lead analysis showed an initial spike, but that quickly dropped, then slowly rebounded over time. Like the other locations, sulfur concentrations were highest in the leach tests using simulated groundwater, which had additional sulfates added.

3.4 Sample Location SF-BH-E-PZ-24

This section discusses the results of the sequential extractions and leach tests for sample location SF-BH-E-PZ-24, which is near the CIA. Lead and zinc concentrations tended to be highest at the surface at this site (Figure 80) and decreased with depth. Cadmium concentrations were highest at 5–6 feet. This location has some of the highest levels of exchangeable cadmium, particularly at 5–8 feet, where almost 50% of the cadmium is in the exchangeable form. On the other hand, the lead is very stable. Less than 5% of the lead is in the exchangeable fraction at this location. The zinc is more easily extracted in the 5–8 foot depth also, but the biggest difference at this site is that the zinc is more easily removed with a weak acid (like that used in the second step of the sequential extraction) than the other locations. Monitoring and controlling pH may have a greater impact on zinc at this location than other locations. There was a general trend for the residual or total Cd and Zn remaining to represent the higher proportions at or near the surface. This was not true with Pb. Again, this suggests that years of oxidation have resulted in higher concentrations of refractory metals at or near the surface.

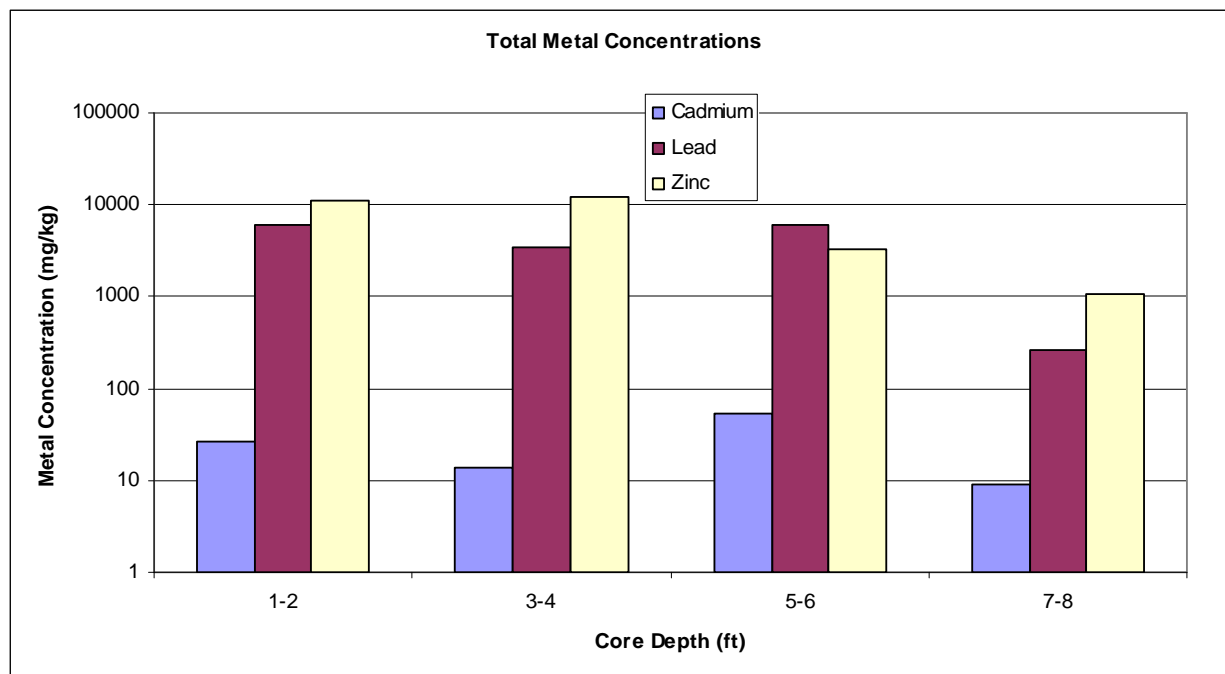


Figure 80. Cadmium, lead, and zinc concentrations at SF-BH-E-PZ-24 from the > 2mm fraction.

Lead and zinc leach rates tended to respond to variations in pH similarly to the other locations. Data collected from groundwater in September and October of 2008 at this location showed higher levels of

phosphorus, iron, magnesium, manganese, potassium, and zinc than the other three locations. This may explain the tendency of cadmium, which leached at slightly lower rates compared to the other three locations. The high concentration of other ions (magnesium, potassium, and calcium) in the groundwater and sediments resulted in substitution of cadmium for these ions initially. This was followed by a drop in concentration, likely associated with precipitation of cadmium with iron and sulfates present in the leach solution. The cadmium present in the leach solution was on order of magnitude lower than the other three sites. Conversely, the total concentration of cadmium present in the soil was only slightly lower than the other locations. The cadmium in the soil was fairly stable and resistant to leaching.

After the first month of leaching there were verily small differences between the aerobic and anoxic treatments for cadmium. The aerobic treatment resulted in slightly higher leach concentrations for lead than the anoxic treatment. Zinc concentrations were not greatly affected by the presence or absence of oxygen, but compared to the other two CIA core locations, this location leached much lower concentrations of zinc, by almost an order of magnitude. This again can be attributed to the high concentrations of phosphorous and iron in the groundwater which will scavenge the zinc and cadmium ions from solution. Another contributing factor is that the pH of the groundwater in this location is slightly higher. At this location, the pH is close to 6, whereas the pH of the groundwater in the other three locations is closer to 5 (see Figures A-5 through A-8).

Leaching tests were conducted on the sediments samples under anaerobic conditions to simulate sediments that are held under saturated anoxic conditions. Under these conditions anaerobic bacteria, especially sulfate reducing bacteria, would be active and could reduce existing metal ions to sulfide minerals. These cores were stored under liquid nitrogen for several months and any sulfate reducing bacteria that were present, probably were killed. The presence of sulfated reducing bacteria may have changed the anoxic leaching test results. The second series of leach tests were performed on sediments which had been exposed to air and several wet/dry cycles in order to simulate microbial sulfide oxidation that would exist above the saturated zone. As stated above, most acidophilic sulfur and iron oxidizing bacteria were probably killed by liquid nitrogen storage. The addition acidophilic sulfur and iron oxidizing bacteria to leaching experiments after wet/dry exposure, could also have changed the results of these leaching experiments. These acidophiles readily oxidize mineral sulfide to metal ions and sulfate, and can reduce the pH dramatically. If similar leaching test are done in the future, addition of leaching with bacteria added would be beneficial.

4. REFERENCES

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Appendix A

Appendix A

Table A-1. Phase I of sequential extraction – laboratory data.

Sample Number	Sample Name-Depth-Replicate #	Conc. (ug/L)		First Extraction of the 3 step Sequential Extraction					
		Cd	Ca	Fe	Pb	Mg	Mn	S	Zn
MJAJH1	SF-OB-PZ-13 1.0–1.8" -1	641	29600	694	14100	23500000	13900	11400	12000
MJAJH2	SF-OB-PZ-13 1.0–1.8" -2	551	26600	3020	13000	22200000	11800	9630	10400
MJAJH3	SF-OB-PZ-13 1.0–1.8" -3	527	24900	8550	16500	22800000	12100	9090	10900
MJAJH4	SF-OB-PZ-13 3.0–4.0" -1	369	52400	U	8510	22000000	16300	2100	9400
MJAJH5	SF-OB-PZ-13 3.0–4.0" -2	357	50300	U	8790	22700000	17100	2160	9640
MJAJH6	SF-OB-PZ-13 3.0–4.0" -3	383	55400	439	8670	25300000	17900	2220	9540
MJAJH7	SF-OB-PZ-13 5.0–5.6" -1	543	32900	1010	14500	24700000	15200	5930	12600
MJAJH8	SF-OB-PZ-13 5.0–5.6" -2	520	32500	2410	18100	24500000	18900	7570	12200
MJAJH9	SF-OB-PZ-13 5.0–5.6" -3	564	33600	2360	17400	23800000	17600	7300	13000
MJAJJ0	SF-BH-E-PZ-12 1.0–2.0" -1	378	19700	1420	93300	23900000	8150	14500	15800
MJAJJ1	SF-BH-E-PZ-12 1.0–2.0" -2	366	19100	2930	95000	23900000	7500	13500	15400
MJAJJ2	SF-BH-E-PZ-12 1.0–2.0" -3	388	19800	4410	96400	24100000	8170	14700	16200
MJAJJ3	SF-BH-E-PZ-12 3.0–4.0" -1	186	137000	1770	12800	24400000	4020	18600	5680
MJAJJ4	SF-BH-E-PZ-12 3.0–4.0" -2	213	144000	1860	12900	29000000	4270	20900	5010
MJAJJ5	SF-BH-E-PZ-12 3.0–4.0" -3	210	144000	3000	12400	25300000	4340	20700	5040
MJAJJ6	SF-BH-E-PZ-12 5.0–6.0" -1	83.2	67300	4470	33900	28500000	5300	10500	1570
MJAJJ7	SF-BH-E-PZ-12 5.0–6.0" -2	78.8	63600	1360	30100	24400000	4650	9600	1270
MJAJJ8	SF-BH-E-PZ-12 5.0–6.0" -3	85.1	66800	2030	32000	25000000	5900	10400	1490
MJAJJ9	SF-BH-E-PZ-12 7.0–8.0" -1	112	25100	7650	85900	23100000	2690	13400	10400
MJAJK0	SF-BH-E-PZ-12 7.0–8.0" -2	136	27700	6790	87900	28000000	2790	13900	10800
MJAJK1	SF-BH-E-PZ-12 7.0–8.0" -3	134	26200	9630	93800	29300000	2700	14100	9960
MJAJK2	SF-BH-E-PZ-12 8.0–9.0" -1	475	63400	9190	44200	32600000	4070	9430	10300
MJAJK3	SF-BH-E-PZ-12 8.0–9.0" -2	543	54400	10500	53000	32500000	3770	8780	10600

Table A-1. (continued).

Sample Number	Sample Name-Depth-Replicate #	Conc. (ug/L)		First Extraction of the 3 step Sequential Extraction					
		Cd	Ca	Fe	Pb	Mg	Mn	S	Zn
MJAJK4	SF-BH-E-PZ-12 8.0–9.0" -3	548	55700	8810	45600	31400000	3520	8900	9720
MJAJK5	SF-BH-E-PZ-16 1.0–2.0" -1	829	129000	7170	153000	25000000	16500	144000	40600
MJAJK6	SF-BH-E-PZ-16 1.0–2.0" -2	818	130000	5420	168000	28600000	17700	146000	40900
MJAJK7	SF-BH-E-PZ-16 1.0–2.0" -3	794	126000	6380	156000	26200000	16600	140000	39400
MJAJK8	SF-BH-E-PZ-16 3.0–4.0" -1	801	116000	6990	132000	28500000	17400	110000	18700
MJAJK9	SF-BH-E-PZ-16 3.0–4.0" -2	780	119000	9330	163000	26600000	17500	116000	19800
MJAJL0	SF-BH-E-PZ-16 3.0–4.0" -3	828	117000	18200	174000	25900000	18600	117000	21500
MJAJL1	SF-BH-E-PZ-16 5.0–6.0" -1	1430	25000	5830	102000	26400000	30900	60700	54200
MJAJL2	SF-BH-E-PZ-16 5.0–6.0" -2	1370	25000	26000	101000	25200000	31100	59100	54200
MJAJL3	SF-BH-E-PZ-16 5.0–6.0" -3	1400	25100	23900	99600	25800000	30600	58100	53900
MJAJL4	SF-BH-E-PZ-16 7.0–8.0" -1	435	71700	8120	7980	26900000	21400	39100	11100
MJAJL5	SF-BH-E-PZ-16 7.0–8.0" -2	429	66300	10900	8320	25900000	21800	35700	11800
MJAJL6	SF-BH-E-PZ-16 7.0–8.0" -3	401	66500	7510	7430	25600000	21900	34900	11100
MJAJL7	SF-BH-E-PZ-24 1.0–2.0" -1	713	120000	3900	15900	25500000	5170	6370	24600
MJAJL8	SF-BH-E-PZ-24 1.0–2.0" -2	701	117000	4550	15400	25200000	4950	5530	24100
MJAJL9	SF-BH-E-PZ-24 1.0–2.0" -3	724	121000	5910	17100	24800000	5090	6230	25400
MJAJM0	SF-BH-E-PZ-24 3.0–4.0" -1	199	199000	3630	1790	28400000	23100	9400	2130
MJAJM1	SF-BH-E-PZ-24 3.0–4.0" -2	158	186000	3160	1250	24700000	21100	8830	1610
MJAJM2	SF-BH-E-PZ-24 3.0–4.0" -3	175	196000	2660	1450	27600000	21900	8980	1700
MJAJM3	SF-BH-E-PZ-24 5.0–6.0" -1	1570	171000	5730	54300	24000000	72400	11400	70600
MJAJM4	SF-BH-E-PZ-24 5.0–6.0" -2	1670	183000	7770	55900	25300000	82700	11900	76400
MJAJM5	SF-BH-E-PZ-24 5.0–6.0" -3	1700	161000	3840	48700	25600000	71600	10300	72100
MJAJM6	SF-BH-E-PZ-24 7.0–8.0" -1	584	59000	549	249	23700000	14100	8380	15100
MJAJM7	SF-BH-E-PZ-24 7.0–8.0" -2	570	65100	864	75.2	23200000	16200	6280	14900
MJAJM8	SF-BH-E-PZ-24 7.0–8.0" -3	591	73700	1420	153	22200000	17500	6660	16000

Table A-2. Phase II of Sequential Extraction – Laboratory Data. Note U indicates that the ion was analyzed for but not detected above the sample quantification limit or detection limit.

Sample Number	Sample Name and Location	Concentration ug/L		Second Extraction of the 3 step Sequential Extraction					
		Cd	Ca	Fe	Pb	Mg	Mn	S	Zn
MJAJN4	SF-OB-PZ-13 1.0–1.8" -1	476	U	6590	312000	113000	25400	1800	52500
MJAJN5	SF-OB-PZ-13 1.0–1.8" -2	665	U	6510	425000	222000	36200	2380	74400
MJAJN6	SF-OB-PZ-13 1.0–1.8" -3	602	U	6100	408000	156000	30800	2200	65000
MJAJN7	SF-OB-PZ-13 3.0–4.0" -1	130	U	20700	95100	124000	35800	364	25900
MJAJN8	SF-OB-PZ-13 3.0–4.0" -2	134	U	25400	97000	322000	39100	341	24300
MJAJN9	SF-OB-PZ-13 3.0–4.0" -3	138	U	24200	96500	95600	38300	291	26100
MJAJP0	SF-OB-PZ-13 5.0–5.6" -1	304	U	14900	106000	113000	21700	885	43500
MJAJP1	SF-OB-PZ-13 5.0–5.6" -2	335	U	11500	150000	103000	28000	1090	49300
MJAJP2	SF-OB-PZ-13 5.0–5.6" -3	346	U	10300	139000	140000	26300	1050	54700
MJAJP3	SF-BH-E-PZ-12 1.0–2.0" -1	2080	U	76500	947000	81700	62600	3140	89500
MJAJP4	SF-BH-E-PZ-12 1.0–2.0" -2	2000	U	75300	939000	81800	61600	3110	90700
MJAJP5	SF-BH-E-PZ-12 1.0–2.0" -3	2290	U	82400	1200000	57300	68500	3200	98000
MJAJP6	SF-BH-E-PZ-12 3.0–4.0" -1	493	225000	202000	455000	355000	105000	6220	70000
MJAJP7	SF-BH-E-PZ-12 3.0–4.0" -2	495	209000	178000	411000	173000	100000	5720	69700
MJAJP8	SF-BH-E-PZ-12 3.0–4.0" -3	513	229000	189000	459000	291000	116000	6420	74400
MJAJP9	SF-BH-E-PZ-12 5.0–6.0" -1	54.4	U	5380	296000	198000	12100	1470	4940
MJAJQ0	SF-BH-E-PZ-12 5.0–6.0" -2	55.7	U	6190	315000	336000	13200	1500	4800
MJAJQ1	SF-BH-E-PZ-12 5.0–6.0" -3	52.5	U	6430	378000	115000	12400	1330	5450
MJAJQ2	SF-BH-E-PZ-12 7.0–8.0" -1	137	U	64100	8420000	230000	21500	2420	117000
MJAJQ3	SF-BH-E-PZ-12 7.0–8.0" -2	150	U	67000	8200000	59800	24200	2760	127000
MJAJQ4	SF-BH-E-PZ-12 7.0–8.0" -3	128	U	57100	9850000	137000	20300	2630	102000
MJAJQ5	SF-BH-E-PZ-12 8.0–9.0" -1	812	129000	198000	449000	156000	61500	3350	317000
MJAJQ6	SF-BH-E-PZ-12 8.0–9.0" -2	826	82600	186000	427000	105000	65100	2440	333000

Table A-2. (continued).

Sample Number	Sample Name and Location	Concentration ug/L		Second Extraction of the 3 step Sequential Extraction					
		Cd	Ca	Fe	Pb	Mg	Mn	S	Zn
MJAJQ7	SF-BH-E-PZ-12 8.0–9.0" -3	866	102000	193000	449000	117000	67700	3020	346000
MJAJQ8	SF-BH-E-PZ-16 1.0–2.0" -1	162	22400	26300	116000	235000	29700	27900	24200
MJAJQ9	SF-BH-E-PZ-16 1.0–2.0" -2	185	18400	19700	110000	141000	29500	28900	22700
MJAJR0	SF-BH-E-PZ-16 1.0–2.0" -3	194	22200	27300	127000	244000	30900	30200	26500
MJAJR1	SF-BH-E-PZ-16 3.0–4.0" -1	365	14600	193000	230000	121000	24200	10400	30200
MJAJR2	SF-BH-E-PZ-16 3.0–4.0" -2	395	U	168000	197000	143000	23600	6940	30000
MJAJR3	SF-BH-E-PZ-16 3.0–4.0" -3	394	U	175000	195000	147000	23600	6860	29600
MJAJR4	SF-BH-E-PZ-16 5.0–6.0" -1	1590	17000	202000	256000	234000	174000	8230	340000
MJAJR5	SF-BH-E-PZ-16 5.0–6.0" -2	1560	17700	200000	263000	230000	169000	8160	349000
MJAJR6	SF-BH-E-PZ-16 5.0–6.0" -3	1580	17400	195000	262000	351000	163000	8480	342000
MJAJR7	SF-BH-E-PZ-16 7.0–8.0" -1	470	U	43000	34900	98900	22100	2790	30300
MJAJR8	SF-BH-E-PZ-16 7.0–8.0" -2	444	U	47500	34600	221000	23800	2520	28700
MJAJR9	SF-BH-E-PZ-16 7.0–8.0" -3	417	U	48900	33500	202000	22900	2360	26900
MJAJS0	SF-BH-E-PZ-24 1.0–2.0" -1	792	499000	881000	255000	146000	252000	8570	237000
MJAJS1	SF-BH-E-PZ-24 1.0–2.0" -2	707	457000	756000	241000	156000	193000	7910	212000
MJAJS2	SF-BH-E-PZ-24 1.0–2.0" -3	769	521000	865000	275000	227000	210000	8670	237000
MJAJS3	SF-BH-E-PZ-24 3.0–4.0" -1	122	1700000	2680000	50500	247000	272000	23300	287000
MJAJS4	SF-BH-E-PZ-24 3.0–4.0" -2	134	1620000	2630000	52600	239000	285000	23500	262000
MJAJS5	SF-BH-E-PZ-24 3.0–4.0" -3	145	1520000	2450000	58600	242000	269000	21900	260000
MJAJS6	SF-BH-E-PZ-24 5.0–6.0" -1	943	310000	606000	268000	417000	164000	5890	126000
MJAJS7	SF-BH-E-PZ-24 5.0–6.0" -2	907	332000	654000	285000	476000	177000	6250	133000
MJAJS8	SF-BH-E-PZ-24 5.0–6.0" -3	1140	309000	583000	317000	539000	200000	5990	126000
MJAJS9	SF-BH-E-PZ-24 7.0–8.0" -1	226	174000	354000	6340	151000	73600	2510	58000
MJAJT0	SF-BH-E-PZ-24 7.0–8.0" -2	228	202000	418000	7220	119000	82500	2840	65900
MJAJT1	SF-BH-E-PZ-24 7.0–8.0" -3	237	209000	435000	6570	231000	80000	2860	66600

Table A-3. Phase III of Sequential Extraction – Laboratory Data. Note U indicates that the ion was analyzed for but not detected above the sample quantification limit or detection limit.

		Concentration ug/L		First Extraction of the 3 step Sequential Extraction					
Sample Number	Sample Name and Location	Cd	Ca	Fe	Pb	Mg	Mn	S	Zn
MJAJT6	SF-OB-PZ-13 1.0–1.8" -1	641	U	23100	263000	U	230000	5880	41500
MJAJT7	SF-OB-PZ-13 1.0–1.8" -2	741	U	22800	224000	U	189000	7290	42700
MJAJT8	SF-OB-PZ-13 1.0–1.8" -3								
MJAJT9	SF-OB-PZ-13 3.0–4.0" -1	69	U	7980	32200	U	38000	9110	6050
MJAJW0	SF-OB-PZ-13 3.0–4.0" -2	65.4	U	9550	33600	U	35600	8080	6800
MJAJW1	SF-OB-PZ-13 3.0–4.0" -3	73.9	U	5060	28100	U	38700	10200	5070
MJAJW2	SF-OB-PZ-13 5.0–5.6" -1	446	U	9220	56900	U	75400	28400	38100
MJAJW3	SF-OB-PZ-13 5.0–5.6" -2	371	U	44300	78700	U	79300	19300	31600
MJAJW4	SF-OB-PZ-13 5.0–5.6" -3	386	U	13800	72300	U	79800	26200	34400
MJAJW5	SF-BH-E-PZ-12 1.0–2.0" -1	569	29500	18000	145000	52200	133000	146000	76800
MJAJW6	SF-BH-E-PZ-12 1.0–2.0" -2	532	29600	15600	142000	49100	125000	137000	73000
MJAJW7	SF-BH-E-PZ-12 1.0–2.0" -3	533	32100	15500	145000	49900	124000	136000	72300
MJAJW8	SF-BH-E-PZ-12 3.0–4.0" -1	210	18900	42600	82200	20100	37700	36900	29700
MJAJW9	SF-BH-E-PZ-12 3.0–4.0" -2	209	19700	49800	84100	18600	39000	33800	29500
MJAJX0	SF-BH-E-PZ-12 3.0–4.0" -3	215	20700	58400	91600	20000	33100	34000	29400
MJAJX1	SF-BH-E-PZ-12 5.0–6.0" -1	53.3	U	16700	138000	U	113000	3600	3540
MJAJX2	SF-BH-E-PZ-12 5.0–6.0" -2	36.5	U	16700	103000	U	94600	5580	2830
MJAJX3	SF-BH-E-PZ-12 5.0–6.0" -3	51.1	U	18000	157000	U	127000	3450	3950
MJAJX4	SF-BH-E-PZ-12 7.0–8.0" -1	3290	28500	10600	97700	55700	148000	249000	415000
MJAJX5	SF-BH-E-PZ-12 7.0–8.0" -2	2990	16100	73100	192000	29700	82300	158000	354000
MJAJX6	SF-BH-E-PZ-12 7.0–8.0" -3	2280	15000	65100	160000	25100	67800	114000	280000
MJAJX7	SF-BH-E-PZ-12 8.0–9.0" -1	6510	46300	45000	89900	32200	99300	266000	510000
MJAJX8	SF-BH-E-PZ-12 8.0–9.0" -2	5860	45900	43400	83400	29900	92100	245000	454000
MJAJX9	SF-BH-E-PZ-12 8.0–9.0" -3	6330	45900	49400	76100	32200	101000	263000	529000

Table A-3. (continued).

Sample Number	Sample Name and Location	Concentration ug/L		First Extraction of the 3 step Sequential Extraction					
		Cd	Ca	Fe	Pb	Mg	Mn	S	Zn
MJAJY0	SF-BH-E-PZ-16 1.0–2.0" -1	387	19100	7190	65900	U	69900	136000	59400
MJAJY1	SF-BH-E-PZ-16 1.0–2.0" -2	294	27400	18900	52200	U	64200	120000	40100
MJAJY2	SF-BH-E-PZ-16 1.0–2.0" -3	352	17100	8920	63500	U	66900	131000	60000
MJAJY3	SF-BH-E-PZ-16 3.0–4.0" -1	773	18300	222000	57800	47300	91600	218000	101000
MJAJY4	SF-BH-E-PZ-16 3.0–4.0" -2	548	14300	239000	44500	40700	83400	192000	70200
MJAJY5	SF-BH-E-PZ-16 3.0–4.0" -3	552	14100	241000	43900	41700	83500	195000	71200
MJAJY6	SF-BH-E-PZ-16 5.0–6.0" -1	991	51300	285000	54200	53800	141000	297000	113000
MJAJY7	SF-BH-E-PZ-16 5.0–6.0" -2	938	55500	313000	57400	58300	138000	294000	112000
MJAJY8	SF-BH-E-PZ-16 5.0–6.0" -3	992	55800	328000	59200	60800	141000	307000	121000
MJAJY9	SF-BH-E-PZ-16 7.0–8.0" -1	223	U	12600	10500	U	21700	46100	27200
MJAJZ0	SF-BH-E-PZ-16 7.0–8.0" -2	209	U	7360	8420	U	21200	40100	24000
MJAJZ1	SF-BH-E-PZ-16 7.0–8.0" -3	201	U	16200	7710	U	23500	36300	24100
MJAJZ2	SF-BH-E-PZ-24 1.0–2.0" -1	427	87900	41500	41100	U	25100	37100	37200
MJAJZ3	SF-BH-E-PZ-24 1.0–2.0" -2	312	77200	30300	32000	U	19300	27600	28600
MJAJZ4	SF-BH-E-PZ-24 1.0–2.0" -3	316	75300	18600	31600	U	19100	28900	26200
MJAJZ5	SF-BH-E-PZ-24 3.0–4.0" -1	244	87800	20800	34700	U	36300	63700	41000
MJAJZ6	SF-BH-E-PZ-24 3.0–4.0" -2	263	89800	19300	34000	U	34700	64400	36400
MJAJZ7	SF-BH-E-PZ-24 3.0–4.0" -3	332	80800	26700	32500	17900	57700	80900	51800
MJAJZ8	SF-BH-E-PZ-24 5.0–6.0" -1	888	45300	28300	42800	18400	45700	40400	18800
MJAJZ9	SF-BH-E-PZ-24 5.0–6.0" -2	727	35300	51200	43300	19800	44000	39800	17300
MJAK00	SF-BH-E-PZ-24 5.0–6.0" -3	660	49000	44900	37400	19500	30600	34600	15900
MJAK01	SF-BH-E-PZ-24 7.0–8.0" -1	155	22600	8060	1840	U	9130	9360	11500
MJAK02	SF-BH-E-PZ-24 7.0–8.0" -2	165	27100	5580	2100	U	9280	9970	10700
MJAK03	SF-BH-E-PZ-24 7.0–8.0" -3	143	32600	9010	1830	U	6590	10700	7080

Table A-4. Total Concentration in Treated and Untreated Sediments used in Sequential Extractions.

Sample Number	Sample Name and Location		Concentration ug/L		First Extraction of the 3-step Sequential Extraction					Zn
			Cd	Ca	Fe	Pb	Mg	Mn	S	
MJAK09	SF-OB-PZ-13 1.0–1.8’	Sediment After Extraction	52.4	492	103000	7390	948	4410	2870	9430
MJAK10	SF-OB-PZ-13 3.0–4.0’	Sediment After Extraction	1.1	408	15100	531	844	369	79.7	530
MJAK11	SF-OB-PZ-13 5.0–5.6’	Sediment After Extraction	6.6	421	33100	1950	891	1430	500	1990
MJAK12	SF-BH-E-PZ-12 1.0–2.0’	Sediment After Extraction	9.3	1450	129000	3940	3930	8410	1930	3380
MJAK13	SF-BH-E-PZ-12 3.0–4.0’	Sediment After Extraction	5.7	563	531000	2380	2250	2640	1590	2180
MJAK14	SF-BH-E-PZ-12 5.0–6.0’	Sediment After Extraction	10.7	514	61400	1650	2050	2490	2500	3350
MJAK15	SF-BH-E-PZ-12 7.0–8.0’	Sediment After Extraction	67.2	1200	147000	53800	3850	5960	14100	13100
MJAK16	SF-BH-E-PZ-12 8.0–9.0’	Sediment After Extraction	106	1590	128000	6310	4270	10900	4890	13000
MJAK17	SF-BH-E-PZ-16 1.0–2.0’	Sediment After Extraction	4.4	417	85000	4240	602	1290	2060	2350
MJAK18	SF-BH-E-PZ-16 3.0–4.0’	Sediment After Extraction	14.2	603	84000	1570	2120	3060	2890	4170
MJAK19	SF-BH-E-PZ-16 5.0–6.0’	Sediment After Extraction	17	1070	139000	1380	3100	5780	6560	5890
MJAK20	SF-BH-E-PZ-16 7.0–8.0’	Sediment After Extraction	0.83	260	23700	446	1320	350	135	527
MJAK21	SF-BH-E-PZ-24 1.0–2.0’	Sediment After Extraction	13.4	18900	109000	4550	3160	5510	1740	8060

Table A-4. (continued).

Sample Number	Sample Name and Location		Concentration ug/L		First Extraction of the 3-step Sequential Extraction					Zn
			Cd	Ca	Fe	Pb	Mg	Mn	S	
MJAK22	SF-BH-E-PZ-24 3.0–4.0'	Sediment After Extraction	7.1	38200	130000	2530	4730	10100	3970	9660
MJAK23	SF-BH-E-PZ-24 5.0–6.0'	Sediment After Extraction	5.4	1500	42100	2200	2070	1320	302	1710
MJAK24	SF-BH-E-PZ-24 7.0–8.0'	Sediment After Extraction	0.89	1460	21900	125	1920	425	91.3	579
MJAK66	SF-OB-PZ-13 1.0–1.8'	Untreated Sediment	72.4	766	74200	11300	671	6320	2290	8560
MJAK67	SF-OB-PZ-13 3.0–4.0'	Untreated Sediment	6.3	803	15600	1920	833	1560	129	886
MJAK68	SF-OB-PZ-13 5.0–5.6'	Untreated Sediment	21.9	821	34200	3730	865	3010	1110	3040
MJAK69	SF-BH-E-PZ-12 1.0–2.0'	Untreated Sediment	37.9	1920	111000	12100	4150	9450	4130	4820
MJAK70	SF-BH-E-PZ-12 3.0–4.0'	Untreated Sediment	14.7	3990	55600	6890	2730	3740	2030	2870
MJAK71	SF-BH-E-PZ-12 5.0–6.0'	Untreated Sediment	2.9	736	37600	7190	1730	2450	475	1110
MJAK72	SF-BH-E-PZ-12 7.0–8.0'	Untreated Sediment	123	1670	98900	116000	3810	5270	17300	11800
MJAK73	SF-BH-E-PZ-12 8.0–9.0'	Untreated Sediment	254	4260	119000	17300	4800	11900	9040	24300
MJAK74	SF-BH-E-PZ-16 1.0–2.0'	Untreated Sediment	19.2	1820	87300	8130	893	2570	6540	3730
MJAK75	SF-BH-E-PZ-16 3.0–4.0'	Untreated Sediment	43.8	2500	100000	5290	3610	5850	10000	6800
MJAK76	SF-BH-E-PZ-16 5.0–6.0'	Untreated Sediment	72.8	2770	127000	5970	4440	11100	15400	11700
MJAK77	SF-BH-E-PZ-16 7.0–8.0'	Untreated Sediment	13.8	1010	27200	1110	1420	1200	1320	1690
MJAK78	SF-BH-E-PZ-24 1.0–2.0'	Untreated Sediment	26.7	34400	92200	6130	3580	4510	2940	11000
MJAK79	SF-BH-E-PZ-24 3.0–4.0'	Untreated Sediment	13.5	59000	137000	3490	5550	12100	6480	11900
MJAK80	SF-BH-E-PZ-24 5.0–6.0'	Untreated Sediment	54.6	6510	34300	5900	2030	3040	1090	3300
MJAK81	SF-BH-E-PZ-24 7.0–8.0'	Untreated Sediment	9.2	2570	24200	258	1810	998	232	1080

Table A-5. Concentrations from pH leach test from 0–90 days.

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
Time 0										
MJAKD2	SF-OB-PZ-13	U	3550	U	U	3030	U	35	U	5770
MJAKD3	SF-BH-E-PZ-12	U	2960	402	U	10700	U	U	U	18600
MJAKD4	SF-BH-E-PZ-16	U	659	U	U	52800	U	U	U	67900
MJAKD5	SF-BH-E-PZ-24	U	656	5200	U	49400	U	U	U	72500
Time 8 Hours										
MJAKD6	SF-OB-PZ-13 pH 2	84.2	7800	573	13600	2600	7450	3.8	7120	2690
MJAKD7	SF-OB-PZ-13 pH 3	20.8	5890	289	759	2880	2310	U	1460	5940
MJAKD8	SF-OB-PZ-13 pH 4	11.4	4990	1010	583	2760	1710	U	811	6210
MJAKD9	SF-OB-PZ-13 pH 5	9.8	5310	889	486	2770	1470	U	693	6230
MJAKE0	SF-OB-PZ-13 pH 6	9.8	6080	1270	672	2820	1800	U	686	6630
MJAKE1	SF-OB-PZ-13 pH 7	9.9	5340	1870	992	2840	1790	U	765	6400
MJAKE2	SF-BH-E-PZ-12 pH 2	130	28600	32800		14300	14800	10.4	39300	1480
MJAKE3	SF-BH-E-PZ-12 pH 3	8.9	15600	1360	1360	12000	1910	U	4640	21700
MJAKE4	SF-BH-E-PZ-12 pH 4	3.2	17000	1030	522	11800	1370	U	1940	23200
MJAKE5	SF-BH-E-PZ-12 pH 5	3.6	15200	1280	695	11800	1230	U	1870	23000
MJAKE6	SF-BH-E-PZ-12 pH 6	U	11900	784	545	11500	1100	U	2020	22000
MJAKE7	SF-BH-E-PZ-12 pH 7	U	12300	717	439	11300	1200	U	2100	22300
MJAKE8	SF-BH-E-PZ-16 pH 2	523	28200	46300	3040	50500	29900	17.2	74900	78500
MJAKE9	SF-BH-E-PZ-16 pH 3	139	19200	1530	399	49600	10700	6.7	16900	88800
MJAKF0	SF-BH-E-PZ-16 pH 4	102	21000	1710	388	54100	9320	4.3	12400	92600
MJAKF1	SF-BH-E-PZ-16 pH 5	82.3	18500	663	237	53600	8040	5.2	9930	89300
MJAKF2	SF-BH-E-PZ-16 pH 6	63	15200	931	228	35900	5910	U	7460	62600
MJAKF3	SF-BH-E-PZ-16 pH 7	74.5	17800	743	219	53500	7320	4.7	9240	87700
MJAKF4	SF-BH-E-PZ-24 pH 2	134	68400	21100	3240	54000	16600	U	15800	79700
MJAKF5	SF-BH-E-PZ-24 pH 3	21.2	26600	5140	186	52000	4190	U	2630	88300

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
MJAKF6	SF-BH-E-PZ-24 pH 4	13.7	23300	1400	136	50600	3160	U	1690	87600
MJAKF7	SF-BH-E-PZ-24 pH 5	11.2	23000	1300	134	50600	3040	U	1550	87200
MJAKF8	SF-BH-E-PZ-24 pH 6	11.3	24600	1620	229	49500	3260	U	1510	87000
MJAKF9	SF-BH-E-PZ-24 pH 7	5.1	16000	1920	290	32000	1600	U	678	58500
Time 16 Hours										
MJAKG0	SF-OB-PZ-13 pH 2	256	15700	11600	3840	4590	24600	22.1	22300	96800
MJAKG1	SF-OB-PZ-13 pH 3	144	12800	6010	2990	4000	13300	U	13200	105000
MJAKG2	SF-OB-PZ-13 pH 4	142	11600	6890	3880	3880	14100	U	13100	111000
MJAKG3	SF-OB-PZ-13 pH 5	124	11400	5650	3590	3750	10700	U	11500	109000
MJAKG4	SF-OB-PZ-13 pH 6	27.2	8240	950	1230	3100	3230	U	2030	15100
MJAKG5	SF-OB-PZ-13 pH 7	15.7	6840	5050	2820	2950	3230	U	1420	7790
MJAKG6	SF-BH-E-PZ-12 pH 2	240	43700	140000	6980	19600	40100	36.1	61000	71300
MJAKG7	SF-BH-E-PZ-12 pH 3	170	31300	112000	3480	17500	28800	26	41600	166000
MJAKG8	SF-BH-E-PZ-12 pH 4	101	33600	51200	8500	15600	20600	19.4	33800	107000
MJAKG9	SF-BH-E-PZ-12 pH 5	6.6	20300	4770	2690	11800	2230	U	1830	26000
MJAKH0	SF-BH-E-PZ-12 pH 6	8.5	18000	2860	1850	12300	3860	U	7400	33300
MJAKH1	SF-BH-E-PZ-12 pH 7	3.7	17500	3070	1570	11200	1720	U	1080	25800
MJAKH2	SF-BH-E-PZ-16 pH 2	730	46100	142000	3430	60000	54700	47.1	101000	260000
MJAKH3	SF-BH-E-PZ-16 pH 3	583	39700	89400	3030	58300	35800	29.4	80600	253000
MJAKH4	SF-BH-E-PZ-16 pH 4	587	41400	46300	1870	56600	33100	18.5	86600	20300
MJAKH5	SF-BH-E-PZ-16 pH 5	233	27500	36200	2390	54500	18200	12.2	33400	151000
MJAKH6	SF-BH-E-PZ-16 pH 6	143	24900	38500	949	53100	12000	5.9	19700	103000
MJAKH7	SF-BH-E-PZ-16 pH 7	113	32700	1440	352	53800	12800	7.4	12300	110000
MJAKH8	SF-BH-E-PZ-24 pH 2	221	142000	73100	2420	54800	47100	26.7	42400	229000
MJAKH9	SF-BH-E-PZ-24 pH 3	171	89300	39000	3360	53000	24200	15.8	22700	197000
MJAKJ0	SF-BH-E-PZ-24 pH 4	115	89600	31200	2710	52900	25500	16.8	19700	185000
MJAKJ1	SF-BH-E-PZ-24 pH 5	24.4	49200	9660	1260	47900	8940	6.8	4630	107000

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
MJAKJ2	SF-BH-E-PZ-24 pH 6	13.6	39500	7030	993	45700	5230	3.5	2060	87000
MJAKJ3	SF-BH-E-PZ-24 pH 7	7.3	35600	5040	686	42500	3340	3.8	994	82200
Time 24 Hours										
MJAKJ4	SF-OB-PZ-13 pH 2	297	16400	16300	3800	4700	31500	18.7	29500	120000
MJAKJ5	SF-OB-PZ-13 pH 3	301	16900	4360	3580	4410	25300	16.5	29300	110000
MJAKJ6	SF-OB-PZ-13 pH 4	204	13800	2960	3140	4170	19300	11	18800	92800
MJAKJ7	SF-OB-PZ-13 pH 5	156	12800	1530	1720	3740	14200	8.1	14500	110000
MJAKJ8	SF-OB-PZ-13 pH 6	29.2	8870	4010	2140	3160	4330	3.4	2350	14800
MJAKJ9	SF-OB-PZ-13 pH 7	2.7	5310	1670	836	2070	570	U	314	7790
MJAKK0	SF-BH-E-PZ-12 pH 2	198	51100	154000	12200	20900	52500	32.5	78500	94400
MJAKK1	SF-BH-E-PZ-12 pH 3	114	42800	85100	8990	18900	40100	25.8	53000	147000
MJAKK2	SF-BH-E-PZ-12 pH 4	108	44800	31200	6350	16700	32600	21.9	51800	118000
MJAKK3	SF-BH-E-PZ-12 pH 5	7.8	28100	5170	3460	12800	4100	3.3	2590	50800
MJAKK4	SF-BH-E-PZ-12 pH 6	4.1	19600	3100	2030	10900	3220	3.1	1670	31100
MJAKK5	SF-BH-E-PZ-12 pH 7	7.6	12200	7060	4860	7900	984	U	1260	25200
MJAKK6	SF-BH-E-PZ-16 pH 2	662	4430	167000	2750	56200	62700	42.1	99400	239000
MJAKK7	SF-BH-E-PZ-16 pH 3	514	39300	93400	2220	54200	41600	26.7	74900	246000
MJAKK8	SF-BH-E-PZ-16 pH 4	624	44700	65800	1800	52700	45600	28.3	89600	243000
MJAKK9	SF-BH-E-PZ-16 pH 5	278	32900	28900	1430	50500	23200	15.7	40800	160000
MJAKL0	SF-BH-E-PZ-16 pH 6	151	28300	3750	756	49000	13500	10.5	19000	127000
MJAKL1	SF-BH-E-PZ-16 pH 7	99.1	32500	2620	457	49900	11800	9	10100	121000
MJAKL2	SF-BH-E-PZ-24 pH 2	242	170000	127000	3090	51800	59700	38.8	50900	308000
MJAKL3	SF-BH-E-PZ-24 pH 3	182	107000	53500	2950	49900	39500	25.2	35600	264000
MJAKL4	SF-BH-E-PZ-24 pH 4	102	105000	28400	1390	51500	35200	23.2	21700	221000
MJAKL5	SF-BH-E-PZ-24 pH 5	19.3	57800	14100	1930	45300	11000	8.1	4150	119000
MJAKL6	SF-BH-E-PZ-24 pH 6	12.9	42200	10600	1520	42700	5840	4.2	2150	84500
MJAKL7	SF-BH-E-PZ-24 pH 7	2.6	33500	1590	234	38800	2490	3	245	78900

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
Time 3 Days										
MJAKL8	SF-OB-PZ-13 pH 2	532	16900	25900	3550	4960	74800	43.7	55600	134000
MJAKL9	SF-OB-PZ-13 pH 3	361	16900	1510	2700	4500	36400	25.6	32800	98400
MJAKM0	SF-OB-PZ-13 pH 4	248	14300	1430	2310	4100	25200	16.1	22600	86800
MJAKM1	SF-OB-PZ-13 pH 5	153	12600	1070	1320	3510	15100	10.7	13800	97700
MJAKM2	SF-OB-PZ-13 pH 6	20.6	8550	5420	2990	2890	4240	4.2	1730	14400
MJAKM3	SF-OB-PZ-13 pH 7	19	3780	11300	7430	1880	4010	3.4	2550	8760
MJAKM4	SF-BH-E-PZ-12 pH 2	209	60500	255000	8950	25700	64600	65.7	74900	164000
MJAKM5	SF-BH-E-PZ-12 pH 3	109	50300	93800	3540	20100	53300	46.7	71200	178000
MJAKM6	SF-BH-E-PZ-12 pH 4	98.9	50600	31000	4910	17200	44100	36.2	62500	141000
MJAKM7	SF-BH-E-PZ-12 pH 5	18.1	36900	4330	2870	13900	11300	7.8	8390	74900
MJAKM8	SF-BH-E-PZ-12 pH 6	5.1	23500	4450	2550	12400	3900	3.9	1820	37500
MJAKM9	SF-BH-E-PZ-12 pH 7	6.9	14600	6260	4550	9560	929	U	1130	28700
MJAKN0	SF-BH-E-PZ-16 pH 2	841	69200	318000	2120	73600	113000	88.1	120000	372000
MJAKN1	SF-BH-E-PZ-16 pH 3	740	66800	209000	1910	69300	84900	76.1	107000	390000
MJAKN2	SF-BH-E-PZ-16 pH 4	715	58800	51800	2140	65700	73800	58.1	98500	263000
MJAKN3	SF-BH-E-PZ-16 pH 5	441	46600	4180	1370	58600	39100	31.4	58500	170000
MJAKN4	SF-BH-E-PZ-16 pH 6	249	44000	14700	2500	55500	19800	19.3	23200	136000
MJAKN5	SF-BH-E-PZ-16 pH 7	156	41400	3330	620	53700	14200	14.5	9360	138000
MJAKN6	SF-BH-E-PZ-24 pH 2	150	279000	237000	2760	63700	93800	75.9	77400	518000
MJAKN7	SF-BH-E-PZ-24 pH 3	56.8	191000	75700	1200	61400	64800	54.1	40000	343000
MJAKN8	SF-BH-E-PZ-24 pH 4	91.8	166000	27300	1200	58200	56100	44.6	32600	297000
MJAKN9	SF-BH-E-PZ-24 pH 5	16	75400	5750	767	49800	11000	10.6	1570	127000
MJAKP0	SF-BH-E-PZ-24 pH 6	10.5	60400	4980	756	45800	6660	7.1	1070	98900
MJAKP1	SF-BH-E-PZ-24 pH 7	9	41300	11500	1410	41000	3780	4.5	1650	155000
Time 7 Days										
MJAKP2	SF-OB-PZ-13 pH 2	699	18800	25100	2390	6010	10900	90.5	58700	146000

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
MJAKP3	SF-OB-PZ-13 pH 3	559	19400	5220	2140	5490	66000	54.5	49800	158000
MJAKP4	SF-OB-PZ-13 pH 4	362	16600	850	2300	4710	37600	28.7	33500	106000
MJAKP5	SF-OB-PZ-13 pH 5	168	13800	437	937	3920	17400	14.9	14200	100000
MJAKP6	SF-OB-PZ-13 pH 6	18	9140	1840	1170	2980	3350	3.6	1140	15800
MJAKP7	SF-OB-PZ-13 pH 7	17.3	4600	9170	6800	2050	3560	3.6	2460	9810
MJAKP8	SF-BH-E-PZ-12 pH 2	313	65900	542000	3140	35000	111000	83.8	95400	405000
MJAKP9	SF-BH-E-PZ-12 pH 3	219	61500	140000	2750	27500	79900	62.1	89600	251000
MJAKQ0	SF-BH-E-PZ-12 pH 4	249	70800	1090	2470	18000	39200	32.6	50100	137000
MJAKQ1	SF-BH-E-PZ-12 pH 5	48.8	42900	970	1210	14400	16700	14.2	14400	90500
MJAKQ2	SF-BH-E-PZ-12 pH 6	2.7	28000	764	592	12000	4960	4.1	1290	44700
MJAKQ3	SF-BH-E-PZ-12 pH 7	3.1	15800	1900	1090	9970	734	4	415	38700
MJAKQ4	SF-BH-E-PZ-16 pH 2	913	76000	633000	1470	82900	140000	103	122000	585000
MJAKQ5	SF-BH-E-PZ-16 pH 3	717	69500	333000	1230	72800	79100	80.8	82400	358000
MJAKQ6	SF-BH-E-PZ-16 pH 4	742	65400	100000	1420	68700	110000	68.6	118000	380000
MJAKQ7	SF-BH-E-PZ-16 pH 5	526	50400	1650	1130	56500	42700	30.3	65600	187000
MJAKQ8	SF-BH-E-PZ-16 pH 6	247	45200	2400	984	53300	21100	15.8	20800	132000
MJAKQ9	SF-BH-E-PZ-16 pH 7	118	41000	1970	510	50900	14300	11.8	5110	138000
MJAKR0	SF-BH-E-PZ-24 pH 2	162	204000	392000	888	64300	128000	77.8	128000	712000
MJAKR1	SF-BH-E-PZ-24 pH 3	130	259000	137000	1020	60000	80600	58.7	75100	499000
MJAKR2	SF-BH-E-PZ-24 pH 4	177	219000	28400	738	57600	65000	48.2	53500	369000
MJAKR3	SF-BH-E-PZ-24 pH 5	15.9	86200	2850	425	46500	14900	12.9	2200	135000
MJAKR4	SF-BH-E-PZ-24 pH 6	11.2	65400	3680	552	44400	8090	7.4	1040	111000
MJAKR5	SF-BH-E-PZ-24 pH 7	8.2	39900	5880	825	38100	3810	3.2	909	81500
Day 31										
MJAKY8	SF-OB-PZ-13 pH 2	746	20100	62400	1780	9160	164000	107	80800	237000
MJAKY9	SF-OB-PZ-13 pH 3	659	21500	1100	1740	7370	110000	76.2	64200	174000
MJAKZ0	SF-OB-PZ-13 pH 4	446	18100	791	1600	5800	55400	39.1	41000	128000

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
MJAKZ1	SF-OB-PZ-13 pH 5	206	15200	2390	1640	4600	22600	U	16000	114000
MJAKZ2	SF-OB-PZ-13 pH 6	14.6	10300	2190	1080	3340	2230	U	930	26800
MJAKZ3	SF-OB-PZ-13 pH 7	16.5	5810	11200	6550	2760	3430	U	2610	10800
MJAKZ4	SF-BH-E-PZ-12 pH 2	533	72000	1220000	3080	60900	213000	138	111000	920000
MJAKZ5	SF-BH-E-PZ-12 pH 3	484	70700	431000	2260	54800	199000	131	109000	629000
MJAKZ6	SF-BH-E-PZ-12 pH 4	355	97400	320	3220	26000	34000	22.7	78500	220000
MJB6G1	Redu	534	82800	442	2950	23400	55600	U	48100	209000
MJAKZ7	SF-BH-E-PZ-12 pH 5	251	56000	849	1460	18000	34100	27	28200	137000
MJAKZ8	SF-BH-E-PZ-12 pH 6	15.2	33200	500	540	13400	5330	U	778	71200
MJAKZ9	SF-BH-E-PZ-12 pH 7	6.9	18800	938	706	11000	841	U	308	78700
MJAL00	SF-BH-E-PZ-16 pH 2	988	82300	1250000	1110	107000	234000	150	143000	1050000
MJAL01	SF-BH-E-PZ-16 pH 3	896	83300	678000	1200	115000	239000	159	120000	837000
MJAL02	SF-BH-E-PZ-16 pH 4	755	76900	131000	1790	92000	148000	101	97800	418000
MJAL04	SF-BH-E-PZ-16 pH 6	360	54600	1960	876	56000	28400	22.3	22400	160000
MJAL05	SF-BH-E-PZ-16 pH 7	192	46100	746	400	53700	16900	U	8190	168000
MJAL06	SF-BH-E-PZ-24 pH 2	109	206000	870000	593	85400	181000	119	177000	969000
MJAL07	SF-BH-E-PZ-24 pH 3	292	253000	53300	946	75000	131000	87	118000	516000
MJAL08	SF-BH-E-PZ-24 pH 4	367	297000	4940	1240	68000	95800	62.2	80700	476000
MJAL09	SF-BH-E-PZ-24 pH 5	22.8	119000	1340	211	51800	20200	14.1	1040	184000
MJAL10	SF-BH-E-PZ-24 pH 6	14.5	76100	1090	191	46300	11100	10.1	609	124000
MJAL11	SF-BH-E-PZ-24 pH 7	5.3	43100	1790	284	38700	2950	3.9	321	95900
Day 60										
MJB689	SF-OB-PZ-13 pH 2	932	26100	153000	2540	14400	194000	U	92000	353000
MJB690	SF-OB-PZ-13 pH 3	839	26200	5210	2050	10700	147000	U	78800	264000
MJB691	SF-OB-PZ-13 pH 4	497	20200	578	1860	7310	70400	U	40100	151000
MJB692	SF-OB-PZ-13 pH 5	193	16800	334	718	5500	28800	U	10300	137000
MJB693	SF-OB-PZ-13 pH 6	7.5	9670	1840	1420	3400	1470	U	522	36400

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
MJB694	SF-OB-PZ-13 pH 7	47.7	5670	25300	24200	1920	8680	U	6610	5640
MJB695	SF-BH-E-PZ-12 pH 2	739	94900	1090000	3030	105000	304000	U	116000	804000
MJB696	SF-BH-E-PZ-12 pH 3	591	90900	495000	1660	94300	268000	U	95300	627000
MJB697	SF-BH-E-PZ-12 pH 4	543	86900	977	3530	27100	64900	U	47500	222000
MJB698	SF-BH-E-PZ-12 pH 5	336	65600	1440	1900	21800	42000	U	24900	167000
MJB699	SF-BH-E-PZ-12 pH 6	45.6	40800	592	642	16000	7620	U	1410	105000
MJB6A0	SF-BH-E-PZ-12 pH 7	15.9	27300	544	439	14000	1890	U	436	117000
MJB6A1	SF-BH-E-PZ-16 pH 2	1010	102000	1360000	1340	145000	266000	U	159000	904000
MJB6A2	SF-BH-E-PZ-16 pH 3	1010	104000	767000	1510	160000	293000	U	128000	821000
MJB6A3	SF-BH-E-PZ-16 pH 4	912	95200	73500	1510	135000	217000	U	86400	461000
MJB6A4	SF-BH-E-PZ-16 pH 5	800	76100	643	1570	78400	74100	U	70700	256000
MJB6A5	SF-BH-E-PZ-16 pH 6	414	67800	639	727	67900	40000	U	22300	213000
MJB6A6	SF-BH-E-PZ-16 pH 7	199	56300	1050	412	62800	24400	U	6150	209000
MJB6A7	SF-BH-E-PZ-24 pH 2	158	268000	45400	673	95200	140000	U	129000	505000
MJB6A8	SF-BH-E-PZ-24 pH 3	67.7	242000	930000	801	115000	216000	U	216000	847000
MJB6A9	SF-BH-E-PZ-24 pH 4	507	323000	947	615	76400	93400	U	80600	477000
MJB6B0	SF-BH-E-PZ-24 pH 5	35.2	138000	1040	191	57500	22000	U	1480	204000
MJB6B1	SF-BH-E-PZ-24 pH 6	18.4	83900	4330	765	52500	11500	U	982	138000
MJB6B2	SF-BH-E-PZ-24 pH 7	5.6	46600	1870	358	42300	2900	U	332	109000
Day 90										
MJB6B3	SF-OB-PZ-13 pH 2	950	27000	204000	1860	17700	207000	U	97400	425000
MJB6B4	SF-OB-PZ-13 pH 3	868	26900	1190	1720	14100	161000	U	82900	281000
MJB6B5	SF-OB-PZ-13 pH 4	492	20000	752	1650	8270	76500	U	34400	153000
MJB6B6	SF-OB-PZ-13 pH 5	152	16000	410	490	6080	28200	U	5280	140000
MJB6B7	SF-OB-PZ-13 pH 6	54.8	14200	549	411	5150	5360	U	2290	79200
MJB6B8	SF-OB-PZ-13 pH 7	36.1	12200	494	391	4400	3980	U	1880	63000
MJB6B9	SF-BH-E-PZ-12 pH 2	960	104000	1220000	1940	143000	468000	U	106000	947000

Table A-5. (continued).

Sample Number	Sample Name and Location	C d ug/L	Ca ug/L	Fe ug/L	P b ug/L	Mg ug/L	Mn ug/L	Se ug/L	Zn ug/L	S ug/L
MJB6C0	SF-BH-E-PZ-12 pH 3	777	107000	345000	1870	158000	469000	21.2	74300	745000
MJB6C1	SF-BH-E-PZ-12 pH 4	628	86400	401	2710	27800	67800	U	50600	228000
MJB6C2	SF-BH-E-PZ-12 pH 5	372	67700	3050	4890	24600	47000	U	21400	184000
MJB6C3	SF-BH-E-PZ-12 pH 6	150	46300	435	731	17900	14100	U	5580	126000
MJB6C4	SF-BH-E-PZ-12 pH 7	179	46400	653	617	17700	14300	U	10400	175000
MJB6C5	SF-BH-E-PZ-16 pH 2	1050	107000	1840000	1470	167000	335000	U	158000	1670000
MJB6C6	SF-BH-E-PZ-16 pH 3	991	107000	844000	1480	174000	345000	U	120000	921000
MJB6C7	SF-BH-E-PZ-16 pH 4	977	104000	2060	1300	163000	296000	U	62900	516000
MJB6C8	SF-BH-E-PZ-16 pH 5	891	77000	887	1740	78700	86800	U	69900	277000
MJB6C9	SF-BH-E-PZ-16 pH 6	467	67400	600	601	65800	45500	U	24000	236000
MJB6D0	SF-BH-E-PZ-16 pH 7	191	55700	1930	540	61600	22600	U	5530	242000
MJB6D1	SF-BH-E-PZ-24 pH 2	1250	106000	1970000	1400	161000	335000	U	156000	1590000
MJB6D2	SF-BH-E-PZ-24 pH 3	393	249000	52400	863	103000	178000	U	181000	589000
MJB6D3	SF-BH-E-PZ-24 pH 4	410	282000	922	337	75800	100000	U	63400	461000
MJB6D4	SF-BH-E-PZ-24 pH 5	60.3	152000	905	170	56700	26700	U	2970	226000
MJB6D5	SF-BH-E-PZ-24 pH 6	16.6	86200	1270	222	51500	11100	U	578	146000
MJB6D6	SF-BH-E-PZ-24 pH 7	5	45500	1020	186	40500	2520	U	223	112000

Table A-6. Concentrations for leach tests in the presence and absence of oxygen from 0–90 days.

		Concentration ug/L		Concentration measured at Lab						
		Cd	Ca	Fe	Pb	Mg	Mn			
	Wet Dry Time 8 hours									
MJAKS8	SF-OB-PZ-13 Surface	22.4	4450	12200	8650	1150	4160	U	3140	2680
MJAKS9	SF-OB-PZ-13 Groundwater		9010	3590	2030	2930	1220	U	935	8020
MJAKT0	SF-BH-E-PZ-12 Surface		14800	2280	1140	1930	512	U	463	10000
MJAKT1	SF-BH-E-PZ-12 Groundwater		22000	9530	5120	11800	1870	U	1870	62400
MJAKT2	SF-BH-E-PZ-16 Surface	142	34300	1520	297	4920	12800	U	12000	47300
MJAKT3	SF-BH-E-PZ-16 Groundwater	144	27000	7380	1040	53700	13100	U	12500	115000
MJAKT4	SF-BH-E-PZ-24 Surface	37.5	21800	49000	10000	3830	6840	U	8100	5260
MJAKT5	SF-BH-E-PZ-24 Groundwater		34000	5640	875	42300	2060	U	900	87000
	Wet Dry Time 16 hours									
MJAKT6	SF-OB-PZ-13 Surface	30.2	4870	15400	12200	1170	5540	U	4260	3040
MJAKT7	SF-OB-PZ-13 Groundwater	14.9	10000	7760	4370	3180	2440	U	1710	8220
MJAKT8	SF-BH-E-PZ-12 Surface		16200	9200	5260	2310	1320	U	1300	10500
MJAKT9	SF-BH-E-PZ-12 Groundwater	16.3	17900	5740	3100	8910	1860	U	2940	49000
MJAKW0	SF-BH-E-PZ-16 Surface	151	33700	4090	790	4680	14000	U	12700	50500
MJAKW1	SF-BH-E-PZ-16 Groundwater	157	30700	3820	646	51300	13800	U	13300	118000
MJAKW2	SF-BH-E-PZ-24 Surface	53.8	26300	66300	14000	5050	9630	U	11000	5550
MJAKW3	SF-BH-E-PZ-24 Groundwater	15.2	37700	17100	2700	42600	3520	U	2440	86400
	Time 24 hours									
MJAKW4	SF-OB-PZ-13 Surface	35	5110	18100	14800	1210	6780	U	4870	3140
MJAKW5	SF-OB-PZ-13 Groundwater	18.1	9700	8440	5230	2820	3090	U	2070	8550
MJAKW6	SF-BH-E-PZ-12 Surface		16700	2040	1070	2080	515	U	387	10900
MJAKW7	SF-BH-E-PZ-12 Groundwater	15.8	19600	4940	2670	9310	2000	U	2710	50600
MJAKW8	SF-BH-E-PZ-16 Surface	161	35800	942	281	5170	14300	12.7	13200	51300
MJAKW9	SF-BH-E-PZ-16 Groundwater	174	35300	8600	1300	53200	14800	11.3	15400	132000

Table A-6. (continued).

		Concentration ug/L		Concentration measured at Lab						
		Cd	Ca	Fe	Pb	Mg	Mn	Se	Zn	S
MJAKX0	SF-BH-E-PZ-24 Surface	53.9	27300	68500	13900	5290	10000	9.9	11100	5740
MJAKX1	SF-BH-E-PZ-24 Groundwater	14.6	40300	15800	2430	43200	3430	U	23100	86500
	Wet Dry Time 3 Days									
MJAKX2	SF-OB-PZ-13 Surface	14.1	4950	6710	4980	1030	2870	U	1820	3780
MJAKX3	SF-OB-PZ-13 Groundwater	9.2	10200	224	104	3000	635	U	549	9020
MJAKX4	SF-BH-E-PZ-12 Surface	1.8	19500	702	477	2510	350	U	164	12500
MJAKX5	SF-BH-E-PZ-12 Groundwater	8.4	22300	149	181	9680	1810	U	1400	51000
MJAKX6	SF-BH-E-PZ-16 Surface	177	38800	1710	403	6140	17500	13.1	12800	59200
MJAKX7	SF-BH-E-PZ-16 Groundwater	187	40200	192	191	52000	16200	12.4	16000	135000
MJAKX8	SF-BH-E-PZ-24 Surface	11.5	25200	14300	2790	2790	2430	3.3	2220	7900
MJAKX9	SF-BH-E-PZ-24 Groundwater	7.2	46300	394	116	41500	2430	3.5	288	88100
	Wet Dry Time 7 Days									
MJAKY0	SF-OB-PZ-13 Surface	29.9	5360	17300	13600	1390	5680	3.6	4330	4320
MJAKY1	SF-OB-PZ-13 Groundwater	11.8	11100	2570	1370	3170	1480	U	918	9720
MJAKY2	SF-BH-E-PZ-12 Surface	2.9	20100	1240	675	2730	401	U	240	17500
MJAKY3	SF-BH-E-PZ-12 Groundwater	6	25800	984	576	9890	1840	U	557	54000
MJAKY4	SF-BH-E-PZ-16 Surface	183	42800	978	323	7300	18900	14.1	11800	65800
MJAKY5	SF-BH-E-PZ-16 Groundwater	231	46500	950	413	54000	19300	12.2	17900	131000
MJAKY6	SF-BH-E-PZ-24 Surface	27.3	26200	32800	6870	3820	4850	4.5	5550	9270
MJAKY7	SF-BH-E-PZ-24 Groundwater	11.8	53600	2730	468	41600	3450	U	684	90800
	Wet Dry Time 30 Days									
MJB6D7	SF-OB-PZ-13 Surface	11.9	7480	610	544	1290	1170	U	508	7470
MJB6D8	SF-OB-PZ-13 Groundwater	11.4	12500	507	431	3620	1580	U	386	14800
MJB6D9	SF-BH-E-PZ-12 Surface	8.6	30400	724	645	4390	1120	U	282	37400
MJB6E0	SF-BH-E-PZ-12 Groundwater	66	38500	644	628	12500	7330	U	2800	91800
MJB6E1	SF-BH-E-PZ-16 Surface	381	54800	514	523	11900	32100	U	23800	102000

Table A-6. (continued).

		Concentration ug/L		Concentration measured at Lab						
		Cd	Ca	Fe	Pb	Mg	Mn			
MJB6E2	SF-BH-E-PZ-16 Groundwater	416	61000	610	679	63200	38000	U	25600	192000
MJB6E3	SF-BH-E-PZ-24 Surface	7.8	31800	7140	1730	3080	1740	U	1190	15000
MJB6E4	SF-BH-E-PZ-24 Groundwater	9.8	62900	933	202	44800	4810	U	344	107000
	Wet Dry Time 60 Days									
MJB6E5	SF-OB-PZ-13 Surface	9.2	6590	2910	2600	1410	1370	U	828	9320
MJB6E6	SF-OB-PZ-13 Groundwater	10.2	12400	919	825	3760	1300	U	426	16300
MJB6E7	SF-BH-E-PZ-12 Surface	22.3	43300	373	436	6160	2740	U	744	50600
MJB6E8	SF-BH-E-PZ-12 Groundwater	293	52000	869	1360	16300	24100	U	17200	126000
MJB6E9	SF-BH-E-PZ-16 Surface	549	62700	2190	1140	16200	44200	U	34400	131000
MJB6F0	SF-BH-E-PZ-16 Groundwater	525	66100	1130	818	66600	47000	U	34600	215000
MJB6F1	SF-BH-E-PZ-24 Surface	4.8	34200	3810	889	3110	1150	U	596	18400
MJB6F2	SF-BH-E-PZ-24 Groundwater	11.8	65700	2500	543	45300	5030	U	559	111000
	Wet Dry Time 90 Days									
MJB6F3	SF-OB-PZ-13 Surface	15.2	5550	8290	7030	1260	2570	U	1900	6180
MJB6F4	SF-OB-PZ-13 Groundwater	9.3	10300	3270	2660	3080	1500	U	808	13500
MJB6F5	SF-BH-E-PZ-12 Surface	38.6	50600	1080	1100	7960	3170	U	1270	61500
MJB6F6	SF-BH-E-PZ-12 Groundwater	428	57700	1400	2270	18800	33000	U	25400	147000
MJB6F7	SF-BH-E-PZ-16 Surface	681	66900	2670	1510	20000	56600	U	43100	156000
MJB6F8	SF-BH-E-PZ-16 Groundwater	621	70100	1870	1230	70100	56400	U	43200	231000
MJB6F9	SF-BH-E-PZ-24 Surface	14.1	30700	14000	3390	3350	2550	U	2330	15300
MJB6G0	SF-BH-E-PZ-24 Groundwater	13.3	54100	5860	1190	35500	4630	U	983	88000

Table A-7. Groundwater constituents measured previously

Location	Date	DTW (ft)	pH	Conductivity	Temp °C	DO	ORP	Ca (mg/L)
SF-OB-PZ-13	9-22-08	9.8	6.47	284	9.7	5.61	213	15.7
SF-BH-E-PZ-12	9-22-08	11.5	5.8	482.9	14.1	0.31	48	35.5
SF-BH-E-PZ-16	9-23-08	10.4	4.7	1528	13.3	0.44	219	150
SF-BH-E-PZ-24	9-23-08	13.6	5.7	1499	12.9	3.9	28	145
	Date	Alkalinity (mg/L CaCO ₃)	Nitrate/ Nitrite	Total P (mg/L)	Cl (mg/L)	Mg (mg/L)	SO ₄ (mg/L)	Fe (mg/L)
SF-OB-PZ-13	9-22-08	56	0.19	0.0073	6.0	4.9	39	0.10
SF-BH-E-PZ-12	9-22-08	80	0.05	0.0072	4.1	15.9	122	4.27
SF-BH-E-PZ-16	9-23-08	10	0.10	0.177	3.7	44.4	592	0.10
SF-BH-E-PZ-24	9-23-08	23	0.05	0.963	6.3	56.5	675	22.6

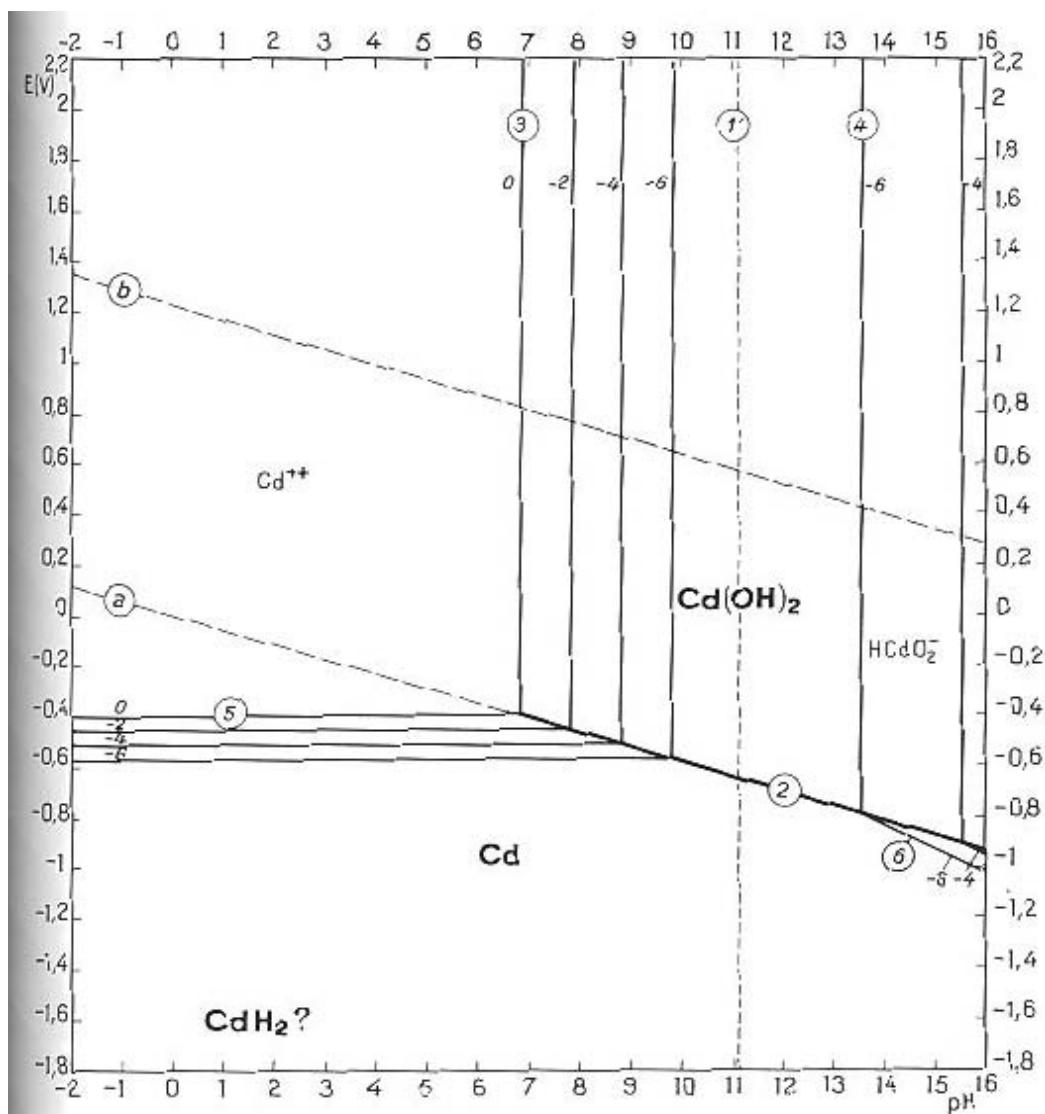


Figure A-1. Cadmium pH equilibrium diagram at 25°C.

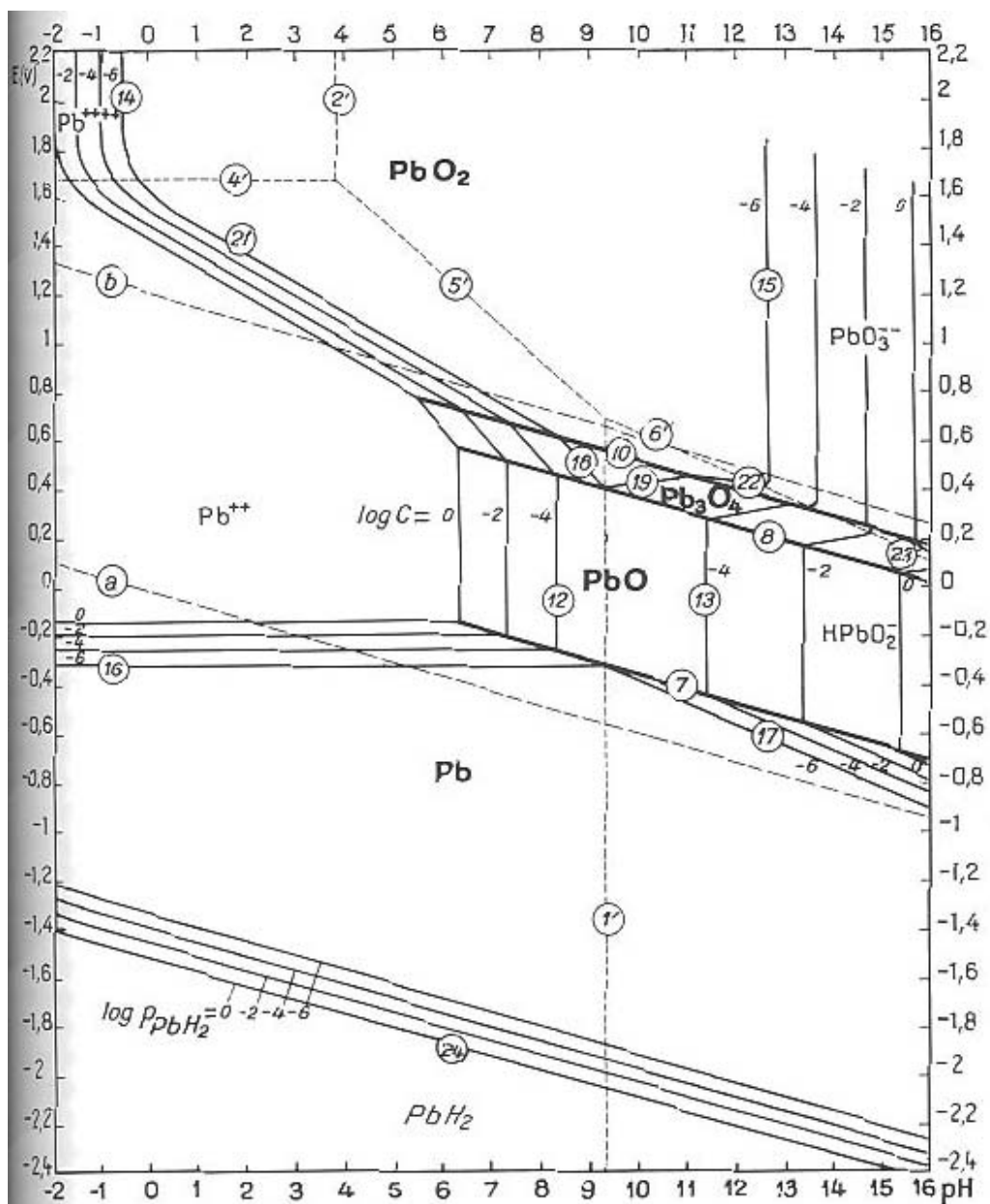


Figure A-2. Lead pH equilibrium diagram at 25°C.

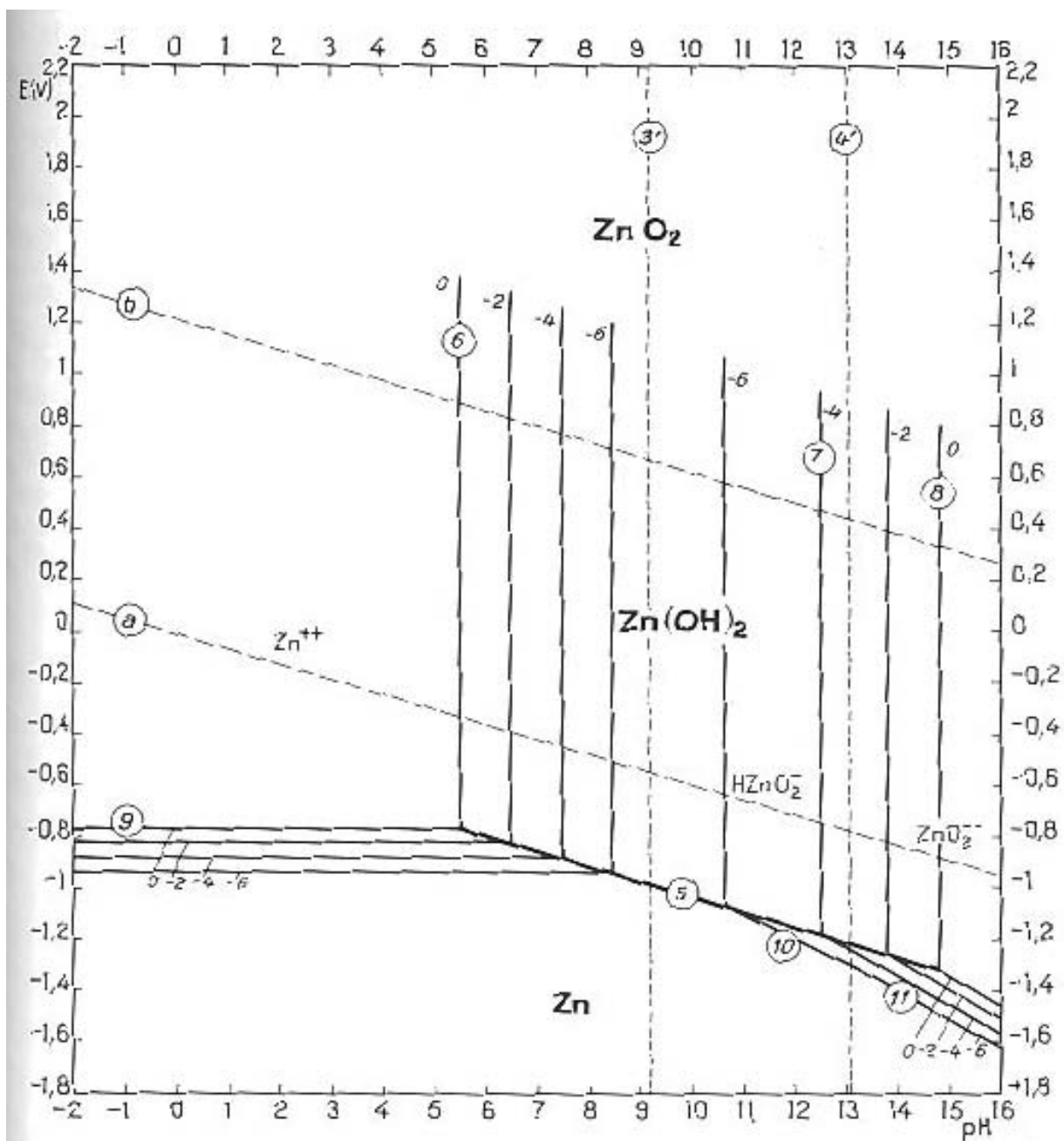
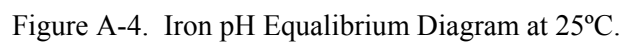


Figure A-3. Zinc pH equilibrium diagram at 25°C.



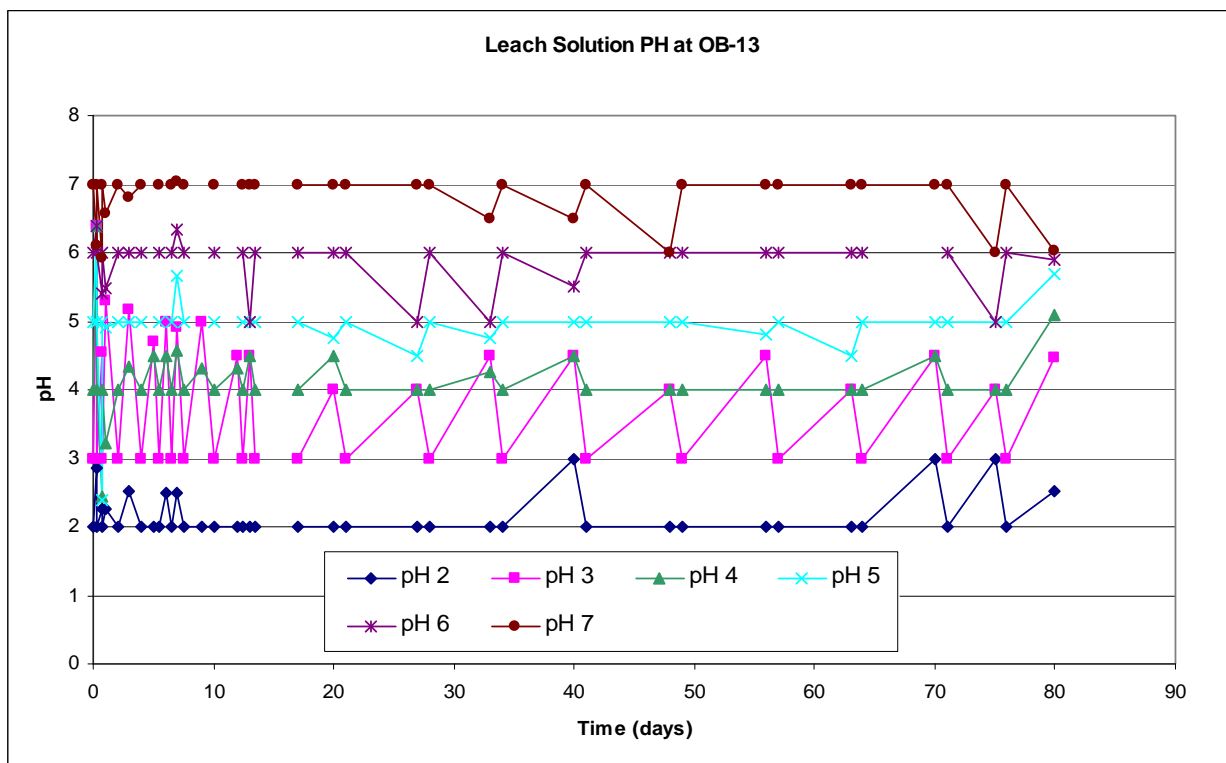


Figure A-5. Leach solution pH for Location SF-OB-PZ-13.

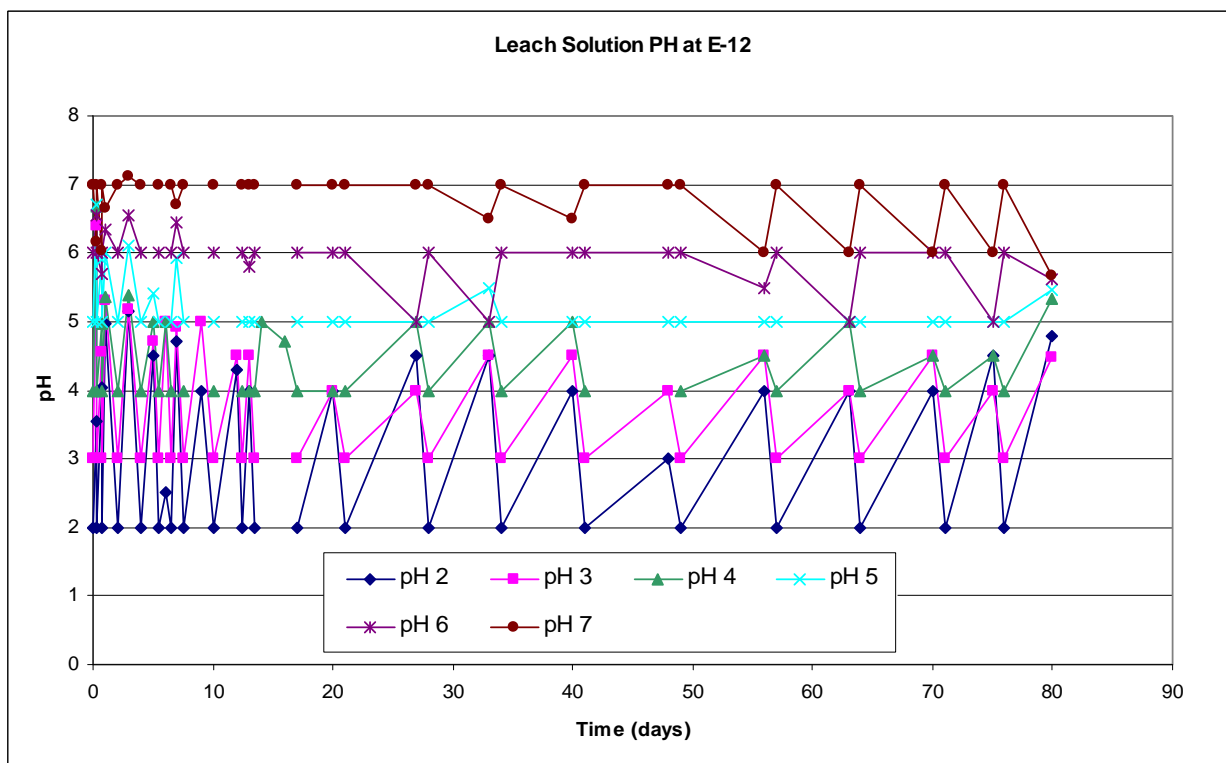


Figure A-6. Leach solution pH for Location SF-BH-E-PZ-12.

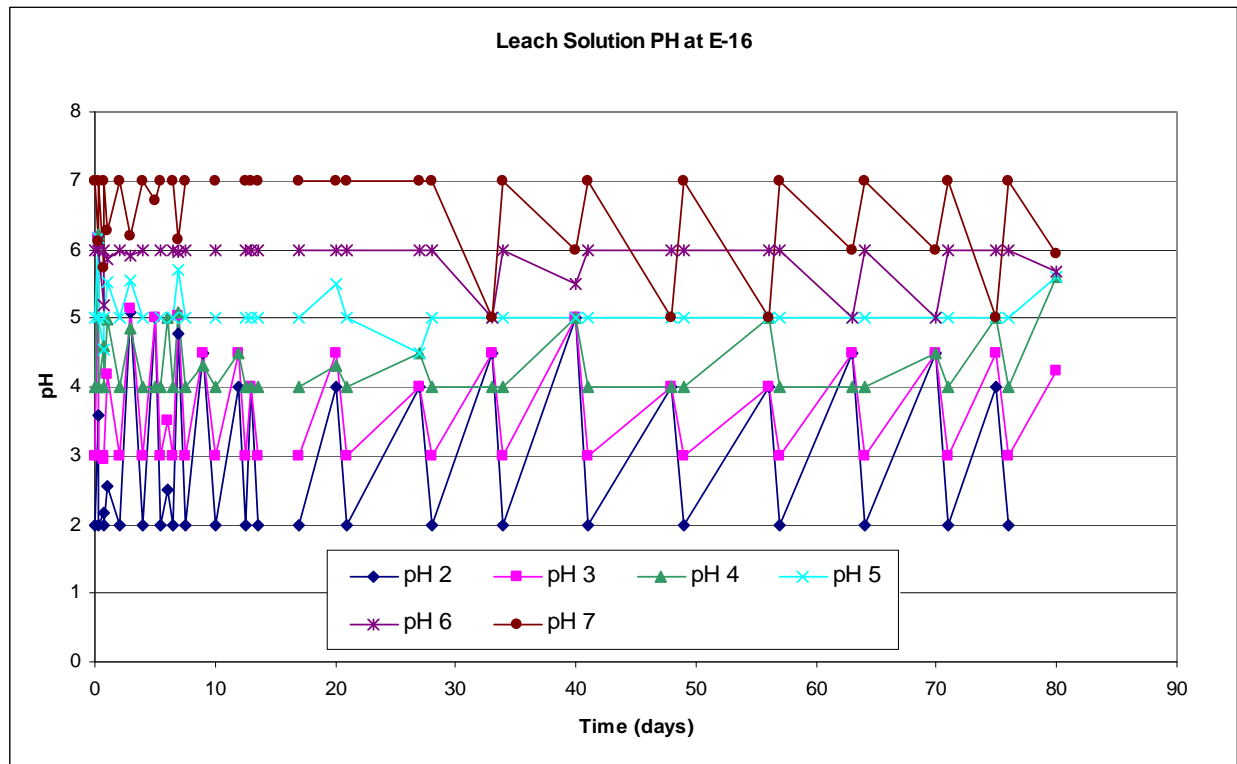


Figure A-7. Leach solution pH for Location SF-BH-E-PZ-16.

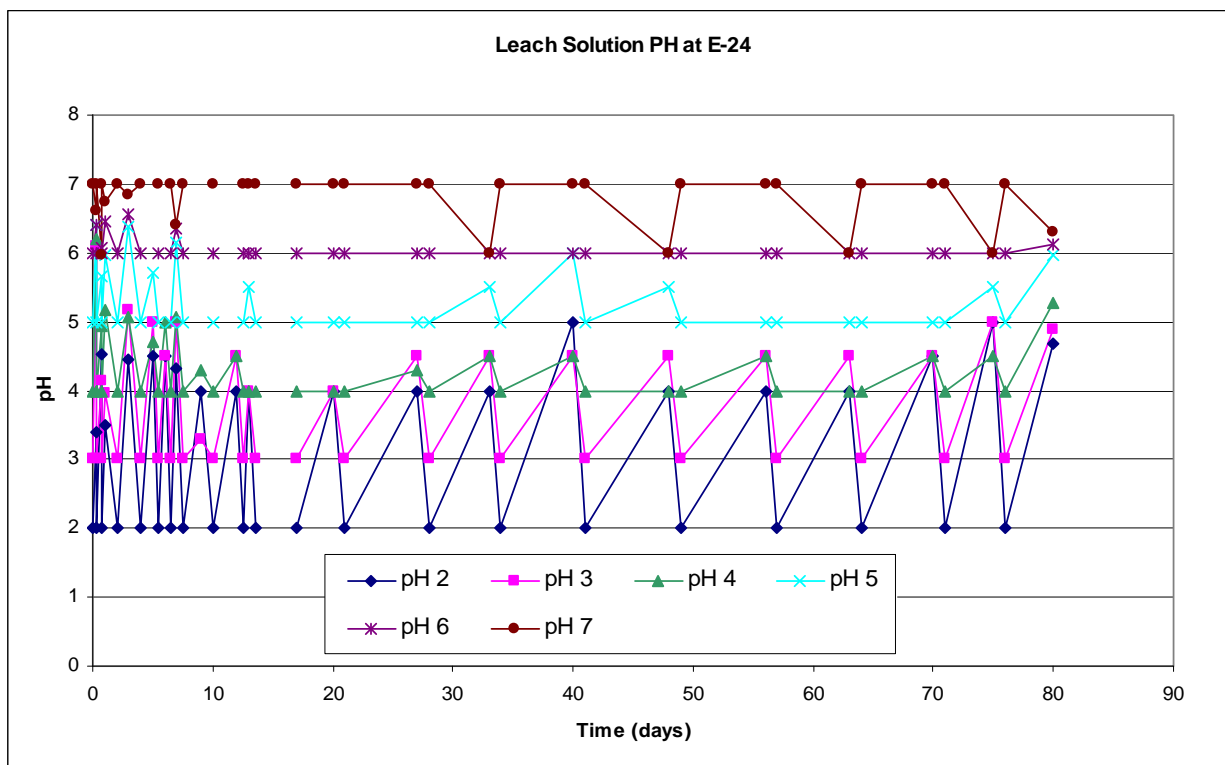


Figure A-8. Leach solution pH for Location SF-BH-E-PZ-24.

Table A-8. Partial data for Percent soil less than 2mm.

Core location	Depth	Mass less than 2mm (gm)	Mass greater than 2mm (gm)	Percent less than 2mm (%)	Percent greater than 2mm (%)
Osborn	1-1.8 ft	154.7	314.2	33.0	67.0
Osborn	3-4 ft	121	289.2	29.5	70.5
Osborn	5-6 ft	135.8	275.8	33.0	67.0
E-12	1-2 ft	Not Available	Not Available	Not Available	Not Available
E-12	3-4 ft	Not Available	Not Available	Not Available	Not Available
E-12	5-6 ft	Not Available	Not Available	Not Available	Not Available
E-12	7-8 ft	Not Available	Not Available	Not Available	Not Available
E-12	8-9 ft	246.3	0.65	99.7	0.3
E-16	1-2 ft	Not Available	Not Available	Not Available	Not Available
E-16	3-4 ft	Not Available	Not Available	Not Available	Not Available
E-16	5-6 ft	Not Available	Not Available	Not Available	Not Available
E-16	7-8 ft	Not Available	Not Available	Not Available	Not Available
E-24	1-2 ft	468.7	102.7	82.0	18.0
E-24	3-4 ft	687.8	54.7	92.6	7.4
E-24	5-6 ft	255.6	78.5	76.5	23.5
E-24	7-7.7 ft	187.6	163.9	53.4	46.6

