

Geochemistry of Surface Sediments, Baker Woodlands, Lancaster, Pennsylvania

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INTRODUCTION

The Baker Woodlands Environmental Research Site, located in Lancaster, PA, is a six acre area which is recovering from past environmental and geological disturbances. Originally, the area was agricultural as was much of the Lancaster area. Osage Orange trees which served as windbreaks still survive, so it is possible to see the extent of the old fields. Later, the area was used as a clay mine. The clays were transformed into bricks at the brickworks which was at the northern end of the property. The mining process created large pits in the ground, which were subsequently used as landfills (de Wet et al., 1999). Although these landfills are inactive and are covered with organic matter, the effects of the waste dumping are still measurable and, in some cases, visible. For example, iron staining is exposed at several leachate seeps and vegetation is obviously less dense in some areas of the landfill than in others. Another important component of the area is the presence of a recently remediated Superfund site, Lancaster Battery, in the Baker Woodlands watershed. The goal of this project was to determine the extent of metal contamination in surface sediments along the edge of the landfill in both an ephemeral stream and a wetland.

Samples were collected along the stream, which runs along the southern edge of the landfill. This stream flows into a large wetland area in the southwest portion of the site. Samples were also collected along the manmade drainage ditch (extant since at least 1947) which flows through the wetland. These samples were analyzed in an Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) for barium, cadmium, cobalt, chromium, iron, magnesium, manganese, lead, vanadium, and zinc.

METHODS

In the Field

- **Sample Collection:** Using a trowel, we took 42 samples of surface sediment of approximately 100 grams each. These samples were gathered over a period of three weeks from various locations at the Baker site. Samples were collected every 20-30 m and additional sites were selected based on visible evidence of seeps (Figure 1).

- **GPS:** Using a Trimble ProXR(S) and TSC-1 asset surveyor, the locations of all sample sites were determined through Global Positioning System (GPS) technology. The points were then downloaded into Trimble Pathfinder Office software and integrated into a Geographic Information System (GIS) using ArcView 3.1.

In the Lab

- **ICP-AES Sample Preparation:** Upon return to the lab, sediment samples were dried overnight at approximately 67° C. Once dry, they were crushed and sifted through a size 20 mesh. 1.0000g ±0.0002g of each sample was massed and subsequently digested to remove organic substances and strip the metals off the surface of the sediment grains. The process of digestion was as follows: add 10 mL 1:1 HNO₃, mix and cover with a watch glass. Heat sample at 95° C for 10 minutes. Allow sample to cool. Add 5 mL of concentrated HNO₃. Return to heat for 30 minutes, making sure that liquid does not all evaporate. Cool Sample and add 5 mL of 1:1 HCl and 10 mL distilled H₂O. Heat for an additional 10 minutes. Cool and filter the slurry into a 50 mL beaker. Add to a 100mL volumetric flask and bring up to volume with distilled H₂O.

- Samples were then analyzed using the ICP-AES. The ICP-AES was prepared with a profile of yttrium (Y) before sample testing. In addition, the ICP-AES was standardized with three control solutions both before testing and after every 15 samples. A flush time of 60 seconds was used to ensure that the nebulizer was clear of impurities from earlier samples.

- Data generated by the ICP-AES was then added to the GIS so that the data could be analyzed with respect to relative geographic position.

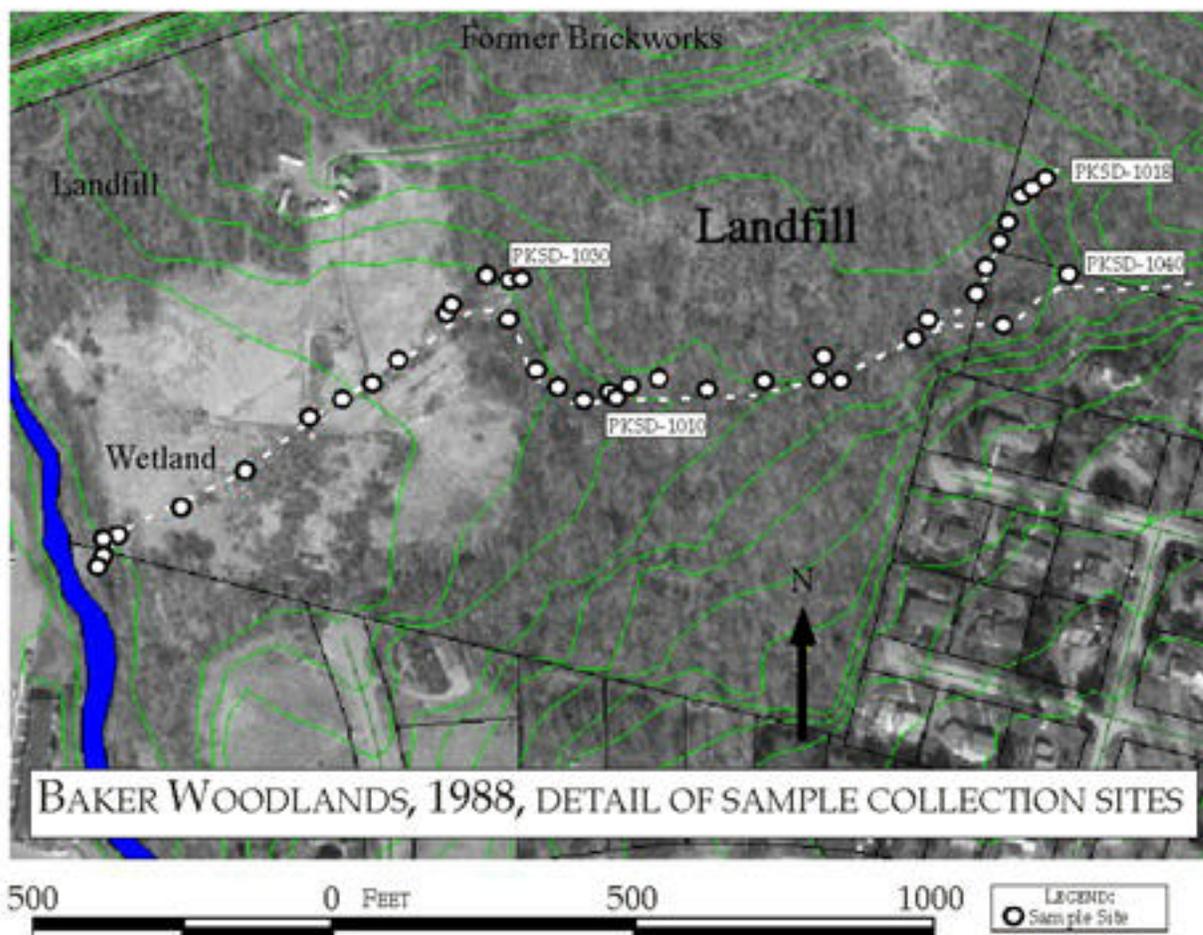


Figure 1: Sample locations at Baker Woodlands. Samples taken from the four main seeps located adjacent to the landfill are labeled (PKSD-1010, 1018, 1030, and 1040).

RESULTS

The elements tested in this research were Ba, Cd, Co, Cr, Fe, Mg, Mn, Pb, V, and Zn. Of these ten elements, four were below mean values as described by Bowen (1979). The elements which were disregarded for interpretation are Co, Cr, Mg, and V. The remaining elements (Ba, Cd, Fe, Mn, Pb, and Zn) were used more extensively for comparison purposes. These elements were charted according to their relative positions and concentrations using a GIS database.

DISCUSSION

The results obtained from the ICP analysis reveal some interesting trends. The elements which were revealed to have high concentrations show similar data trends in many respects. Because similar traits exist for multiple elements, generalizations are possible for these elements.

The samples of Cd, Fe, Zn, and Pb that were collected in the ephemeral stream all exhibit a rapid decrease in concentration after introduction to the surface water system at seeps. This is seen most vividly in samples PKSD-1018, PKSD-1010, and PKSD-1020. These seeps were marked by peaks in the graphs of each of the above elements (Figure 2). The samples collected downstream from the seeps plateau at relatively low concentrations (in comparison to seep concentrations) within about 30 m, and sometimes in as little as 10 m (Figure 2). These metals apparently precipitate out of solution very quickly under the conditions of this stream causing visible staining (especially Fe). This hypothesis is supported by the Eh-pH graphs of Pb and Fe which show that under Baker Woodlands conditions ($\text{pH}=7\pm 1.5$, $\text{Eh}>0$), neither Pb nor Fe will be retained as a cation in aqueous solution (Garrels and Christ, 1965). Fe precipitates as Fe_2O_3 and Pb as PbCO_3 . Ba, Cd, and Zn were expected to follow similar patterns of precipitation.

Mn is the exception to the pattern of high concentrations at the seeps; indeed, the seeps exhibit the lowest concentrations. Higher Mn values were obtained from fertile soils, for example, PKSD-1038 was taken from the small wetland, and contains high Mn concentrations. This pattern continues throughout the wetland, where the values crested 9000 ppm in the thick soil. It is likely that the high Mn values are the result of high background concentrations of MnO in normal soil. Mn in acidic environments breaks down to its cation form in solution. The digestion process was easily acidic enough to cause the MnO to be reduced.

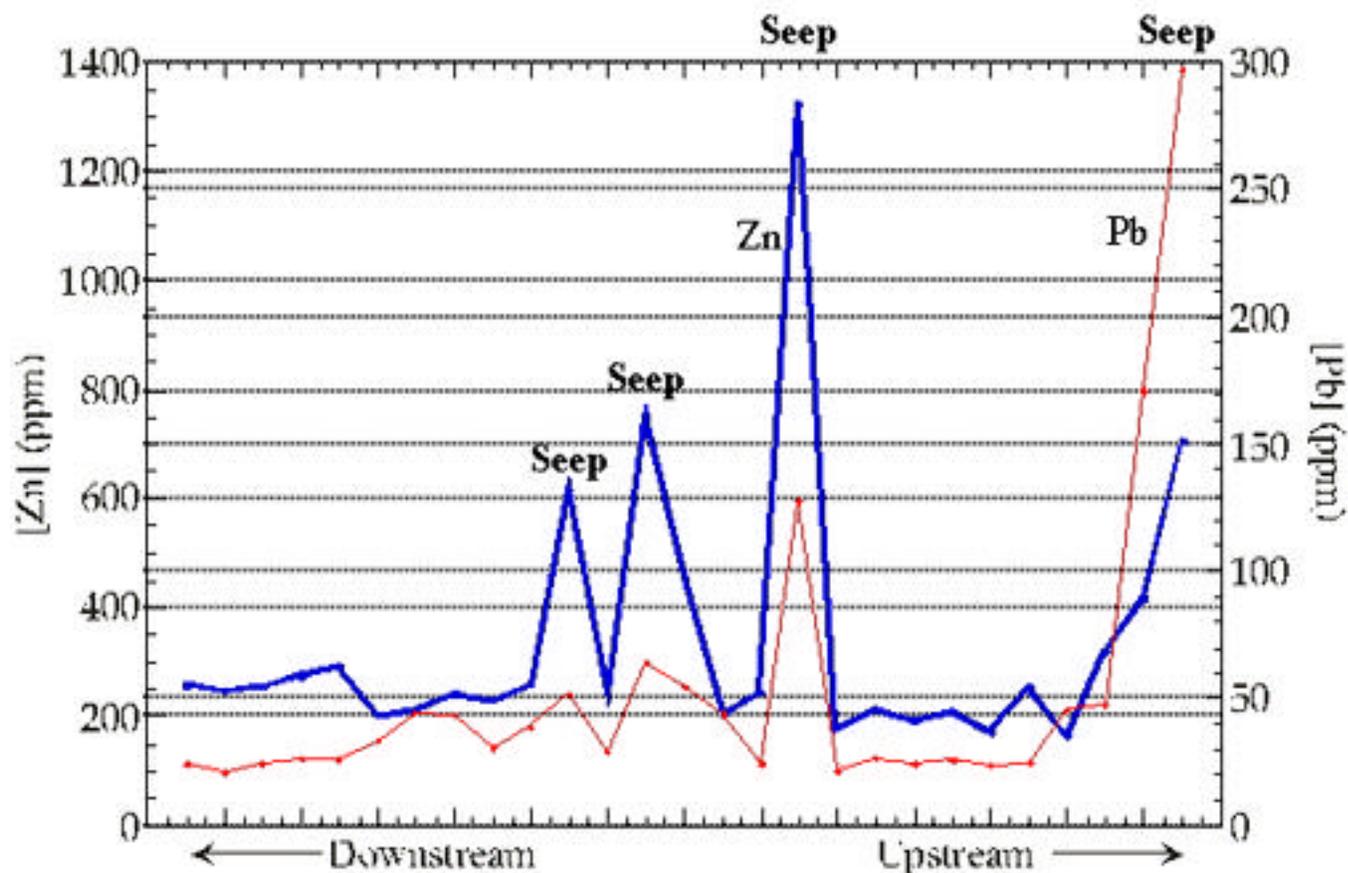


Figure 2: Zn and Pb plotted against distance from upstream (right) to downstream (left).

The other elements did not parallel one another in the wetlands as they did along the stream. Ba, Cd, and Fe once again exhibited a rapid decrease in concentration from the highest values at the seep at PKSD-1030 (Figure 3). Pb and Zn, however, were more variable. This inconsistency may be attributed to low initial concentrations of Pb and Zn in the seep as a result of heterogeneity of the landfill contaminants (Smith, 1977).

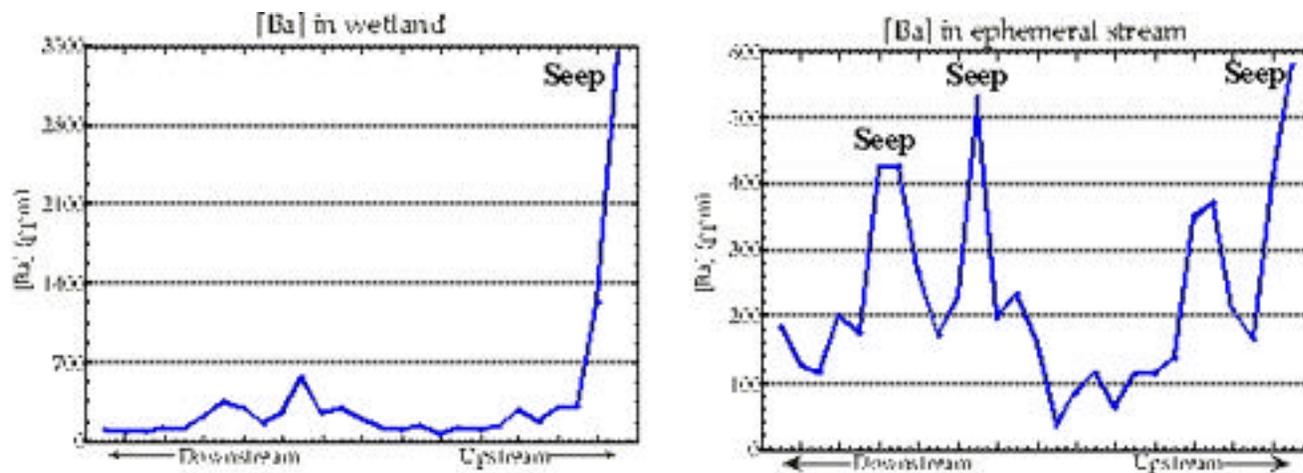


Figure 3: Ba plotted as a function of distance from source. Note that the stream drains into the wetland.

The sources of the highly concentrated metals are an important consideration. Iron is the most concentrated element in the sediment and appears to originate in the landfill. Geophysics research at the Baker Campus supports this hypothesis; large amounts of scrap iron were found in the landfill. There are several possible sources of cadmium in the Baker sediments. Lancaster Battery is probably the source of a minimal amount of the Cd found in the sediments (up to 2 ppm). The rest of the Cd is presumably of landfill origin. The pattern of cadmium concentrations along the stream verifies this conclusion. Possible sources for Cd contamination are paint, fertilizer, and plating on metal (Sparks, 1995). Both lead and zinc seem to be related to cadmium because they are all used in the manufacture of batteries. Coincidentally, all three elements are also present in paint. The barium concentrations are higher than normal in and around the landfill due to the presence of waste products from the Armstrong linoleum plant near the Baker site. Linoleum is commonly found on the surface of the ground in the site, and has also been discovered underground during geophysical excavations.

CONCLUSIONS

- The Baker Woodlands are rich in Ba, Cd, Fe, Mn, Pb, and Zn. Ba is a byproduct of nearby linoleum manufacture. Cd, Pb, and Zn contamination are present in the landfill. Their source is likely residual waste from the battery plant and/or paint remains in the landfill. The iron present in the sediments is a result of bulk iron waste dumping. The high concentration of Mn in the samples is a natural result of the digestion process and as such does not represent an environmental threat.
- The remediation distance for Ba, Cd, Fe, Pb, and Zn is between 10 and 30 meters in the Baker stream and wetland.

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