EEDP-02-14
September 1991

Environmental Effects of Dredging
Technical Notes

Long-term Evaluation of Plants and Animals Colonizing Contaminated Estuarine Dredged Material Placed in an Upland Environment

Purpose

This technical note summarizes data collected between 1983 and 1989 that relate to plant and animal communities colonizing the upland disposal site of the US Army Corps of Engineers/Environmental Protection Agency Field Verification Program (FVP). The management of contaminated dredged material and the mobility of contaminants from the dredged material into plants and animals are also described. This site will be evaluated through September 1995 under the Long-Term Effects of Dredging (LEDO) Program.

Background

Long-term evaluation of ecosystems developing on dredged material has been accomplished on some of the marsh creation sites established during the Dredged Material Research Program (DMRP). These sites were not classified as contaminated and their evaluations did not consider contaminant mobility. Contaminated dredged material has been evaluated only on a short-term basis, such as laboratory tests before dredging and disposal operations and during the operational phases of some confined disposal facilities (CDFs). Monitoring is normally conducted during the operational phase of a dredging/disposal project and perhaps during the first year after completion of the dredging/disposal activity. Changes in contaminant mobility may occur over the long-term, but no long-term evaluation data are available to document such changes.

Additional Information

Contact one the authors, Dr. Charles R. Lee, (601) 634-3585, or Mr. Dennis L. Brandon, (601) 634-2807, or the manager of the Environmental Effects of Dredging Program, Dr. Robert M. Engler, (601) 634-3624.

Introduction

Contaminated sediment was dredged from Black Rock Harbor, Connecticut, in October 1983 and placed in aquatic, upland, and wetland environments as part of the US Army Corps of Engineers/Environmental Protection Agency Field Verification Program (FVP), 1981-1986 (Peddicord 1988). Upland tests (plant and earthworm bioassays) were conducted on the sediment before dredging to evaluate potential contaminant mobility under the upland disposal alternative. Laboratory test results were subsequently field verified at the field test site at "Tongue Point," Bridgeport, Connecticut. The results of the upland disposal portion of the FVP and the changes occurring since the completion of the FVP for the upland disposal environment are summarized herein. This technical note emphasizes the contaminant mobility of heavy metals. Contaminant mobility and the progressive development of the upland ecosystem at this site will be evaluated until September 1995.

Site History

Before construction, the field site was used as an open dump. The debris consisted mainly of urban building rubble (bricks, cement, and rebar). Both upland and wetland ecosystems were present as were assortments of flora and fauna characteristic of each. During the initial field survey conducted in July 1983, plants were collected along four transects that included both upland and wetland areas. *Phragmites australis* (common reed), *Solanum dulcamara* (nightshade), *Robinia pseudoacacia* (black locust), and *Populus deltoides* (cottonwood) were collected and the tissues analyzed for metals (Brandon and others, in preparation). Both plant species and the general rubble constituents were typical of the urban neighborhood adjacent to "Tongue Point." The field survey described the abundance and diversity of the animal species on site. These included rats, insects, snakes, and several species of birds.*

Construction

All grading and dike construction were performed with conventional equipment. Total surface area was approximately 2,600 m^2. A weir with adjustable

* Lance L. Stewart, Douglas Moffat, Kurt Buchholz, and Michael Coon. 1983. "Field Work Report," unpublished report, Marine Sciences Institute/Sea Grant Advisory program, University of Connecticut, Groton, CT.

risers was installed to control overflow. Peddicord (1988) provides additional information on site design and preconstruction evaluations. Folsom and others (1988) provide further discussion of upland construction.

Physicochemical Changes in Dredged Material

Placement of Black Rock Harbor sediment in an upland disposal environment resulted in pronounced changes in the contaminated sediment. Following upland disposal, the dredged material dried and oxidized. Salinity dropped from a high of 29 to <1 ppt. The pH of the dredged material dropped from 7.6 in 1983 to 3.2 by the end of the FVP in 1986. This substantial decrease in dredged material pH was presumably a result of the decomposition of organic matter, the oxidation of sulfide, limited pH buffering capacity in Black Rock Harbor sediment, low percent $CaCO_3$ equivalent, and the acid rainfall of pH 4.0-4.5 at the field site location (Skogerboe and others 1987). This substantial decrease in the pH of the dredged material enhanced the solubility and availability of the toxic metals: zinc, cadmium, copper, nickel, chromium, and lead (Folsom and others 1988). After placement in an upland environment, control plots of unamended dredged material have been barren of vegetation from 1985 through 1989 even after repeated attempts to establish acid-tolerant, salt-tolerant, and metal-tolerant plant species (Brandon and others, in preparation).

Plants

The FVP laboratory test predicted that *Spartina alterniflora* would not grow in unamended dredged material in the field. This was field verified as no *S. alterniflora* plants survived in the unamended dredged material. The lab test also predicted plant species might grow in amended material. *Sporobolus virginicus* survived in amended material in the lab as well as the field (Folsom and others 1988).

Sediment $CaCO_3$ content was as low as 1.0 percent. Limited buffering of sediment pH occurred and the pH dropped from 7.6 to 3.2. Lime was added to neutralize the acids generated upon drying and oxidation of the dredged material. Manure was added to replace the organic matter oxidized, increase surface metal adsorption, immobilize metals released when organic bound metals were oxidized, and ameliorate the toxic effects of excess salinity. Before planting, a layer of sand and limestone gravel was used to provide a nontoxic microhabitat and a substrate for seed germination. Coarse limestone gravel was placed on the surface to neutralize acid rainfall that might impact the plot and also provide release of acid-neutralizing material over the longer term. The site was partitioned into plots with each amendment being randomly assigned to four plots. The lime and lime + manure amendments were surface broadcast, and then a surface layer of sand and limestone gravel was placed over the lime and manure (Brandon and others, in preparation).

Amendments of lime, lime + manure, lime + sand + gravel, and lime + manure + sand + gravel resulted in vegetation becoming established on the dredged material. Of the plant species seeded on the field plots, only *Agrostis alba* (redtop) became permanently established. *Phragmites australis* had extended its rhizomes from the upland containment facility dike of construction rubble onto some of the plots. Other plant species observed on the plots in 1989 are typical Eurasian species and urban weeds that probably originated from seed sources in the Bridgeport area.

In 1985, the best vegetative establishment was observed on the lime + manure + sand + gravel amended plots. These plots were 97 percent covered with vegetation in 1989. Apparently, the sand and gravel cover allowed rainfall to soak the surface-applied lime and manure into the surface of the dredged material, enhancing plant growth and establishment. The lime and lime + manure plots showed 51 and 28 percent cover, respectively, in 1989. However, subplots receiving an additional application of 56 metric tons/hectare (mt/ha) of lime and rototilling resulted in a soil pH of 4.4 and 4.1 and produced 96 and 99 percent vegetative cover, respectively, in 1989.

Contamination of Plants

The chemical analyses of *Agrostis alba* tissues are presented in Table 1. Lee and others (1991) compiled plant tissue information from a number of sources to indicate demonstrated effects of contaminants on plants. When these data are used as guidance, *Agrostis alba* leaf tissue contents of zinc are within the normal range of 15-150 μg/g found in agricultural crops. Plant cadmium concentrations are equal to or slightly above the normal range and substantially below the critical content level of 8 μg/g. Copper concentrations appear to be either in the normal range or slightly elevated above phytotoxic levels of 25-40 μg/g. However, there was considerable variability in the analyses of the elevated samples. Nickel concentrations were equal to or slightly above the critical content level of 11 μg/g. Chromium concentrations were above normal (1 μg/g) in 1988, and three of the four amendments showed tissue content above phytotoxic levels of 20 μg/g in 1989. Lead concentrations were equal to or slightly above the normal range of 2-5 μg/g. The only mercury reference tissue concentration available was 1.0 μg/g in wheat kernels as an action level for human foodstuff. Mercury contents of *A. alba* were approximately one tenth this action level and therefore should not be of concern (Brandon and others, in preparation).

Animals

The upland animal bioassay predicted that earthworms would not survive in this dredged material under oxidized conditions. Through 1986, earthworms could not survive on this dredged material (Folsom and others 1988). Presently, control plots devoid of vegetation contain few animals. In particular, no soft-bodied animals (slugs) were observed or collected from this environment. Those animals that were collected or observed were transient, foraging arthropod species. In contrast, establishment of vegetation on the amended dredged material enhanced the abundance and diversity of animals present. There were numerous species of macroinvertebrates associated with the plant cover and the leaf litter layer of the soil. The animals observed, while relatively abundant, provided too little biomass per species for chemical analysis. Consequently, no data are available to evaluate contaminant uptake (Brandon and others, in preparation).

Summary

Upland control plots of unamended dredged material were barren of vegetation from 1985 through 1989. Six years after placement in an upland disposal environment, unamended estuarine dredged material decreased in salinity to <1 ppt. However, soil pH remained extremely acidic at 3.4, keeping toxic metals soluble and available to plants that attempt to colonize the unamended dredged material. In contrast, amended dredged material became vegetated and soil and vegetation-dwelling macroinvertebrates have begun to colonize these plots, and food webs involving vertebrates have evolved.

In the upland disposal field site, there are developing plant and animal communities. The extent of the populations and the species compositions of the ecosystems may require management procedures if unanticipated routes of contaminant mobility develop. Continued evaluation will better define the extent and nature of contaminant mobility at the FVP site. This evaluation should include the contaminant mobility of organics into both plants and animals. The development of the upland ecosystem at this site will be evaluated through September 1995.

References

Brandon, Dennis L., Lee, Charles R., Simmers, John W., Skogerboe, John G., and Wilhelm, Gerould S. "Interim Report: Long-Term Evaluation of Plants and Animals Colonizing Contaminated Estuarine Dredged Material Placed in Both Upland and Wetland Environments," Miscellaneous Paper in preparation, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, Bobby L., Jr., Skogerboe, John G., Palermo, Michael R., Simmers, John W., Pranger, Stephen A., and Shafer, Robert A. 1988. "Synthesis of the Results of the Field Verification Program Upland Disposal Alternative," Technical Report D-88-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, Charles R., Tatem, Henry E., Brandon, Dennis L., Kay, Stratford H., Peddicord, Richard K., Palermo, Michael R., and Francingues, Norman R., Jr. 1991. "General Decisionmaking Framework for Management of Dredged Material, Example Application to Commencement Bay, Washington," Miscellaneous Paper D-91-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Peddicord, Richard K. 1988. "Summary of the US Army Corps of Engineers/US Environmental Protection Agency Field Verification Program," Technical Report D-88-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Skogerboe, John G., Lee, Charles R., Price, Richard A., Brandon, Dennis L., and Hollins, George. 1987. "Prediction of Surface Runoff Water Quality from Black Rock Harbor Dredged Material Placed in an Upland Disposal Site," Miscellaneous Paper D-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Table 1

Tissue Contaminant Contents of *Agrostis alba* Plants Growing on the FVP Upland Disposal Site

Contaminant	1988	1989	From Lee and others (1991) Normal	Critical	Phytotoxic
	Amended Lime				
	N=3	N=4			
Zn	85.4 (76.3)	138.7 (40.1)	15-150	200	500-1,500
Cd	1.1 (0.1)	1.5 (0.9)	0.1-1	8	5-700
Cu	15.0 (1.8)	92.2 (80.0)	3-20	20	25-40
Ni	13.4 (4.0)	11.9 (5.1)	0.1-5	11	500-1,000
Cr	6.7 (0.8)	26.5 (9.2)	0.1-1	--	20
Pb	3.1 (1.7)	6.2 (4.0)	2-5	--	--
Hg	0.1 (0.03)	0.1 (0.01)	--	--	--
	Amended Lime + Manure				
	N=3	N=3			
Zn	105.0 (27.5)	124.9 (32.2)			
Cd	1.0 (0.3)	1.1 (0.8)			
Cu	21.6 (8.0)	15.3 (5.4)			
Ni	12.8 (4.0)	15.2 (4.4)			
Cr	11.2 (3.3)	10.6 (4.0)			
Pb	4.6 (1.4)	6.4 (3.7)			
Hg	0.1 (0.01)	0.05 (0.01)			
	Amended Lime + Sand + Gravel				
	N=1	N=4			
Zn	110.1 (0.0)	128.5 (57.8)			
Cd	1.7 (0.0)	1.5 (0.8)			
Cu	23.6 (0.0)	101.0 (77.0)			
Ni	13.7 (0.0)	13.5 (5.3)			
Cr	11.1 (0.0)	34.8 (27.6)			
Pb	6.6 (0.0)	11.0 (7.9)			
Hg	0.2 (0.0)	0.07 (0.03)			
	Amended Lime + Manure + Sand + Gravel				
	N=1	N=2			
Zn	111.0 (0.0)	1.5 (26.0)			
Cd	1.1 (0.0)	1.4 (0.06)			
Cu	140.9 (0.0)	79.9 (73.1)			
Ni	13.7 (0.0)	11.9 (1.4)			
Cr	24.4 (0.0)	36.0 (28.5)			
Pb	8.6 (0.0)	6.5 (6.6)			
Hg	0.1 (0.0)	0.1 (0.02)			

Notes: Measurements are given in micrograms per gram dry weight. N equals the number of samples collected and analyzed. Values given in parentheses are the standard deviations.