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Dredged material decontamination demonstration for the port of New York / New Jersey

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Abstract

Management of contaminated dredged material is a significant challenge in the Port of New York and New Jersey as a result of more stringent regional ocean placement regulations with escalating costs for upland placement. 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 progressed through phased testing of commercial technologies at the bench scale (15 liters) (Marcor, Metcalf & Eddy, Gas Technology Institute, Westinghouse Science & Technology, BioGenesis, International Technology, and BioSafe) and pilot-scale (1.5–500 m^3) (BioGenesis, Gas Technology Institute, and Westinghouse Science & Technology) levels. The technologies developed by Gas Technology Institute and BioGenesis are now going forward to commercial demonstration facilities that are intended to treat from 23 000 to 60 000 m^3 of dredged material during their first operational period in 2001–2002. Beneficial use products are soils and cement. Treatment costs for the final commercial facilities are estimated at US$ 39 per m^3. Selection of the technologies was 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. Published by Elsevier Science B.V.

Keywords: Dredged material; Decontamination; Beneficial use; Commercialization; NY/NJ Harbor

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1. Introduction

Sediments contaminated with organic and inorganic compounds of anthropogenic origin are commonly found in waterways surrounding 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 (NY/NJ) serves as one example of a region where a search is going on to find environmentally and economically acceptable methods for dealing with contaminated sediments. More stringent regional ocean disposal criteria have reduced the volume of dredged material acceptable for placement at the Historic Area Remediation Site (HARS) formerly known as the "mud dump" that is located approximately six miles off Sandy Hook, NJ in the coastal Atlantic Ocean. At the same time, efficient operation of the Port of NY/NJ is essential because of its key role in the economy of the eastern United States. The maintenance and improvement of navigation and shipping channels causes, on average, the generation of several million m^3 per year of dredged material each year. A portion of this material, perhaps 25%, is presently used for closure of the HARS. The major fraction of the material must be handled in other ways that presently include placement in confined disposal facilities, use at brownfield sites, and closure of abandoned acid mines in Pennsylvania. Decontamination and beneficial use of dredged material is an additional approach that treats dredged material as a resource for production of end products that can generate a revenue stream to help reduce disposal costs while at the same time removing contaminants from the environment. Products that can be produced from decontaminated dredged material include soils, cement, glass, bricks, and light-weight aggregate.

Contaminated dredged material is not only of concern for the Port of NY/NJ, but is a problem worldwide. Other ports where work on the disposal of contaminated dredged material is in progress include Baltimore; Seattle/Tacoma; Venice, Italy; Hamburg; Rotterdam; and Shanghai. It seems possible that environmental challenges will act to bring about corresponding work in South America and other continents. The problems encountered in the Port therefore exemplify a true national and international concern.

This is demonstrated below by comparing contaminants found in the Port of NY/NJ region with those found in Puget Sound to show the similarity in compounds and concentrations of toxic materials found in the sediments of the two regions. These concentrations are also similar to the results found for sediments from the Port of Venice, Italy. Progress in dredged material decontamination methods for the Port of NY/NJ is therefore relevant on a national and international scale.

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 decontaminated sediments. The project is aimed at producing facilities that can process approximately 375 000 m^3 of dredged material each year or roughly 25% of the total dredged material in the Port of NY/NJ. Presently, the initial operations for the first two facilities, one a sediment washing technology by BioGenesis Enterprises and the other a rotary kiln thermo-chemical technology by the Gas Technology

Institute/Endesco Clean Harbors are scheduled for the end of 2001. The goal for treatment costs for decontamination is set at US$ 39 per m^3 in addition to costs associated with dredging and transport of the material to the processing facility. The project direction is provided by the US Environmental Agency, Region 2 and the US Army Corps of Engineers, New York District with the assistance of the US Department of Energy Brookhaven National Laboratory. In addition, scientists from New Jersey Institute of Technology, Rensselaer Polytechnic Institute, Rutgers University, and Stevens Institute of Technology have participated in technical reviews and public outreach activities.

This paper is intended to provide a concise 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 (see [1–16]) is included. Most of these papers and technical program reports can be found on our World Wide Web site at http://www.wrdadcon.bnl.gov.

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

2. Types and concentrations of contaminants found in sediments

The organic and inorganic contaminants found in dredged materials and sediments in port regions are similar. This can be seen by comparison of the data for surficial concentrations shown in Table 1 for Newark Bay, Arthur Kill, and Newtown Creek areas in the Port of NY/NJ and in Table 2 for average concentrations in core samples from the Port and for the Puget Sound region where the ports of Seattle and Tacoma are located. Note that the data shown for Puget Sound are for results from samples in the ≥95th percentile, and thus, do not include samples from the cleaner areas of the Sound. Values are reported for the median concentrations for samples in the ≥95th percentile portion of the data only. The New Jersey data shown in Table 2, however, give values for the minimum, maximum, and average concentrations. It can be seen that the concentrations for the two regions are similar, thus, indicating a wide need for development of effective decontamination systems since regulatory agencies in both areas are concerned with the environmental effects associated with the methods chosen for disposal of dredged material with these characteristics.

3. Sediment transport and visualization

Choice of disposal options for dredged material in 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 that 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

Table 1
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 soil cleanup objectives and cleanup levels

Contaminant	Newark Bay[a]	Arthur Kill[a]	Newtown Creek[a]	NJ non-residential[b]	NJ residential[c]	NY residential[d]
2,3,7,8 TCDD (ppt)	130	39	9.8			
OCDD (ppt)	5494	3016	15369			
TCDD/TCDF TEQ (ppt)	197	61	224			
Total PCBs (ppm)	0.92	1.16	2.86	2	0.49	1
Anthracene (ppm)[e]	1400	880	5820	10000	10000	0.5
Benzo(a)anthracene (ppb)	3070	1460	6190	4000	900	224
Chrysene (ppb)	3100	1630	6050	40000	9000	400
Total PAHs (ppb)	32550	19120	59380			384
Total herbicides and DDT (ppb)	145	1219	420			
Arsenic (ppm)	9–17	17–25	5–33	20	20	7.5 or SB[f]
Cadmium (ppm)	1–2	1.5–3	1–20	100	39	1 or SB[f]
Chromium (ppm)	175	161	305			10 or SB[f]
Copper (ppm)	105–131	178–304	61–770	600	600	25 or SB[f]
Lead (ppm)	109–136	111–261	68–554	600	400	SB[f]
Total mercury (ppm)	2–3	2–4	1–3	270	14	0.1
Nickel (ppm)	33–40	20–60	12–140	2400	250	13 or SB[f]
Silver (ppm)	2–4	2–5	2–3	4100	110	SB[f]
Zinc (ppm)	188–244	230–403	104–1260	1500	1500	20 or SB[f]

[a] Chen, ASC, 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.
[b] NJ Department of Environmental Protection. Non-residential soil, direct contact. NJAC 7:26D, revised 3 May 1999.
[c] NJ Department of Environmental Protection. Residential soil, direct contact. NJAC 7:26D, revised 3 May 1999.
[d] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046, revised 24 January 1994.
[e] Health based criterion exceeds the 10 000 mg/kg maximum for total organic contaminants.
[f] SB = site background.

Table 2
Comparison of chemical concentrations found in sediment samples from Puget Sound and from the New Jersey waters of the Port of NY/NJ[a]

Chemical	Puget Sound		New Jersey Waters of the Port of NY/NJ			
	Number of samples	Median	Number of samples	Average concentration	Minimum concentration	Maximum concentration
Metals (mg/kg, dry weight)						
Antimony	91	126	214	11.6	0.2	44
Arsenic	177	404	218	12.1	1.2	67
Cadmium	148	7.9	221	4.8	0.13	29
Copper	192	1025	216	206	0.44	2470
Lead	189	1070	213	306	5.6	2500
Mercury	80	4.3	220	3.0	0.1	12
Nickel	166	102	221	47	7.1	369
Silver	112	5.9	206	4.2	0.11	42
Zinc	192	1935	213	483	21	1900
Organics (μg/kg, dry weight)						
Anthracene	127	8300	213	2868	31	230000
Fluorene	106	5850	215	1993	11	140000
Phenanthrene	138	15500	216	5877	26	570000
Benzo(a)anthracene	127	9300	216	3087	58	150000
Benzo(a)pyrene	131	6824	216	2892	67	130000
Benzo(b)fluoranthene	58	9050	–	–	–	–
Benzo(k)fluoranthene	55	8000	–	–	–	–
Benzo(g,h,I)perylene	92	3850	–	–	–	–
Chrysene	142	11000	216	3240	79	150000
Fluoranthene	153	23000	216	5962	100	320000
Indeno(1,2,3-c,d)pyrene	103	3900	–	–	–	–
Pyrene	152	20000	216	5989	100	340000
Bis(2-ethylhexyl)phthalate	90	7600	–	–	–	–
Total PCBs	56	3180	131	1308	19	17200

[a] The format for reporting the data from the two regions are different, but comparison of the median and average values show that concentrations are similar. Data from Puget Sound Confined Disposal Site Study, Programmatic Environmental Impact Statement, Draft, February 1999, and from the New Jersey Office of Maritime Resources. The Puget Sound data are for the most contaminated samples (>95th percentile).

material in an environmentally and cost 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 the Port of NY/NJ, functions as a source of contaminants to the upper estuary and overlying air (e.g. Feng et al. [17]). 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 [18,19]. These contaminants can also be laterally transported with particles to upper estuary regions and redistributed over the course of a tidal cycle [20]. 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), a small amount of 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 [21]. 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 be 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 visually displayed in an accessible way that is intelligible to the regulatory agencies and to the engineers responsible for making management decisions/recommendations for specific dredging projects, as well as comprehensive ecosystems restoration programs.

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 is shown in Figs. 1 and 2. Newark Bay is critical to New Jersey port commerce, transportation, and economic development since it contains the berths of Port Newark and Port Elizabeth Marine Terminal, a centerpiece of the third largest port in US. The maps show localized regions of high contamination within the

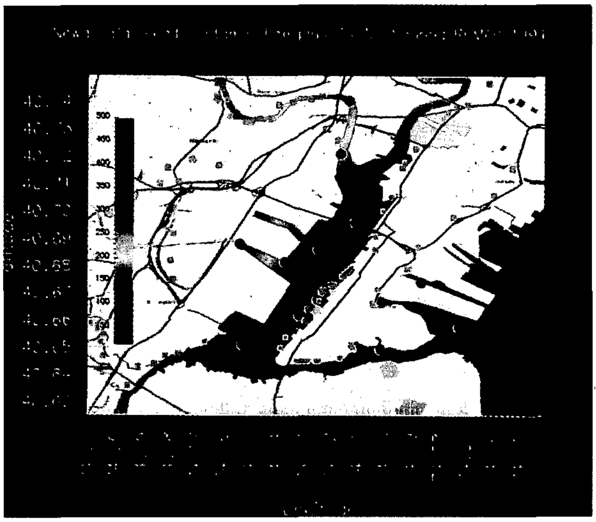

Fig. 1. Surficial concentrations of Pb in Newark Bay from Regional Environmental Monitoring and Assessment Program (REMAP) 1994. The concentrations are shown on the color scale in units of micrograms/gram (ppm). Combined sewer overflows (CSOs) are shown with orange circles. Locations of data points are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

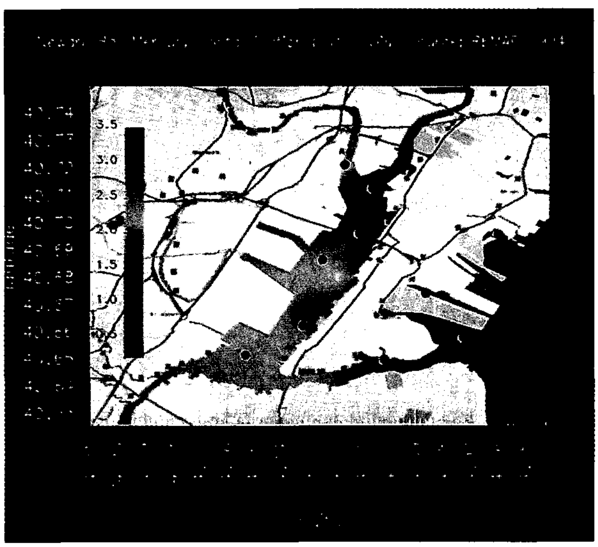

Fig. 2. Surficial concentrations of Hg in Newark Bay showing data from Regional Assessment and Monitoring Program (REMAP) 1994. The color-scale concentrations are in units of micrograms/gram (ppm). Combined sewer overflows (CSOs) are shown with orange circles. Locations of data points are shown with magenta circles (courtesy of J. Spiletic, G.J. Smith, and M. McGuigan, Brookhaven National Laboratory).

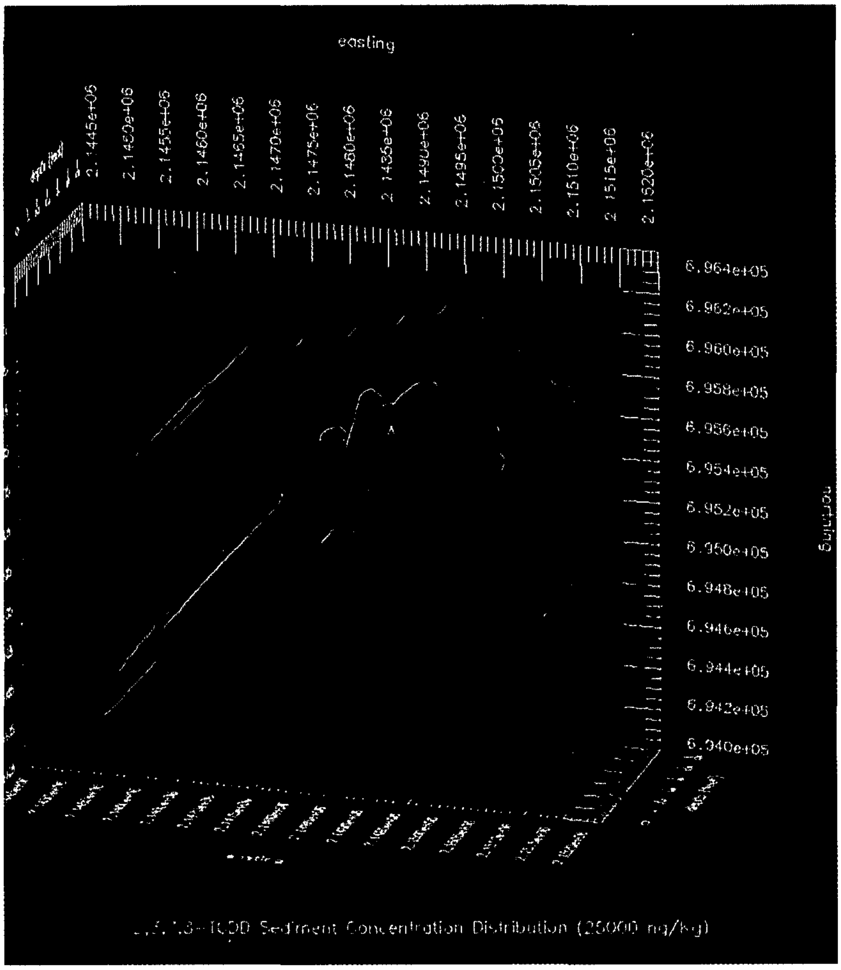

Fig. 3. 2,3,7,8-TCDD "Hot Spot" sediment concentrations in the Passaic River close to Newark, NJ (courtesy of Hong Ma, Brookhaven National Laboratory).

Bay and also in the Passaic River that enters the Bay from the northwest. The locations of data points and of combined sewer overflows as potential sources of contamination input are shown. The sediment concentrations found in the Passaic River are enriched in dioxins and heavy metals and identify it as a potentially important source of toxic contaminants that could cause problems if transported into Newark Bay where dredging is necessary. This 6-mile stretch of the Passaic River has the highest levels of dioxins, caused by an industrial accident in the early 1960s. The depth distribution of the dioxins at this location is shown in Fig. 3.

The wide distribution of the organic and inorganic contaminants found in the Port is indicative of the need for decontamination technologies. Existence of the high local

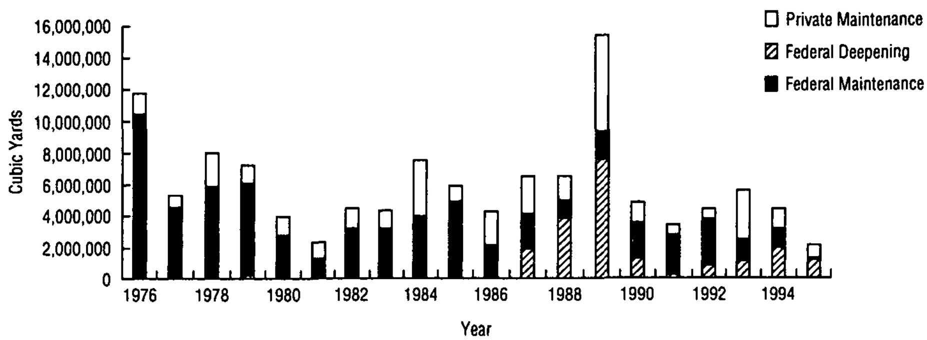

Fig. 4. Summary of yearly dredging in the Port of New York/New Jersey from 1976–1995.

concentration for dioxin shown in Fig. 3 also has implications for decontamination technologies. One choice in dealing with this specific location would be to isolate the material so no transport could take place to contaminate other regions. If the material is to be dredged, then a decontamination technology that has high efficiency for dioxin removal could be employed. We have applied this type of information in the decontamination demonstration so that optimum treatment methods are available for application to specific Port locations.

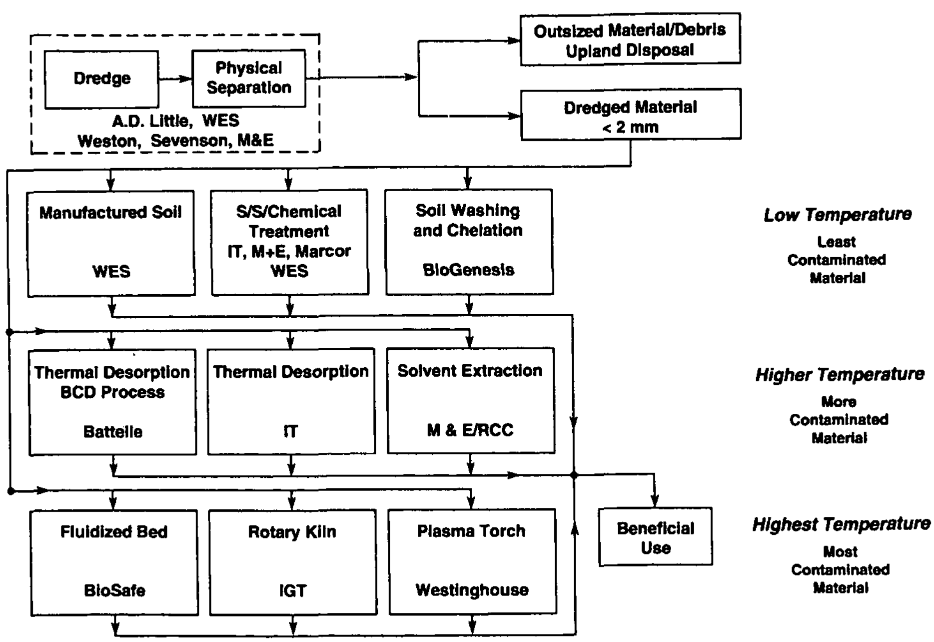

Fig. 5. WRDA treatment train. The different technologies tested in the program are displayed according to the temperature used in the processing. The technology providers are shown in the figure. Acronyms used are: BCD, base-catalyzed decomposition; IGT, Gas Technology Institute; IT, International Technology; M&E, Metcalf & Eddy; RCC, Resources Conservation Company; S/S, solidification/stabilization; and WES, US Army Waterways Experiment Station.

Thus, it is concluded that sediment visualization can be used for deciding on methods for removing or sequestering contaminated sediments from specific locations. The visualization results combined with transport models help in assessing dredging priorities, volume considerations, hot spot removals, and assurance that what is dredged does not leave bioaccumulation toxicity on the sediment substrate.

4. Yearly dredging required in the port of New York/New Jersey

A large amount of material must be dredged each year to maintain depths of 12.2–15.2 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 Fig. 4. Values for private maintenance, federal deepening, and federal maintenance are summarized. The average for the period was about 4 408 000 m^3 per year.

The disposal of this material has become a challenging problem. Environmental restrictions have made ocean disposal problematic 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, that is, a volume of about 400 000 to 500 000 m^3 per year.

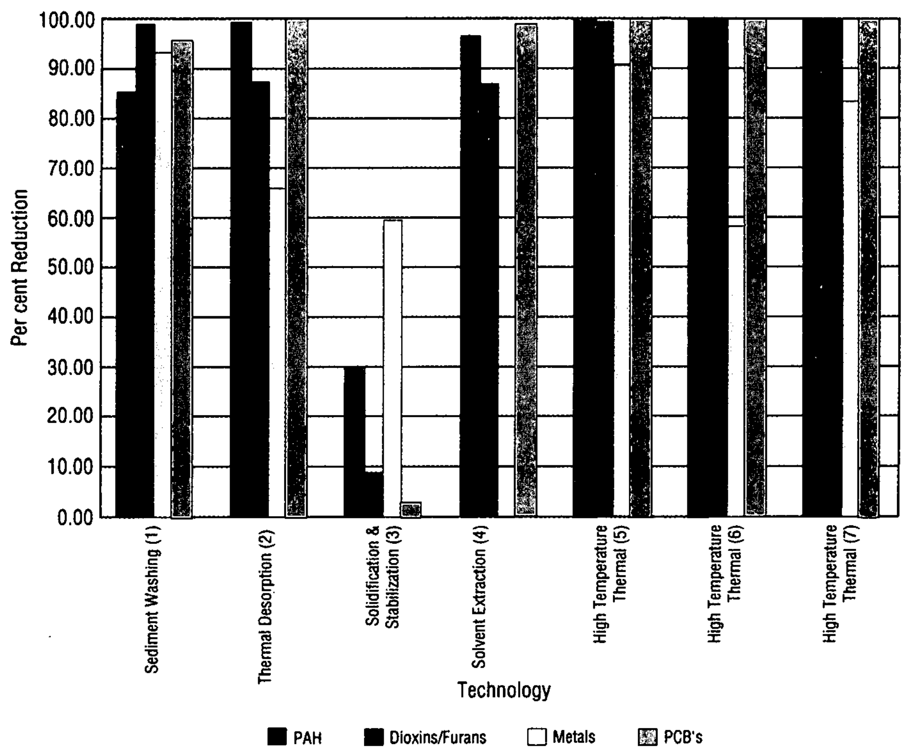

Fig. 6. Summary of technology effectiveness in reduction of contaminants found in dredged material. The technologies were provided by: (1) BioGenesis, (2) International Technology Corporation, (3) Marcor, (4) Metcalf & Eddy, (5) BioSafe, (6) Gas Technology Institute, and (7) Westinghouse.

5. Technology test results

A total of nine different technologies were tested on the bench scale (15 liters). The approaches included sediment washing, solvent extraction, thermal desorption, and

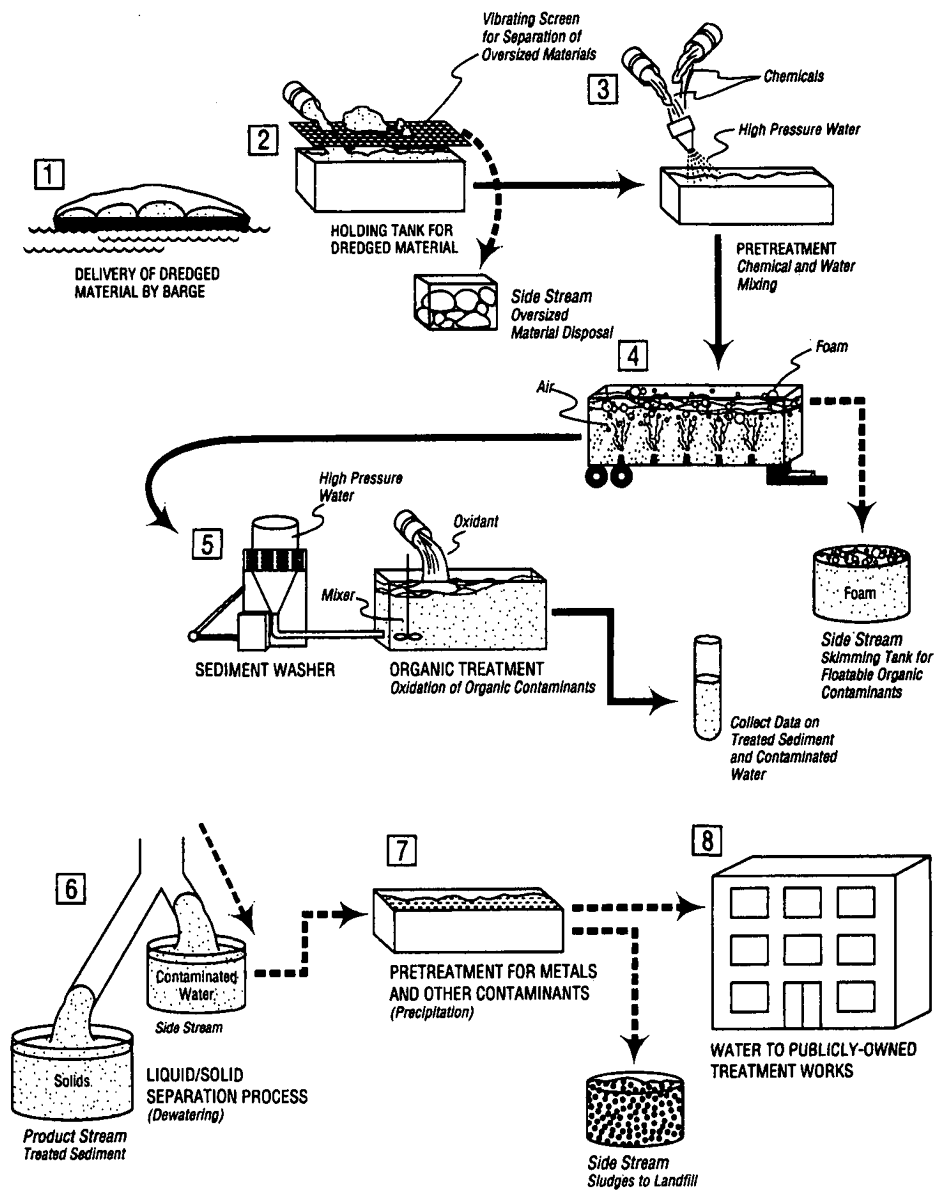

Fig. 7. Schematic diagram showing the BioGenesis sediment washing apparatus for decontamination of dredged material. A manufactured soil is created from the cleaned sediment through the addition of organic materials.

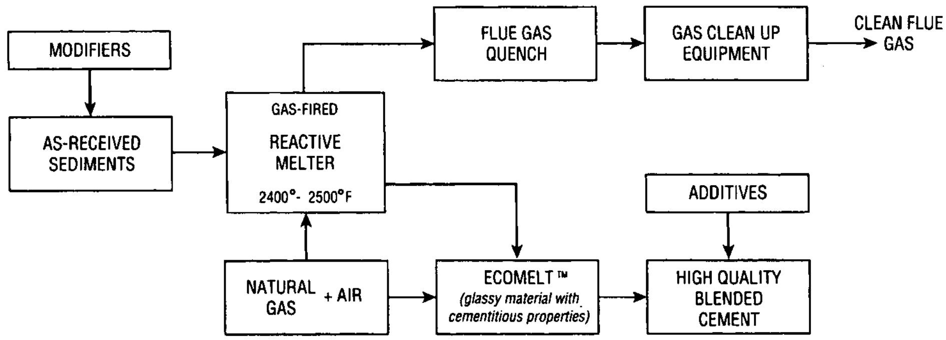

Fig. 8. Schematic diagram showing the steps used in the Gas Technology Institute rotary kiln process for decontamination of dredged material. The cleaned material is used for production of construction grade cement.

thermal destruction. These technologies can be viewed as components of a treatment train for dredging, treatment, and beneficial use of contaminated dredged material. The treatment train is shown schematically in Fig. 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 Fig. 6. Generally, the high temperature technologies attained superior results by destruction of the organic materials and incorporation/immobilization of metals to a stable cement- or glass-like matrix. Further tests on the pilot-scale level were carried out by the Gas Technology Institute using a rotary kiln to produce cement, Westinghouse Science and Technology Center using a plasma torch to produce glass, and BioGenesis Enterprises using a sediment washing process to produce a manufactured soil. The pilot-scale tests verified the results obtained on the bench-scale level and also provided data that could be used to design full-scale treatment facilities. Schematic diagrams of the process steps are given in Figs. 7–9 for the BioGenesis, Gas Technology Institute, and Westinghouse decontamination technologies, respectively.

The results of the pilot tests showed that the washing technique could produce a material from moderately contaminated material that could be used 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. Vendor cost processing estimates were close to those found for other placement options. We concluded from this work that decontamination could be used effectively as part of an overall dredged material management plan for the Port.

6. 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 and the cement production process of the Gas Technology Institute

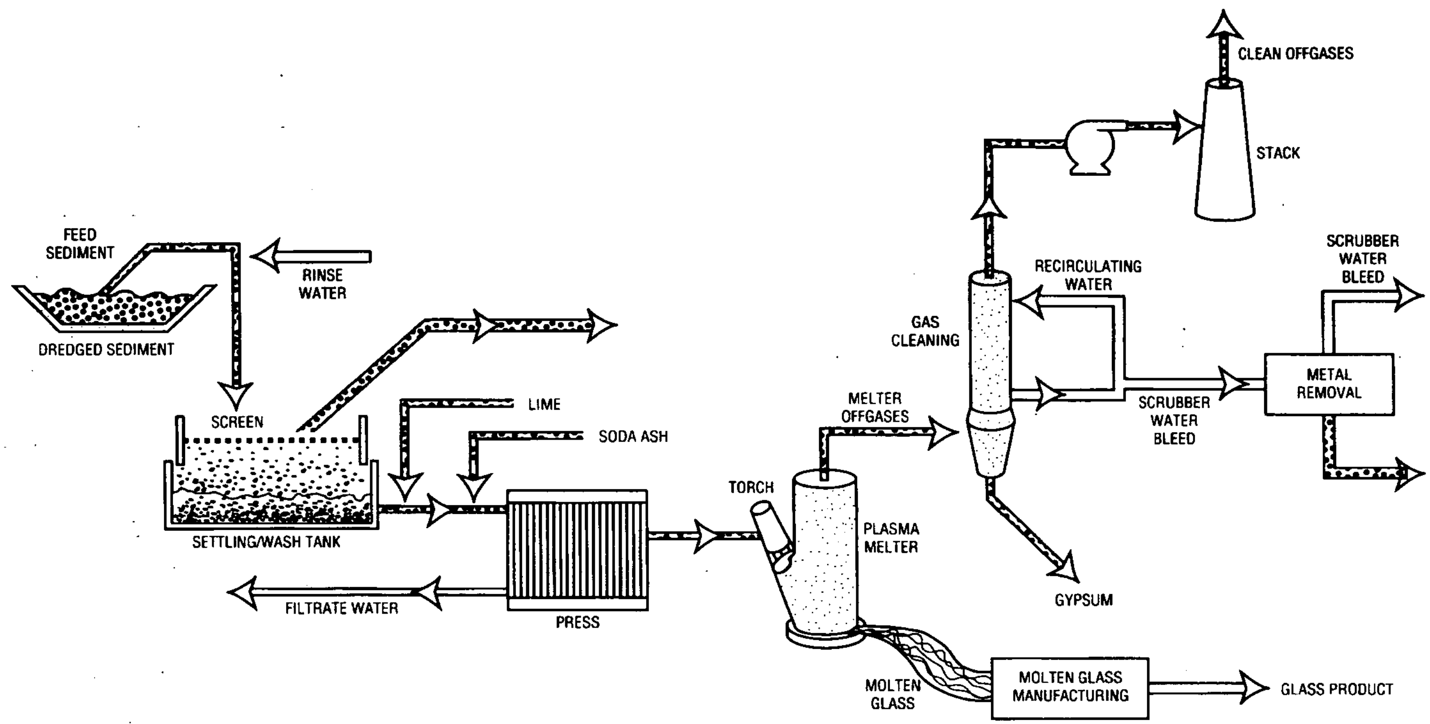

Fig. 9. Schematic diagram showing the steps used in the Westinghouse Science and Technology plasma arc process for decontamination of dredged material. The process yields a glassy material that can be used for the production of glass tiles.

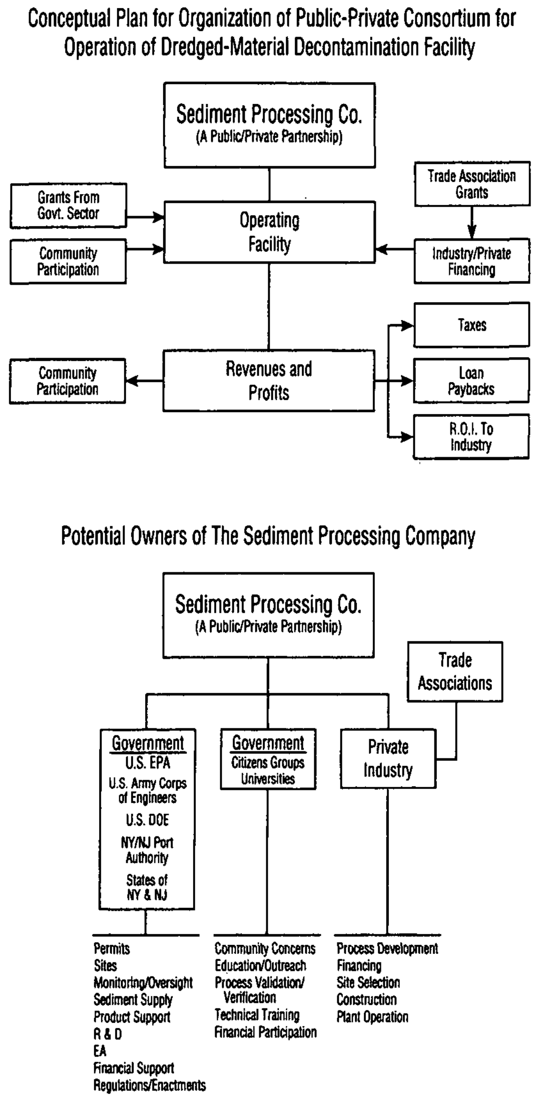

Fig. 10. Conceptual plan for organization of a public–private consortium for operation of a dredged-material decontamination facility. Two schematic diagrams are given that show the consortium organization and the potential owners of the company.

are the furthest advanced in this respect. BioGenesis 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 per hour or 180 000 m^3 per year. The cement production facility is also to be installed on a site in New Jersey. It will have a final cap to treat about 75 000 m^3 per 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 a rotary kiln facility to produce a lightweight aggregate material for construction applications. A pilot-scale test of the process will take place in 2001.

It is important to emphasize that in order to have a successful commercial venture, it will be necessary to have a technology that can be operated at a cost affordable by the customers in the region. This level is now set at about US$ 39 per m^3 for treatment of as-dredged material 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.

7. 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 Fig. 10. The assistance of the public sector in providing funding for the initial tests and operation is critical for the process. Further, if the private sector is to raise capital funding for treatment facilities, it seems necessary for the public sector to devise ways of supporting long-term processing contracts as an aid in showing the commercial viability of the project. Our experience also indicates that the sediment processing company may be a consortium of companies with compatible objectives. For example, the JCI/Upcycle group combines a major dredging company with one with specific expertise in production of light-weight aggregate.

The challenge that we are now working on is to turn this conceptual design for commercialization into reality.

8. Summary

Our project for sediment decontamination and beneficial use has been successful on a small-scale. That is, it has been shown that contaminated dredged material can be treated effectively to reduce concentrations of contaminants to acceptable levels and that beneficial use products including soils, cements, and glass can be produced for disposal of the cleaned material. The size of the demonstrations has ranged from 1–500 m^3. Estimates of the treatment cost made from these small-scale tests combined with initial design work on commercial-scale plants indicate that treatment costs for full-scale operations will be competitive with other present treatment options. Whether these costs can be achieved in practice will be tested in the next phases of the demonstration. 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. The projected time-scale for realizing this objective is for the 2001–2002 period.

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