LEAD CONTENT FROM AN URBAN TO RURAL GRADIENT

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INTRODUCTION

Lead (Pb) is the most dangerous environmental health hazard for children in the US (CDC 1991). Lead poisoning often leads to brain and central nervous system damage that can result in mental retardation and other neurological disorders (As reviewed by Michopoulos et al. 2005). Precipitation and dry deposition are the presumed ways that Pb, in particulate form, enters ecosystems (As reviewed by Smith et al. 1981). The main sources of lead found in ecosystems are from lead-based paint and leaded gasoline that was once used in internal combustion engines (As reviewed by Yesilonis et al. 2007). Lead is released in the combustion processes and introduced into the environment (Van Bohemen et al. 2003). Soil Pb concentrations in Baltimore City are closely related to roads implying that the major contributor of Pb in the soil is from automotives. As traffic increases on these roads so has the concentration of Pb. Therefore roadside levels of Pb are directly related to the annual average daily traffic and traffic density (As reviewed by Yesilonis et al. 2007). While it is proven that soils near roads are often more polluted than soils in rural areas, remote areas still receive precipitation with a higher Pb content than is expected. This is due to the fine particles containing Pb being transported with air masses over long distances. These air masses can move from urban to rural areas releasing precipitation with the fine particles containing Pb and thus, increase the Pb content of soil in these rural areas (As reviewed by Michopoulos et al. 2005). While leaded gasoline was banned by Congress in 1986 and lead-based paint banned in residential use in 1978 (U.S. Consumer Product Safety Commission), it is estimated that 4 to 5 million metric tons of Pb residue is still left in the environment (As reviewed by Yesilonis et al. 2007). A study as recent as 2007 shows the background concentration of Pb range from 22 to 29 mg kg^{-1} for eastern and central Maryland respectively. The median concentration was 227 mg kg^{-1}, and the maximum measured was 5,391 mg kg^{-1} (Pouyat et al. 2007).

While Pb is relatively immobile in soil, various changes in soil chemical conditions can influence its mobility and form, thus increasing its bioavailability and toxicity to humans and other organisms (As reviewed by Yesilonis et al 2007). Metals can enter trees through the soils, roots, or bark and become integrated into the tree rings. When the majority of Pb uptake is through roots, there is a period of lag before the Pb appears in the tree rings due to the slow movement of Pb. Metals can be absorbed through the leaves and are deposited in the outermost tree rings after translocation in the phloem. This translocation is most likely minimal but can occur during ideal conditions such as acid fogs or in industrial areas. It has also been shown that metal tends to translocate toward areas of growth such as the shoot tips rather than towards the root. This further suggests that leave uptake of metals is not the primary pathway for metals to be found in tree rings. Levels of Pb found through bark update suggest that it could be one of the major pathways for Pb entry. The difference between soil and bark uptake, however, will differ depending on the soil's chemical and organic make up, tree species, and chemical composition of rainfall in the area (As reviewed by Watmough 1999).

Soil pH can be one of the most contributing factors to the uptake of Pb in trees. Studies have shown that as the soil pH increases, so does the solubility of Pb, making it more bioavailable for humans and other organisms such as trees (As reviewed by Yesilonis et al. 2007). Yesilonis et al. 2007 study suggest that the characteristics of soil, in particular pH and concentrations of Mn(III,IV)- and Fe(III)(hydr) oxides, are important in determining the form of Pb in the soil solution. Wang et al. 1996 study also implies that relationship between pH and Pb solubility may not be as simple as previously suggested. This study found that pH may influence the mobility of Pb indirectly.

As Al and Fe are released at a relatively low pH in the surface organic layer, they might outcompete Pb for surface complexation or ion exchange sites and cause Pb to release into solution (Wang et al. 1996).

However, less is known about the cycling of Pb and how the uptake of Pb by trees varies across a rural to urban gradient. Since the form of Pb influences its movement, it is important to understand under what conditions Pb moving and where it is moving to. The locations of Pb in the cycle and their concentrations at these locations can help us to understand how people might interact with it, both in the urban and rural forests. Quantifying the pools of Pb in urban and rural forests would aid in understanding what areas need more attention for the removal of lead from our environment.

METHODS

Study Sites

The possible study areas consisted of ten "urban" and "rural" forests sites within Baltimore city and county. Two of the sites are considered to be "rural" sites based on their distance to downtown Baltimore, averaging 18.31 km from the urban core. Eight of the sites are considered to be "urban" sites and average 9.67 km from the downtown area of Baltimore. Herring Run Park, Moores Run Park, and Lakeshore Park are sites situated on the Atlantic Coastal Plains, which tend to have sandy loam soils. The remaining seven sites are on the Piedmont Plateau and these soils tend to be loamy (Pouyat et al. 2007) (Figure 1).

Methods

Three composite soil samples from each of the ten sites and from two depths (0-7.5 cm and 7.5-15 cm) were collected for a total of 60 soil samples. Samples were digested by adding nine milliliters of nitric acid (HNO_3) to 0.5 grams of each soil sample. Each sample was then microwave digested. Following microwave digestion, samples were analyzed for Pb content with an Inductively Coupled Plasma spectrometer. Previous work on study sites provided information on soil pH and percent carbon (organic matter).

RESULTS

Table 1 displays the averages for lead content in parts per million for the top and bottom soil samples at all sample sites. Averages indicate that lead content for top soil was consistently higher than for bottom soil. Top and bottom soil averages were graphed on an urban to rural gradient and showed no correlation (Figure 2).

The Annual average daily traffic (AADT) represents the total number of vehicle traffic of a highway or road for the year. This number is then divided by 365 days. The numbers were collected from the Interstate Guide website, using the closest major highway to each study site. Figure 3 shows the correlation between top soil lead content and AADT numbers as being significant, while the bottom soil lead content showed no correlation.

Grouping soil types together (loamy and sandy loam) and comparing them with lead content also yielded insignificant P values. The same was true of comparing pH with site lead content. Soil organic matter did have a significant correlation when compared with site lead content.

DISCUSSION

Overall, no single sample surpassed a lead content of 137 ppm, well below the 400ppm marker dangerous for children. All samples did show a level of lead higher than background levels. When discussing the accumulation of lead in regards to proximity of sources, such as major highways, distance to urban center and distance to closest highway did not correlate. There was, however, a correlation between traffic density (AADT) and top soil lead content. Since a majority of lead pollution was assumed to be the result of leaded gasoline exhaust, the top soil of sites close to heavily trafficked highways would most likely be a source where lead would collect.

Distance to urban centers and closest highway would then logically be insignificant unless these areas contained high levels of traffic. Lead's slow mobility throughout the soil might explain the lack of correlation between traffic data and bottom soil levels. The range of values for lead content in the various study sites suggests that all sites had relatively similar lead inputs, leading to the question of how this lead is retained in the soil.

Soil types and pH contained no correlation to lead content in terms of soil retention of lead. In the case of top soil and bottom soil, as organic matter increase so did the level of lead. One explanation for this might be that as the organic matter decomposes and moves to lower levels of soil, the attached molecules of lead move with it. It is possible that bioturbation through the soil might also explain the retention of lead. The retention of lead in areas of higher soil organic matter could mean a higher ability to reserve lead in the soil, preventing it from reaching water supplies. Conversely, higher retention levels might mean an extended amount of time to interact with leaded soils.

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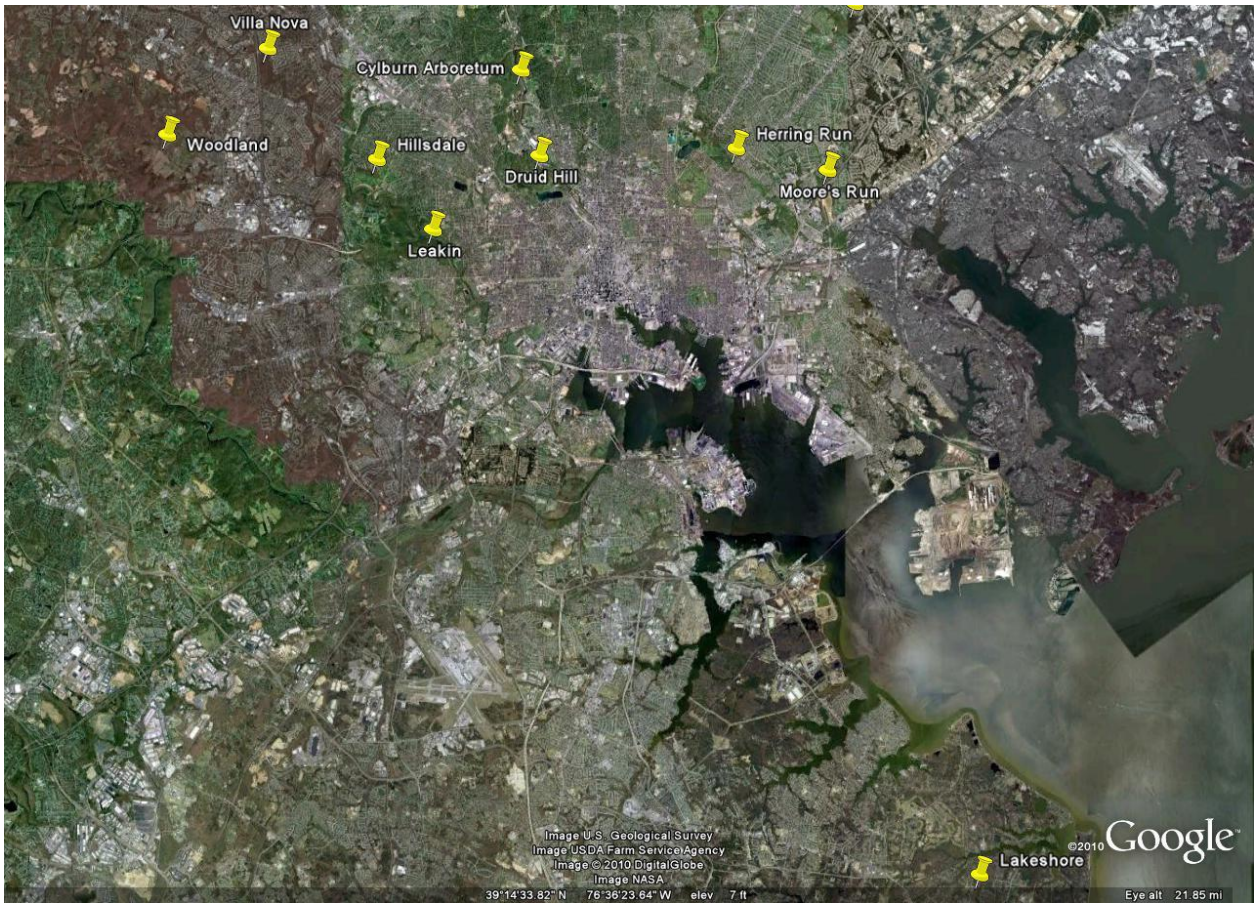

FIGURE 1. "Urban" and "rural" forests sites within Baltimore city and county.

TABLE 1. Comparison of lead content at study sites

Site	Pb Average - Top (ppm)	Pb Average - Bottom (ppm)
Hillsdale Park	67.618	31.500
Villa Nova	68.673	28.307
Herring Run Park	83.789	53.256
Moores Run Park	69.113	48.934
Double Rock Park	91.727	43.719
Lakeshore Park	50.161	17.049
Cylburn Arboretum	52.334	41.385
Druid Hill Park	50.887	27.442
Leakin Park	38.632	24.514
Woodland's Golf Course	38.534	20.350
Total Averages	61.147	33.646

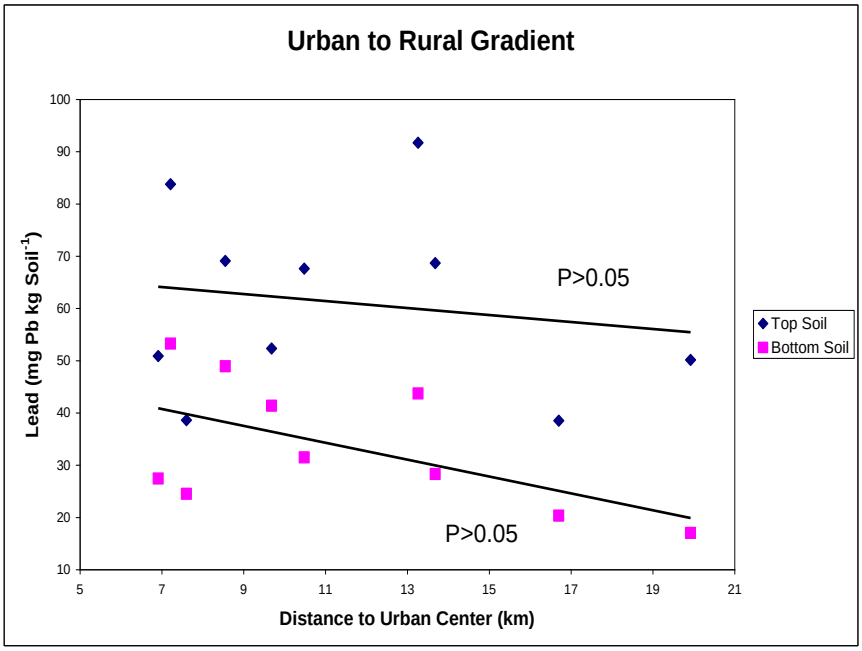

FIGURE 2. Urban to rural gradient was established by measuring the distance to urban core, or downtown Baltimore City.

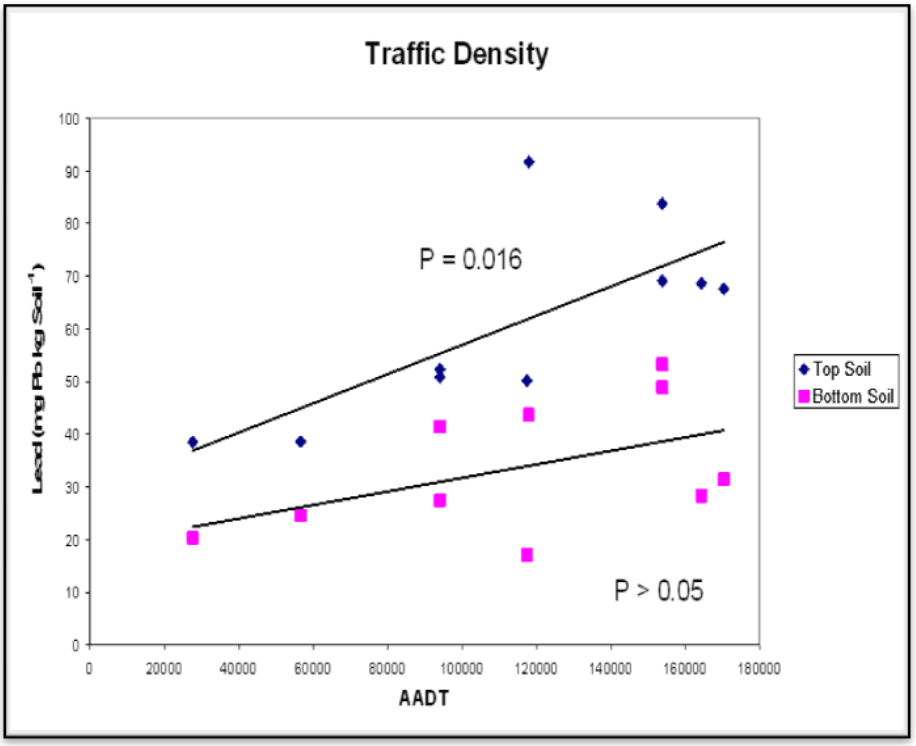

FIGURE 3. The correlation between top soil lead content and AADT numbers is significant, while the bottom soil lead content showed no correlation.

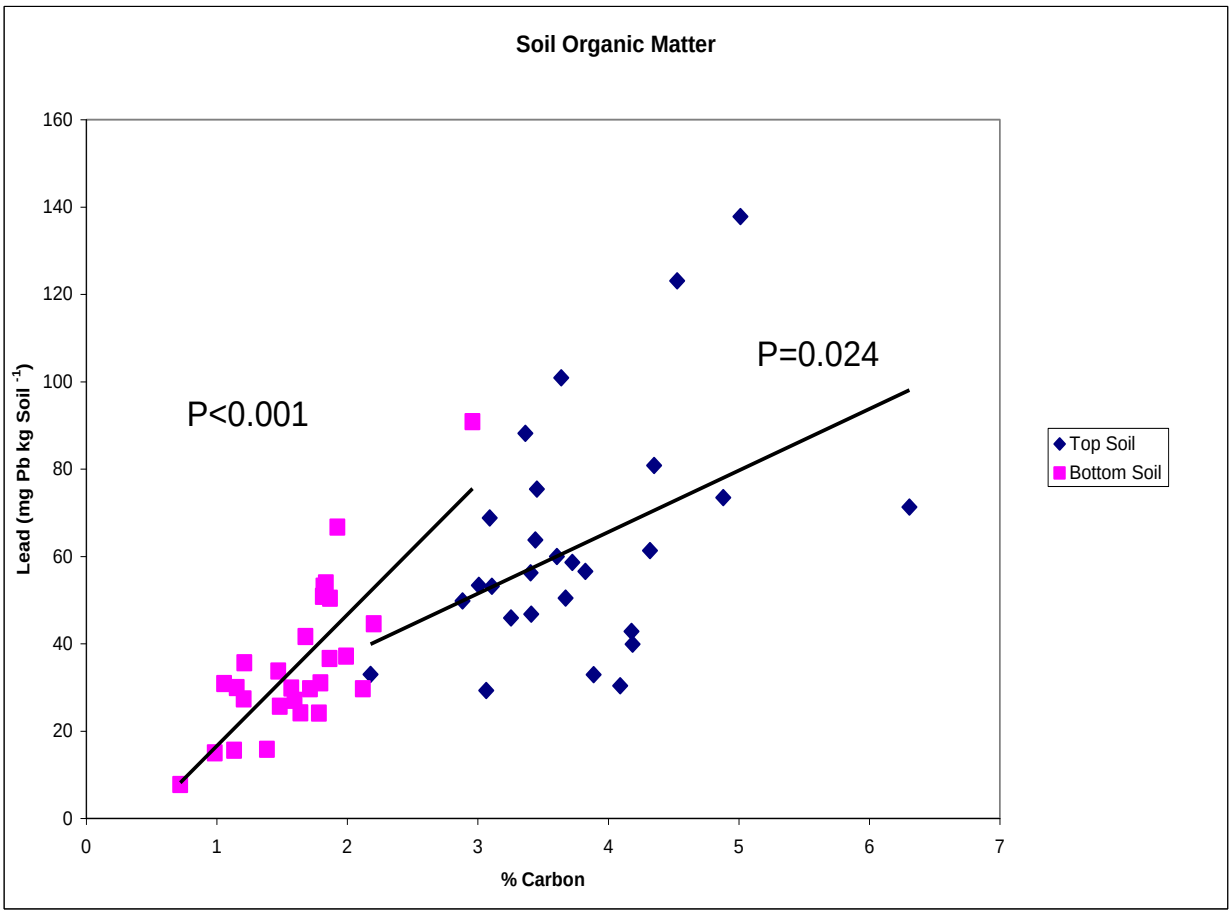

FIGURE 4. Soil organic matter