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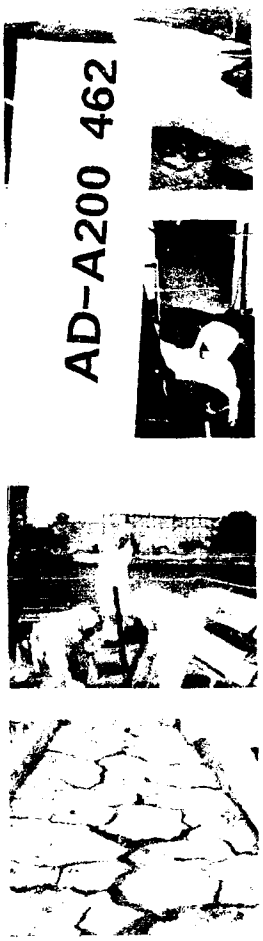

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NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

Report 4

SURFACE RUNOFF QUALITY EVALUATION FOR CONFINED DISPOSAL

by

John G. Skogerboe, Richard A. Price, Dennis L. Brandon

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39181-0631

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ENVIRONMENTAL LABORATORY

NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

No. in Series	Report Title
1	Study Overview
2	Sediment and Contaminant Hydraulic Transport Investigations
3	Characterization and Elutriate Testing of Acushnet River Estuary Sediment
4	Surface Runoff Quality Evaluation for Confined Disposal
5	Evaluation of Leachate Quality
6	Laboratory Testing for Subaqueous Capping
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11	Evaluation of Conceptual Dredging and Disposal Alternatives
12	Executive Summary

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Surface runoff water quality tests were conducted on contaminated sediment collected from New Bedford Harbor/Acushnet River, New Bedford, MA. The site was contaminated with polychlorinated biphenyl (PCB) concentrations ranging from 10 to 100,000 mg/kg. Sediment with PCB concentrations less than 100 mg/kg was selected for the surface runoff tests because similar dredged material would be used to cap other dredged material with the higher concentrations.

The sediment was transported to the US Army Engineer Waterways Experiment Station (WES), placed in a lysimeter 4.57 by 1.22 m, and tested using the WES rainfall simulator. Three storm events (5.08 cm/hr for 30 min) were applied to the sediment immediately after being placed in the lysimeter. The sediment was allowed to dry and oxidize for 6 months and was tested again using the same rainfall simulation procedure. Surface runoff

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samples were collected from each storm event and analyzed for suspended solids, pH, conductivity, arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron, manganese, PCBs, and polyaromatic hydrocarbons.

Results of the surface runoff tests conducted immediately after filling the lysimeter showed the contaminants to be tightly bound to the particulates, and not very soluble. Suspended solids concentrations were high (>7,000 mg/ℓ) and resulted in high total concentrations of several heavy metals and PCBs. Filtered or soluble concentrations were low compared with unfiltered concentrations, and only copper was statistically greater than or equal to the US Environmental Protection Agency (USEPA) Acute Water Quality Criteria for the Protection of Marine Aquatic Life.

Results of surface runoff tests conducted 6 months later showed that filtered cadmium, copper, and zinc concentrations were statistically equal to unfiltered concentrations. Other heavy metals and PCBs were not very soluble. Filtered copper and zinc concentrations were statistically greater than or equal to the USEPA criteria.

The surface runoff water quality tests predicted that filtered copper and zinc concentrations would exceed the selected criteria in surface runoff water quality from the New Bedford sediment. Initially, total or unfiltered concentrations of heavy metals and PCBs would be high, but associated primarily with the particulates. Contaminants during this period could be controlled by removing the sediment particulates in the runoff before being discharged from the site. As the material dries and oxidizes, some heavy metals will become more soluble; however, only soluble copper and zinc will exceed the USEPA criteria at the discharge weir. A mixing zone beyond the discharge weir should be considered to evaluate the concentration of the metals in the receiving water and the need for further restrictions or control measures. Keywords: Sediments, pollution; water pollution; pollution management; (KT).

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PREFACE

This study was conducted as a part of the Acushnet River Estuary Engineering Feasibility Study (EFS) of Dredging and Dredged Material Disposal Alternatives. The US Army Corps of Engineers (USACE) performed the EFS for the US Environmental Protection Agency (USEPA), Region 1, as a component of the comprehensive USEPA Feasibility Study for the New Bedford Harbor Superfund Site, New Bedford, MA. This report, Report 4 of a series, was prepared by the US Army Engineer Waterways Experiment Station (WES), in cooperation with the New England Division (NED), USACE. Coordination and management support was provided by the Omaha District, USACE, and dredging program coordination was provided by the Dredging Division, USACE. The study was conducted between June 1986 and February 1987.

Project manager for the USEPA was Mr. Frank Ciavattieri. The NED project managers were Messrs. Mark J. Otis and Alan Randall. Omaha District project managers were Messrs. Kevin Mayberry and William Bonneau. Project managers for the WES were Messrs. Norman R. Francingues, Jr., and Daniel E. Averett.

The report was prepared by Messrs. John G. Skogerboe, Richard A. Price, and Dennis L. Brandon of the Soil Restoration and Surface Runoff Water Quality Team, Contaminant Mobility and Regulatory Criteria Group (CMRCG), Ecosystem Research and Simulation Division (ERSD), Environmental Laboratory (EL), WES. Sample analysis was conducted by the Analytical Laboratory Group, Environmental Engineering Division, EL, under the supervision of Ms. Ann Strong. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

The study was conducted under the supervision of Dr. Charles R. Lee, Chief, CMRCG; Mr. Donald L. Robey, Chief, ERSD; and Dr. John Harrison, Chief, EL.

COL Dwayne G. Lee, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY
ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED
MATERIAL DISPOSAL ALTERNATIVES

SURFACE RUNOFF WATER QUALITY EVALUATION FOR CONFINED DISPOSAL

PART I: INTRODUCTION

1. In August 1984, the US Environmental Protection Agency (USEPA) reported on the Feasibility Study of Remedial Action Alternatives for the Upper Acushnet River Estuary above the Coggeshall Street Bridge, New Bedford, MA (NUS Corporation 1984). The USEPA received extensive comments on the proposed remedial action alternatives from other Federal, state, and local officials, potentially responsible parties, and individuals. Responding to these comments, the USEPA chose to conduct additional studies to better define available cleanup methods. Because dredging was associated with all of the removal alternatives, the USEPA requested the Nation's dredging expert, the US Army Corps of Engineers (USACE), to conduct an Engineering Feasibility Study (EFS) of dredging and disposal alternatives. A major emphasis of the EFS was placed on evaluating the potential for contaminant releases from both dredging and disposal operations.

2. The technical phase of the EFS was completed in March 1988. However, as part of Task 8 of the EFS, the results of the study were compiled in a series of 12 reports, listed below.

a. Report 1, "Study Overview."

b. Report 2, "Sediment and Contaminant Hydraulic Transport Investigations."

c. Report 3, "Characterization and Elutriate Testing of Acushnet River Estuary Sediment."

d. Report 4, "Surface Runoff Quality Evaluation for Confined Disposal."

e. Report 5, "Evaluation of Leachate Quality."

f. Report 6, "Laboratory Testing for Subaqueous Capping."

g. Report 7, "Settling and Chemical Clarification Tests."

h. Report 8, "Compatibility of Liner Systems with New Bedford Harbor Dredged Material Contaminants."

i. Report 9, "Laboratory-Scale Application of Solidification/ Stabilization Technology."

j. Report 10, "Evaluation of Dredging and Dredging Control Technologies."

k. Report 11, "Evaluation of Conceptual Dredging and Disposal Alternatives."

l. Report 12, "Executive Summary."

This report is Report 4 of the series. The results of this study were obtained from conducting EFS Task 6, element 3 (see Report 1).

Background

3. Sediments removed from waterways by construction projects sometimes contain high concentrations of contaminants such as heavy metals, polychlorinated biphenyls (PCB), and polyaromatic hydrocarbons (PAH). The potential for causing adverse environmental impacts depends on several factors, including the chemical form of the contaminants and the type of disposal environment. Wet, unoxidized dredged material usually has a pH ≥ 7, with most contaminants tightly bound to the sediment particulates. Movement of contaminants from the disposal site by surface runoff would result primarily from sediment being eroded from the disposal site (Skogerboe et al. 1987). Suspended solids concentrations in surface runoff could range from 5,000 to 50,000 mg/ℓ. Unfiltered (total) contaminant concentrations in surface runoff could also be very high, but filtered (dissolved) contaminant concentrations would be relatively low. When the dredged material is placed in an upland confined disposal facility (CDF), physicochemical changes occur when dredged material dries and oxidizes. These changes may significantly affect the surface runoff water quality, particularly the filtered contaminant concentrations. As the sediment dries and oxidizes, a hard surface crust forms, making the sediment more resistant to erosion and decreasing suspended solids to between 10 and 1,000 mg/ℓ. Unfiltered contaminant concentrations will decrease by several orders of magnitude, but filtered concentrations of some contaminants may increase. If the filtered concentration statistically equals the unfiltered concentration, the contaminant is mostly soluble (Skogerboe et al. 1987).

4. The prediction of surface runoff water quality from USACE CDFs is one of the evaluations described by Francingues et al. (1985) for the management of dredged material. The interpretation of the test data was generally

described in the decisionmaking framework of Peddicord et al. (in preparation). The US Army Engineer Waterways Experiment Station (WES) developed a rainfall simulator, lysimeter system to predict surface runoff water quality from USACE project sites. The WES system is a rotating disk-type rainfall simulator modified from a design of Morin, Goldberg, and Seginer (1967). It incorporates the latest methods to accurately duplicate the drop size and terminal velocities of natural rainfall, factors which are critical in erosion and infiltration studies (Westerdahl and Skogerboe 1982). Extensive field verification studies have been conducted with the WES Rainfall Simulator, Lysimeter System on a wide range of USACE project sites (Westerdahl and Skogerboe 1982, Lee and Skogerboe 1984, Skogerboe et al. 1987). The WES Rainfall Simulator, Lysimeter System (Figure 1) proved to be an effective tool for predicting surface runoff rates, soil loss, and contaminant concentrations.

Objective and Approach

5. This study was designed to predict potential surface runoff water quality from an upland CDF containing moderately PCB-contaminated dredged material (PCB <100 mg/kg) from the New Bedford Harbor. Sediment was collected from the proposed dredging site and tested using the WES Rainfall Simulator, Lysimeter System. Surface runoff water quality tests were conducted on the wet, unoxidized sediment and again 6 months later when the sediment had air-dried and oxidized. Runoff samples were analyzed for suspended solids, pH, conductivity, arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, manganese, PCB, and PAH. Results of the surface runoff water quality tests were then compared with the USEPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987).

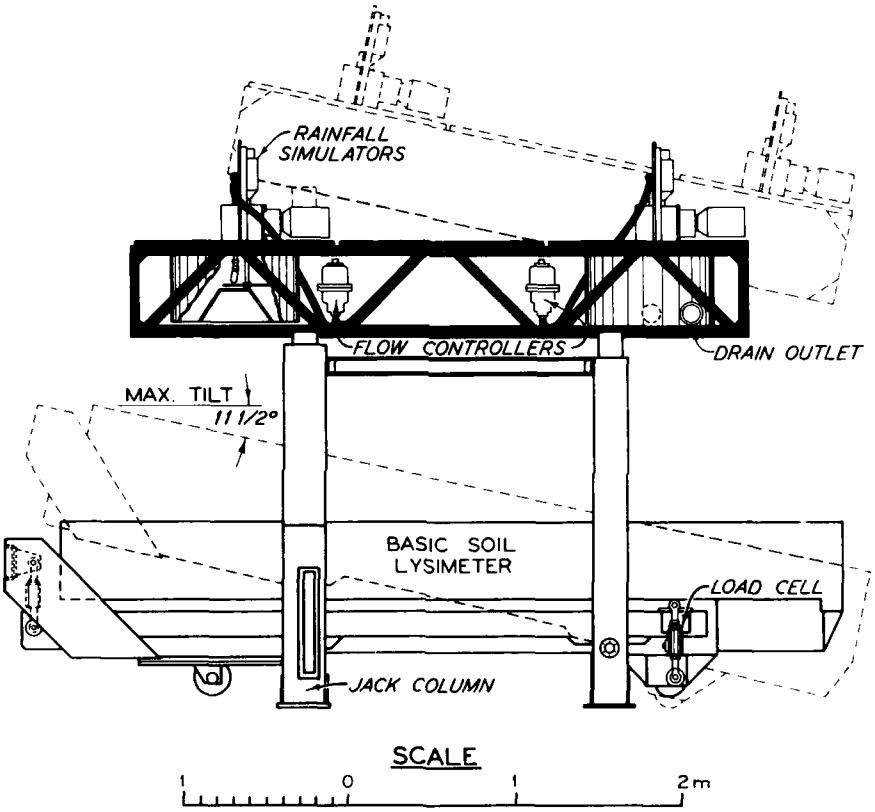

Figure 1. The WES Rainfall Simulator, Lysimeter System

PART II: MATERIALS AND METHODS

Surface Runoff Water Quality Tests

6. Sediment was collected from three areas in New Bedford Harbor (HMM Associates, Inc. 1986), transported to the WES in a refrigerated truck, and placed in a lysimeter 4.57 by 1.22 m (Figure 2). The lysimeter was filled to a depth of 0.33 m and mixed thoroughly (Figure 3). Standing water on the sediment was decanted off the surface of the lysimeter. A composite sediment sample was collected from the lysimeter and analyzed for pH, arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron, manganese, PCB, and PAH (USEPA 1986). The sediment was then tested with the WES Rainfall Simulator using three 30-min storm events at 5.08 cm/hr on successive days (Skogerboe et al. 1987). Runoff rates were measured every minute, and 4-ℓ samples were collected for chemical analysis at 5, 15, and 25 min after runoff began to occur. Additional samples were collected for suspended solids determinations at other points along the hydrograph. The 4-ℓ samples were combined into a composite sample for each test run and analyzed for filtered and unfiltered heavy metals, PCB, and PAH (USEPA 1984).

7. The lysimeter was then covered with a semitransparent top that allowed air movement over the surface of the sediment. After 6 months of drying and oxidation (Figure 4), the sediment was sampled, and three storm events were conducted on the lysimeter. Storm events, sample collection, and sample analysis were the same as the wet stage tests.

Statistical Analysis

8. One-tailed t-tests were used to compare filtered concentrations with the USEPA Marine Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987). Filtered concentrations equal to or greater than the criteria were postulated as the null hypothesis. Filtered concentrations less than the USEPA Criteria served as the alternate hypothesis. A rejection of the null hypothesis suggests that values were less than the criteria.

9. Statistical procedures were used to compare filtered (soluble) and unfiltered (total) contaminant concentrations. The null hypothesis was that

Figure 2. Sediment being placed in the soil lysimeter

Figure 3. Wet, unoxidized sediment

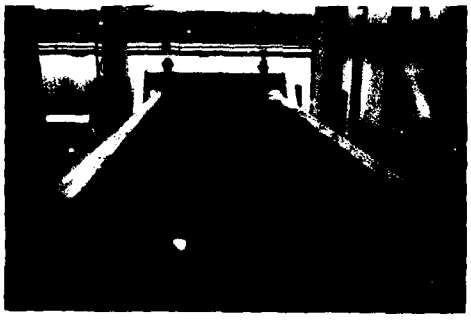

Figure 4. Dry, oxidized sediment

filtered concentrations equal unfiltered concentrations. The alternate hypothesis was that filtered concentrations were not equal to unfiltered concentrations. Cochran's C statistic rejected the homogeneity of variance assumption; therefore, a nonparametric method was used. Mean filtered and unfiltered concentrations were compared using Wilcoxon's two-sample test.

10. The t-tests and Cochran's C statistic were conducted at the 0.05 level of significance. Wilcoxon's two-sample test was conducted at the 0.1 level of significance. A detailed description of t-tests and Cochran's C statistic is given by Winer (1971). Sokal and Rohlf (1981) give a detailed description of Wilcoxon's two-sample tests.

PART III: RESULTS AND DISCUSSION

Wet, Unoxidized Surface Runoff Test

11. Results of the sediment analysis are presented in Table 1. The sediment was moderately contaminated with heavy metals and PCB (<100 mg/kg), relative to the highly PCB-contaminated sediment found elsewhere in the New Bedford Harbor (HMM Associates, Inc. 1986).

12. As shown in the tabulation below, suspended solids concentrations were 7,730 mg/ℓ in surface runoff from the wet, unoxidized sediment. Surface runoff pH was 7.54, and conductivity was 2.53. Results of the lysimeter tests showed that heavy metals in surface runoff were not highly soluble. Concentrations of filtered (soluble) metals were statistically lower than unfiltered (total) concentrations (Table 2). Filtered concentrations of heavy metals were compared with the USEPA Acute Maximum Criteria for the Protection of Marine Aquatic Life, and only copper was statistically greater than or equal to the criteria. No criteria are currently available for comparison with unfiltered concentrations.

Parameter	Wet, Unoxidized Sediment	Dry, Oxidized Sediment
Suspended solids, mg/ℓ	7,730	268
pH	7.54	6.45
Conductivity, mmhos/cm	2.53	1.71

13. Unfiltered total PCB concentrations in surface runoff were statistically greater than filtered concentrations, indicating that PCBs were also not highly soluble (Table 3). Of the seven PCB aroclors analyzed, only PCB 1242 and 1254 were detectable in surface runoff (>0.0001 mg/ℓ). Filtered total PCB concentrations were statistically less than the USEPA criteria. Surface runoff samples were also analyzed for 22 PCB congeners (Table 4). No water quality criteria were available for comparison with individual PCB aroclors or congeners.

14. Surface runoff samples were analyzed for 16 PAHs, and all concentrations were near or below detection limits in both filtered and unfiltered samples (Table 5). Filtered concentrations of total PAH were statistically less than the USEPA criteria.

15. Results showed that contaminants were tightly bound to the sediment particulates. Filtered copper concentrations were statistically less than unfiltered concentrations but were greater than or equal to the USEPA criteria. Surface runoff PCB concentrations should not exceed the USEPA criteria. Management of surface runoff from wet, unoxidized dredged material should be directed toward removal of particulates. Approximately 90 to 99 percent of the contaminants in surface runoff could be removed by removing suspended solids with settling, flocculation, and/or filtration processes.

Dry, Oxidized Surface Runoff Test

16. Concentrations of suspended solids in surface runoff from the dry, oxidized tests decreased compared with concentrations from the wet, unoxidized tests (see tabulation, paragraph 12). A hard crust formed on the surface of the sediment, reducing the erosiveness of the sediment and the resulting suspended solids concentrations. Runoff pH was also lower than runoff pH from the wet, unoxidized test. Unfiltered heavy metal concentrations were less than concentrations from the wet, unoxidized tests (Table 2). Filtered concentrations were compared with unfiltered concentrations and showed that cadmium, copper, and zinc were mostly soluble. Filtered copper and zinc concentrations were statistically greater than or equal to the USEPA criteria.

17. Both unfiltered and filtered total PCB concentrations decreased in surface runoff after drying and oxidation (Table 3). Numbers 1242 and 1254 were the only PCB aroclors greater than the detection limits. Filtered total PCB concentrations were statistically less than the USEPA criteria. Surface runoff samples were also analyzed for PCB congeners (Table 4); however, no criteria existed for comparison with individual PCB aroclors or congeners. Analysis of surface runoff samples for PAH showed all samples, including filtered and unfiltered, to be below detection limits.

18. Results of the surface runoff water quality tests on the dry, oxidized sediment showed that cadmium, copper, and zinc became more soluble in surface runoff. Filtered copper and zinc concentrations exceeded the USEPA criteria, and concentrations of PCB and PAH were below the USEPA criteria.

19. A mixing zone beyond the discharge weir should be evaluated to determine the need for further restrictions or control measures. Management of surface runoff from dry, oxidized dredged material should be directed

toward control of soluble heavy metals. Potential control measures could include trapping all runoff on the site, treating the surface runoff, reducing the solubility of the heavy metals, or capping.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

20. Potential surface runoff water quality problems during the wet, unoxidized period of a CDF would be associated primarily with eroded particulates. Management of a CDF to remove particulates from surface runoff would remove 90 to 99 percent of all contaminants in surface runoff. Only soluble copper concentrations, which exceeded the USEPA criteria, may require some additional consideration of a mixing zone outside the CDF or further treatment.

21. Soluble copper and zinc concentrations in surface runoff from the dry, oxidized material were statistically greater than or equal to the USEPA criteria. Cadmium was also mostly soluble but less than the USEPA criteria. Removing the particulates from surface runoff would remove most of the PCB in surface runoff but would not significantly reduce the soluble metals. A mixing zone beyond the discharge weir should be considered to evaluate the need for further restrictions or control measures. If an adequate mixing zone is not available, other alternatives should be considered for treatment of soluble heavy metals in surface runoff. This could include runoff treatment, capping, or immobilization of the contaminants in the dredged material.

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Table 1

Characterization of Sediment Contaminant Concentrations in Greenhouse Lysimeter, mg/kg

Parameter	Wet, Unoxidized	Dry, Oxidized
	Heavy Metals	
As	0.080	0.090
Cd	0.088	0.148
Cr	2.98	3.01
Cu	6.37	5.96
Pb	0.008	0.006
Hg	0.0132	0.0083
Ni	0.380	0.426
Zn	5.00	5.82
Fe	183	202
Mn	1.50	1.92
	PCB Aroclors	
PCB 1016	<0.05	<0.5
PCB 1221	<0.05	<0.5
PCB 1232	<0.05	<0.5
PCB 1242	46	21
PCB 1248	<0.05	<0.5
PCB 1254	58	35
PCB 1260	<0.05	<0.5
Total PCB	79	68
	PCB Congeners	
PCB 7	<0.002	<0.002
PCB 8	1.5	0.55
PCB 28	3.4	1.7
PCB 44	1.6	0.93
PCB 49	0.63	0.33
PCB 50	3.4	1.7
PCB 52	3.0	0.2
PCB 70	2.3	1.7
PCB 77	4.7	3.7
PCB 82	0.86	0.82
PCB 87	1.3	1.3
PCB 97	1.1	0.76
PCB 101	2.8	1.9
PCB 105	1.6	1.7
PCB 118	1.3	1.2
PCB 136	0.55	0.39
PCB 138	1.1	0.93
PCB 143	0.39	0.42

(Continued)

Table 1 (Concluded)

Parameter	Wet, Unoxidized	Dry, Oxidized
	PCB Congeners (Continued)	
PCB 155	2.6	1.7
PCB 167	0.30	0.34
PCB 180	0.44	0.56
PCB 185	<0.002	0.14
	PAH	
Napthalene	<0.73	<0.33
Acenaphthylene	<0.73	<0.33
Fluorene	<0.73	<0.33
Phenanthrene	1.9	1.1
Anthracene	<0.73	<0.33
Fluoranthene	3.0	1.9
Pyrene	3.2	2.2
Chrysene	2.8	1.9
Benzo (A) anthracene	3.1	2.5
Benzo (B) fluoranthene	2.7	1.9
Benzo (K) fluoranthene	2.7	1.9
Benzo (A) pyrene	1.7	0.92
Indeno (1 2 3-C D) pyrene	1.1	0.76
Dibenzo (A H) anthracene	<0.73	<0.33
Benzo (G H I) perylene	0.94	0.76

Table 2

Heavy Metal Concentrations* in Surface Runoff, mg/ℓ

Parameter	Filtered	Unfiltered	USEPA Criteria
	Wet, Unoxidized Sediment Test		
As	<0.005	0.058 ± 0.012	N**
Cd	0.004 ± 0.0003	0.148 ± 0.057	0.043
Cr	0.007 ± 0.003	3.46 ± 0.551	N
Cu	0.013 ± 0.013†	7.75 ± 1.18	0.0029
Pb	0.003 ± 0.001	1.05 ± 0.087	0.140
Hg	<0.0004	0.009 ± 0.001	0.0021
Ni	0.004 ± 0.0003	0.429 ± 0.056	0.075
Zn	0.047 ± 0.005	6.39 ± 1.03	0.095
Fe	0.213 ± 0.050	192 ± 29.3	N
Mn	0.018 ± 0.006	1.58 ± 0.229	N
	Dry, Oxidized Sediment Test		
As	0.005 ± 0.0003	0.020 ± 0.001	N
Cd	0.029 ± 0.011††	0.025 ± 0.010	0.043
Cr	0.008 ± 0.001	0.223 ± 0.033	N
Cu	0.104 ± 0.009†,††	0.421 ± 0.102	0.0029
Pb	0.014 ± 0.0002	0.344 ± 0.283	0.140
Hg	<0.0008	<0.0008	0.0021
Ni	0.022 ± 0.003	0.046 ± 0.010	0.075
Zn	0.574 ± 0.086†,††	0.747 ± 0.153	0.095
Fe	0.123 ± 0.088	7.27 ± 2.10	N
Mn	0.050 ± 0.007	0.104 ± 0.018	N

* Concentration ± standard error.

** No criteria available for the parameter.

† Filtered concentrations were statistically significantly greater than or equal to the USEPA Criteria. T-tests were conducted at the 0.05 level of significance.

†† Filtered concentrations were not statistically different from unfiltered concentrations using Wilcoxon's two-sample test at the 0.01 level of significance.

Table 3

Concentrations* of PCB Aroclors in Surface Runoff, mg/ℓ

Parameter	Filtered	Unfiltered	USEPA Criteria
	Wet, Unoxidized Sediment Test		
Total PCB	0.0039 ± 0.0003	0.0653 ± 0.0075	0.010
PCB 1016	<0.0002	<0.0002	N**
PCB 1221	<0.0002	<0.0002	N
PCB 1232	<0.0002	<0.0002	N
PCB 1242	0.0026 ± 0.0005	0.0247 ± 0.0116	N
PCB 1248	<0.0002	<0.0002	N
PCB 1254	0.0014 ± 0.0004	0.096 ± 0.0038	N
PCB 1260	<0.0002	<0.0002	N
	Dry, Oxidized Sediment Test		
Total PCB	0.0001 ± 0.0004	0.0310 ± 0.0021	0.010
PCB 1016	<0.0002	<0.0002	N
PCB 1221	<0.0002	<0.0002	N
PCB 1232	<0.0002	<0.0002	N
PCB 1242	0.0008 ± 0.0005	0.0220 ± 0.0023	N
PCB 1248	<0.0002	<0.0002	N
PCB 1254	0.0005 ± 0.0003	0.0088 ± 0.0036	N
PCB 1260	<0.0002	<0.0002	N

Note: No filtered concentrations were statistically significantly greater than or equal to the USEPA Criteria. T-tests were conducted at the 0.05 level of significance.

All filtered concentrations were statistically different from unfiltered concentrations using Wilcoxon's two-sample test at the 0.01 level of significance.

* Concentration ± standard error.

** No criteria available for the parameter.

Table 4

Concentrations* of PCB Congeners in Surface Runoff, mg/ℓ

Parameter	Filtered	Unfiltered
	Wet, Unoxidized Sediment Test	
PCB 7	<0.00001	<0.00001
PCB 8	0.00019 ± 0.00001	0.00350 ± 0.00029
PCB 28	0.00089 ± 0.00007	0.0120 ± 0.00115
PCB 44	<0.00001	<0.00001
PCB 49	0.00005 ± 0.000003	0.00132 ± 0.00021
PCB 50	<0.00001	<0.00001
PCB 52	0.00027 ± 0.00003	0.00783 ± 0.0071
PCB 70	0.00027 ± 0.00002	0.00683 ± 0.00067
PCB 77	<0.00001	0.0153 ± 0.00145
PCB 82	<0.00001	<0.00001
PCB 87	0.00006 ± 0.00001	0.00123 ± 0.00015
PCB 97	0.00007 ± 0.00004	0.00273 ± 0.00030
PCB 101	0.00029 ± 0.00004	0.00710 ± 0.00070
PCB 105	<0.00001	<0.00001
PCB 118	0.00018 ± 0.00001	0.00470 ± 0.00044
PCB 136	0.00004 ± 0.000003	0.00049 ± 0.00003
PCB 138	0.00021 ± 0.00001	0.00234 ± 0.00121
PCB 143	<0.00001	<0.00001
PCB 155	<0.00001	<0.00001
PCB 167	0.00005 ± 0.00001	0.00049 ± 0.00005
PCB 180	0.00004 ± 0.00001	0.00072 ± 0.00006
PCB 185	<0.00001	<0.00001
	Dry, Oxidized Sediment Test	
PCB 7	<0.00001	<0.00001
PCB 8	<0.00001	0.00015 ± 0.00014
PCB 28	0.00016 ± 0.00008	0.00216 ± 0.00046
PCB 44	<0.00001	0.00068 ± 0.00008
PCB 49	0.00002 ± 0.000003	0.00025 ± 0.00001
PCB 50	0.00007 ± 0.00006	0.00277 ± 0.00018
PCB 52	<0.00001	0.00128 ± 0.00006
PCB 70	0.00008 ± 0.00007	0.00138 ± 0.00012
PCB 77	<0.00001	0.00402 ± 0.00040
PCB 82	0.00003 ± 0.00002	0.00093 ± 0.00015
PCB 87	0.00003 ± 0.00002	0.00039 ± 0.00005
PCB 97	<0.00001	0.00080 ± 0.00005
PCB 101	0.00006 ± 0.00005	0.00175 ± 0.00013
PCB 105	0.00008 ± 0.00007	0.00154 ± 0.00043
PCB 118	0.00004 ± 0.00003	0.00066 ± 0.00017
PCB 136	<0.00001	0.00074 ± 0.00005
PCB 138	<0.00001	0.00167 ± 0.00009
PCB 143	<0.00001	<0.00001
PCB 155	0.00009 ± 0.00004	0.00093 ± 0.00004
PCB 167	0.00004 ± 0.00002	0.00014 ± 0.00007
PCB 180	0.00003 ± 0.00002	0.00017 ± 0.00016
PCB 185	<0.00001	<0.00001

* Concentration ± standard error.

Table 5

Concentrations* of PAH in Surface Runoff, mg/ℓ

Parameter	Filtered	Unfiltered	USEPA Criteria
	Wet, Unoxidized Sediment Test		
Total PAH	0.044	--	0.30
Naphthalene	<0.005	<0.005	
Acenaphthylene	<0.005	<0.005	
Acenaphthene	<0.005	<0.005	
Fluorene	<0.005	<0.005	
Phenanthrene	<0.005	<0.005	
Anthracene	<0.005	<0.005	
Fluoranthene	<0.005	<0.005	
Pyrene	0.006	<0.005	
Chrysene	<0.005	<0.005	
Benzo (A) anthracene	0.0051	<0.005	
Benzo (B) fluoranthene	0.008	<0.005	
Benzo (K) fluoranthene	0.008	<0.005	
Benzo (A) pyrene	0.006	<0.005	
Indeno (1 2 3-C D) pyrene	0.005	<0.005	
Dibenzo (A H) anthracene	<0.005	<0.005	
Benzo (G H I) perylene	0.006	<0.005	
	Dry, Oxidized Sediment Test		
Total PA	--	--	0.30
Naphthalene	<0.005	<0.005	
Acenaphthylene	<0.005	<0.005	
Acenaphthene	<0.005	<0.005	
Fluorene	<0.005	<0.005	
Phenanthrene	<0.005	<0.005	
Anthracene	<0.005	<0.005	
Fluoranthene	<0.005	<0.005	
Pyrene	<0.005	<0.005	
Chrysene	<0.005	<0.005	
Benzo (A) anthracene	<0.005	<0.005	
Benzo (B) fluoranthene	<0.005	<0.005	
Benzo (K) fluoranthene	<0.005	<0.005	
Benzo (A) pyrene	<0.005	<0.005	
Indeno (1 2 3-C D) pyrene	<0.005	<0.005	
Dibenzo (A H) anthracene	<0.005	<0.005	
Benzo (G H I) perylene	<0.005	<0.005	

Note: No filtered concentrations were statistically significantly greater than or equal to the USEPA Criteria. T-tests were conducted at the 0.05 level of significance.

* Concentration ± standard error.