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# Processing of NY/NJ Harbor Estuarine Dredged Material

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## Abstract

Management of contaminated dredged material is a major problem for the ports and harbors of the United States. One attractive solution to processing the dredged material is to remove or stabilize the contaminants and produce a material suitable for beneficial use or unrestricted upland disposal. The components of a comprehensive dredged material processing project designed for treatment of the estuarine sediments found in the Port of NY-NJ are described here.

## Introduction

Contaminated dredged material constitutes a major disposal problem for the Port of New York/New Jersey as it also does for most ports in the United States. The problem comes about because of the need to remove sediment which has accumulated in navigational channels and shipping berths to an extent that interferes with shipping and port operations. In the Port of NY/NJ approximately 3 to 4 million $m^3$ of dredged material containing low levels of

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metals, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), dioxins, etc. are removed from the Port each year. Of that amount, approximately 75% does not pass the bioaccumulation/biotoxicity tests for ocean disposal and thus cannot be disposed of at the Mud Dump Site, located 10 km from coastal NJ in the Atlantic Ocean.

Processing of the dredged material to render it suitable for beneficial use or unrestricted upland disposal is very attractive if two conditions can be met. First, the solution must be environmentally acceptable and second, the cost must be acceptable. From a technical standpoint there is no question that the dredged material can be processed to meet relevant environmental disposal criteria. In the past, processing has appeared to be prohibitively more costly than other alternatives. Processing costs have been reduced dramatically and in some cases are estimated to be below $\$50/m^3$. Many decontamination technologies will operate with costs of less than $\$67/m^3$. It appears that processing will be of increasing importance, since from the public's view, the sediment processing scenarios may be deemed superior environmentally, potentially more acceptable to the interested public groups involved, and potentially operational on a similar time scale.

It should be clear that the development of a processing facility is not strictly an engineering and scientific project. The overall goals, approaches, and favored solutions are strongly influenced by input from the variety of concerned parties. Public input has been achieved through the NY/NJ Harbor Estuary Program (HEP) Policy Committee which is composed of many different members. The composition of HEP is shown in Fig. 1. An overall description of the components of a solution to the problem of dredged material in the Port of NY/NJ is given by Tripp (1996) and Helmick et al. (1996).

We report here on the results of the first phase of a program to provide large scale processing facilities for the Port of NY/NJ. Attention has been given to many different aspects of concern to facility development in addition to narrow consideration of processing equipment. Subsequent phases will be devoted to tests at the pilot-scale (1-20 $m^3$) and large-scale (76,000-376,000 $m^3$)level.

Characteristics of Dredged Material

There does not appear to be an established data base that describes the characteristics of the dredged material found in the Port of NY/NJ as a function of latitude, longitude, and depth below the sediment surface.

Parameters of interest for development of the processing facility include the major element composition, mineral content, salt content, moisture content, plasticity indices, and grain size distribution. Concentrations of organic carbon, sulfides, ammonia, hydrocarbons, organic compounds, and metals are also imperative for choosing the processing technologies.

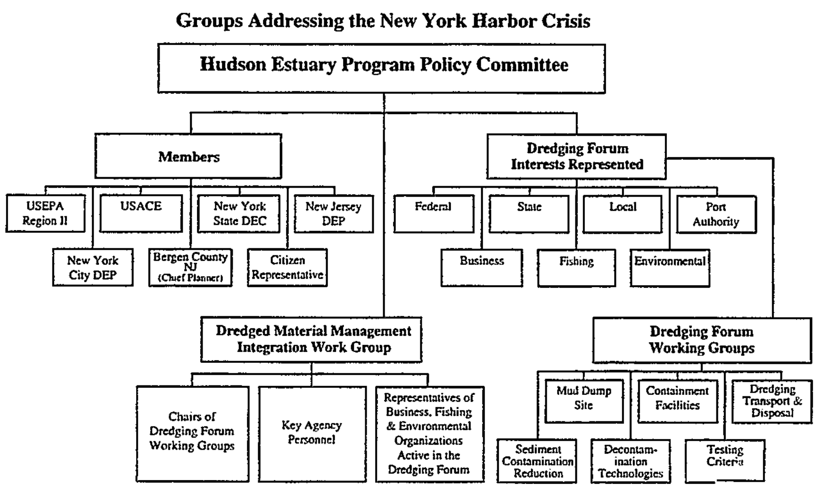


Fig. 1. Participants in policy decisions affecting the Hudson estuary. (From Tripp, 1996)

Visual inspection of sediments obtained from Newtown Creek (lying between Brooklyn and Queens in New York City) Howland Hook Marine Terminal on Staten Island, several regions around Newark Bay, and the USACE facility at Caven Point at Jersey City indicate a strong similarity in physical appearance and implies that a large fraction of the dredged material will be similar in nature. The grain size distribution of Newtown Creek sediment is shown in Fig. 2.

The mineralogy of Newtown Creek sediment was measured using x-ray diffraction (McLauglin and Ulerich, 1996). The results are summarized in Table 1. This type of information is of importance for high temperature technologies (see below) that are used to produce products for beneficial use such as glass, cement, pozzalanic materials, and construction fill aggregate. Measurements of variability for different locations need to be made to establish that there are no large variations from point-to-point for this fine-grained material.

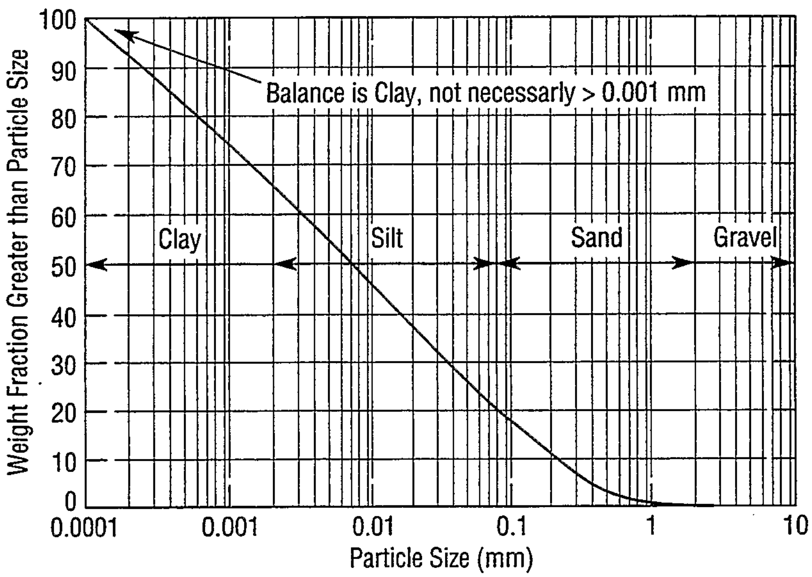


Fig. 2. Fraction of Newtown Creek sediments passing through different size sieves.

Table 1. Sediment Mineralogy of Newtown Creek

| Mineral Species | Chemical Formula | Weight Percent |
|---|---|---|
| Quartz | $SiO_2$ | 66 to 75 |
| Muscovite (Mica) | $K_2O \cdot 2MgO \cdot Al_2O_3 \cdot 8SiO_2 . 2H_2O$ | 11 to 15 |
| Amorphous Phase | Organics | 3 to 13 |
| Kyanite | $Al_2O_3 \cdot SiO_2$ | 6 to 7 |
| Hydrated Aluminum Silicate | $19Al_2O_3 \cdot 173SiO_2 \cdot 9H_2O$ | 5 to 6 |
| Cronstedtite | $4FeO \cdot 2Fe_2O_3 \cdot 3SiO_2 \cdot 2H_2O$ | 4 to 6 |

Measurements of the concentrations of metal and organic contaminants found in three locations at NY/NJ Ports have been reported previously. (Stern et al., 1997). A summary of the results found for the organic contaminants in Newtown Creek sediment are given in Table 2.

Table 2. Summary of Organic Contaminants in Newtown Creek Sediments

| Contaminant | Concentration ($\mu$g/g dry basis) |
|---|---|
| Total Sulfides | 7830 |
| Total Organic Carbon (TOC) | 73,200 |
| Total Polychlorinated Biphenyls (PCB) | 5.26 |
| Total Chlorinated Pesticides | 0.462 |
| Total Polyaromatic Hydrocarbon (PAH) | 117 |
| Bis-2-ethylhexylphtalate | 48.6 |
| Fluoranthene | 10.3 |
| Phenanthrene | 6.5 |
| Others (24) | 51.6 |
| Total Dioxins | 0.00645 |
| Total Furans | 0.0165 |

Visualization of Contaminant Distributions

It is known that the distribution of contaminants in the Port is not uniform. Thus, the type of processing appropriate for dredged material taken from different locations must be chosen with this in mind. One example is found on the Passaic River in Newark, NJ, where a herbicide-manufacturing facility was responsible for the discharge of large amounts of dioxins and furans into the river. Measurements of the contamination as a function of position can be used to define positions, including depth information, where the dredged material may need decontamination prior to disposal. Visualization of a three dimensional data set is necessary to make informed decisions on remedial actions. Contaminant transport models can also be visualized in the same way and compared with the present distributions so that the future contaminant movement can be understood.

The visualization of the concentrations of dioxin (TCDD-2378), the most toxic congener among the dioxins and furans, is given in Figs. 3 and 4. (Ma and Jones, 1997) The spatial coordinates are given in the universal Transverse Mercatur (UTM) system. An interpolation procedure has been used to generate the plots from an original data set of 78 core samples over a 10-km length of the Passaic River. Further sampling would be desirable for validating the interpolation procedures.

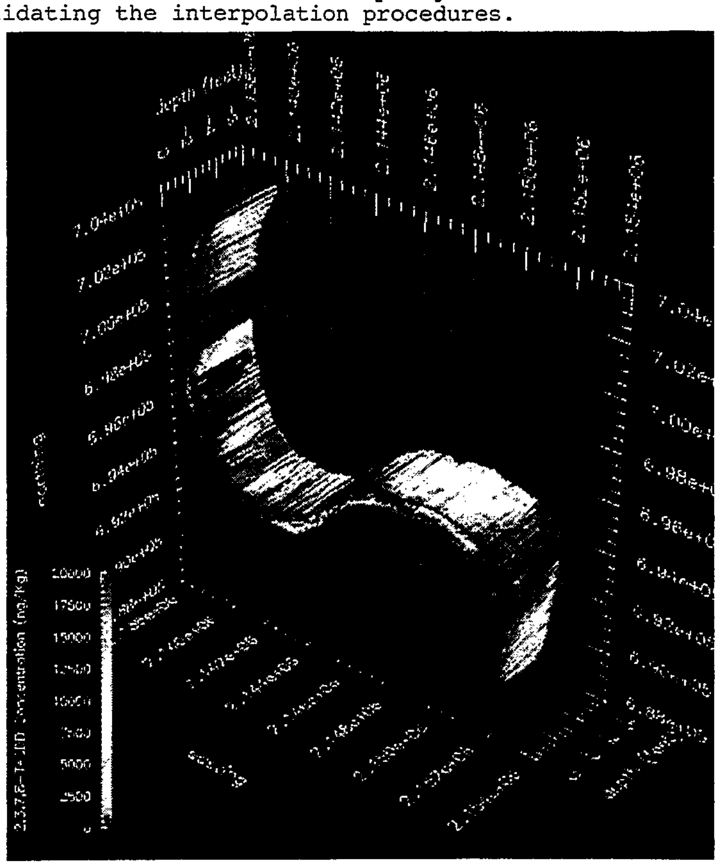

Fig. 3. Three-dimensional visualization of the distribution of TCDD-2378 in the Passaic River. The depth below the surface of the sediments is shown in feet.

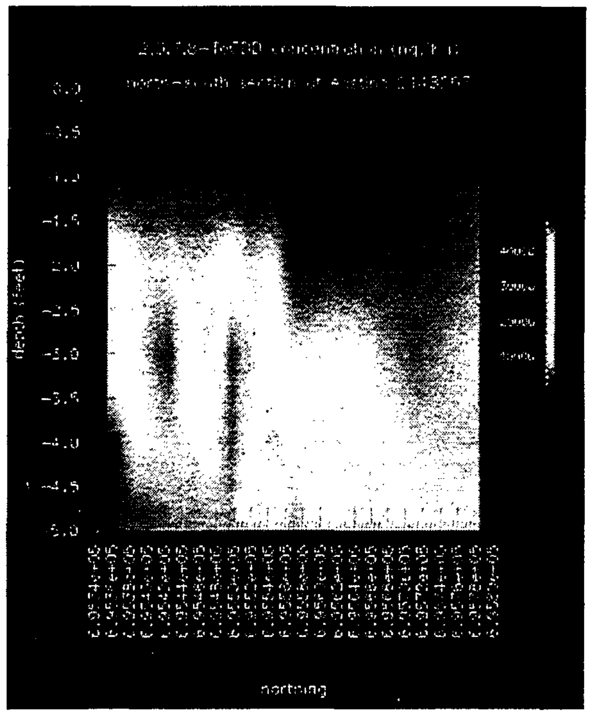


Fig. 4. North-south section of the Passaic River at Easting 2148263 showing the localization of TCDD-2378 as a function of the depth in feet below the sediment surface.

Dredging and Transport of Dredged Material

Obtaining dredged material for input to the processing system is a well-known procedure that usually utilizes equipment that has not changed for many years. The present need to minimize volumes of dredged material and to precisely excise "hot spots" of contaminated material is providing impetus to improvements in dredging technologies. (Helmick et al., 1996; A. D. Little, 1996).

A related problem is that of efficiently transporting the wet fine-grained gel-like dredged material to the location of the processing facility. Solutions to the transport problem start with a physical separation to remove extraneous large objects to prepare the material for the next steps in processing or decontamination. Transportation from barge to the treatment location by pumping may require a reduction in solids content of the as-dredged material by addition of water. If fresh water is used, salinity will be reduced. However, the increase in moisture content would be a problem for processes operating at high temperatures. Clearly, the dredging and transport processes need to be considered as important parts of an overall processing facility treatment train. In the present project, such questions are to be considered in the part of the work leading to design of an integrated system.

## Processing Technologies

A number of treatment technologies have been investigated and considered for inclusion in a treatment train. Basically, it is important to have a mix of technologies for use with the range of dredged material types that must be handled in the Port of NY/NJ. The bench- and pilot-scale tests described here reflect that idea. They range from production of a viable top-soil, which may use no decontamination treatment at all, to use of high temperatures to almost totally destroy the organic compounds while, at the same time, incorporating or immobilizing the metals into a stable solid matrix.

### Creation of a Manufactured Soil

Clays and sand can be the major components of soils. The harbor sediments can be used to create manufactured soils by the addition of organic materials that contain nutrients such as potassium, nitrogen, and phosphorous. Investigations carried out on the bench-scale (Sturgis et al., 1996) showed that a soil could be formed with a mixture of 30% dredged material, 60% sawdust, and 10% cow manure that was suitable for growing grass and other plants. The soil produced from untreated dredged material could be considered for possible cover at Superfund sites, mining sites, land fills, or industrial brown fields. The uptake of contaminants into the plants or the possible transport of contaminated soil particles in the atmosphere may limit the potential uses of untreated dredged material.

Another approach would be to apply a decontamination procedure to the dredged material prior to producing the manufactured soil. It could then be feasible to use the material for a wider range of applications including parks, landscaping, and golf courses.

Manufactured soil is attractive since there is excellent potential for beneficial use applications. For this reason, a pilot-scale test was carried out at Port Newark where a total of 7.6 $m^3$ were used. This test was showed that good grass yields could be obtained if proper gardening practices were followed to ensure adequate drainage in the soil.

Solidification/Stabilization

A number of tests of handling the dredged material using solidification/stabilization technologies were carried out using both untreated and treated dredged material. WES (Channell et al., 1996) used lime, fly ash, and Portland cement in varying proportions. Production of solidified/stabilized material after solvent extraction (DiGasbarro,1996), thermal desorption (Hall, 1996), and treatment with a proprietary additive (Hartley, 1996) was also investigated.

Solidification/stabilization is an attractive approach because of its inherent simplicity and potential for different types of beneficial reuse. Important factors to consider in the evaluation are the physical properties of the material to ensure that standards for fill material, construction material, or landfill grade material or cover can be met. If untreated material is used then it must be shown that leachate tests based on the Toxicity Characteristic Leaching Procedure (TCLP) or Sequential Batch Leach Test (SBLT) procedures. It was found that, in most cases, contaminants were tightly bound to the dredged material, and the TCLP tests were satisfied. SBLT tests were not carried during this phase of the project. As with manufactured soil, use of the material produced following decontamination would result in less restricted beneficial use. Typical test results for some physical properties are given in Table 3. Detailed consideration of other parameters will be necessary when considering specific end uses, but no insurmountable problems are anticipated in doing this.

Solvent Extraction

Solvent extraction can be an effective method for removing contaminants sorbed to grain surfaces. Two tests of this approach were carried out.

BioGenesis (Rougeux, 1996) worked at a low temperature using proprietary surfactants combined with a high pressure soil washing technology to scour surface material from the particles. This is an attractive approach, but it was

Table 3. Physical Properties of Solidified/Stabilized Materials.

| Binder Ratio | Moisture Content (%) | Bulk Density ($kg/m^3$) | Volume Increase (%) | Cone Index 48 hour ($kg/m^2$) | Unconfined Compr. Strength 28 day ($kg/m^2$) |
|---|---|---|---|---|---|
| 0.2 Cement | 37.7 | 1188.0 | | 271396.6 | 170853.3 |
| 0.2 Cement | 35.3 | 1187.1 | 54.7 | 262256.3 | 179290.5 |
| 0.2 Cement | 37.5 | 1167.9 | | 263662.5 | 174368.8 |
| 0.4 Cement | 30.5 | 1364.9 | | 527325.0 | 509747.5 |
| 0.4 Cement | 31.0 | 1385.7 | 55.0 | 527325.0 | 502716.5 |
| 0.4 Cement | 34.5 | 1360.1 | | 527325.0 | 532949.8 |
| 0.6 Cement* | 22.6 | 1550.7 | | 527325.0 | 613103.2 |
| 0.6 Cement* | 22.2 | 1496.3 | 57.0 | 527325.0 | 603259.8 |
| 0.6 Cement* | 21.5 | 1590.8 | | 527325.0 | 869734.7 |
| 0.8 Cement* | 21.3 | 1629.2 | | 527325.0 | 854969.6 |
| 0.8 Cement* | 21.8 | 1643.7 | 65.0 | 527325.0 | 557558.3 |
| 0.8 Cement* | 21.5 | 1696.5 | | 527325.0 | 506935.1 |
| 0.3/0.4 Lime/Fly ash | 24.6 | 1257.6 | | 527325.0 | 120230.1 |
| 0.3/0.4 Lime/Fly ash | 24.1 | 1227.1 | 107.0 | 527325.0 | 150463.4 |
| 0.3/0.4 Lime/Fly ash | 24.0 | 1244.8 | | 527325.0 | 125854.9 |
| 0.3/0.6 Lime/Fly ash | 19.6 | 1374.5 | | 37264.3 | 145541.7 |
| 0.3/0.6 Lime/Fly ash | 21.2 | 1371.3 | 112.0 | 54841.8 | 175071.9 |
| 0.3/0.6 Lime/Fly ash | 19.6 | 1332.9 | | 61169.7 | 151166.5 |
| 0.4/0.4 Lime/Fly ash | 22.7 | 1366.5 | | 65388.3 | 149760.3 |
| 0.4/0.4 Lime/Fly ash | 22.2 | 1396.9 | 99.9 | 56248.0 | 225695.1 |
| 0.4/0.4 Lime/Fly ash | 23.9 | 1332.9 | | 58357.3 | 143432.4 |
| 0.4/0.6 Lime/Fly ash | 16.8 | 1344.1 | 126.0 | 63279.0 | 189837.0 |
| 0.4/0.6 Lime/Fly ash | 20.1 | 1364.9 | | 64685.2 | 191946.3 |
| 0.4/0.6 Lime/Fly ash | 20.4 | 1308.8 | | 75934.8 | 153275.8 |

*Denotes that sample specimens contained voids that affected the Unconfined Compr. Strength.

found in the first bench-scale tests that only minimal reductions in contaminant levels were achieved. Indeed, there was evidence that the treatment process changed the surface chemistry so that contaminants were more readily leached from the treated material than the untreated material. Modifications to the procedures were made and additional bench-scale testing was performed. The concentrations of contaminants were then found to be reduced by an order of magnitude.

Metcalf & Eddy (DiGasbarro, 1996) worked at higher temperatures and also used proprietary solvents. In this case, with the exception of metals, significant reductions of contaminant levels were also achieved.

Thermal Desorption

Thermal desorption was demonstrated by the International Technology Corporation (Hall, 1996). They used a rotary kiln to raise the dredged material to a temperature of 550°C for 5 minutes. This resulted in a decrease of organic contaminants to levels between the solvent extraction methods and the high temperature methods discussed below.

High Temperature Thermal Destruction

Three high-temperature technologies were demonstrated (McLauglin and Ulerich, 1996;, Bettinger, 1996; Mensinger and Rehmat, 1996). High-temperature treatment effectively destroys the organics. Metal concentrations can be reduced through volatility or through dilution resulting from materials added to produce something suitable for beneficial reuse. The temperature s used in these studies ranged from about 900°C to around 3000°C.

Proposed beneficial end use includes production of blended cement, glass fiber products, and construction aggregate. Most of these have high valued added which will help to reduce the overall treatment cost for decontamination.

Effectiveness of Treatment Technologies

A detailed comparison of the effectiveness of each technology extends far beyond the scope of this survey. The per cent reductions obtained for polynuclear aromatic hydrocarbons (PAHs), dioxins/furans, metals, and poly-chlorinated biphenyls (PCBs) are shown in Fig. 5. The solvent extraction work of BioGenesis and M&E reduce the levels by about one order of magnitude although the Metcalf and Eddy treatment was not effective for metals. The high-temperature thermal methods have reductions for organic contaminants of about three orders of magnitude. Metal concentrations are somewhat reduced by addition of materials for formation of cements or glass and through volatilization in gaseous side streams.

The actual selection of a technology will be driven by many factors, such as treatment cost, so that it is emphasized that the data shown in Fig. 5 represents a small part of the entire story.

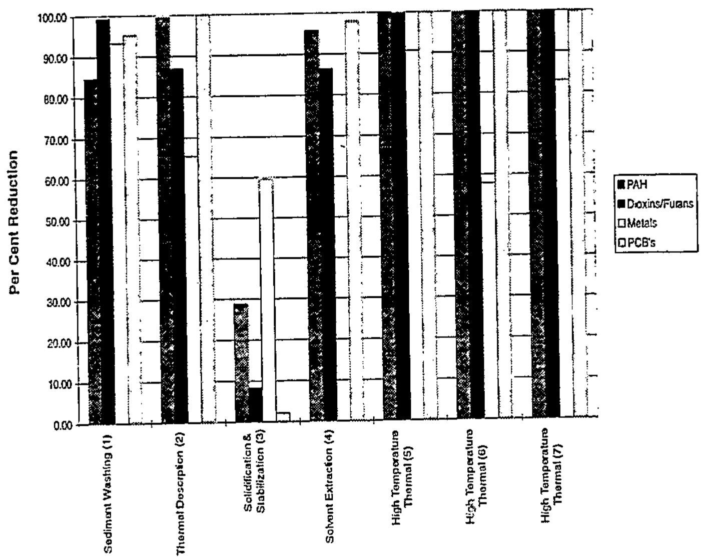


Fig. 5. Summary of technology effectiveness in reduction of contaminants found in dredged material. From left to right the technologies were provided by: 1) BioGenesis, 2) IT Corp., 3) Marcor, 4) Metcalf & Eddy, 5) BioSafe, 6) IGT, 7) Westinghouse.

## Environmental and Human Risks

### Biotoxicity Testing

Disposal of the dredged material in the ocean is governed by criteria based on biotoxicity and bioaccumulation testing in selected species of benthic marine organisms (U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, 1991). At present, there are no federal regulatory testing guidelines for ocean disposal of dredged material that has undergone decontamination or some level of treatment. Unrestricted ocean disposal of dredged material at the NY/NJ Dredged Material Disposal Site (Mud Dump Site) located six miles east of the New Jersey coast has always been the preferred mode of dredged material disposal because of its low cost. For lack of aquatic disposal criteria for post-treated dredged material, upland beneficial use is also being pursued. A preliminary toxicity assessment of sediment decontamination technologies applied to a contaminated marine sediment was made as a first step to determine suitability for placement of treated sediment in an aquatic environment (Ferretti et al., 1996).

Three marine organisms were included in the study design: Ampelisca abdita(amphipod), Mysidopsis bahia (crustacean), and Arbacia punculata (purple sea urchin). The objective of the biological analyses was to determine the effectiveness of removing or reducing toxicity in post-treated sediment. Best survival rates were found for glass produced by Westinghouse (McLauglin and Ulerich, 1996) and the agglomerate of BioSafe (Bettinger, 1996).

Human Exposure

Human exposure and resulting health effects are clearly a primary concern in assessing the impact of the sediment processing facility. A preliminary evaluation of has been carried out (Rowe, et al., 1997).

Consideration was given to occupational exposures to dredging crews and to workers in the processing facility. It was concluded that there would be no significant problems and that scrupulous enforcement of standard occupational health standards would be sufficient. On the other hand, exposure of neighboring population is a more stringent because of the possibility of chronic exposure to side streams of contaminants produced in the processing. In order to investigate this calculations were done for an assumed plant location in Port Newark. Values were found for maximum gaseous and particulate emissions for exposure of the nearest population. The results of the calculation can then be used to set emission rates from any technology used at the facility. Design of the facility has not progressed to the point where firm conclusions on exposures can be drawn. The calculations do give criteria for specifying the efficiency of any air scrubber systems that are part of the system. This is a critical part of the system and an increasing amount of work will be needed during the design stage of a large scale operation.

## Disposal of Processed Dredged Material

### Ocean Disposal

There are many uncertainties in the various legal issues involved in obtaining permission for disposal of the processed dredged material in addition to questions of biotoxicity or bioaccumulation. If these can be resolved the use of the material for capping disposal sites or sub-aqueous disposal pits, habitat restoration, or beach replenishment can be considered. Extensive disposal of the materials in this way presently seems unlikely at this time.

### Beneficial Use and Upland Disposal

Upland disposal presents many different possibilities and is a preferred disposal option at this time. Many options have been proposed in the studies already cited. A further study was carried out at WES (Lee, 1996). As with ocean disposal there are legal issues that need to be resolved and environmental testing criteria that must be promulgated by the states.

It should be feasible to develop end uses for cement, pozzalanic materials, glass, and aggregate produced in the high temperature processes. There is reason to believe that there will be a substantial economic return from the sale of the material in different markets. For example, cement now has a market value of $65/ton in the New York/New Jersey region.

## Public Involvement

One of the lessons to be learned from the efforts to deal with dredged material in the Port of NY/NJ is that public involvement needs to be a prime consideration of any project. For that reason, one component of the present project has been the creation of an active public program that involves information meetings and meetings for public comment, but also has sought actively and continuously to use public involvement in developing the program technologies, in searching for suitable sites, and in bringing about increased interest in the positive potential of this program.

## Creation of a Dredged Material Processing Facility

The end goal of this project is to create a facility that can process sediment on a full-scale basis. In order to do this we have chosen to work in terms of developing a public-private partnership to create and operate the facility. Substantial progress has been made in discussions for providing sites and technologies. Funding for the effort will be raised largely from private sources, but the public participation is essential in overcoming issues involved with permits, contracting for dredged material, public participation, validation of technology effectiveness and other issues. It is believed that the end result will be the creation of a self-sustaining business or businesses that will make a major contribution to solution of the dredged material problem in the NY/NJ region.

Conclusions

The project has to date completed bench-scale testing and small-scale pilot demonstrations of selected treatment processes and has had measured success in demonstrating technologies that can be used to process estuarine dredged material from the Port of NY/NJ. The processed material can be used in environmentally-responsible ways. Preliminary cost estimates of processing the materials have been generated by the technology firms responsible for the studies and may well be competitive with other methods used for managing dredged material.

The crucial phase of the project will extend over the next few years. Presently, it appears that a complete treatment train is feasible from a technical standpoint. The key question at this time is whether timely agreement can be reached with respect to political, financial, public acceptance and other issues that must be resolved.

It should be emphasized that even though this is a very directed project with definite applied goals there are, nevertheless, many scientific and engineering issues that should be investigated to improve the knowledge base upon which the work depends. Improved mechanisms for federal and state support of these topics is needed so that a creative mix of R&D work is brought to bear to improve the efficiency and economy of the processing plants as they go into operation.

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