

Environmental Assessment and Risk Analysis Element



Research Project Summary



May, 2003

Ambient Levels of Metals in New Jersey Soils

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Abstract

Between 1996 and 2001, three studies were conducted to determine the ambient levels of extractable metals in New Jersey soils. These studies were conducted to gather information to support the development of soil cleanup criteria, which cannot be set below ambient levels. A total of 248 soil samples were taken from the urban Piedmont region, the urban Coastal Plain region, and rural regions of the Valley and Ridge, Highlands, and Coastal Plain provinces. Local or point sources of contamination were avoided by the use of Geographic Information System databases and by following sample location guidelines in the field. Surface soil samples (0-6") were analyzed for acid-extractable Target Analyte List (TAL) metals using USEPA SW-846 methods that are normally used to conduct initial investigations at hazardous waste sites. With one exception, median and 90th percentile concentrations of all metals were below current soil cleanup criteria. The exception was the 90th percentile arsenic concentration from the urban Piedmont study, which slightly exceeded the arsenic criterion. Otherwise, only certain individual samples contained metal concentrations above current criteria. A single rural soil sample yielded a beryllium concentration slightly above the corresponding criterion. For the urban Coastal Plain study, three of the 91 samples contained levels of arsenic above the current criterion. The urban Piedmont study yielded eight samples out of 67 where levels of arsenic or lead exceeded the criteria.

Introduction

Current New Jersey law requires that the NJDEP determine background levels of contaminants in soils and that "Remediation [of contaminated areas] shall not be required below regional natural background levels for any particular contaminant" [N.J.S.A. 58:10B-12(g)(4)]. "Natural background level" is further defined as "...the concentration of a contaminant consistently present in the environment of the region of the site and which has not been influenced by localized human activities...." Therefore, naturally occurring constituents in soil and those resulting from regional deposition are included, but not those from point contamination sources. The concentrations of contaminants included in this definition are referred to as "ambient concentrations." To support the above directive, three studies were conducted to determine ambient levels of metals in several regions of New Jersey (BEM Systems, Inc., 1997, 1998, 2002). The first two studies investigated metal concentrations in the urban Piedmont and urban Coastal Plain regions of New Jersey. These two areas contain a majority of the hazardous waste sites in the state. Furthermore, the high population density and significant industrial activity in these

regions yields an upper estimate of ambient metal concentrations, due to a larger impact of regional atmospheric deposition. The third study focused on rural areas of the Ridge and Valley, Highlands and Coastal Plain provinces, and provided an indication of metals concentrations in areas less impacted by atmospheric deposition.

Methods

A total of 248 soil samples were taken in the three studies: 67 from the urban Piedmont region, 91 from the urban Coastal Plain region, and 90 from the three rural provinces (Figure. 1). The rural soil samples were distributed among the predominant soil types in each of the regions on a rural acreage basis. The sample locations for the urban studies were generally distributed among municipalities classified as "urban" by population density criteria. For the urban Piedmont studies, the criterion usually applied was a population density of 7,500 or more people per square mile, as per the State Development and Redevelopment Plan. For the urban Coastal Plain study, the population density criteria was reduced to 4,000 or more people per square mile because a

higher population density would have resulted in only eight municipalities being sampled. In addition, municipalities were added to both urban studies that did not meet the density criteria because they contained high population density regions or substantial industrial activity. For the urban studies, samples were located in public parks because of ease of access, a likelihood that these soils have been undisturbed for some time, and because they usually met a specified 50% open space (lawn) requirement. This latter requirement was specified because forest cover or other obstructions could reduce the impact of atmospheric deposition. Sports fields or other manicured areas were not acceptable locations because of turf maintenance issues often associated with them, including chemical applications. For the rural study, sampling in forested areas was usually unavoidable since this is the natural vegetation cover of much of New Jersey, and it was desired to avoid areas impacted by human activity. For all studies, sample locations were also required to be specified minimum distances from known hazardous waste sites, roadways, and railroads.

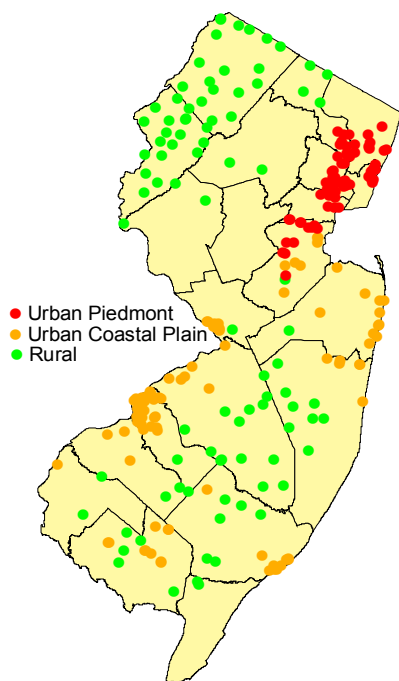


Figure 1. Sample locations

Soil samples were taken from a depth of 0-6 inches after removing surface litter. Samples were analyzed for acid-extractable Target Analyte List (TAL) metals using New Jersey certified laboratories. The methods used were those used to conduct site investigations at hazardous waste sites, specifically

the U.S. Environmental Protection Agency Office of Solid Waste SW-846 methods. The extraction method used was Method 3050. Many metals were analyzed using inductively coupled plasma – atomic emission spectrometry (Method 6010). For certain metals, lower detection limits were desired because of low ambient concentrations or low soil ingestion criteria based on toxicity concerns. Atomic absorption furnace methods were used for arsenic, lead, selenium and thallium (Methods 7060, 7421, 7740 and 7841, respectively). Mercury was analyzed via cold vapor atomic adsorption (Method 7471).

Results

Acid-extractable median and 90th percentile concentrations, and the corresponding method detection limits for the twenty-three target analyte metals in 248 surface soil samples from the three studies were calculated (Table 1). The rural study results are separately presented for each of the three physiographic provinces.

Aluminum, iron, calcium, sodium, potassium, magnesium and manganese are abundant in soils and were frequently measured at several hundred to several thousand mg/kg. (Sodium concentrations are lower because it is largely leached from soils in humid climates.) Barium, chromium, vanadium and zinc are also relatively common in soils and were frequently measured at concentrations between 10 and 100 mg/kg. Zinc showed some indication of anthropogenic contribution in urban areas in that a few samples yielded concentrations in the 150-350 mg/kg range. (Naturally occurring total zinc concentrations in soil do not commonly exceed 100 mg/kg [Kabata-Pendias and Pendias, 1984].)

Nickel, copper, cobalt and lead are somewhat less common. The first three of these metals were generally measured at levels less than 50 mg/kg. Some samples in urban areas had copper concentrations in the 50-150 mg/kg range, while rural samples never exceeded 30 mg/kg. This suggests urban contribution above natural levels. Lead is well known to be elevated in surface soils due to industrial activities and the historical use of leaded gasoline (Kabata-Pendias and Pendias, 1984). Lead concentrations were highest in the urban Piedmont region (several samples in the 300 mg/kg range), somewhat lower in the urban Coastal plain (usually less than 200 mg/kg), and lowest in the rural study (only two samples greater than 125 mg/kg).

Mean total arsenic concentrations in United States soils have been reported to be 5-8 mg/kg (Kabata-Pendias and Pendias, 1984). In this study, median

Table 1. Ambient Concentration of Extractable Metals Measured in 248 New Jersey soil samples.

Urban Piedmont				Urban Coastal Plain				
<i>Method Detection Limit (mg/kg)</i>	<i>No. of detects n=67</i>	<i>Median Concentration (mg/kg)</i>	<i>90th Percentile Concentration (mg/kg)</i>	<i>Method Detection Limit (mg/kg)</i>	<i>No. of detects n=91</i>	<i>Median Concentration (mg/kg)</i>	<i>90th Percentile Concentration (mg/kg)</i>	
Aluminum	1.5	67	10500	14400	20	91	6800	10800
Antimony	1.7	17	<DL	3.48	6	0	<DL	<DL
Arsenic	0.13	67	5.2	24.2	1	82	5.2	13.6
Barium	0.22	67	80.6	168	20	60	28.3	65.8
Beryllium	0.14	65	0.51	0.82	0.5	15	<DL	0.68
Cadmium	0.4	21	<DL	0.67	0.5	5	<DL	<DL
Calcium	11.2	67	1425	3010	500	59	995	2000
Chromium	0.9	67	18.5	29.9	1	91	11.8	34.7
Cobalt	0.5	67	6.3	10.4	5	7	<DL	<DL
Copper	0.52	67	29.5	75.5	2.5	82	9.3	33.3
Iron	2.2	67	14600	20000	10	91	8830	21100
Lead	0.063	67	111	297	10	82	37.6	144
Magnesium	5	67	2190	4614	500	54	673	1870
Manganese	0.21	67	311	859	1.5	91	62.4	206
Mercury	0.1	50	0.18	0.63	0.1	39	<DL	0.21
Nickel	0.9	67	12.4	24.6	4	43	<DL	12.3
Potassium	32	67	693	1524	500	45	<DL	1750
Selenium	0.5	61	0.41	0.71	1	0	<DL	<DL
Silver	0.22	28	<DL	0.86	1	3	<DL	<DL
Sodium	16.4	60	90.1	141	500	0	<DL	<DL
Thallium	0.2	28	<DL	0.25	1	2	<DL	<DL
Vanadium	0.95	67	29.6	41.7	5	86	16	35.5
Zinc	2	67	75.3	162	2	88	39.9	106

Rural Areas of New Jersey										
<i>Rural studies</i>	<i>Ridge and Valley Province</i>			<i>Highlands Province</i>			<i>Coastal Plain Province</i>			
<i>Method Detection Limit (mg/kg)</i>	<i>No. of detects n=23</i>	<i>Median Concentration (mg/kg)</i>	<i>90th Percentile Concentration (mg/kg)</i>	<i>No. of detects n=23</i>	<i>Median Concentration (mg/kg)</i>	<i>90th Percentile Concentration (mg/kg)</i>	<i>No. of detects n=44</i>	<i>Median Concentration (mg/kg)</i>	<i>90th Percentile Concentration (mg/kg)</i>	
Aluminum	3.23	23	15300	21080	23	16800	28980	44	1375	6760
Antimony	0.42	0	<DL	<DL	0	<DL	<DL	11	<DL	0.56
Arsenic	0.28	23	4.9	7.32	23	4.8	9.96	36	1.15	6.15
Barium	0.09	19	60.2	101.16	22	69.6	96.64	34	7.25	55.31
Beryllium	0.01	8	<DL	0.91	19	0.73	1.08	9	<DL	0.14
Cadmium	0.03	0	<DL	<DL	11	<DL	0.32	9	<DL	0.13
Calcium	41.7	10	<DL	2272	20	1160	4518	33	76.4	341.7
Chromium	0.17	23	14.3	21.2	23	17.7	26.64	44	2.9	11.76
Cobalt	0.18	12	7.3	11.4	18	6.8	12.44	32	0.37	1.18
Copper	0.33	23	17.2	26.04	23	16	28.96	44	4.2	11.43
Iron	4	23	14800	28540	23	18700	27860	44	1795	10587
Lead	0.22	23	31.6	54	23	26.6	59.02	44	17.5	54.05
Magnesium	14.4	19	2600	7182	23	2340	4024	34	79.65	513.2
Manganese	0.27	23	470	1192	23	407	836.8	44	11.65	35.39
Mercury	0.016	22	0.1	0.15	23	0.09	0.18	28	0.04	0.14
Nickel	0.21	20	15.7	22.5	23	11.6	19.04	30	0.84	3.87
Potassium	6.63	17	961	1660	21	955	1456	30	76	328
Selenium	0.49	0	<DL	<DL	10	<DL	0.99	7	<DL	0.68
Silver	0.1	0	<DL	<DL	5	<DL	0.21	0	<DL	<DL
Sodium	6.78	0	<DL	<DL	8	<DL	85.1	28	54.65	91.9
Thallium	0.41	0	<DL	<DL	0	<DL	<DL	1	<DL	<DL
Vanadium	0.07	23	20.7	29.68	23	32.3	52.98	40	7.8	20.68
Zinc	0.18	23	75.8	112.3	23	69.7	111.6	44	6.7	27.64

extractable arsenic concentrations were typically about 5 mg/kg, and concentrations never exceeded 15 mg/kg in the rural study. In the urban studies, the maximum concentration was 83 mg/kg, and 95th percentile values were below 30 mg/kg. These higher concentrations are within the normal ranges for soils, particularly glauconitic soils naturally high in arsenic (Dooley, 2001). Some soil samples in the urban Coastal Plain study were taken from glauconitic soils, and they yielded some of the higher concentrations measured (including the maximum value measured, 83 mg/kg). However, other samples from this study

with elevated arsenic were not from glauconitic regions. Furthermore, the urban Piedmont study did not include glauconitic soils, where a significant percentage of the samples also exhibited elevated levels of arsenic relative to the rural study. This suggests some anthropogenic contribution of arsenic to urban surface soils.

Mean total beryllium concentrations in United States soils are about 1-2 ppm (Kabata-Pendias and Pendias, 1984). Extractable concentrations of beryllium in this study ranged from non-detectable to

3 mg/kg. Total antimony concentrations in United States soils are generally less than 1 ppm (Kabata-Pendias and Pendias, 1984). This study yielded extractable antimony concentrations that ranged from non-detectable levels to 13 mg/kg, with the higher concentrations being associated with the urban Piedmont samples. Thallium, mercury, cadmium, silver and selenium are naturally present at only trace levels in soils (usually less than 1 ppm) in soils (Kabata-Pendias and Pendias, 1984). In this study, thallium and silver were seldom detected, and selenium, cadmium and mercury were either not detected or measured at concentrations that were usually less than 1 mg/kg. A few samples, mostly from urban areas, contained cadmium at concentrations above 0.5 mg/kg or mercury above 1.0 mg/kg, which suggests contribution from industrial activity or regional atmospheric deposition.

Statistically, several metals were found at lower concentrations in the coastal plain regions of the state relative to the remainder of the state. Coastal Plain soils have high sand contents, lower organic carbon contents and lower pH values than soils in the remainder of the state, which decrease their affinity for metals.

Discussion

The metals concentration data collected in these series of studies are useful for determining typical ambient levels of the various metals in the geographical regions studied. Levels significantly above these concentrations may indicate a spill or discharge has occurred. The metals of greatest environmental concern are those in which ambient levels in surface soils equal or exceed concentrations that are considered hazardous to human health. In such cases, regulatory levels applicable for remedial activities at contaminated sites may be limited by prevailing ambient concentrations. The most important example of this situation occurs with arsenic. The health-based soil ingestion criterion for arsenic (0.4 mg/kg) is significantly below observed ambient levels, even in soils unaffected by human activity. All studies except the rural Coastal Plain study yielded median extractable arsenic concentrations of about 5 mg/kg, more than ten times the health-based number. The rural Coastal Plain median concentration (1 mg/kg) was also above the health-based ingestion criteria.

The current soil cleanup criterion for arsenic in soil is 20 mg/kg, based on an earlier assessment of ambient levels. The 90th percentile concentration of arsenic from the urban Piedmont study (26 mg/kg) is somewhat higher than this value. In the urban Coastal Plain study, three of the ninety-one samples

yielded arsenic levels above 20 mg/kg. The rural areas of the state yielded 95th percentile concentrations ranging from 5-10 mg/kg, and no samples exceeded 20 mg/kg.

Total arsenic levels in glauconite-bearing soils in New Jersey have been reported to range from 13-131 mg/kg, with a median of 30 mg/kg (Dooley, 2001). When only extractable arsenic from 0-6" soil samples are considered from the glauconite study, the median, 90th percentile and maximum concentrations are 8.2, 27.5, and 63.3 mg/kg, respectively. These concentrations are only moderately higher than those observed for the urban studies.

The health-based non-residential soil criterion for hexavalent chromium based on soil inhalation is 20 mg/kg, which is below the 90th percentile ambient concentrations reported in this study. However, chromium in soil has been reported to be dominated by the much less toxic trivalent form, so ambient concentrations are not likely to be of concern for this metal. A hexavalent chromium-specific method would be recommended for analysis of soil when this metal is known to be of concern.

With regards to the remaining metals, only one sample yielded a result where current criteria were exceeded. This sample was taken from the urban Piedmont region and yielded a lead concentration of 464 mg/kg, which is slightly greater than the current lead criterion of 400 mg/kg.

Other than arsenic, the only other metal with the current soil criterion set by ambient levels is beryllium (criterion = 2 mg/kg, based on earlier New Jersey data and other literature). In this study, 90th percentile concentrations frequently approached 1 mg/kg (Table 1), 95th percentile concentrations in the rural highlands exceeded 1 mg/kg (1.4 mg/kg), and overall, ten samples out of 248 yielded concentrations between 1 and 2 mg/kg. Only one sample exceeded 2 mg/kg (2.8 mg/kg from the rural Highlands province).

The thallium criterion is currently set by the Practical Quantitation Level (2 mg/kg), since the health-based criteria is lower (zero). Reporting Levels and/or Practical Quantitation Levels for this metal from the two New Jersey certified laboratories used in this study were somewhat lower (1 mg/kg or less), which suggests that analytical capabilities may have improved since the thallium criterion was set.

Metal concentrations reported in this summary were acid-extractable metals, not necessarily total metal concentrations. The extraction method (USEPA

Method 3050) is a vigorous extraction method designed to remove all metals that could become “environmentally available”. In practice, the extraction method likely overestimates metals that could become available, since the sample is refluxed with both concentrated nitric acid and hydrogen peroxide. However, by design, the method will not extract chemicals incorporated in silica minerals, as they are usually not mobile in the environment. Thus, concentrations reported in these studies may be lower than those indicated from analyses using methods designed to measure total metal concentrations, such as x-ray fluorescence methods.

Funding

These studies were funded by the Hazardous Waste Research fund and conducted by BEM Systems, Inc.

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