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EVALUATION OF THE SIGNIFICANCE OF SEDIMENT-ASSOCIATED CONTAMINANTS TO WATER QUALITY

R. Anne Jones, George M. Mariani, and G. Fred Lee[1]

ABSTRACT: On the order of 400 x 10^6 m^3 of U.S. waterway sediment are dredged each year. Especially near urban and industrial centers, waterway sediments typically contain large amounts of chemical contaminants, which, if released from the sediments in available forms or if the contaminated sediments were ingested by organisms, could cause adverse impacts on aquatic organisms or man if he were to eat sufficient amounts of the organisms. A five-year study was undertaken by the authors to examine the release of approximately 30 chemical constituents from dredged sediment, both under laboratory conditions (i.e., elutriate test) and during dredged material disposal operations, and to evaluate the toxicity to test organisms of contaminants associated with dredged sediment. The results of this study indicate that large amounts of dredged sediment-associated contaminants are unavailable to affect water quality. Some sediments processed through the elutriate test, however, showed toxicity to aquatic test organisms. It was conclude that a combination of leaching tests, such as the elutriate test as modified by the authors, and bioassays as outlined by the authors, should be used to assess the potential toxicity of dredged sediment-associated contaminants on a site-specific basis.
(KEY TERMS: dredging; dredged sediment disposal; bioassay; benthic organism; heavy metals; sediment/water contaminant exchange; water quality criteria.)

INTRODUCTION

Many contaminants of concern to water quality, such as heavy metals and chlorinated hydrocarbon pesticides, are found associated with particulate matter in the environment. This is largely the result of their sorption on clay particles and organic detritus and/or their association with iron and aluminum hydrous oxides. The association of potentially hazardous chemicals with sediments becomes of greater concern when, through either activities of man or natural phenomena, these particulates become suspended in surface waters, such as occurs during wind- and other current-induced mixing or during dredging and dredged sediment disposal activities. Contaminants are present in the sediments and interstitial water in a variety of physical and chemical forms, some of which can, if released to the water column in sufficient concentrations, cause adverse effects on aquatic organisms and other beneficial uses of the water.

[1] At the time of preparation of this paper: Jones and Lee, respectively, Research Assistant Professor and Professor, Colorado State University, Department of Civil Engineering, Environmental Engineering Program, Fort Collins, CO; Mariani, E.G.&G., Environmental Consultants, Waltham, MA. Presently, Jones (Jones-Lee) and Lee are the Principals of G. Fred Lee & Associates, El Macero, CA [www.gfredlee.com]

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On the order of 400 million cubic meters of sediment are dredged each year in the US for the development and maintenance of waterway navigability. Especially near urban and industrial centers where substantial amounts of dredging take place, waterway sediments typically contain large amounts of chemicals that would be of potential concern if they were released from the sediment in available forms or if the contaminated sediments were ingested by organisms. Lee et al. (1978) found, for example, that dry weight concentrations of cadmium in US waterway sediments were as high as 90 mg/kg; zinc ranged from about 10 mg/kg to as much as 30 g/kg. PCB concentrations were as high as about 8 mg/kg.

In the early 1970s, bulk sediment criteria came into use as the method for determining whether or not a dredged sediment was "clean" enough for open water disposal, generally the easiest and least expensive method of disposal and at that time assumed by some regulatory agencies to be the method most likely to cause environmental degradation. A set of sediment concentration limits was set by a number of US EPA Regions such that if the concentration of cadmium, copper, zinc, etc., was above the limit, the sediment in question, if dredged, would have to be disposed of by some other, generally more expensive, means than in open water. Use of the bulk criteria increased the costs of dredging and disposal from $0.30 to $0.40 per cubic yard to over $10.00 per cubic yard in some areas of the country because alternate disposal methods had to be used. In an effort to better understand the actual potential water quality hazard associated with disposal of dredged sediment, the US Army Corps of Engineers Dredged Material Research Program (DMRP) was developed and provided funding to define the availability of sediment-associated contaminants to aquatic organisms, develop test procedures to estimate contaminant release and assess the environmental hazard associated with that release, begin to establish criteria upon which to judge when a dredged sediment should not be disposed of in open waters, and to a lesser extent evaluate the environmental hazard associated with other methods of dredged material disposal. The DMRP studies conducted by Lee et al. (1978) provided a basis for understanding the potential significance to water quality of contaminants associated with waterway sediments. This paper provides a summary of the Lee et al. (1978), Jones and Lee (1978), and Mariani (1979) contaminant leaching and bioassay studies, and major conclusions reached regarding evaluation of the water quality significance of sediment-associated contaminants.

DREDGED SEDIMENT STUDIES

As part of the overall DMRP, which has recently been completed, Lee et al. (1978) and Jones and Lee (1978) conducted a five-year coordinated field and laboratory study to assess the release of contaminants from dredged sediment. Sediments from 43 different dredging sites in the approximately 20 areas shown in Figure 1 were evaluated in the laboratory for bulk contaminant content and contaminant release using the elutriate test and elutriate bioassays. Detailed field studies were conducted in about 10 of those areas during several disposal operations each, to measure the amounts of contaminants released during hopper disposal of hydraulically dredged sediment (several sites in the Texas Gulf Coast and New York Harbor); barge disposal of mechanically dredged sediment (Puget Sound and New York Harbor); and pipeline disposal of hydraulically dredged sediment (James River, Mobile Bay, Apalachicola Bay, and Upper Mississippi River). Comparisons could then be made between laboratory test results and contaminant release in the field during disposal activities.

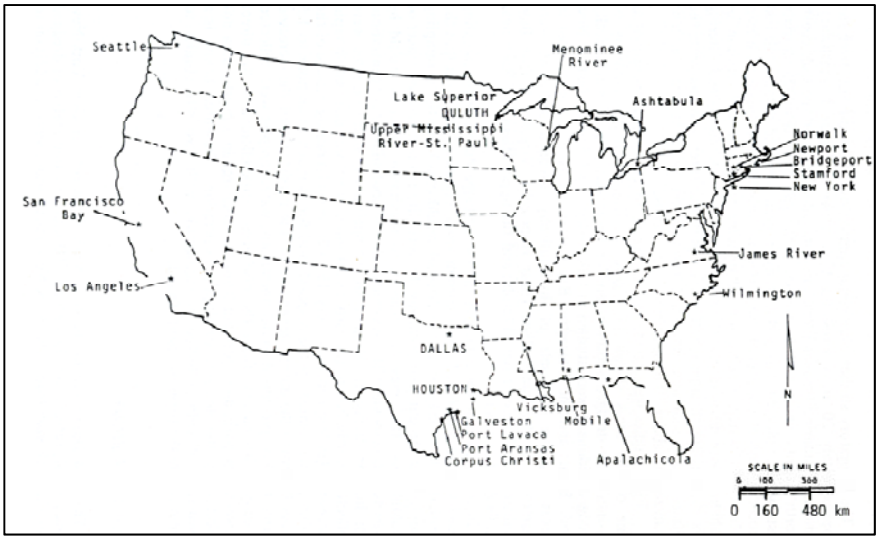

Figure 1. Sampling Locations (in Lee et al., 1978 study.)

Methods

The elutriate test was designed by the US EPA and Corps of Engineers to provide a technically more appropriate alternative to the bulk chemical criteria approach for evaluating dredged sediments for their potential adverse effects on water quality. Test specifications were designed to reproduce the dredging/disposal conditions that exist during hydraulic dredging–hopper disposal operations, and to determine the amount of contaminant release likely to occur in the disposal area during such operations. In the elutriate test, one volume of dredging site sediment is combined with four volumes of dredging site water, mixed with compressed air for 30 minutes, and allowed to settle for one hour. The supernatant is decanted, filtered, and analyzed for constituents of concern; in the case of the Lee et al. study, about 30 parameters (heavy metals, aquatic plant nutrients, and chlorinated hydrocarbon pesticides) were determined. The 20 percent (by volume) sediment-to-water ratio generally used is frequently cited as the optimum dredging pumping ratio. Since that ratio is generally highly variable, some tests were also run using different percentages of sediment for comparison. Detailed discussion of sample handling and evaluation of factors affecting this test and its use in predicting chemical release has been presented by Lee et al. (1975) and Jones and Lee (1978).

Mariani (1979), Lee et al. (1978), and Jones and Lee (1978) developed a benthic organism screening bioassay to be used in conjunction with the elutriate test to evaluate the significance to water quality of dredged sediment-associated chemical contaminants. To perform the bioassay on marine waters, one volume sediment is combined with four volumes (20 percent test) or 19 volumes (5 percent test) synthetic ocean water in five-gallon aquaria test chambers, mixed for 30 minutes with compressed air and allowed to settle for one hour. Ten grass shrimp (*Palaemonetes pugio*) are then added to duplicate preparations; the number of live organisms is counted daily for four days (96 hours). Control tests are also run with clean sand and synthetic ocean water. Similar tests were run for fresh water systems using *Daphnia magna* in 250-mL beakers. For

ease of handling, the unfiltered supernatant from the elutriate test was used for the assays. Lee et al. (1978) provide a detailed description of this procedure.

For field monitoring of a hopper dump of dredged sediment, a sampling vessel(s) was positioned down-current from a marker buoy. As the hopper dredge passed the marker, the command was given to dump the sediment so that the "turbid plume" created by the disposal would pass beneath the sampling vessel. Several water samples were collected at several depths over the 30-minute or so period prior to disposal; samples were collected as frequently as every 15 seconds during passage of the turbid plume, and then less frequently for an hour or so after the dump event. These water samples were analyzed for approximately the same 30 chemical parameters measured in the elutriates of the sediment collected from the dredging areas. Disposal of dredged sediment typically produced a pattern of a short (few-minute) increase in turbidity shortly after the dump event, which typically returned to background levels within a few minutes. Within an hour or so after a dump event, all of the turbidity produced by the dump was generally completely dispersed and/or settled to the bottom. Contaminants released or taken up during disposal typically followed the turbidity pattern. The same sampling principles were used for monitoring barge and pipeline disposal operations.

Results

The New York Harbor dredged sediment studies provide one example to illustrate the types of results collected during the Lee et al. (1978) studies. Table 1 presents the concentrations of heavy metals found in three New York Harbor sediments from areas scheduled to be dredged and dumped for disposal monitoring purposes. These concentrations are typical of contaminant levels found in many of the sediments examined in their study, for most heavy metals evaluated the concentrations being in the tens to hundreds of mg/kg dry weight of sediment. Table 2 shows the concentrations of the same set of heavy metals in the filtered elutriates of these sediments. In general, only manganese and iron were released in measurable amounts in the elutriate. As indicated in Table 2, the concentrations of most of the heavy metals in most of the elutriates were below analytical detection. During the New York Harbor dredged sediment disposal operations, manganese, zinc, iron, and possibly some cadmium were released to the water column at the disposal site. The highest concentration of cadmium found during disposal monitoring was a factor of 2 to 3 below the US EPA Red Book criterion (US EPA, 1976) for life-time exposure to available cadmium in marine waters. Based on data presented by the US EPA (1976), it is unlikely that the release of zinc to 10 to 50 ug/L found during passage of the turbid plume, would cause water quality problems. Above-ambient levels of those heavy metals released during disposal only lasted for 15 to 30 minutes at the disposal site. Results of the elutriate test bioassays (Table 3) show that there was little mortality in 96 hours of exposure to the settled elutriate sediment system for Bay Ridge and Perth Amboy Anchorage sediments. However, for the Perth Amboy Channel sediments (20 percent elutriate), there was 60 percent mortality in 96 hours. Concentrations of the heavy metals measured in this sediment were not generally higher than in either of the other two sediments and concentrations in the oxic elutriates were, except for manganese and iron, generally below analytical detection.

As was demonstrated for the New York Harbor area sediments above, the Lee et al. (1978) studies repeatedly demonstrated that there is no relationship between the bulk content of a contaminant in a sediment and the amount of contaminant released either in laboratory leaching

tests or under field conditions. Further, it is not possible in general to determine by chemical analytical techniques, the effect of disposal of a dredged sediment containing a variety of forms of a variety of contaminants on aquatic organisms. The bioassay approach is, at this time, the only approach that can be used to make that assessment.

TABLE 1. Heavy Metal Concentrations: New York Harbor Area Sediment Samples (mg/kg)*

Sample Designation	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe**	Hg	As
Perth Amboy Channel	99**	1.7	18	140	11.6	8.9	380	14	3.44	15.1
Perth Amboy Anchorage	245	3.3	69	97	30	84	487	15	4.77	57.5
Bay Ridge Channel	183	6.9	3.2	103	2.5	48	257	16	2.21	<5

* Concentrations are means of triplicate analyses except for mercury and arsenic concentrations, which are means of duplicate analyses.
** g/kg
[after Lee et al. (1978)]

In the studies of Lee et al. (1978), and Mariani (1979) about 150 dredged sediment bioassays were run. Table 4 summarizes these results and shows that even though many of the sediments evaluated had seemingly large amounts of a variety of chemical contaminants, mortality at the end of a four-day exposure period was typically on the order of 0 to 20 percent. There were instances, however, in which as many as 65 percent of the test organisms died in 96 hours. It is important to note that neither the mortality nor the amounts of contaminants released was related to the bulk chemical composition of the sediment evaluated.

DISCUSSION

Several major conclusions can be drawn from the results of the dredged material disposal studies conducted by Lee and his associates that are pertinent to evaluating the water quality significance of sediment-associated contaminants. It is important to note that while focused on dredging, the general conclusions are applicable to the transfer of contaminants from any aquatic sediment to the water column and organisms, upon resuspension. First, the sediments of many US waterways contain large amounts of contaminants that could be adverse to aquatic organisms if they were made available to them. Second, there is no relationship between the bulk composition of sediments and their toxicity, or the contaminant release from them in the field during dredged material disposal or in laboratory leaching tests.

Table 5 shows for the heavy metals determined by Lee et al. (1978), what the concentration would be in the elutriate if all of the heavy metal present in the sediment were released during elutriation; how much of each was actually released; how those values compared with LC50 values and marine Red Book criteria for those heavy metals; and the mortality after 96 hours' exposure of *P. pugio* to the elutriates. This table demonstrates, using two of the most heavily contaminated sediments in terms of bulk content of heavy metals evaluated by Lee et al. (1978)

TABLE 2. Soluble Heavy Metal Concentrations: New York Bight Area Elutriate Tests (ug/L)

		Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PERTH AMBOY CHANNEL																					
Site Water		<10	--	<0.5	--	<2	--	6.1	--	<2	--	<1	--	3.6	0.6	8	6	0.03	0	2	--
5% Oxic	A	52	12	<0.5	--	<2	--	3	0.2	<2	--	<1	--	<1	--	5	0	0.03	0	<2	--
	B	44	0	<0.5	--	<2	--	<1	--	2.5	0.4	<1	--	<1	--	31	--	0.03	0	3	--
20% Oxic	A	28	0	<0.5	--	<2	--	<1	--	<2	--	<1	--	<1	--	689	--	0.03	0	<2	--
	B	19	12	<0.5	--	<2	--	<1	--	2.6	0.1	<1	--	<1	--	31	0	0.03	0	<2	--
20% Anoxic	A	28	--	<0.5	--	<2	--	<1	--	<2	--	<1	--	<1	--	32	8	0.03	0	16	--
	B	44	--	<0.5	--	<2	--	<1	--	<2	--	<1	--	1.3	--	248	--	0.03	0	13	--
PERTH AMBOY ANCHORAGE																					
Elutriate Tests:																					
Site Water		28	11	<0.5	--	<2	--	<1	--	<2	--	<1	--	3.9	0.1	22	3	0.03	0	4	--
5% Oxic	A	36	--	0.7	0	<2	--	<1	--	<2	--	<1	--	<1	--	25	1	0.03	0	12	--
	B	28	11	0.6	--	<2	--	<1	--	<2	--	<1	--	<1	--	11	4	0.05	0	<2	--
20% Oxic	A	<10	--	0.6	--	7	--	<1	--	<2	--	<1	--	1	--	161	10	0.03	0	19	--
	B	<10	--	<0.5	--	<2	--	<1	--	4.1	1.6	<1	--	<1	--	48	7	0.03	0	13	--
20% Anoxic	A	20	--	<0.5	--	<2	--	<1	--	<2	--	<1	--	2.8	--	71	15	0.07	0	44	--
	B	84	--	<0.5	--	<2	--	<1	--	<2	--	<1	--	<1	--	65	4	0.03	0	44	--
Plop Tests:	A	52	23	<0.5	--	7.7	2.9	<1	--	<2	--	<1	--	<1	--	82	2	0.03	0	14	--
	B	12	11	0.7	0	<2	--	<1	--	<2	--	<1	--	1.2	--	45	6	0.07	0.028	6	--
BAY RIDGE CHANNEL																					
Site Water		44	23	<0.5	--	2.6	--	7.4	2	<2	--	1.8	--	4.9	0.1	8	2	0.02	0.014	<2	--
5% Oxic	A	<10	--	<0.5	--	2.8	0.2	1.8	--	3.2	--	2.3	--	<1	--	11	3	0.02	0	<2	--
	B	<10	--	<0.5	--	2.2	0.3	1.2	--	<2	0	4.5	1	<1	--	23	2	0.02	0	<2	--
20% Oxic	A	28	--	<0.5	--	2.6	0.1	<1	--	2.8	0.6	<1	--	<1	--	1081	--	0.18	0.014	<2	--
	B	<10	--	<0.5	--	2.7	0.6	<1	--	3.9	1.5	1.6	0.6	<1	--	679	--	0.02	0	<2	--
20% Anoxic	A	93	--	<0.5	--	2.6	0.6	<1	--	3.2	--	6	3.1	<1	--	1100	--	0.02	0	6	--
	B	76	23	<0.5	--	3.6	0.3	<1	--	<2	--	3.1	0.4	<1	--	1286	--	0.02	0	<2	--

Notes: A and B are replicate elutriates.
Mean and SD calculated from duplicate analyses of one sample.
Dash (--) indicates single analysis or not applicable.
After Lee et al. (1978)

TABLE 3. Response of *P. pugio* to 20 Percent Sediment Elutriate as a Function of Time: New York Harbor Area Elutriate Bioassays.

Time (hr)	Number of *P. pugio* Living			
	Control		20% Elutriate	
	A	B	A	B
PERTH AMBOY CHANNEL				
0	10	10	10	10
12	10	10	10	10
24	10	10	10	10
36	10	10	10	10
48	10	10	10	10
60	10	10	6	8
72	10	10	6	4
84	10	10	5	4
96	10	10	4	4
PERTH AMBOY ANCHORAGE				
0	10	10	10	10
12	10	10	9	10
24	10	10	9	9
36	10	10	8	9
48	10	10	8	9
60	10	10	8	7
72	10	10	8	7
84	10	10	8	7
96	10	10	8	7
BAY RIDGE CHANNEL				
0	10	10	10	10
12	10	10	10	10
24	10	10	10	9
36	10	10	10	9
48	10	10	10	9
60	10	10	10	9
72	10	10	10	9
84	10	10	10	9
96	10	10	10	9

Note: A and B are replicate elutriate bioassays.

(Texas City Channel, Texas and Perth Amboy Anchorage), the fact that while large amounts of a variety of heavy metals are associated with some waterway sediments, little of this is released during elutriation or during open water dredged sediment disposal. If even half of the amount of almost any of the heavy metals measured were released, concentrations in excess of the 96-hour

TABLE 4. Summary of Acute Toxicity for Selected US Waterway Sediments

Sediment Location	% Surviving at 96 hrs in Bioassay Elutriate Tests								
	5%			10%			20%		
	A	B	Mean	A	B	Mean	A	B	Mean
Mobile Bay, AL	100	100	100			--	100	100	100
San Francisco Bay, CA									
Rodeo Flats	90	100	95	70	70	70	60	80	70
Mare Island	100	90	95	80	90	85	80	80	80
Oakland Inner Harbor	100	100	100			--	100	100	100
Los Angeles Harbor, CA									
Buoy A-7 (Site 1)	70	80	75			--	40	--	40
Buoy C-2 (Site 2)	90	100	95			--	90	100	95
Bridgeport, CT	80	70	75	50	40	45			--
Norwalk River, CT									
North Site	100	100	100			--	100	100	100
South Site	100	100	100			--	90	90	90
Stamford, CT West Branch	100	100	100			--	90	100	95
Apalachicola, FL									
Site 1	100	100	100			--	80	100	90
Site 5	90	90	90			--	80	80	80
Menominee River, MI	100	100	100			--	40	30	35
Upper Mississippi River, St. Paul, MN	100	100	100			--	100	100	100
Hudson River, NY									
Foundry Cove - *P. pugio*			--			--	100	90	95
Foundry Cove - *D. magna*			--			--	90	80	85
New York/New Jersey Harbors									
Perth Amboy Anchorage	80	70	75			--	80	70	75
Perth Amboy Channel	60	80	70			--	40	40	40
Bay Ridge Channel	100	50	75			--	100	90	95
Perth Amboy Channel									
Site 1			--			--	90, 80, 90*		87
Site 2			--			--	60, 60, 60*		60
Site 3			--			--	80, 80, 90*		83
Ashtabula Harbor, Lake Erie, OH	Reproduction Occurred			Reproduction Occurred			100	100	100
Newport, RI Offshore	100	100	100			--	100	100	100
Corpus Christi, TX									
Site 3	90	80	85	80	100	90	90	90	90
Houston Ship Channel, TX									
Site 2	100	100	100			--	90	90	90
Site 3	100	100	100			--	100	100	100
Morgan's Point, TX	90	90	90	80	80	80	70	60	65
Port Lavaca, TX	100	100	100	100	100	100	100	100	100

TABLE 4. Summary of Acute Toxicity for Selected US Waterway Sediments (cont'd)

Sediment Location	% Surviving at 96 hrs in Bioassay Elutriate Tests								
	5%			10%			20%		
	A	B	Mean	A	B	Mean	A	B	Mean
Galveston Bay Entrance Channel, TX									
Buoy 1	90	90	90	100	100	100	90	80	85
Buoy 9			--	100	100	100			--
Buoy 11	100	100	100	100	100	100	90	90	90
Texas City Channel, TX									
Site 1	100	100	100	100	100	100	80	80	80
Site 2	90	90	90	90	90	90	80	80	80
Site 3	90	90	90	90	90	90	80	80	80
Site 4	80	100	90	90	70	80	90	80	85
Site 5	100	100	100	100	100	100	100	100	100
Site 6	100	100	100	100	100	100	90	100	95
Bailey Creek, VA									
April 1976	100	100	100			--	80	100	90
July 1976	80	60	70			--	80	100	90
James River, VA	90	60	75			--	80	100	90
Near Windmill Pt Dredge Dischg			--			--	100	100	100
Duwamish River, Seattle, WA	100	90	95			--	100	100	100

Notes: A and B are replicate bioassays.
Freshwater test organisms: *Daphnia magna*
Marine test organisms: *Palaemonetes pugio*
* Triplicate bioassays run
After Jones and Lee (1978)

LC50 values would be found in the elutriates. As discussed earlier, only in a few instances was greater than 20 percent or so mortality found in the 96-hour exposure period to the equivalent of settled dredging pump discharge.

Some sediments do cause mortality to grass shrimp in contact with the sediments and their elutriate leachate during four-day static bioassays. Reliable criteria must be developed to properly use such information in assessing the potential hazard to water quality of dredged sediment disposal. Presented in the following section are some of the factors that need to be considered in using elutriate test bioassay data in a hazard assessment scheme.

INTERPRETATION OF ELUTRIATE TEST BIOASSAY DATA

A number of factors must be considered when the information gained from the elutriate test bioassay are used to assess the water quality hazard associated with disposal of a particular dredged sediment in terms of water column and sediment effects. Most notable of these at present is the dilution that occurs at the disposal site. The elutriate tests and bioassays were designed to be "worst case" screening tests. They actually tell how well these organisms can survive in settled dredging pump discharge. As discussed previously, there is a peak in elevated concentrations of turbidity and contaminants at the disposal site that lasts only a few minutes. Based on the studies of Lee et al. (1977), the turbidity resulting from the hopper disposal of hydraulically dredged sediment is indistinguishable from ambient levels within an hour or two

TABLE 5. Comparison of Potential and Realized Contaminant Release from Dredged Sediment with Water Quality Criteria

Parameter	Cr	Zn	Ni	Cu	Hg	Mn	Cd	% Mortality at 96 hrs
Approximate LC50 (ug/L) (marine)	3,000 -- 133,000 (freshwater)	6,700	600 -- 800	4,000	1 ug/L distinct threat	--[1]	--[1]	
Red Book Criteria (ug/L) (marine)	100 (freshwater)	None Given	~ 8	~ 400	0.1	100	5	
Texas City Channel-5								
Theoretical Concentration[3] (ug/L)	7,700	15,000	2,700	5,700	4	74,000	--[2]	
Elutriate Concentration (ug/L)	< 2	22.8	37.5	8.1	0.025	1,950		0
Perth Amboy Anchorage								
Theoretical Concentration[3] (ug/L)	8,300	11,600	3,600	58,400	580	29,400	400	
Elutriate Concentration (ug/L)	< 2	< 1	< 2	1 -- 2	0.03	< 10	0.6	25

Notes: [1] No value found

[2] Sediment concentration below detection.

[3] Based on bulk sediment content.

after the dump. Even if the disposal site organisms moved with the turbidity plume arising from the dump, they would be exposed to elevated levels of contaminants for only an hour or so. Rarely were there any deaths in the Lee et al. (1978) study bioassays during the first 24 hours of organisms' exposure to the undiluted elutriate. The four-day exposure in the elutriate test bioassay is longer than an organism would be exposed to elevated concentrations during dredged material disposal, and the elutriate is an undiluted dredged sediment–water mixture; therefore, an impact in the bioassay cannot necessarily be directly translated into a likely impact in the field. Mortality in a bioassay must be interpreted in terms of the dilution that occurs at the disposal site. The concentration or response–duration of exposure couplings in each system must be evaluated since aquatic organisms can tolerate higher concentrations of contaminants without adverse effect, provided that the exposure time is shorter. This topic has been discussed in some detail by Lee et al. (1979).

In response to federal legislation, the US EPA and Corps of Engineers (US EPA/CE, 1977) have developed a bioassay test procedure for dredged sediments that is similar in some respects to that presented here, except that the US EPA/CE require separation of the three phases of the elutriate and the running of separate bioassays on each phase using several different organisms for each. That procedure is, in the opinion of the authors, overly complex and does not provide any greater amount of information that can be used to determine whether a dredged sediment should be dumped at a particular place or not, than the grass shrimp/*Daphnia* screen test. Any statistically significant difference between the mortality in the controls and test solutions is, according to the US EPA/CE (1977), to be indicative of potential environmental hazard associated with open water disposal of the sediment. Unfortunately, this is being interpreted by some regulatory agencies as meaning that sediments so-identified should not be disposed of in open water, rather than as an indication that the evaluation of them should be continued.

The direct uptake of sediment-associated contaminants by disposal site benthic and epibenthic organisms is also of concern in assessing the significance of sediment-associated contaminants. This facet of contaminant uptake is taken into account by the grass shrimp bioassay recommended by Lee et al. (1978) and Jones and Lee (1978), as it combines all three phases – dissolved, suspended particulate, and settled sediment – into one test. It also must be remembered that dredged material disposal sites are high energy sites; if the sediments remained there for extended periods, it would not be a useful disposal site since it would soon fill up. Therefore, there is fairly rapid dilution and dispersion of the redeposited sediments with natural sediments at most disposal areas. The direct uptake phenomenon is also overestimated by the screening test since sediment dilution is not considered. Even if organism toxicity were found in the immediate area of dredged sediment disposal, it may be of limited concern since the use given to that area is dredged sediment disposal. What is of concern is the toxicity outside the designated area, especially that which would cause impairment or death of commercially or ecologically important organisms.

The other problem, besides toxicity, that must be addressed in evaluating the potential hazard associated with dredged sediment-associated contaminants is the bioconcentration of chemicals such as PCBs, mercury, etc. Currently, the only way to properly make an assessment of the significance of this problem in association with dredged sediment disposal is by collecting edible, preferably less-mobile, bottom-dwelling organisms from a discharge or dump area, and

analyzing them for constituents of concern. The only measure available by which an assessment can be made of the significance of the concentrations found in organism flesh is the FDA limits for human food available for a few contaminants. If the organisms collected have concentrations greater than those levels, studies need to be conducted to determine the source of their contamination and the potential significance of dredged sediment disposal in contributing to the problem.

From an overall point of view, the DMRP studies have provided valuable insight into the potential environmental significance of contaminants associated with waterway sediment. It is evident from the results of these studies that large amounts of the contaminants associated with waterway sediments are unavailable to affect water quality. There are some sediments that are toxic to aquatic organisms or from which there is sufficient transfer of contaminants such as PCBs to aquatic organisms to cause concentrations within their flesh to exceed FDA or other fish flesh limits. It is evident that a combination of leaching tests and bioassays should be used to assess the potential toxicity of sediment-associated contaminants.

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