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Environmental Effects of Dredging Technical Notes

UPLAND DISPOSAL SITE MANAGEMENT FOR SURFACE RUNOFF WATER QUALITY

PURPOSE: This technical note describes how the results of the surface runoff water quality test can be used to predict the water quality of surface runoff from confined upland disposal sites and to develop appropriate management plans before dredging. This procedure was developed as part of the Field Verification Program (FVP) and is based on (a) test data collected from Black Rock Harbor, Conn., dredged material using the surface runoff water quality test in a laboratory environment and (b) the results of field studies that tested techniques for controlling surface runoff water quality from an upland disposal site that contained the same contaminated dredged material from Black Rock Harbor used in the laboratory study.

BACKGROUND: Contaminated dredged material is often placed in confined upland disposal sites where movement of contaminants by surface runoff during storms is an important environmental concern. When dredged material is first placed in a confined upland disposal site, it is usually anaerobic with a near-neutral pH (7.0) and a high moisture content (>40 percent). Under these conditions, many contaminants such as heavy metals remain tightly bound to particulates and are poorly soluble. As the dredged material dries and oxidizes, physicochemical changes occur in the material that may increase the solubility of many heavy metals. The more soluble forms of the heavy metals then have a greater potential for causing adverse environmental effects due to increased mobility through surface runoff and increased bioavailability.

The surface runoff water quality test was developed by the Environmental Laboratory to provide Corps of Engineers (CE) Field Operating Agencies (FOAs) with a method for evaluating surface runoff water quality from contaminated dredged material before dredging and disposal. This test can be used in conjunction with plant and animal bioassay, leachate, and effluent tests to evaluate upland disposal of contaminated dredged material. If needed, effective control measures and restrictions can be identified before disposal. Upland disposal can also be evaluated in relation to other disposal alternatives such as open-water or wetland disposal to select the most environmentally sound disposal alternative.

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Introduction

The surface runoff water quality test was developed under the Environmental Impact Research Program (EIRP) to predict soil loss and surface runoff water quality from CE construction sites (Lee and Skogerboe 1984). The test was further refined and field verified for confined upland disposal of contaminated dredged material under the FVP (Skogerboe et al. 1987).

The surface runoff water quality test uses the Waterways Experiment Station (WES) rotating disk rainfall simulator designed to duplicate the kinetic energy of natural rainfall (Westerdahl and Skogerboe 1982) and laboratory lysimeters placed in a temperature-controlled greenhouse. Sediment is collected from a proposed dredging site, brought to the WES, and tested during both the wet anaerobic stage and the dry oxidized stage. Results are then statistically compared to water quality criteria chosen by the agency sponsoring the study. This technical note reports results collected from surface runoff water quality tests conducted on contaminated dredged material from Black Rock Harbor.

Results of field tests conducted to evaluate methods for controlling surface runoff water quality are also presented. Soil amendments such as lime, sand, gravel, and horse manure were incorporated into field plots to reduce the solubility of heavy metals, increase establishment of vegetation, and reduce erosion of contaminated material from the FVP upland disposal site. The soil amendments along with several tolerant plant species were selected from an instruction report, "Restoration of Problem Soil Materials at Corps of Engineers Construction Sites," developed by Lee et. al. 1985. Surface runoff water quality tests were conducted on the field plots to test the effectiveness of the amendments for controlling surface runoff water quality.

Methods

Dredged material from Black Rock Harbor was brought to WES and tested using the surface runoff water quality test. The laboratory lysimeter had a surface area of 4.5 by 1.5 m and was filled to a depth of 0.3 m. A series of rainfall simulations were applied to the dredged material while wet and anaerobic. Approximately 6 months later, another series of rainfall simulations were applied to the dry oxidized dredged material. Each rainfall simulation was 5.1 cm/hr for 0.5 hr. Runoff samples were collected during each storm and analyzed for suspended solids (SS), cadmium (Cd), copper (Cu), chromium (Cr), manganese (Mn), nickel (Ni), and zinc (Zn) in unfiltered and filtered water samples.

The results of the tests were compared to the US EPA Water Quality Criteria for the Protection of Aquatic Life. Criteria (such as the Lake Michigan Water Quality Standards for receiving water quality or background water quality) have been used for similar evaluations of other contaminated dredged material. All of these criteria were used for comparison to filtered or soluble contaminants in surface runoff. No criteria currently exist for comparison to unfiltered or total heavy metal concentrations in water samples.

Methods for controlling surface runoff water quality from the contaminated Black Rock Harbor dredged material were tested at the upland disposal site in Bridgeport, Conn. The test plots (2 by 6.1 m), which included five soil treatments and four plant species, were established 2 years after disposal when the dredged material had dried and oxidized.

a. Treatments.

1. Control, no amendments
2. Lime, 28.2 mt/ha (metric tons/hectare)
3. a. Lime, 28.2 mt/ha
   b. Sand, 13 cm surface layer
   c. Limestone gravel, 6.6 cm surface layer
4. a. Lime, 28.2 mt/ha
   b. Horse manure, 112 mt/ha
5. a. Lime, 28.2 mt/ha
   b. Sand, 13 cm surface layer
   c. Limestone gravel, 6.6 cm surface layer
   d. Horse manure, 112 mt/ha

b. Plant Species.

1. *Agropyron elongatum* (Tall Wheatgrass) 'Alkar'
2. *Festuca arundinacea* (Tall Fescue) 'Alta'
3. *Puccinella distans*
4. *Sporobolus virginicus*

One year after the test plots were established, surface runoff water quality tests were conducted at the upland disposal site on control plots; plots amended with lime, sand, and gravel; and plots amended with lime, sand gravel, and manure. The rainfall simulator was transported to the field site for the tests. Simulated storms were identical in duration and intensity to those used in the greenhouse lysimeter surface runoff water quality tests.

Results and Discussion

Laboratory lysimeter tests

During the wet anaerobic period, heavy metals were poorly soluble in surface runoff (Table 1). Concentrations of metals in unfiltered water

Table 1

Surface Runoff Water Quality from Black Rock Harbor Dredged Material

Condition of Dredged Material	Parameter	Concentrations, Mg/ℓ Unfiltered	Filtered	EPA Criteria mg/ℓ
Wet anaerobic	SS	10,326	N	N
	Cd	0.328	0.005	0.0015-0.0024
	Cu	34.6	0.011	0.012-0.043
	Mn	3.83	0.112	N
	Ni	2.04	0.013	1.3-3.1
	An	16.0	0.120	0.180-0.570
	Cr	19.3	0.004	2.2-9.9
Dry oxidized	SS	167	N	N
	Cd	0.133	0.112*	0.0015-0.0024
	Cu	0.970	0.622*	0.012-0.043
	Mn	0.190	0.158	N
	Ni	0.183	0.128	1.3-3.1
	Zn	3.62	1.06	0.180-0.570
	Cr	0.255	0.008	2.2-9.9

* Filtered concentrations statistically greater than the EPA criteria (P = 0.05).
N Indicates that no values are available.

samples exceeded the concentrations in filtered samples by 1 to 3 orders of magnitude, indicating that the heavy metals were tightly bound to the particulates. During this period, the dredged material was highly erosive so that high concentrations of insoluble heavy metals would have been discharged from a disposal site if the SS were not removed from the surface runoff.

As the dredged material dried and oxidized, many of the heavy metals became more soluble in surface runoff. Except for Cr, filtered concentrations were not significantly different (P = 0.05) from the unfiltered concentrations, indicating that the metals were present in mostly soluble forms. The SS and metal concentrations in the unfiltered surface runoff from the dry oxidized dredged material were significantly less than concentrations from the wet anaerobic dredged material. Filtered heavy metal concentrations from the dry oxidized dredged material, however, were equal to or greater than the filtered concentrations from the wet anaerobic dredged material.

Results of the surface runoff water quality test on the Black Rock Harbor dredged material showed that very different management strategies would be required for controlling contaminants in surface runoff during the wet anaerobic period and during the dry oxidized period. During the wet anaerobic period, most of the heavy metals in surface runoff could be removed by trapping the SS before the runoff is discharged from the disposal site. Concentrations of Cd, Cu, Cr, Ni, Mn, and Zn in filtered surface runoff from the wet anaerobic Black Rock dredged material were statistically equal to or less than the EPA criteria and would require no restrictions or control measures. If the values had exceeded the criteria, additional restrictions or control measures would have been required.

After the dredged material dried and oxidized, the management strategy changed for controlling surface runoff water quality. Heavy metals were no longer tightly bound to the particulates and had become mostly soluble. Trapping of particulates could, therefore, no longer contain the contaminants in the disposal site. Comparing of metal concentrations in filtered surface runoff to the EPA criteria showed that concentrations of Cd, Cu, and Zn exceeded the criteria. Concentrations of Cd, in particular, exceeded the criteria by two orders of magnitude. Management practices under these conditions might include selecting one or more restrictions or control measures: capping, containment of all runoff on the site, runoff treatment, or soil amendments to reduce the solubility of the contaminants. (The FVP field upland disposal site was managed to contain most of the contaminants and surface runoff in the disposal site.)

Field tests

Because of the high salinity in the dredged material, establishment of vegetation on the upland Black Rock Harbor disposal site was difficult. No vegetation grew on the control plots, lime plots, or lime, sand, and gravel plots. Some vegetation was established on plots amended with lime and manure and on the plots amended with lime, manure, sand, and gravel. Vegetation on these plots grew mostly in cracks in the dredged material where the amendments had accumulated.

Results of surface runoff water quality tests conducted on the site management test plots are presented in Table 2. Heavy metal concentrations in

Table 2

Effect of Soil Amendments on Heavy Metal Concentrations in Filtered and Unfiltered Samples

Sample Type	Treatment	Parameter - Concentration, mg/ℓ*					
		Cd	Cu	Cr	Ni	Mn	Zn
Unfiltered	Control	0.55 A	57 A	12 A	3.5 A	4.1 A	40 A
	Lime, sand, gravel	0.40 AB	38 AB	7.9 AB	2.7 AB	3.4 A	27 AB
	Lime, sand, gravel, manure	0.06 B	10 B	3.9 B	0.95 B	0.85 B	3.7 B
Filtered	Control	0.56 A#	47 A#	0.49 A	3.1 A	3.1 A	40 A#
	Lime, sand, gravel	0.36 AB#	31 A#	0.23 AB	2.2 A	2.6 A	27 AB#
	Lime, sand, gravel, manure	0.02 B#	2.0 B#	0.004 B	0.21 B	0.33 B	2.3 B#

* Treatments with the same letters were not significantly different (P = 0.05).
\# Value exceeds the EPA criteria (P = 0.05).

surface runoff from plots amended with lime, sand, and gravel tended to be lower than concentrations in surface runoff from the control plots but were not significantly different. The addition of horse manure to lime, sand, and gravel did, however, significantly reduce concentrations of Cd, Cu, Cr, Ni, Mn, and Zn in unfiltered and filtered water samples. The addition of horse manure also significantly reduced the solubility of Cd, Cu, Ni, and Zn in surface runoff (Table 3).

Table 3

Percentage of Soluble Heavy Metals in Surface Runoff from Field Plots Treated with Different Soil Amendments

Treatment	Parameter - Concentration, mg/ℓ*					
	Cd	Cu	Cr	Ni	Mn	Zn
Control	104 A	73 A	5 A	77 A	69 A	100 A
Lime, sand, gravel	99 A	72 A	3 A	73 A	66 A	92 A
Lime, sand, gravel, manure	47 B	15 B	1 A	22 B	35 A	57 B

* Treatments with the same letters were not significantly different (P = 0.05).

Discussion

Heavy metal concentrations in surface runoff from the field plots were greater than those of the laboratory lysimeter tests. The field plots contained dredged material that had undergone considerable weathering beyond that of the dredged material tested in laboratory lysimeters and earlier field verification test plots (Skogerboe et al. 1987). The field plots were established 2 years after the dredged material was placed in the upland disposal site, and the surface runoff tests were conducted 3 years after disposal. During the 3 years, a control measure based on the laboratory lysimeter data was implemented by maintaining weir structures to prevent contaminants from being discharged from the site. This control measure had significant effects by containing salts, eroded particulates, surface runoff water, and soluble and insoluble heavy metals within the disposal site.

Soil amendments were effective in reducing heavy metal concentrations in filtered and unfiltered surface runoff from the Black Rock Harbor dredged material. Filtered metal concentrations were reduced by an order of magnitude by the addition of the horse manure but still exceeded the EPA criteria and required additional restrictions or control measures. If a mixing zone were being considered in the receiving water body outside of the disposal site, the size of the required mixing zone could be reduced by an order of magnitude. If heavy metal concentrations in surface runoff had been reduced to levels equal to or less than the selected criteria, then no additional control measures or restrictions would have been required.

The previous discussion illustrates how surface runoff water quality tests can be used to evaluate potential contaminant mobility from upland disposal sites and the influence of selected restrictions or control measures such as soil amendments and the use of tolerant plant species to control soil erosion and surface water quality.

References

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