Superfund Risk Assessment in Soil Contamination Studies

SECOND VOLUME

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EDITOR

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Peer Review Policy

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To make technical information available as quickly as possible, the peer-reviewed papers in this publication were prepared "camera-ready" as submitted by the authors.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

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Overview

Since 1976, the release of chemicals to our environment and the potential adverse effects these chemicals may have on human health has captured the attention of the public and their representatives in all levels of government. Federal rules and guidelines require that releases of chemical compounds to the environment be evaluated to determine their effect on human health and the environment in general. One of the largest parts of the evaluation is the health risk assessment. This is a process by which an environmental professional converts data from the various environmental media into a measure of the probability of a health effect. This process originated in the field of industrial hygiene and is used extensively by the Occupational Safety and Health Agency to make the workplace more hospitable. The risk assessment process attempts not only to quantify the concentrations of various chemicals, but also the exposure parameters that would describe how and how long a person would be exposed to the chemicals. Over the years, numerous improvements and modifications have been made to the basic process. Keeping current with the changes is one of the more challenging parts of being a risk assessor.

The purpose of the Second Symposium on Superfund Risk Assessment in Soil Contamination Studies, which generated this Special Technical Publication (STP), was to collate the current modifications of the EPA's basic risk assessment methodology in a series of symposia and technical publications. We hope this type of symposium will serve both research and practical needs.

To produce this STP, two proactive organizations combined their talents and resources. The American Society for Testing and Materials (ASTM), through its Committee D-18 on Soil and Rock, and the United States Army Center for Health Promotion and Preventive Medicine (formerly the U.S. Army Environmental Hygiene Agency) cosponsored the second of a series of symposia on this type of risk assessment.

The evaluation of these risks should follow the EPA's booklet entitled, "Risk Assessment Guidance for Superfund (RAGS)." This booklet outlines the general process of risk assessment that has been adopted in this STP to organize the paper topics. However, we do not pretend this STP is an instructional device for the basic EPA method. While beginners can benefit greatly from the papers presented here, this collection finds its best use in the hands of the experienced risk assessor. The papers contained in the STP present modifications of the basic EPA methodology that have been acceptable to regulators at specific sites. This should not be construed to mean that these methods will be acceptable at all sites, in all situations, or to all regulators. Rather, it is a state-of-the-art laundry list of methods that may be helpful for complex issues at your site.

Papers in this STP were selected from the symposium submittals based upon pertinency, originality, and technical quality. All have undergone peer review, and most were extensively revised between presentation and publication. In this STP, papers were selected in the following categories:

- background determination,
- data collection validation,
- exposure assessment, and
- ecological assessment.

In addition to the authors of the individual papers, any success of this publication reflects the contributions of many people. The Symposium Committee worked diligently in soliciting abstract submittals, selecting promising presentations, and chairing the sessions.

The continued support of this symposium by the officers of ASTM Committee D-18 also was vital since time from a more than full committee meeting schedule needed to be allocated for this endeavor.

Critical to maintaining the techincal quality of this STP was the diligent work of the reviewers of the technical papers. At least three reviewers were obtained for each paper to help ensure that the work reported was accurate, reproducible, and meaningful.

Considerable staff support was also required for the completion of this effort. The help of the Symposium Committee, the ASTM Committee D-18 officers, the paper reviewers, and the ASTM staff is most appreciated. We trust that the papers in this STP, which the contributors labored hard to develop, will aid the efforts of environmental professionals towards the reliable prediction and quantification of risk.

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BACKGROUND DETERMINATION OF ELEMENT AND ANTHROPOGENIC COMPOUNDS IN SOILS OF THE MARYLAND COASTAL PLAIN

REFERENCE: Nemeth, G. R., Romano, D. J., Smegal, D., and Paul, J., **Background Determination of Element and Anthropogenic Compounds in Soils of the Maryland Coastal Plain,"** Superfund Risk Assessment in Soil Contamination Studies: Second Volume, ASTM STP 1264, Keith Hoddinott, Ed., American Society for Testing and Materials, 1996.

ABSTRACT: Background concentrations of elements and anthropogenic compounds in soil were determined for the coastal plain region of the northern Chesapeake Bay in the vicinity of a major military facility. Soils used to establish background are from off-site locations. Lead and octachlorodibenzodioxin were determined to be anthropogenic regional contaminants. The background concentrations of arsenic, beryllium, and manganese exceed Region III Environmental Protection Agency risk based criteria for residential soils.

KEYWORDS: soil element concentrations, regional anthropogenic soil contamination, soil background, coastal plain, Aberdeen Proving Ground, Chesapeake Bay

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INTRODUCTION

The Aberdeen Proving Ground (APG) in Maryland is a military research and development facility. The historical manufacturing, testing, storage, and disposal operations have created the potential for environmental contamination at numerous sites in dozens of study areas. A substantial amount of environmental work is currently being performed at APG. This work includes remedial investigations, human health and ecological risk assessments, remedial feasibility studies, and cleanup actions. The large scale of the investigation and risk assessment efforts suggested the need for a program to determine the reference background concentrations of elements and anthropogenic materials in soil, sediment, surface water, and groundwater. This paper presents results of the background soil investigation.

BACKGROUND

APG is located in northeastern Baltimore County and southeastern Harford County, Maryland on the northwest shore of the Chesapeake Bay (see location map). It is bordered to the east and south by the Chesapeake Bay; to the west by Gunpowder Falls State Park, an electric power generation facility which uses fossil fuels, and residential areas; and to the north by the towns of Edgewood, Magnolia, Aberdeen,

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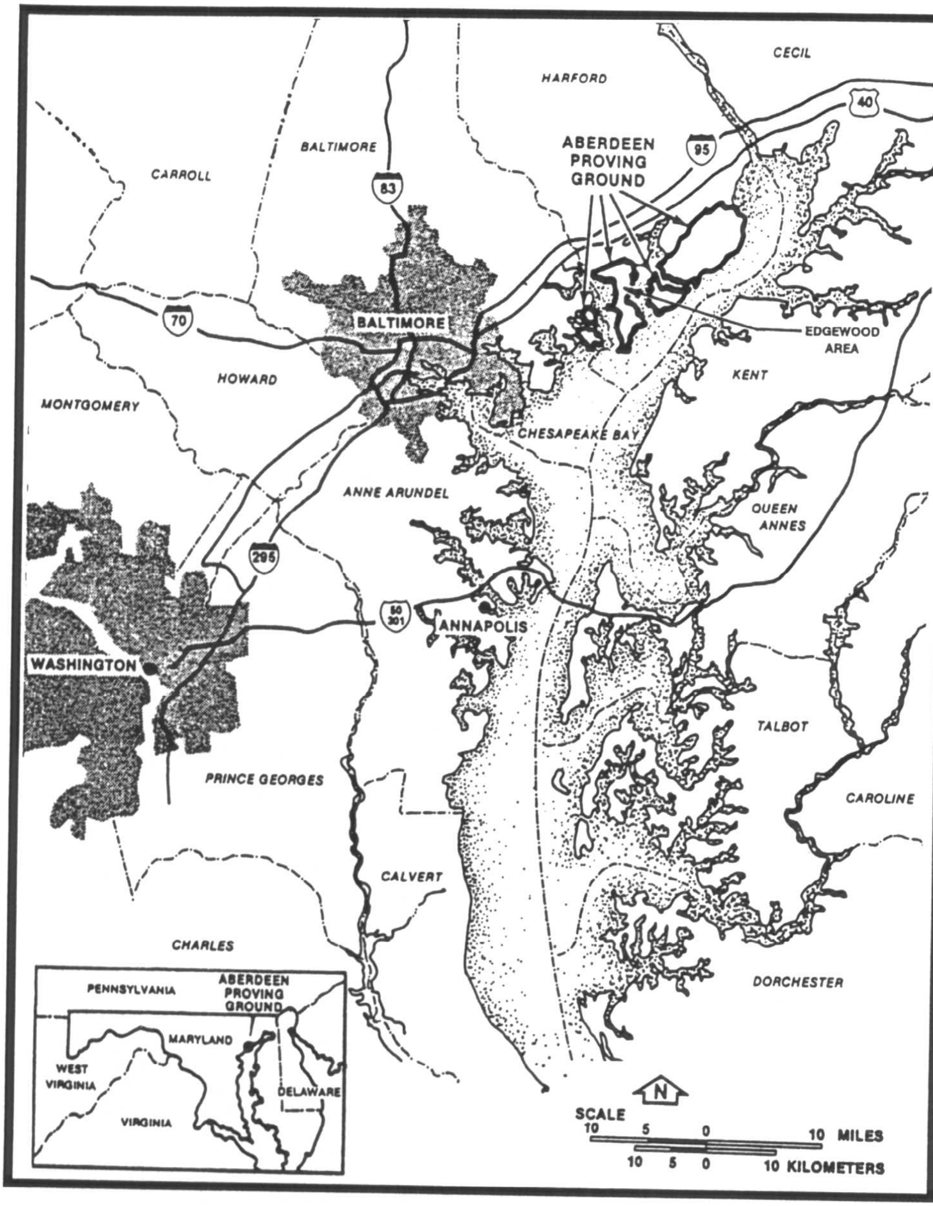

Location of U.S. Army Aberdeen Proving Ground and Perryman. The land and water area of APG is roughly 79,000 acres, of which approximately 30,000 acres are land area consisting of two major portions, the southwestern being the Edgewood Area and the northeastern the Aberdeen Area.

The regional climate is classified as humid temperate, with hot humid summers and relatively mild winters. The average temperature is 12°C and an average relative humidity is 74 percent. The average annual precipitation at APG is approximately 45 inches, with maximum rainfall occurring during the summer [1]. Approximately 28 inches of rainfall per year are lost through evapotranspiration.

The land surrounding APG is used for farming and industry, but also includes residential areas. Industry is most concentrated along Route 40 throughout Baltimore and Harford County. Residential areas are predominantly new townhouses and developments and are located in Harford County. Areas on the eastern shore of the Chesapeake Bay (Eastern Shore) are more agricultural and less populated. Approximately 65 percent of the total land area of APG itself is undeveloped, consisting of extensive woodlands, wetlands, and shoreline bordering the Chesapeake Bay, the Bush River, and the Gunpowder River.

The region surrounding APG extends across two physiographic provinces, the Piedmont Plateau and the Coastal Plain. The Piedmont is characterized by rolling to hilly terrain, and the Coastal Plain is generally characterized by a low lying, gently rolling terrain. Some areas surrounding the Chesapeake are nearly level while others have been dissected, making the local terrain rolling, to moderately hilly. APG is located within the Coastal Plain and is predominantly low lying along the shores of the Chesapeake Bay.

GENERAL TECHNICAL CONSIDERATIONS

The development and chemistry of soils is strongly influenced by several factors, including (1) the nature of the parent material from which the soil is derived, (2) climate, and (3) the mode of placement at a site. On the coastal plain where APG is located, soils have been physically transported from the parent rock materials from which the soils were formed. Therefore, element concentrations in coastal plain soils are expected to be different than in soils developed by chemical weathering over parent rock material. All reference background soil samples were collected from the coastal plain.

Climate is the principal factor responsible for the development of soils into horizons. The general types of soil horizons are the uppermost organic (O) horizons containing large amounts of plant and animal residue, the eluvial (A) horizons from which minerals are leached, and the illuvial (B) horizons in which minerals are deposited. Beneath these horizons are the C horizon which is the original unweathered soil deposit. These typical soil horizons are described in Table 1.

Exposure to contaminated soil is through direct contact, ingestion, and respiration of soil particulates. Except for activities involving excavation, such as construction, human exposure is generally restricted to surface soils. Furthermore, much of the initial investigative soil sampling efforts will emphasize sampling and analysis of surface soils. This does not imply that exposure will be to soil of the "O" and "A" horizons because erosion and human activities may have removed the uppermost soil horizons at a site.

TABLE 1 -- The soil profile

HORIZON TYPES	HORIZONS	HORIZON DESCRIPTIONS
ORGANIC HORIZONS	O1	Organic horizon wherein the original forms of plant and animal residues can be recognized by the naked eye.
	O2	Organic horizon wherein the original plant and animal forms cannot be so distinguished.
ELUVIAL HORIZONS (mineral)	A1	Topmost mineral horizon, containing a strong admixture of humified organic matter which tends to impart a darker color than that of the lower horizons.
	A2	Horizon of maximum eluviation of clay, iron, and aluminum oxides and a corresponding concentration of resistant minerals, such as quartz, in sand and quartz sizes. Generally lighter in color than the A1 horizon.
	A3	Transition layer between A and B horizons with properties more nearly like those of A1 or A2 than of the underlying B. Sometimes absent.
ILLUVIAL HORIZONS (mineral)	B1	Transition layer between A and B horizons with properties more nearly like B than A. Sometimes absent.
	B2	Zone of maximum accumulation of clays and hydrous oxides. These may have moved down from upper horizons or may have formed in place. Organic matter content is generally higher than that of A2 horizon. Maximum development of blocky or prismatic structure or both.
	B3	Transition between B and C horizons with properties more like those of B.
	C	Unconsolidated material underlying the solum. Outside the zones of major biological activities and is little effected by the solum forming process.

Horizon descriptions taken from Nyle C. Brady, "The Nature and Properties of Soils", 8th Edition, MacMillan, 1974.

REGIONAL SOILS

Coastal Plain soils of the region are deep, nearly level to steep, well-drained and moderately well-drained, and are underlain by sandy, loamy, gravelly, or clayey sediment on smooth uplands (such as Sassafras, Elkton, Beltsville, Loamy and Clayey Land, and Matapeake-Mattapex Series) [2, 3, 4]. Soils of the flood plains and low terraces are generally deep, nearly level, well-drained and moderately well-drained and are underlain by stratified alluvial sediment (such as Cordorus, Hatboro, Delanco, and Alluvial Land Series).

TABLE 2 -- Soil types of APG and the nearby coastal plain area

Region	USDA Soil Classification
Edgewood Area of APG	Elkton silt loam Keyport silt loam Sassafras loam Sassafras silt loam Tidal marsh
Aberdeen Area of APG	Elkton silt loam Keyport silt loam Sassafras loam Sassafras silt loam Tidal marsh Sassafras sandy loam Meadow
Coastal plain upland soils	Beltsville-Loamy and clayey land-Sassafras Association Beltsville soils Loamy and clayey land Sassafras soils other less extensive soils Mattapex-Matapeake association Matapeake soils Mattapex soils Keyport soils other less extensive soils Neshaminy-Chillum-Sassafras association Neshaminy soils Chillum soils Sassafras soils other less extensive soils
Coastal plain flood plains and low terraces	Elsinboro-Delanco association Elsinboro soils Delanco soils other less extensive soils Codorus-Hatboro-Alluvial land association Codorus soils Hatboro soils Alluvial land other less extensive soils

The soils found at APG generally are similar to those found in the remainder of the coastal plain areas of the region. The most recent soil survey at APG was conducted in 1927 [5]. Recent soil surveys use classifications which differ somewhat from those used in 1927, but are generally similar [2, 3, 4].[3] Based on a comparison of the soil type descriptions, the dominant soils on-site at APG are Sassafras Series, Elkton Series, and Keyport Series. Along most nontidal wetland areas, the Meadow Series (Alluvial Land Series) is dominant, and Tidal Marsh

[3]Certain soil series used in 1927 are no longer used, for example, the Conagree series. Several series found on APG (e.g. Sassafras, Elkton, and Keyport) were in use in 1927 and are still used in recent soil surveys.

Series is dominant in tidally influenced wetlands. A list of the soil types found at APG and throughout the region is presented in Table 2.

GENERAL TECHNICAL APPROACH

The initial field work was an evaluation of soils on APG. The purposes of this on-post evaluation were to provide information which would allow verification that reference soil types are the same as those that exist on APG, and that the range and distribution of soil physical characteristics at on-post study sites are adequately represented by the background sampling program. The evaluation was accomplished in 15 areas of APG in which risk assessment is being performed. The field work involved the examination of surface soil at numerous sites within each area, and the use of hand augers at several sites in each area to determine the soil profile to a depth of 3-5 feet. Hand augers were used as a simpler, safer, and more cost effective approach because most on-post sites contain unexploded ordnance. While the use of hand augers is not as effective as trenches for soil survey work, the information obtained was adequate for project purposes.

The initial off-site sampling effort involved collection of soil at 30 sites believed to be representative of APG soil types previously identified. The principal objective was to obtain an adequate number of samples of each major soil type found on APG where risk assessment work is being performed or is planned. More than a dozen individual soil series are believed to be present on APG. It was expected that element concentrations in many of these soils are similar, and these chemically similar soils comprise population groupings. If the number of soil population groups is small, then it is expected that the planned 30 samples would be adequate to provide an initial estimate of population characteristics. This would provide the basis for determining the number of additional samples which will be necessary during a second phase of reference soil sampling. It was also anticipated that the 30 initial soil samples would provide for most elements and compounds all the data necessary to establish background concentrations for use in risk assessments. The concentrations of anthropogenic organic compounds in surface soil as a result of regional air transport was expected to be largely independent of soil series and more likely related to surface soil characteristics such as grain size and organic matter content. The planned 30 samples with analysis for these compounds were expected to provide adequate reference data.

Another major consideration was collection of the reference soil samples from a geographically broad portion of the nearby coastal plain area such that regional variations in element and especially air transported anthropogenic elements/compounds are detected and appropriately considered. The distribution of reference soil sampling locations from northeastern Baltimore County northeastward into Cecil County provides a geographically broad distribution in the southwest to northeast direction. The area of sampling was restricted to a several mile wide band in the southeast to northwest direction because of the close proximity of APG to the Piedmont Plateau.

The third major consideration in selecting reference soil sampling locations is avoidance of sites possibly contaminated by local pollution sources, such as nearby incinerators or sludge disposal operations. While efforts were made to avoid local sources of contamination, the restriction of sampling sites to the coastal plain in the general vicinity of APG also restricts sampling to the transportation and industrial corridor along Route 40 where both local and regional contaminant sources are most likely to exist.

SAMPLING AND ANALYSIS APPROACH

The investigation at each proposed reference sampling location started with examination of the soil to a depth of at least three feet using shovels and hand augers. The field log for each site includes observations concerning site topography, vegetation, other pertinent observations, and for each soil horizon the primary and secondary constituents, including approximate grain size and sorting; color (using a Munsell color chart); plasticity; and moisture content. If field observations indicated that the soil survey maps are not accurate and the soil type at the site was not as anticipated, a new location was selected in the same general area.

After a sampling site had been confirmed as suitable, surface soil samples were collected from the uppermost soil horizon immediately beneath the vegetation mat to a depth not exceeding 6 inches. In most instances where the soil had not been subject to disturbance by human activity or significant erosion it was the "A" horizon which was sampled. Field observations of soil grain size, organic matter content, color, and plasticity were used in an attempt to sample only one soil horizon. Surface soil from all sampling sites was collected for analysis to determine soil characteristics (grain size distribution, plasticity, organic carbon content, pH, moisture content, USCS classification) and concentrations of Target Analyte List (TAL) inorganics, Target Compound List (TCL) semivolatiles, and TCL pesticides/PCBs.[4] Surface soil samples from one half of the sites were collected for analysis to determine levels of gross alpha, gross beta, and dioxins/furans.

If the surface soil sample was collected from the "O" or "A" horizons and a "B" horizon was identified within 5 feet of the ground surface, a second sample was collected at the site from the deeper "B" horizon. This second sample at the site was analyzed to determine TAL metals concentrations and soil characteristics. The purpose of this deeper sample at each site was to determine if element concentrations are significantly higher in the illuvial "B" horizon and to better represent background soils for APG study areas where soils have been recently disturbed (within last 10 or 20 years) and surface soils present are not the original "O" or "A" horizons. These "B" horizon samples were not analyzed for anthropogenic organic compounds. These compounds are transported by air, are expected to have been deposited across APG primarily during the years since the soils at the study sites have been disturbed, and are expected to be present primarily in surface soils. Therefore, the particular soil horizon being present at the surface is not normally a factor in determining concentration of air transported anthropogenic compounds.

Portions of APG, especially the range areas, are geographically distant from off-post air emissions sources of anthropogenic compounds. Therefore, the concentrations of these compounds in APG soils may be less than in soils along the coastal plain corridor where the background soil samples were collected. For example, the concentrations of lead in the reference soil samples was expected to be higher than in soils of the southern Gunpowder Neck peninsula because of the proximity of the reference sampling sites to major highways. To address this consideration, six surface soil samples were collected from APG areas which are expected to be relatively free of contamination. These samples were analyzed for the complete range of parameters determined for off-post background soil samples.

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[4]The TAL analytes and TCL compounds are specified in the Statement of Work for the USEPA Contract Laboratory Program (CLP).

FINDINGS AND DATA EVALUATION

The evaluation of APG soils found that roughly 70% of the sites at which hand auger profiles were obtained matched the soil series mapped in 1927. Sassafras soils were found at 13 sites, Keyport soils at 12 sites, Elkton soils at 6 sites, and tidal marsh at 1 site. There were five sites at which the hand auger profile did not allow classification of the soil by series.

Data handling practices routinely used in risk assessment were employed in analysis of the background data [6, 7]. The Sample Quantitation Limit (SQL) was reported as the detection limit for TAL analytes. For non-detect results, one half of the sample-specific and chemical-specific quantitation limit has been used to represent the concentration in that sample. For those cases where the detection limit was two or more times higher than the maximum detected concentration, the data point was removed from the data set. Field duplicate sample results have been averaged together and the average used thereafter as the reference concentration for that sampling location/time.

Silver, antimony, beryllium, cadmium, hexavalent chromium, mercury, selenium, and thallium were either not detected at all or were infrequently detected in background soils. A small portion of samples contained detectable concentrations of 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE. More than 10 polynuclear aromatic hydrocarbon (PAH) compounds were detected in soil samples, with many of the samples containing detectable levels of at least one such compound. The frequency of detection of the individual PAHs was low, with fluoranthene being the most frequently detected and observed in 10 of 29 samples. All samples analyzed for dioxins/furans contained detectable concentrations of octachloro-dibenzodioxin (OCDD) and several samples also contained heptachloro-dibenzoparadioxins. The results of analysis of off-site background samples are summarized in Table 3. The results of analysis of on-site soils at APG were not included in the calculation of these summary statistics.

TABLE 3 -- Summary of Off-Site Background Concentrations

All Soil Horizons Inorganics: mg/kg; Organics: ug/kg; Radionuclides: pCi/g				
Analyte[a]	**Freq[b] of Detection**	**Arithmetic Mean[c]**	**Std[c] Dev**	**Range of Concentrations**
Organics:				
4,4'-DDD	2/29	0.96	1.38	2.80 - 7.83 <1.00 - <1.45
4,4'-DDE	9/29	16.9	72.5	4.08 - 392 <1.00 - <1.45
4,4'-DDT	7/29	7.62	26.7	1.62 - 143 <1.00 - <2.00
Anthracene	0/29	46.0	5.73	<70 - <140
2-methylnaphthalene	0/26	65.7	3.97	<120 - <145
Phenanthrene	6/29	52.0	26.7	25 - 170 <70 - <140
Fluorene	0/29	46.0	5.73	<70 - <140
Acenaphthene	0/29	46.0	5.73	<70 - <140
Dibenzofuran	0/26	78.0	4.64	<140 - <175

All Soil Horizons Inorganics: mg/kg; Organics: ug/kg; Radionuclides: pCi/g				
Analyte[a]	Freq[b] of Detection	Arithmetic Mean[c]	Std[c] Dev	Range of Concentrations
Benzo(a)anthracene	4/29	71.3	31.7	53 - 230 <110 - <200
Benzo(a)pyrene	4/29	109	74.9	57 - 440 <150 - <280
Benzo(b)fluoranthene	9/29	73.1	55.0	35 - 350 <110 - <200
Benzo(g,h,i)perylene	2/29	108	22.7	73 - 200 <170 - <320
Benzo(k)fluoranthene	4/29	65.8	18.2	29 - 140 <110 - <200
Carbazole	0/26	65.6	3.97	<120 - <145
Chrysene	4/29	78.6	59.0	67 - 380 <110 - <200
Fluoranthene	10/29	62.3	55.3	20 - 320 <80 - <140
Dibenzo(a,h)anthracene	0/29	106	12.9	<170 - <320
Indeno(1,2,3-cd)pyrene	5/29	101	31.8	40 - 210 <170 - <320
Pyrene	8/29	73.7	108	38 - 620 <70 - <140
Total PeCDFs	1/13	0.05	0.09	0.290 <0.018 - <0.430
Total HxCDFs	1/13	0.03	0.03	0.120 <0.022 - <0.052
1,2,3,4,6,7,8-HpCDD	2/8	0.03	0.01	0.041 - 0.057 <0.036 - <0.110
Total HpCDDs	2/13	0.07	0.03	0.098 - 0.140 <0.045 - <0.190
OCDD	13/13	2.37	2.21	0.30 - 9.1
Diethyl Phthalate	3/26	47.1	5.83	41 - 72 <80 - <100
Inorganics:				
Aluminum	40/40	7,940	3,690	1,390 - 17,300
Magnesium	40/40	1,010	892	63 - 3,920
Calcium	40/40	534	462	66.8 - 1,980
Iron	40/40	12,300	5,570	2,610 - 23,500
Manganese	40/40	276	296	4.95 - 1,140
Sodium	38/38	7.46	114	206 - 937
Potassium	39/40	384	376	70.6 - 1,700 <72.6