DECONTAMINATING AND PROCESSING DREDGED MATERIAL FOR BENEFICIAL USE

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ABSTRACT

Management of contaminated dredged material is a major problem in the Port of New York and New Jersey. One component of an overall management plan can be the application of a decontamination technology followed by creation of a product suitable for beneficial use. This concept is the focus of a project now being carried out by the US Environmental Protection Agency-Region 2, the US Army Corps of Engineers-New York District, the US Department of Energy-Brookhaven National Laboratory, and regional university groups that have included Rensselaer Polytechnic Institute, Rutgers University, New Jersey Institute of Technology, and Stevens Institute of Technology. The project has gone through phased testing of commercial technologies at the bench scale (15 liters) and pilot scale (1.5-500 m^3) levels. Several technologies are now going forward to large-scale demonstrations that are intended to treat from 23,000 to 60,000 m^3. Selections of the technologies were made based on the effectiveness of the treatment process, evaluation of the possible beneficial use of the treated materials, and other factors. Major elements of the project are summarized here.

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INTRODUCTION

Sediments contaminated with organic and inorganic compounds of anthropogenic origin are commonly found in waterways in industrialized areas. Trace amounts of these contaminants can be toxic and pose a potential threat to the environment and to human health. In addition, the operation of ports for commercial shipping is contingent upon dredging to maintain adequate depths in navigation channels. Disposal of the contaminated dredged material then becomes difficult since it is desirable to do this in a way that will not harm the environment.

The Port of New York/New Jersey serves as one example of a region where a search is going on to find feasible solutions to this problem. This is, however, a worldwide problem. Other ports where work on the disposal of contaminated dredged material is in progress include Baltimore, Seattle/Tacoma, Venice, Hamburg, and Rotterdam. It seems possible that environmental concerns will act to bring about corresponding work in South America and other continents.

In New York/New Jersey the federal government has provided funding for an investigation and demonstration of the feasibility of removing or stabilizing the contaminants and in finding a beneficial use for the cleaned sediments. This paper is intended to provide a short overview of the work accomplished to date and now in progress. For those who are interested in more detail, a list of relevant project publications is included. Most of these papers and additional information can be found on our World Wide Web site at http://www.wrdadcon.bnl.gov.

Similar projects are going on in the State of New Jersey Office of Maritime Resources and the Port of Baltimore. The way these projects have been organized represents a natural progression from some of the insights gained in our work. We are actively collaborating with the New Jersey group in the work entailed in commercializing decontamination technologies.

TYPES AND CONCENTRATIONS OF CONTAMINANTS FOUND IN SEDIMENTS

The contaminants found in dredged materials and sediments in port regions are similar. This can be seen by comparison of the data shown in Table 1 for the Puget Sound region where the ports of Seattle and Tacoma are located with Table 2 which gives values for contaminants in core samples from New Jersey waters in the Port of NY/NJ and Table 3 which gives surficial concentrations for three specific locations in the Port. It can be seen that the concentrations for the two regions are similar. Regulatory agencies in both areas are concerned with the environmental effects associated with the methods chosen for disposal of dredged material with these characteristics.

SEDIMENT TRANSPORT AND VISUALIZATION

A dredged material management program (DMMP) is critically dependent on an accurate knowledge of the geographic and depth distribution of sediment contaminants in the region of

interest. The inventory must consider an entire system since there may be contaminant sources lying outside the navigation channels and berthing areas which must be dredged to ensure efficient port operation. The inventory then makes it possible to devise strategies for reducing the input of pollutants from specific sources and to choose the most efficient ways of disposing of dredged material in an environmentally-acceptable way. We point out here that a comprehensive approach is needed that will assess the fate and transport of the contaminants through the sediments, water column, and atmosphere, and the associated risks to the environment and human health.

The lower Hudson River estuary, including NY/NJ Harbor, functions as a source of contaminants to the upper estuary and overlying air (e.g., Feng et al., 1998a). These lower estuary contaminants in sediments enter the water column by diffusive-advective processes via pore spaces in the sediments and resuspension of surficial sediments due to wave activity and currents (Feng et al., 1999a,b). These contaminants can also be laterally transported with particles to upper estuary regions and redistributed over the course of a tidal cycle (Feng et al., 1999c). These processes are especially important for the fine-grained sediments found in most estuaries. If the contaminants are volatile compounds, such as Hg and polychlorinated biphenyls (PCBs), these contaminants can finally enter the air by volatilization (e.g., elemental mercury vapor). The pathways that impact human health are through eating seafood with high contaminant levels or through inhalation.

It is also worthwhile to point out that sediment resuspension can cause movement and transport of particles and associated contaminants previously considered to be part of a 'permanent' deposit of bottom sediments. Excess ^{234}Th and ^{7}Be activities in the surface sediments indicated that surface sediments often received the recent input of particles and associated contaminants in less than a 3- to 8-month time scale (Feng et al., 1998b). This supports the conclusion that particles and associated contaminants could be transported and redistributed within the estuary during a short time period. The semi-diurnal tidal cycle is an important driving force for particles and associated contaminants dynamics.

Contaminant concentrations in the water column in a local area are determined by a combination of benthic diffusion through pore spaces from contaminated sediments to overlying water, local contaminated sediment resuspension and lateral contaminant advection. Instant high contaminant concentrations in the water column may suggest temporary discharge of these contaminants from land-based sources or advective transport from areas with high contaminant concentrations, implying that sediments can not only be mixed in the water column due to turbulence, but also advectively redistributed somewhere else depending on the magnitude of currents and the dynamic equilibrium between sediment surface and tidal currents.

It can be seen that this evaluation is a complex problem that benefits from source identification and modeling of sediment transport and related motions of contaminants. The experimental data and modeling results must also be displayed in an accessible way that is intelligible to the regulatory agencies and to the engineers responsible for producing recommendations for specific dredging projects.

Our decontamination project has been directly concerned with work on the visualization of contaminant distributions since this is useful in choosing appropriate technologies for use in different locations in the Port of NY/NJ. The distribution of lead and mercury in surficial sediments of Newark Bay are shown in Figures 1 and 2, respectively. Newark Bay is critical since it contains the berths of Port Newark and Port Elizabeth. The maps show localized regions of high contamination within the Bay and also in the Passaic River which enters the Bay from the northwest. The locations of data points and of combined sewer overflows are shown. The concentrations found in the Passaic River are high and identify it as a potentially important source of material that could cause problems if transported into Newark Bay. The Passaic is well known to have very high levels of dioxins caused by an industrial accident many years ago. The depth distribution of the dioxins at this location is shown in Figure 3. This visualization result can be used deciding on methods for removing or sequestering the contaminated sediments and for evaluation of the magnitude of transport downstream to Newark Bay.

YEARLY DREDGING REQUIRED IN THE PORT OF NY/NJ

A large amount of material must be dredged each year to maintain depths of 12.2 to 15.2 m in the 386 km of navigational channels in the Port since the natural depth of the Port is about 5.8 m without dredging. The yearly dredging totals for the period from 1976 to 1995 are shown in Figure 4. Values for private maintenance, federal deepening, and federal maintenance are summarized. The average for the period was about 4,408,000 m^3/y.

The disposal of this material has become a challenging problem. Environmental restrictions have made ocean disposal impossible for a major fraction of the material. Multiple solutions are now being used. The decontamination option at this time may be able to deal with about 10% the total.

TECHNOLOGY TEST RESULTS

A total of 9 different technologies were tested on the bench scale (15 liters).The approaches included sediment washing, solvent extraction, thermal desorption, and thermal destruction. These technologies can be viewed as pieces of a treatment train for dredging, treatment, and beneficial use of contaminated dredged material. The treatment train is shown schematically in Figure 5 where the technologies are divided according to the temperatures at which they operate.

The percentage removal efficiencies achieved for the different methods are shown in Figure 6. Generally, the high temperature technologies attained superior results by destruction of the organic materials and incorporation of metals in a stable cement- or glass-like matrix. Further tests on the pilot-scale level were carried out by the Instititute of Gas Technology using a rotary kiln to produce cement, Westinghouse Plasma using a plasma torch to produce glass, and BioGenesis/Weston using a washing process to produce a manufactured soil. The pilot-scale tests verified the results obtained on the bench-scale level and also gave data that could be used to design full-scale treatment facilities.

The results of the pilot tests showed that the washing technique could produce a material from moderately contaminated material that could be disposed of as a soil product, while the high temperature methods could be used for the more highly contaminated materials, and the final cement or glass product had characteristics compatible with similar materials found in general commercial use. Estimates of cost of processing were close to those found for other disposal options. We concluded from this work that decontamination could be used effectively as part of an overall plan for disposing of dredged material in the Port.

COMMERCIALIZATION

The present focus of our project is to bring the technologies into commercial operation as a viable component of the management plan for dredged material. The sediment washing process of BioGenesis/Weston and the cement production process of the Institute of Gas Technology are the furthest advanced in this respect. BioGenesis/Weston is now working on the installation of a processing facility on a site in the Newark Bay area. The facility, when complete, will be capable of handling about 30 m^3/hr or 180,000 m^3/year. The cement production facility is to be installed on a site on the Arthur Kill in New Jersey. It will have a final ability to treat about 75,000 m^3/year. The work on site preparation is now in progress, and the rotary kiln apparatus is complete and awaiting installation.

Together with the New Jersey Office of Maritime Resources we have also worked with JCI/Upcycle. They propose to use an existing rotary kiln facility to produce a lightweight aggregate material for construction applications. A test of the process in this commercial-scale process will take place during the next 12 months.

It is important to emphasize that in order to have a successful commercial venture, it will be necessary to have a technology which can be operated at a cost affordable by the customers in the region. This level is now set at about \$38/m^3 exclusive of dredging cost. Proof that this cost can be met when large scale facilities are in operation is the next challenge for bringing these technologies into general use.

PUBLIC PRIVATE PARTNERSHIPS

One lesson learned from our work has been the realization that the introduction of decontamination technologies benefits from development of working partnerships between the public and private sectors. A conceptual diagram showing the organization of a sediment processing company and the potential owners of the company is shown in Figure 7. The challenge that we are now working on is to turn this conceptual design into reality.

SUMMARY

Our project for sediment decontamination and beneficial use has been successful on a small scale. The present direction of the project is to show that it is possible to create large-scale operations that are environmentally sound, produce material with a beneficial use, and are profitable and self sustaining when competing with other disposal options.

REFERENCES

Feng, H. and J. K. Cochran and D. J. Hirschberg. 1999a. ^{234}Th and ^{7}Be as tracers for the transport and dynamics of suspended particles in a partially mixed estuary. Geochimica et Cosmochimica Acta, 63, 2487-2505.

Feng, H., J. K. Cochran and D. J. Hirschberg. 1999b. ^{234}Th and ^{7}Be as tracers for transport and sources of particle-associated contaminants in estuaries. The Science of the Total Environment, 237/238, 401-418.

Feng, H., J. Kirk Cochran and D. J. Hirschberg. 1999c. ^{234}Th and ^{7}Be as tracers for the sources of particles to the turbidity maximum zone of the Hudson River estuary. Estuarine, Coastal and Shelf Science, 49, 629-645.

Feng, H., J. K. Cochran, H. Lwiza, B. Brownawell, and D. J. Hirschberg. 1998a. Distribution of Heavy Metal and PCB contaminants in the sediments of an urban estuary: the Hudson River. Marine Environmental Research, 45, 69-88.

Feng, H., J. K. Cochran, D. J. Hirschberg, and R. E. Wilson. 1998b. Small-scale spatial variations of natural radionuclide and trace metal distributions in sediments from the Hudson River Estuary. Estuaries, 21,263-280.

RELEVANT PROJECT PUBLICATIONS

Stern, E. A., Olha, J., Wisemiller, B., and Massa, A. Recent assessment and decontamination studies of contaminated sediments in the New York and New Jersey Harbor. Proceedings of the Second International Conference on Dredging and Dredged Material Placement, Lake Buena Vista, Florida, November 13-16, 1994, E. Clark McNair, Jr, Editors, pp. 458-467.

Massa, A. A., Del Vicario, M., Pabst, D., Pechko, P., Lechich, A., Stern, E. A., Dieterich, R., and May B. Disposal of wastes and dredged sediments in the New York Bight. Published with papers for the American Association for the Advancement of Science (AAAS) Symposium "Dredged Material Disposal and Waste Management in the Nearshore Environment." Northeastern Geology and Environmental Sciences 18, 265-285 (1996).

Waisel, Laurie B. Three-dimensional visualization of sediment chemistry in the New York Harbor. Communique Data Explorer Newsletter 4, 1-3 (1996).

Stern, E. A., Donato, K., Jones, K. W., and Clesceri, N. L. Processing contaminated dredged material from the Port of New York/New Jersey. Estuaries 21(4A), 646-51 (1998).

Stern, E. A., Donato, K. R., Clesceri, N. L., and Jones, K. W. Integrated sediment decontamination for the New York/New Jersey Harbor. Proceedings, National Conference on Management and Treatment of Contaminated Sediments, Cincinnati, Ohio, May 13-14, 1997, EPA/625/R-98/001, US Environmental Protection Agency, Cincinnati, Ohio, August 1998.

Jones, K. W., Stern, E. A., Donato, K., and Clesceri, N. L. Processing of NY/NJ Harbor estuarine dredged material. Proceedings of Sessions on Dredging and Management of Dredged Material, Geo-Logan >97, Logan, Utah, July 16-19, 1997, Geotechnical Special Publication No. 65, J. N. Meegoda, T. H. Wakeman III, A. K. Arulmoli, and W. J. Librizzi, Editors, pp. 49-66, American Society of Civil Engineers, New York, New York, 1997.

Stern, E. A., Jones, K., Donato, K., Pauling, J. D., Sontag, J. G., Clesceri, N. L., Mensinger, M. C., and Wilde, C. L. Maintaining access to America's intermodal ports/technologies for decontamination of dredged sediment: New York/New Jersey Harbor. Technical Paper #8007. Presented at The Society of American Military Engineers 1998 National Conference – "Renewing America Through Engineering," New York, New York, May 19-23, 1998.

Jones, K. W., Guadagni, A. J., Stern, E. A., Donato, K. R., and Clesceri, N. L. Commercialization of dredged-material decontamination technologies. Remediation, Special Issue: Innovative Remediation Technology 8(2), 43-54 (1998).

Jones, K. W., Stern, E. A., Donato, K. R., and Clesceri, N. L. 1999. Decontamination of dredged material from the Port of New York and New Jersey. Proceedings of the 5th Intern. Petroleum Environmental Conference, Albuquerque, New Mexico, October 20-23, 1998, Kerry L. Sublette, Editor, pp. 225-239, The Integrated Petroleum Environmental Consortium, Albuquerque, New Mexico, 1998.

Ma, Hong, Jones, Keith W., and Stern, Eric A. Scientific visualization and data modeling of scattered sediment contaminant data in New York/New Jersey estuaries. Proceedings, Vis98 (IEEE Visualization 1998), Research Triangle Park, North Carolina, October 18-23, 1998, D. Ebert, H. Hagen, and H. Rushmeier, Editors., pp. 467-70, IEEE Computer Society, The Institute of Electrical and Electronics Engineers, Inc., ACM Press, New York, New York, 1998.

Jones, K. W., Stern, E. A., Donato, K. R., and Clesceri, N. L. 1999. Decontamination of dredged material from the Port of New York and New Jersey. Northeastern Geology and Environmental Sciences, 21(4), 289-295.

Jones, K. W., Stern, E. A., Donato, K. R., and Clesceri, N. L. 1999. Sediment decontamination treatment train: commercial-scale demonstration for the Port of New York/New Jersey. Proceedings of the Western Dredging Association Nineteenth Technical Conference and Thirty-first Texas A&M Dredging Seminar, Louisville, Kentucky, May 16-18, 1999, CDS Report No. 371, R. E. Randall, Editor, pp. 513-531, Texas A&M University Center for Dredging Studies, College Station, Texas, 1999.

McLaughlin, D. F., Dighe, S. V., Keairns, D. L., and Ulerich, N. H. Decontamination and beneficial reuse of dredged estuarine sediment: the Westinghouse plasma vitrification process. Proceedings of the Western Dredging Association Nineteenth Technical Conference and Thirty-first Texas A&M Dredging Seminar, Louisville, Kentucky, May 16-18, 1999, CDS Report No. 371, R. E. Randall, Editor, pp. 533-553, Texas A&M University Center for Dredging Studies, College Station, Texas, 1999.

Rehmat, A., Lee, A., Goyal, A., and Mensinger, M. C. Construction-grade cement production from contaminated sediments using Cement-Lock™ Technology. Proceedings of the Western Dredging Association Nineteenth Technical Conference and Thirty-first Texas A&M Dredging Seminar, Louisville, Kentucky, May 16-18, 1999, CDS Report No. 371, R. E. Randall, Editor, pp. 555-566, Texas A&M University Center for Dredging Studies, College Station, Texas, 1999.

Amiran, M. C., Wilde, C. L., Haltmeier, R. L., Pauling, J. D., Sontag, J. G., Jr. Advanced sediment washing for decontamination of New York/New Jersey Harbor dredged materials. Proceedings of the Western Dredging Association Nineteenth Technical Conference and Thirty-first Texas A&M Dredging Seminar, Louisville, Kentucky, May 16-18, 1999, CDS Report No. 371, R. E. Randall, Editor, pp. 567-573, Texas A&M University Center for Dredging Studies, College Station, Texas, 1999.

Derman, J. D. and Schlieper, H. A. Decontamination and beneficial reuse of dredged material using existing infrastructure for the manufacture of lightweight aggregate. Journal of Dredging Engineering 1(2), 3-15 (1999).

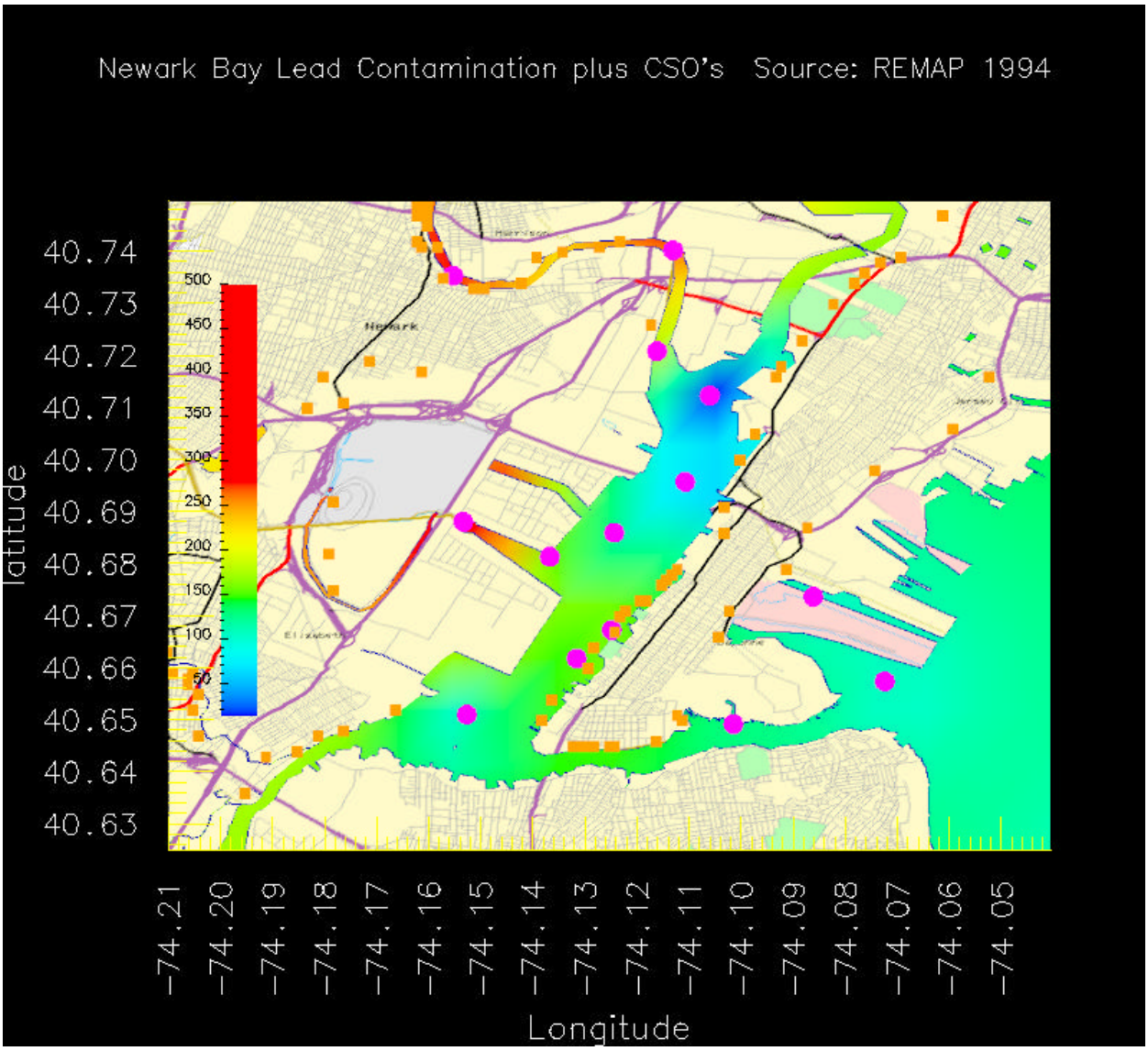

Figure 1. Surficial concentrations of Pb in Newark Bay from Regional Environmental Monitoring and Assessment Program (REMAP) 1994. The concentrations are shown on the color scale in units of micrograms/gram (ppm). Combined sewer overflows (CSOs) are shown with orange circles. Locations of data points are shown with magenta circles. (Courtesy of J. Spiletic, G. M. Smith, and M. McGuigan, Brookhaven National Laboratory.)

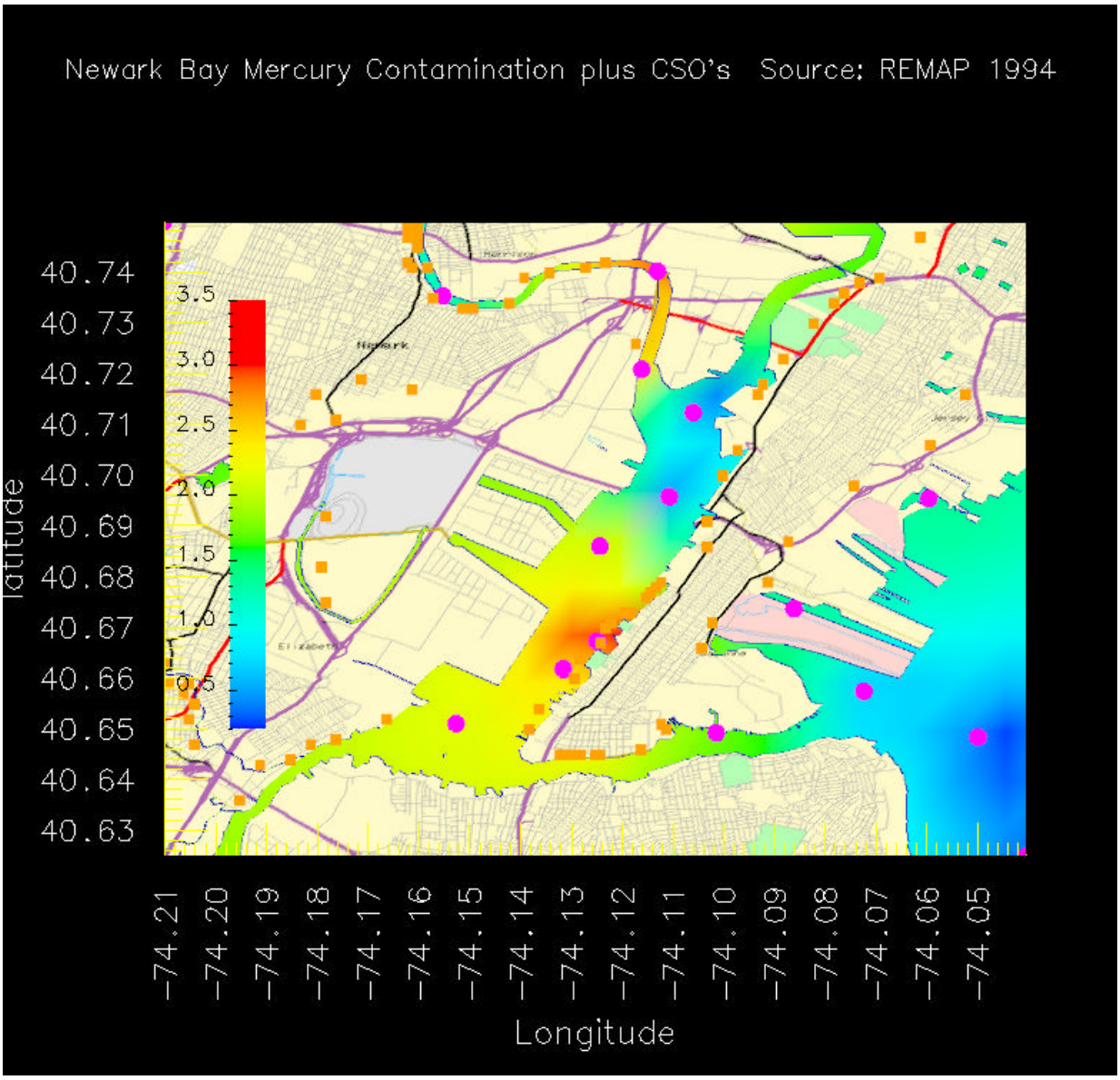

Figure 2. Surficial concentrations of Hg in Newark Bay showing data from Regional Assessment and Monitoring Program (REMAP) 1994. The color bar concentrations are in units of micrograms/gram (ppm). (Courtesy of J. Spiletic, G. J. Smith, and M. McGuigan, Brookhaven National Laboratory.)

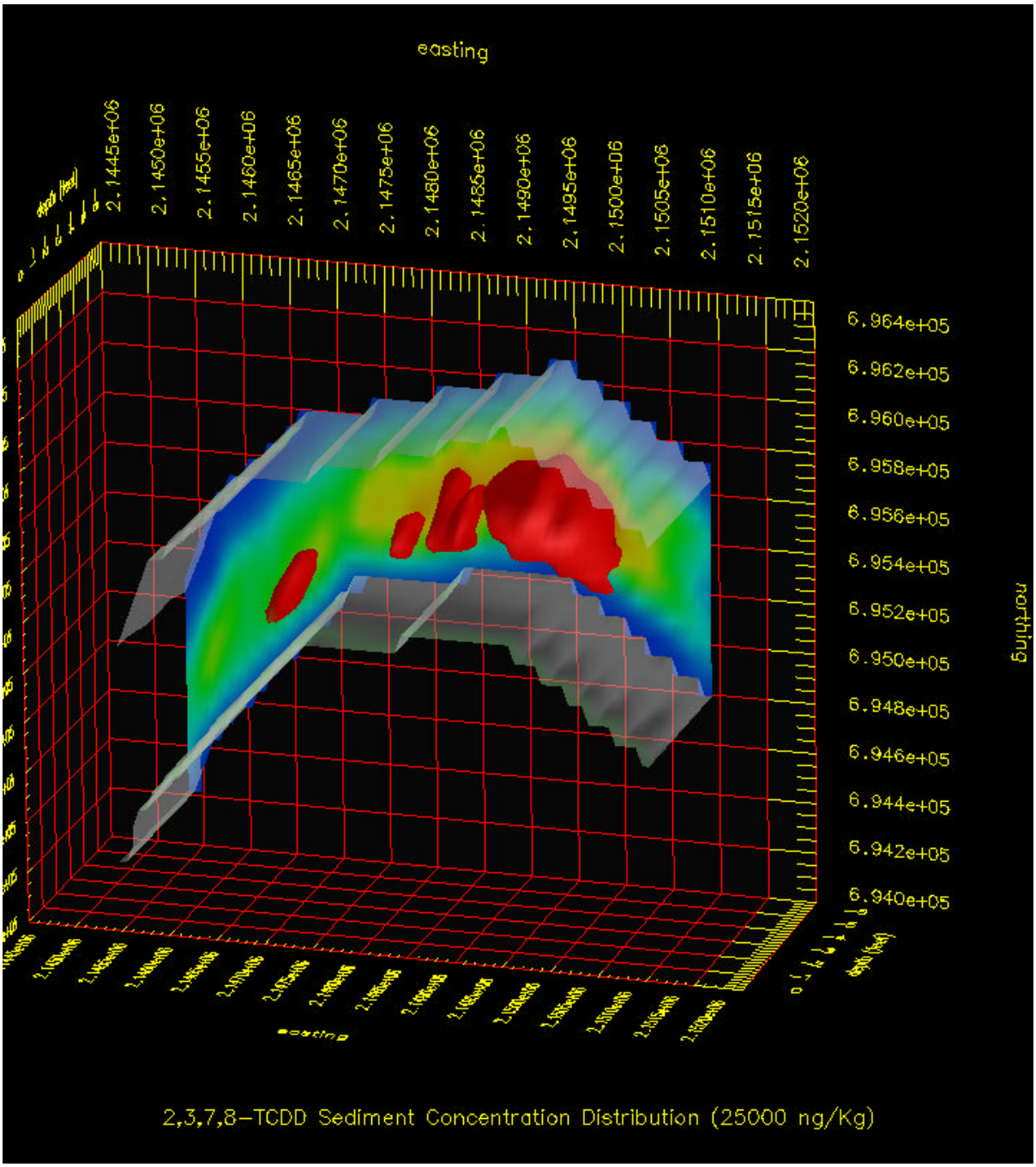

Figure 3. "Hot spots" in the concentration of 2,3,7,8-TCDD in the sediments of the Passaic River close to Newark, NJ. (Courtesy of Hong Ma, Brookhaven National Laboratory.)

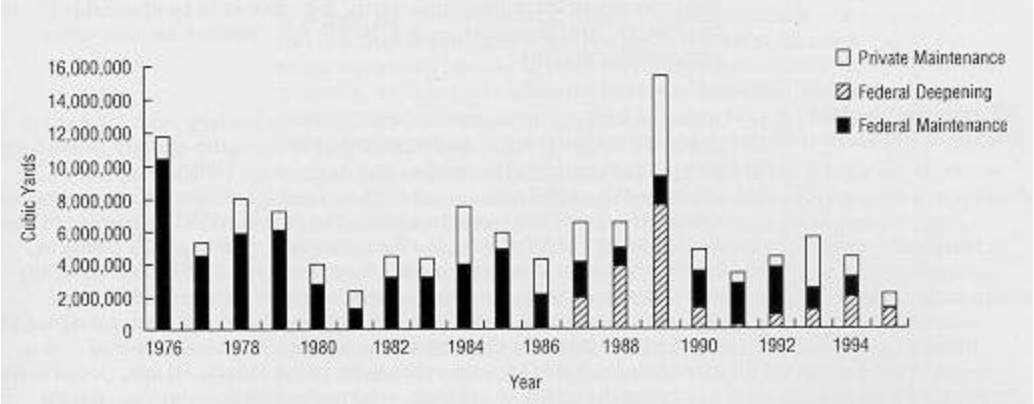

Figure 4. Summary of yearly dredging in the Port of New York/New Jersey from 1976-1995.

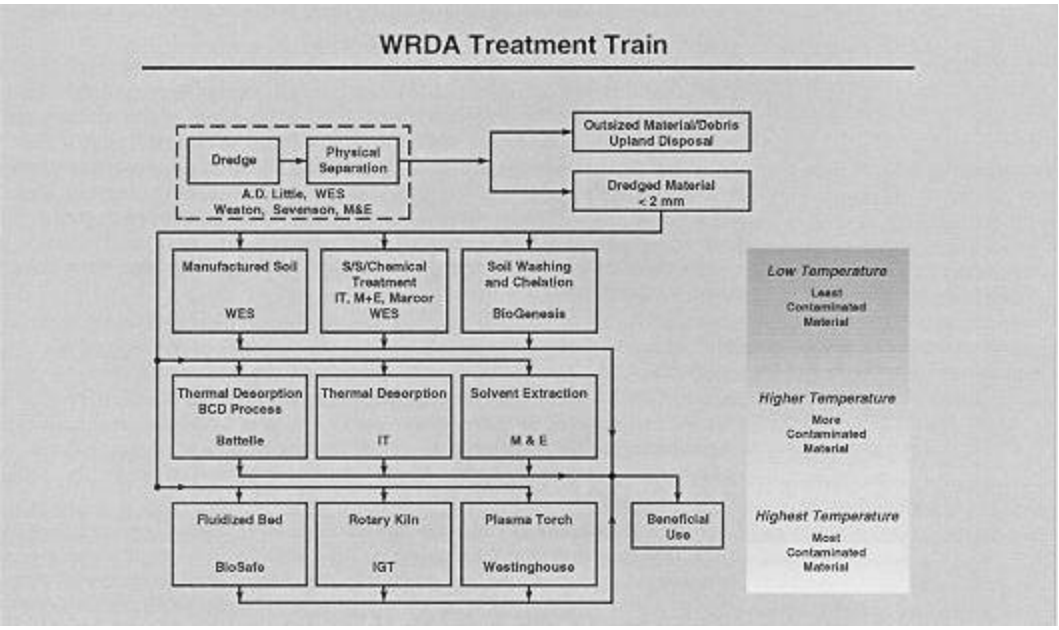

Figure 5. WRDA Treatment Train. The different technologies tested in the program are displayed according to the temperature used in the processing.

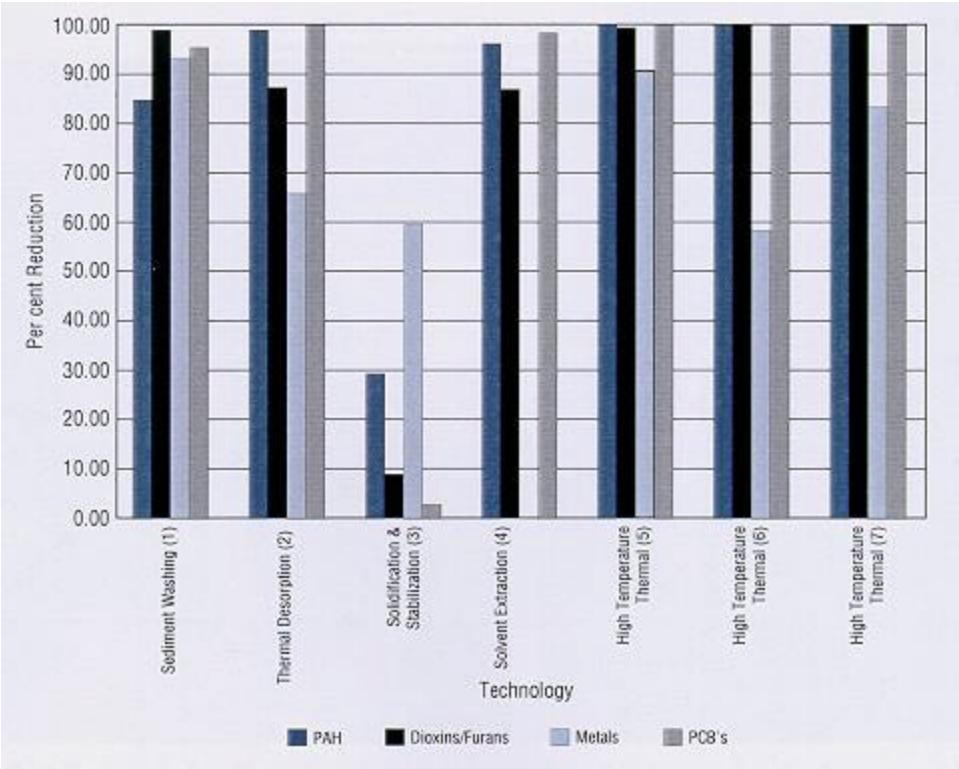

Figure 6. Summary of technology effectiveness in reduction of contaminants found in dredged material. The technologies were provided by: 10 BioGenesis, 2) International Technology Corporation, 3)Marcor, 4) Metcalf & Eddy, 5) BioSafe, 6)Institute of Gas Technology, and 7)Westinghouse.

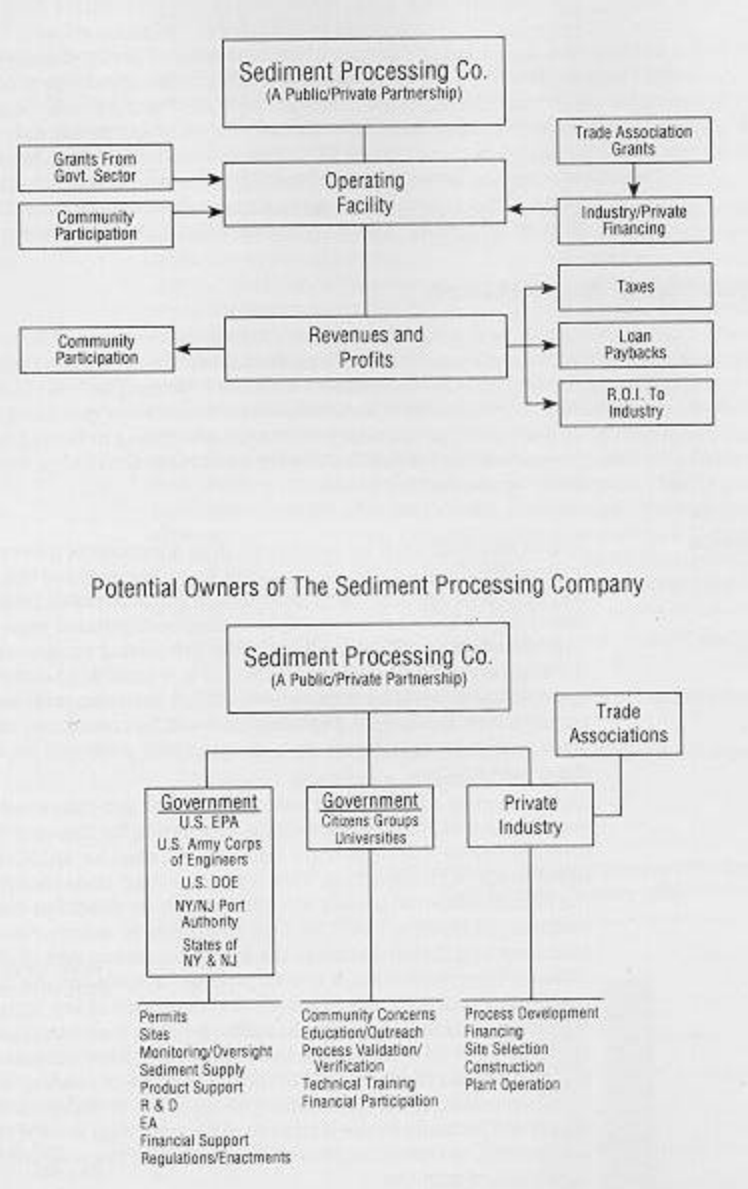

Figure 7. Conceptual plan for organization of a public-private consortium for operation of a dredged-material decontamination facility. Two schematic diagrams are given that show the consortium organization and the potential owners of the company.

Table 1. Summary Statistics for Chemicals Detected in Over Two-Thirds of Puget Sound Samples. (Puget Sound Confined Disposal Site Study, Programmatic Environmental Impact Statement, Draft, February 1999).

	All SEDQUAL Data				Data $95th Percentile	
Chemical	**Number of Samples**	**Median**	**95th Percentile**	**PSDDA ML**	**Number of Samples**	**Median**
Metals (mg/kg,dry weight)						
Antimony	1,801	2.2	56.0	200	91	126
Arsenic	3,498	11	102	700	177	404
Cadmium	2,896	0.7	6.5	14.0	148	7.9
Copper	3,814	53	439	1,300	192	1,025
Lead	3,779	38	486	1,200	189	1,070
Mercury	3,188	0.2	1.8	2.3	80	4.3
Nickel	3,189	30	71	370	166	102
Silver	2,229	0.4	3.6	8.4	112	5.9
Zinc	3,829	100	777	3,800	192	1,935
Organics (:g/kg, dry weight						
Anthracene	2,550	130	3,180	13,000	127	8,300
Fluorene	2,047	84	2,300	3,600	106	5,850
Phenanthrene	2,823	260	6,000	21,000	138	15,500
Benzo(a)anthracene	2,545	230	4,800	5,100	127	9,300
Benzo(a)pyrene	2,584	240	4,000	3,600	131	6,824
Benzo(b)fluoranthene	1,149	540	6,271	9,900[2]	58	9,050
Benzo(k)fluoranthene	1,093	450	5,580	--	55	8,000
Benzo(g,h,i)perylene	1,826	150	2,274	3,200	92	3,850
Chrysene	2,834	342	6,400	21,000	142	11,000
Fluoranthene	3,021	440	9,900	30,000	153	23,000
Indeno(1,2,3-c,d)pyrene	2,106	150	2,200	4,400	103	3,900
Pyrene	3,028	490	10,264	16,000	152	20,000
Bis(2-ethylhexyl)phthalate	1,714	198	4,200	--	90	7,600
Total PCBs	1,156	95	1,500	3,100	56	3,180

[1]Sediment chemical data were downloaded from SEDQUAL for all of Puget Sound; only detected values were compiled.
[2]Guideline values apply to Total Benzo(b+k)fluoranthenes only.

Table 2. Concentrations of contaminants found in New Jersey waters in the Port of New York and New Jersey. (Source: New Jersey Office of Maritime Resources).

Chemical Code	Count	Average Concentration	Minimum Concentration	Maximum Concentration	Units of Concentration
Acenapthen	215	3754.2940	10.00000	420000.00000	PPB
Acenaptyle	215	1178.0211	7.00000	46000.00000	PPB
Anthracene	213	2867.7994	31.0000	230000.00000	PPB
Antimony	214	11.6465	0.20000	43.90000	PPM
Arsenic	218	12.0511	1.20000	67.40000	PPM
BAA	216	3087.3057	58.00000	150000.00000	PPB
BAP	216	2891.9281	67.00000	130000.00000	PPB
Cadmium	221	4.8351	0.13300	29.00000	PPM
Chlordane	37	31.1411	1.04000	210.00000	PPB
Chlordan_A	158	23.1883	0.27000	233.00000	PPB
Chlordan_G	122	22.9867	1.99000	125.00000	PPB
Chromium	221	147.8348	6.60000	860.00000	PPM
Chrysene	216	3240.4537	79.00000	150000.00000	PPB
Copper	216	206.4992	0.44000	2470.00000	PPM
DDT_Total	51	194.2807	3.77000	1325.70000	PPB
Dibnzfuran	164	1953.4756	120.00000	70000.00000	PPB
Dibnzthio	22	195.5455	10.00000	1900.00000	PPB
Dieldrin	216	19.9835	0.20000	270.00000	PPB
Endrin_Ald	156	13.6626	2.00000	126.00000	PPB
Endrin_Ket	146	74.8442	3.85000	2360.00000	PPB
Fluoranthn	216	5962.2975	100.00000	320000.00000	PPB
Fluorene	215	1992.8692	11.00000	140000.00000	PPB
HPAH	136	26137.5590	668.00000	1115000.00000	PPB
Lead	213	305.6568	5.60000	2500.00000	PPM
Mercury	220	3.0452	0.10000	12.40000	PPM
Methnap_2	215	1391.2836	12.0000	46000.00000	PPB
Metnap26_2	4	73.9875	30.09000	134.22000	PPB
Napthalene	215	1799.7437	36.0000	54000.00000	PPB
Nickel	221	47.0657	7.10000	369.00000	PPM
OCDD	91	6500.2275	13.00000	25200.00000	ng/kg
OCDF	94	1545.1585	1.90000	25200.00000	ng/kg
OP_DDD	51	21.1682	0.290000	145.88100	PPB
OP_DDE	51	11.4927	0.14000	88.30000	PPB
OP_DDT	51	6.1799	0.03000	131.34400	PPB
PCB_SUM	131	1308.1950	18.76000	17200.00000	PPB
PCD1234678	231	544.8477	2.40000	14200.00000	ng/kg
PCD123478	231	9.6201	0.23000	120.00000	ng/kg
PCD123678	231	37.3593	0.57000	1730.00000	ng/kg
PCD12378	231	11.1964	0.36000	760.00000	ng/kg
PCD123789	231	18.5379	0.55000	547.00000	ng/kg
PCD12478	24	6.8833	0.50000	23.00000	ng/kg
PCD2378	231	428.8457	0.20000	13500.00000	ng/kg
PCD8	125	4738.8400	17.00000	81000.00000	ng/kg
PCD_T4	79	231.5610	0.69000	1180.00000	ng/kg
PCD_T5	79	93.8549	0.36000	1190.00000	ng/kg
PCD_T6	79	261.7392	1.40000	1700.00000	ng/kg

Chemical Code	Count	Average Concentration	Minimum Concentration	Maximum Concentration	Units of Concentration
PCD_T7	79	990.7823	8.60000	5890.00000	ng/kg
PCD_T8	12	5075.0000	1300.00000	17000.00000	ng/kg
PCF1234678	231	1084.6621	0.75000	64000.00000	ng/kg
PCF123478	231	277.4374	0.36000	20000.00000	ng/kg
PCF1234789	231	30.1943	0.41000	1400.00000	ng/kg
PCF123678	231	58.1059	0.22000	2900.00000	ng/kg
PCF12378	231	17.2246	0.25000	580.00000	ng/kg
PCF123789	231	9.1648	0.23000	300.00000	ng/kg
PCF12478	10	74.5000	17.00000	130.00000	ng/kg
PCF234678	231	29.5579	0.37000	780.00000	ng/kg
PCF23478	221	50.4082	0.38000	1400.00000	ng/kg
PCF2378	231	48.4258	0.31000	480.00000	ng/kg
PCF8	125	1804.3824	1.60000	130000.00000	ng/kg
PCF_T4	79	717.5366	0.39000	12000.00000	ng/kg
PCF_T5	79	607.3558	0.61000	11000.00000	ng/kg
PCF_T6	79	1027.6589	0.45000	36000.00000	ng/kg
PCF_T7	79	1824.0500	0.75000	76000.00000	ng/kg
PCF_T8	12	847.8333	54.00000	2400.00000	ng/kg
Phenanthrn	216	5876.6790	26.00000	570000.00000	PPB
PP_DDD	211	125.0845	1.46000	5980.00000	PPB
PP_DDE	211	53.7005	1.52000	353.00000	PPB
PP_DDT	209	87.7590	0.08000	2470.00000	PPB
Pyrene	216	5988.6053	100.00000	340000.00000	PPB
Silver	206	4.2375	0.10800	42.30000	PPM
TOC	204	6.0228	0.00113	40.90000	PCT
Total_PAH	140	41033.9906	799.80000	2483200.00000	PPB
Zinc	213	482.7606	20.50000	1900.00000	PPM
LPAH	113	18650.7612	131.80000	1368200.00000	PPB

Table 3. Concentrations of contaminants found at selected locations in the Port of NY/NJ compared to New Jersey non-residential and residential soil standards and New York residential soil standard.

Contaminant	Newark Bay	Arthur Kill	Newtown Creek	NJ Non-Resid.[2]	NJ Resid.[3]	NY Resid.[4]
2,3,7,8 TCDD (ppt)	130	39	9.9	---	---	---
OCDD (ppt)	5494	3016	15369	---	---	---
TCDD/TCDF TEQ (ppt)	197	61	224	---	---	---
Total PCBs (ppm)	.92	1.16	2.86			
Anthracene (ppb)	1400	880	5820	2	0.49	1
Benzo(a)anthracene (ppb)	3070	1460	6190			
Chrysene (ppb)	3100	1630	6050	10,000	10,000	50,000
Total PAHs (ppb)	32550	19120	59380	4000	900	224
Total Herbicides and DDT (ppb)	145	1219	420	40,000	9000	400
Arsenic (ppm)	9-17	17-25	5-33	---	n/a[5]	396,500
Cadmium (ppm)	1-2	1.5-3	1-20			
Chromium (ppm)	175	161	305	20	20	7.5
Copper (ppm)	105-131	178-304	61-770	100	1	1
Lead (ppm)	109-136	111-261	68-554	---	---	10
Mercury (ppm) total	2-3	2-4	1-3	600	600	25
Nickel (ppm)	33-40	20-60	12-140	600	400	SB[6]
Silver (ppm)	2-4	2-5	2-3	270	14	0.1
Zinc (ppm)	188-244	230-403	104-1260	1500	1500	20

[1]Chen, A. S. C. 1994. *Letter Report: Analytical Results of NY/NJ Harbor Sediments.* Base-Catalyzed Dechlorination Demonstration Project, Battelle, Columbus, OH. Correspondence to A. Massa, US EPA, Region 2, New York, NY.

[2]NJ Department of Environmental Protection. Non-residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.

[3]NJ Department of Environmental Protection. Residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.

[4]NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.

[5]n/a = not available.

[6]SB = Site background.