Lead Distribution in Surface Soil
Adjacent to a Secondary Lead Smelter

An Honors Thesis (HONRS 499)

by

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6/22/99

7/99

Abstract

Industrial atmospheric deposition of heavy metals such as lead can have profound long term effects on soil quality. The following study explores lead deposition patterns in the surface soil around a lead battery recycling plant located in Muncie, Indiana. Soils were sampled at various distances and directions from the plant in order to determine the mobility of lead emissions, as well as the effects of prevailing wind patterns on deposition.

Introduction

Various industrial activities release lead metal fume to the environment. Among these are lead battery recycling plants, primary and secondary lead smelters, and coal and oil-fired power stations. While steps have been taken to reduce lead emissions from smelters, soils located near lead smelters are reported to contain elevated levels of lead, as high as 62,000 mg/kg in one instance (Mattigod et al., 1983).

The city of Muncie, Indiana is home to various metal-related industries, including a lead battery recycling plant equipped with a secondary lead smelter. The plant is located on Pleasant Boulevard, between Delaware drive to the west and Hamilton drive to the east. It is hypothesized that this battery recycling plant has emitted significant quantities of metal to the environment, which have accumulated in the surrounding soils. Although the plant is currently kept under negative pressure conditions to reduce the level of lead emissions, periodic fugitive emissions may still cause significant atmospheric emissions. In this study, the distribution and mobility of lead was examined with relation to prevailing wind directions. Residential areas in the direct vicinity of the plant were also evaluated concerning the extent of soil lead contamination.

Health Significance of Lead

Lead toxicity is of greatest concern to exposed children. This is because lead is highly neurotoxic and has the capacity to cause permanent learning deficits in young children (Klaassen, 1996). The Centers for Disease Control currently recommend that a child's blood-lead level be kept below 10 μg/dl (EPA, 1993). 10 μg/dl should not be considered a safe blood-lead level; it is cause for concern, especially if many children in a community display blood lead levels of greater than or equal to 10 μg/dl. If this situation arises, community prevention activities should be undertaken. The fatal dose to a young child is 100 - 150 μg/dl, only 10 times the level of concern (EPA, 1993).

Children tend to absorb lead more thoroughly than adults do. A child's absorption of lead will depend on his/her level of exposure, as well as diet (Klaassen, 1996). Because lead ions are very similar in size and charge to calcium ions, they have a tendency to be stored in bone. Children whose diets contain greater nutrition will therefore absorb less lead.

Exposure to soil lead can occur when contaminated soil is brought into the home from outdoors, on shoes, clothing, or other objects. The contaminated soil can then become part of the house dust. This is of special concern to crawling children, who have a

great level of contact with floor surfaces that may be dusty. Very young children are also inclined to have a high level of hand-to-mouth contact; ingestion of lead contaminated dust may account for a great deal of their exposure.

Outdoor play areas in which the soil is lead contaminated can also cause children to become exposed. Under section 403 of Title X, the EPA recommends that interim controls be implemented for areas that are expected to be used by children where soil lead levels are between 400 and 5,000 $\mu g/g$ (EPA, 1996). For soil contaminated with lead above 5,000 $\mu g/g$, the agency recommends soil abatement, regardless of the probability of children's exposure.

The Current Project

The purpose of the reported research was to determine the degree of lead contamination in surface soils due to atmospheric deposition from the secondary lead (Pb) smelter located on Pleasant Boulevard. Soil contamination was analyzed at distances 1-2 miles away from the plant, as well as within a 0.5 mile radius of the plant, to determine the level of mobility of lead emissions.

Experimental Methods

A wind rose for Delaware County, Indiana, was constructed using wind data records obtained from the Ball State Weather Station. Four of the most prominent wind directions were chosen as directions in which to collect the first set of samples. The sample directions obtained from the wind rose were N, S, SW, and SSE. In addition, samples were collected at three distances: 1 mile, 1.5 miles, and 2 miles from the plant in each of the four wind directions. Specific latitudes and longitudes for each of the sample points were determined using a U.S. Geological Survey map of the Muncie West Quadrangle. The coordinates were located during sampling with the aid of a GPS. A total of twelve samples were taken using this method. The second set of samples was collected randomly within a 0.5 mile radius of the battery recycling plant. This set of samples focused mainly on residential areas within the vicinity of the plant, in order to determine the level of danger to any children living in these areas. A large residential area directly to the west of the plant was sampled, along with the Southwind Village housing addition. The lawn of a single family home located to the southeast of the plant was also sampled. In addition, two samples were taken on the grounds of the plant, and three were taken in a field north of the plant, for a total of twelve samples taken using this method.

Wind Rose for Delaware County Indiana
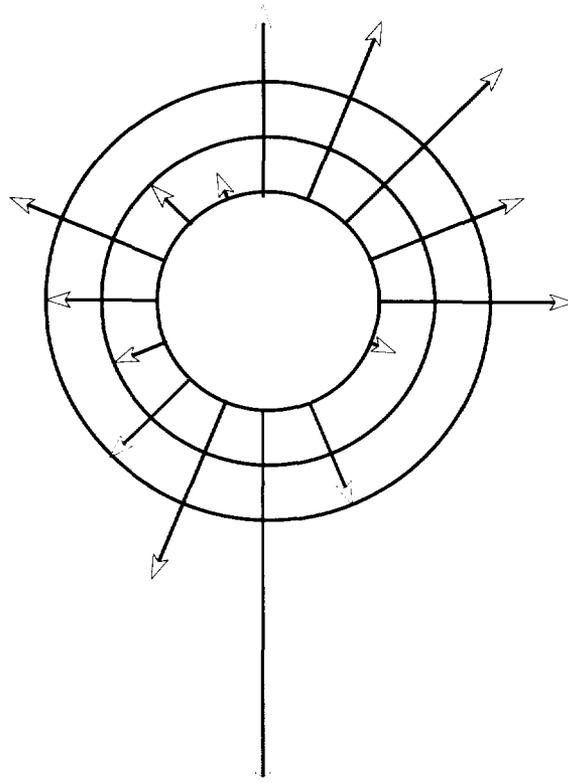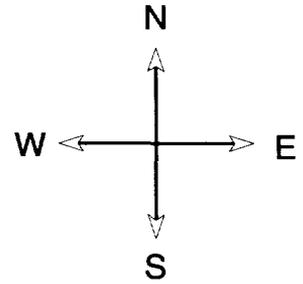
* Red Lines Indicate Sampling Directions

Samples were collected using a clean, 1 1/8-in diameter, stainless steel soil-recovery probe with cross-bar handle, 6-in length. The soil recovery probe consists of a 12-in stainless steel core sampler, equipped with replaceable 1-in diameter plastic inserts. Composite core samples of the top 0.5 in. of soil were taken at each sample location. Composite samples consist of three top 0.5 in. soil cores taken at each sampling location.

Samples were dried by exposure to room-temperature air over the period of one week. Each composite sample was thoroughly crushed and blended together, and a one-gram portion of each was removed for analysis. Soils were digested using a 25% HNO_3 solution, and sonicated for a period of 30 minutes. Samples were then diluted by 50 times using deionized water, thoroughly shaken, and then centrifuged for a period of five minutes. Concentrations of soluble Pb were then measured via atomic absorption spectrophotometry (AAS). Readings were taken in order to determine background absorbance and to increase the accuracy of results.

Statistical tests performed consisted of one-way and two-way analysis of variance (ANOVA). The tests were conducted using a student version of Minitab statistical software.
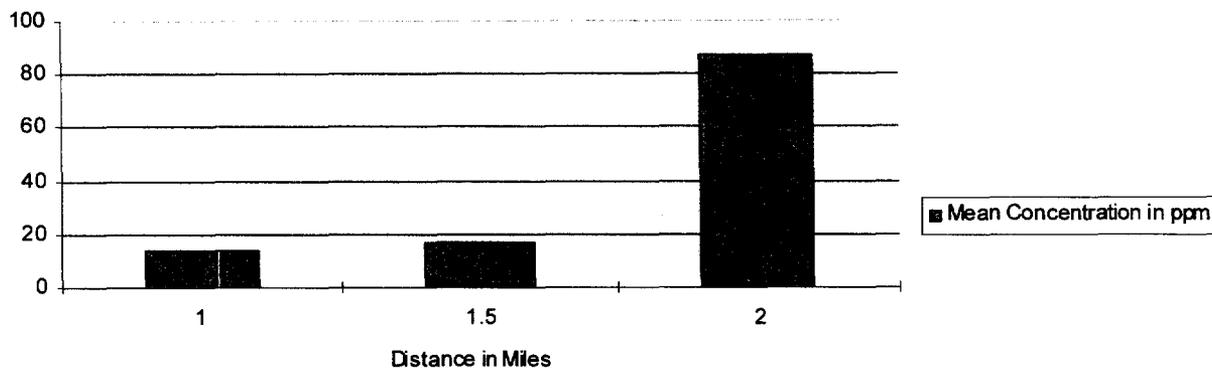
Results and Discussion

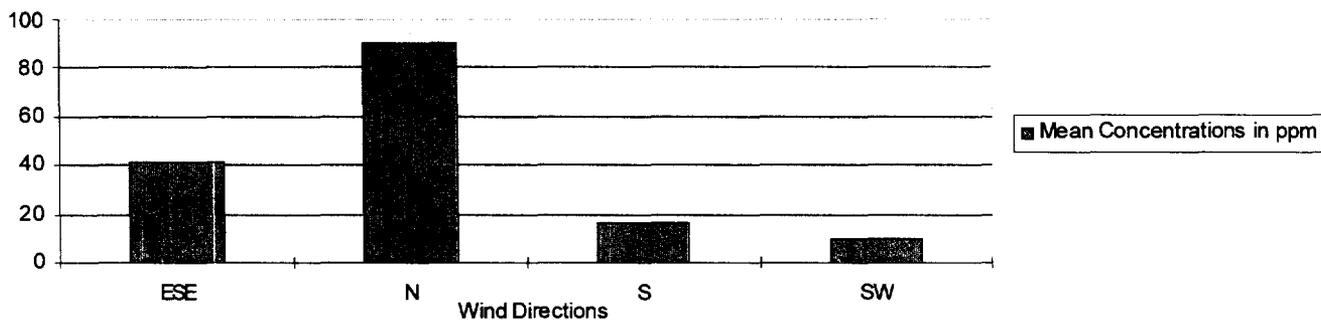Figure 1: Mean Pb Concentrations and Distance (first sample set).

Figure 2: Mean Sample Concentrations in ppm (first sample set).

Spatial Distribution of Lead in Surface Soil

Mean lead concentrations from the first set of samples taken ranged from 14 µg/g to 87 µg/g, with regard to distance away from the plant (Fig. 1). When Pb concentrations were compared on the basis of wind direction, sample means ranged from 10 µg/g to 91 µg/g (Fig. 2). Two-way analysis of variance (ANOVA) revealed that

sample means differed significantly with distance as well as wind direction. The pattern of increasing sample means with increasing distance from the plant was unexpected. However, the data were skewed by samples of unusually high concentration, which were considered to be outliers. One such sample, taken two miles north of the plant in Westside Park, displayed a lead concentration of 238 μg/g, a considerably higher concentration than the other samples. However, this concurs with the results obtained by Liberti (1998); the highest lead concentrations were found to occur in downtown Muncie, presumably due to heavy vehicular traffic. Similar patterns of Pb distribution in soil were also found to exist in Warsaw, Poland by Pichtel *et al.* (1997). Again, Pb concentrations were highest in the city's center. Thus, the high Pb concentration found in the sample taken at Westside Park is more likely the result of factors that are unrelated to emissions generated by the plant.
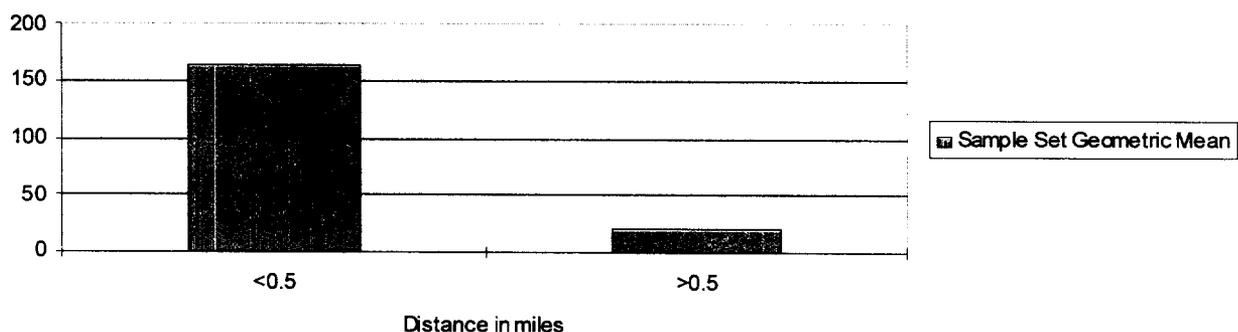

Figure 3: First Sample Set vs. Second Sample Set

Pb concentrations in the second set of samples varied from the highest of 12,936 μg/g (taken on the grounds of the battery recycling plant) to 19 μg/g, taken in the Southwind Village housing addition, located south of the plant. When the second set of samples was compared to the first, ANOVA revealed significantly different means between the sample sets. Samples taken closer to the plant (within a 0.5 mile radius) revealed much higher concentrations than those taken at a greater distance from the plant did (Fig. 3). Two samples were taken on the grounds of the plant, both of which displayed concentrations above 5,000 μg/g. Above this level, the EPA recommends soil abatement, regardless of the likelihood of children's exposure (EPA, 1996). The sample taken on the lawn of the single family home displayed a relatively high Pb concentration of 377 μg/g. This level of contamination is very near the 400 μg/g level at which the EPA recommends that interim controls be implemented. The soil lead concentration found at the single family home is borderline dangerous to children who might play there; the homeowners would benefit from further testing of the soil, especially if young children are present.

Conclusions

The highest levels of lead contamination were found on site
at the battery recycling plant. The level of contamination on
site was above 5000 μg/g, and should probably be cleaned up,
since workers use the areas sampled.

The surrounding residential areas that were sampled
displayed concentrations between 19 - 377 μg/g. The lowest levels
of lead contamination were found in the Southwind Village housing
addition, directly south of the plant. Due to prevailing wind
patterns, it was expected that this area would be somewhat highly
contaminated. However, it is a rather new housing addition, and
the soil may have been disturbed during construction.

Lead emissions from the plant do not appear to migrate in
great quantities over large distances. The first set of samples
displayed much lower Pb concentrations than the second set.
Ignoring the two outliers, sample concentrations ranged from 8 -
24 μg/g. This pattern suggests that most of the atmospheric lead
emissions are deposited on site. At a distance of greater than
0.5 miles from the plant, significantly less quantities of lead
are deposited in soil.

Most of the samples taken did not reveal significantly high
levels of lead contamination, with regard to public health.
However, distance from the plant and wind patterns were found to
have a significant effect on lead deposition. Over time,

significant levels of lead may accumulate in soils that currently are contaminated at low levels.

Acknowledgments

Thank you to Dr. Thad Godish, my thesis advisor, for his willingness to assist and advise me during the project. Thanks also to Marilyn Williams and Dale Scheidler for making themselves available to perform the necessary lab work.

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