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SEDIMENT DECONTAMINATION TREATMENT TRAIN:

COMMERCIAL-SCALE DEMONSTRATION

FOR THE PORT OF NEW YORK/NEW JERSEY

K. W. Jones
Brookhaven National Laboratory, Upton, New York 11973-5000

E. A. Stern
U. S. Environmental Protection Agency-Region 2, New York, New York 10007-1866

K. R. Donato
U. S. Army Corps of Engineers-New York District, New York, New York 10278-0090

N. L. Clesceri
Rensselaer Polytechnic Institute, Troy, New York 12180-2080

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SEDIMENT DECONTAMINATION TREATMENT TRAIN: COMMERCIAL-SCALE DEMONSTRATION FOR THE PORT OF NEW YORK/NEW JERSEY

K. W. Jones[1], E. A. Stern[2], K. R. Donato[3], and N. L. Clesceri[4]

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ABSTRACT

Decontamination and beneficial use of dredged material is a component of a comprehensive Dredged Material Management Plan for the Port of New York and New Jersey. We describe here a regional contaminated sediment decontamination program that is being implemented to meet the needs of the Port. The components of the train include: 1) dredging and preliminary physical processing (materials handling), 2) decontamination treatment, 3) beneficial use, and 4) public outreach. Several types of treatment technologies suitable for use with varying levels of sediment contamination have been selected based on the results of bench- and pilot-scale tests. This work is being conducted under the auspices of the Water Resources Development Act (WRDA).

The use of sediment washing is suitable for sediments with low to moderate contamination levels, typical of industrialized waterways. BioGenesis Enterprises and Roy F. Weston, Inc. performed the first phase of an incremental decontamination demonstration with the goal of decontaminating 700 cubic yards (cy) (pilot-scale) for engineering design and cost economics information for commercial scale operations. This pilot test was completed in March, 1999. The next phase will scale-up to operation of a commercial facility capable of treating 40 cy/hr. It is anticipated that this will be completed by January 2000 (250,000 cy/yr). Manufactured topsoil is one beneficial use product from this process.

Tests of two high-temperature treatment technologies are also in progress. They are well suited to produce almost complete destruction of organic compounds in moderate to highly contaminated dredged materials and for production of high-value beneficial reuse products.

The Institute of Gas Technology is demonstrating a natural gas-fired thermochemical manufacturing process with an initial treatment capacity of 30,000 cy/yr into operation by the fall of 1999. Design and construction of a 100,000 cy/yr facility will be based on the operational results obtained from the demonstration facility. The decontaminated dredged material will be converted to a construction-grade cement. Prior bench- and pilot-scale tests showed that this treatment removes 99.99% of the organic contaminants and immobilizes the metals.

The Westinghouse Science and Technology Center has demonstrated use of a high-temperature plasma to achieve 99.99% removal efficiencies for organic contaminants while immobilizing metals in a glass matrix. It was shown that a glass product such as tiles or fibers can be produced and that it can be used for manufacturing high quality glass tiles on a commercial scale.

Keywords: dredged material decontamination, beneficial use, New York/New Jersey Harbor

[1]Jones, K. W., Senior Physicist, Brookhaven National Laboratory, Upton, NY 11973-5000.
[2]Stern, E. A., Regional Contaminated Sediment Program Manager, U.S. Environmental Protection Agency, Region 2, 290 Broadway, New York, NY 10007-1866.
[3]Donato, K. R., Environmental Engineer, U.S. Army Corps of Engineers – New York District, 26 Federal Plaza, New York, NY 10278-0090.
[4]Clesceri, N. L., Professor of Environmental Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180-2080.

INTRODUCTION

Contaminated sediments in the rivers, lakes, and coastal waters of the United States are a major environmental problem (National Research Council, 1989, 1997). In addition, dredging of these waters is often necessary for maintenance of navigation channels and private berthing areas. The disposal of the contaminated dredged material in an environmentally-responsible manner is difficult because of the restrictions placed on both ocean placement and upland disposal by regulators.

A major effort to address the disposal problem through decontamination and beneficial use of the dredged material has been undertaken for the New York/New Jersey Harbor over the past nine years. The funding for the work has been provided through the Water Resources Development Acts (WRDA) of 1990, 1992, and 1996. The WRDA program has progressed through a number of phases: literature survey, bench-scale testing, pilot-scale testing, and the commercialization phase which is in progress. The goal of the WRDA Program will be the construction and implementation of one or more sediment decontamination facilities encompassing a treatment train systems approach that takes the dredged material from the dredging process through decontamination and to a final beneficial use application.

A review of the program is presented here. Many aspects of the program have been discussed as it progressed through the several phases just listed (Jones et al., 1997, 1998; Stern et al. 1998a, 1998b).

DISPOSAL OF DREDGED MATERIAL IN THE PORT OF NEW YORK AND NEW JERSEY

The New York Bight Dredged Material Disposal Site (Mud Dump Site) was designated in 1984 for disposal of up to 100 million cubic yards (cy) of dredged material from the Port and nearby harbors. The Mud Dump Site, and its environs, located 5.3 nautical miles east of Highlands, New Jersey and 9.6 nautical miles south of Rockaway, New York has historically been the major option for dredged material disposal since 1914. Surveys have shown that contaminants in the dredged material were found to cause sediment toxicity and bioaccumulation effects in estuarine organisms. For example, worms at the disposal site were found to accumulate dioxins, and lobsters both dioxins and polychlorinated biphenyls (PCBs). Effective September 19, 1997, the U.S. Environmental Protection Agency (EPA) de-designated and terminated the use of the Mud Dump Site (MDS). Simultaneous with the closure of the Mud Dump Site, the site and surrounding areas that have been used historically as disposal sites for dredged materials were redesignated as the Historic Area Remediation Site (HARS). Approximately 4,000,000 cy needs to be dredged annually from the Port. It is estimated that about 75% of that material must find suitable placement options other than at the HARS.

The major options now in use for non-HARS disposal of dredged material in the Port include solidification/stabilization followed by placement as construction fill or for brownfield remediation and aquatic confined disposal pits in Newark Bay. Solidification/stabilization followed by use for remediation of abandoned mines in Pennsylvania has been utilized as another option for dredged material placement.

Decontamination of the sediments is attractive compared to solidification/stabilization since organic compounds can be destroyed and inorganic compounds either reduced in magnitude or bound to a stable solid. Decontamination technologies need to be able to process on the order of 500,000 cy/yr of dredged material in order to make a significant contribution to the management of dredged material in the Port.

DEVELOPMENT OF THE WRDA TREATMENT TRAIN

The WRDA dredged material *treatment train* has been developed through a number of phases starting with literature surveys and culminating in the near future in the construction and operation of commercial-scale facilities that can treat 500,000 cy/yr or more with high value beneficial use applications. Development of the *treatment train* is considered below.

Study of Alternative Methods for Disposal of Dredged Material

Methods for the handling and disposal of dredged material have been studied and developed for many years. An extensive evaluation of these methods was carried out so that an informed selection of the best existing methods for forming a complete treatment train could be made. The evaluation covered a number of different areas that are summarized below. Overall, the information gathered in this initial study provided a summary of the existing state-of-the-art at this time--1990. This work provided an excellent starting point for planning the later phases of the project.

Evaluation of Innovative Technologies

Information on more than 500 treatment technologies was obtained through inquiries to government agencies and through literature and database surveys. A review of these technologies was performed, and six vendor-specific technologies and eight conceptual technologies were chosen for consideration for further evaluation, testing, and/or development.

Evaluation of Potential Fast-Track Demonstration Technologies

A second evaluation of technologies was done to search for technologies, which had potential for use in a fast-track demonstration at the pilot-scale size scale. Possible technologies were found from discussions with representatives of government agencies and research institutions. More than 400 technologies were found for consideration. After review, 60 technologies were considered to have potential for a fast-track demonstration. More detailed consideration was given in two further reviews using the following criteria: effectiveness, implementability, cost, full-scale suitability, and potential for beneficial use of the post-treated materials. After completion of the three-step selection process, seven technologies were finally selected as the best candidates for further evaluation and testing. The seven types of selected technologies are as follows:

- Low energy extraction process
- Soil and sediment washing
- Critical fluid solvent extraction
- Thermal desorption
- Dehalogenation/stabilization/solidification
- Solidification/stabilization with silicate compounds
- Anaerobic thermal processor.

Demonstration Project Site Screening

A decontamination treatment train must be able to handle dredged material volumes on the order of 500,000 cy/y. There must be rapid processing and turnaround since a decontamination facility may receive up to three barges a day each holding approximately 4800 cy of dredged material. The scale of the operation is such that an appropriate site will need to have an area of 10 to 20 acres, good access to barge, rail, and truck transportation, and crucially, be acceptable to the community in which it is to be located. A list of 27 potential locations in New York and New Jersey was developed. However, many of those sites were found to have serious drawbacks and were eliminated from further consideration during following phases of the decontamination demonstration. In the later phases of this project it has been found most effective to make the site acquisition the responsibility of the private sector since it is envisioned that the private sector will develop a long-term self-sustaining profitable enterprise in decontaminating dredged material from the Port. The federal agencies contribute by "seeding" and verifying technologies and treatment effectiveness to the state agencies responsible for permitting and to the site owners and general public.

Bench- and Pilot-scale Demonstrations

The application of decontamination technologies to the sediments found in the Port of NY/NJ on a scale large enough to significantly contribute to solution of the dredged material management problem is a task that has not been attempted previously in the United States. A phased approach is required to validate the performance of the technologies and to acquire data needed to engineer operational facilities. These needs were met by setting up a series of steps running from an initial technical demonstration at the bench-scale (5 gallons) and pilot-scale (2-20 cy) on through to construction of the final plants. The Phase 2 work was devoted to the bench- and pilot-scale testing steps.

Development of a Treatment Train

Sediment decontamination ties together a series of operations starting with removing sediment from the Harbor and finishing with production of a material that is suitable for disposal or, preferably, beneficial use. In the WRDA Program dredged material is considered a resource since the mineralogy and geotechnical characteristics are conducive to manufacturing beneficial use products. The complete system defines a treatment train. The objective of the testing of decontamination technologies is to provide viable methods for incorporation into the decontamination and beneficial use portions of the treatment train.

The choice of technologies utilized results from the initial surveys and also incorporated findings from the EPA Assessment and Remediation of Contaminated Sediments (ARCS) and Superfund Innovative Technology Evaluation (SITE) programs. However, the characteristics of the estuarine sediments found in the Harbor may differ from those of the fresh water sediments and soils used in the ARCS and SITE tests, and results of the earlier tests needed to be revalidated for the WRDA Program. It was also felt that a series of tests at different volume scales were necessary for actually assembling a viable treatment train.

The guiding principles in selection of technologies for the demonstration testing were:

- selection of a range of approaches for flexibility in treating different sediment types and different levels of contamination
- selection of existing commercially-relevant technologies that could be extended rapidly to full-scale operation.

The bench-scale testing selections actually defined a matrix of technologies that fit into the treatment train concept. They included low-, medium-, and high- temperature methods that could be used to treat dredged material with different contamination levels and yielded different products for beneficial use. Note that this adds parallel tracks into the decontamination procedures so that the path followed by the treatment train can be optimized to fit the needs of the Harbor.

Bench- and Pilot-scale Technology Testing

The specific approaches tested were (listed in order of increasing temperature used in the processing):

U.S. Army Corps of Engineers, Waterways Experiment Station (WES). Manufactured Soil created by addition of compost (yard waste), and other materials such as cellulose and biosolids (cow manure) to the as-dredged sediment.

Manufactured soil production has been developed by WES and applied in test projects such as in Toledo, Ohio. Its inherent simplicity makes it an attractive approach. Initially, contaminant reductions are accomplished only through dilution coming from the addition of materials needed for soil formation. Over time, however, it is possible that organic contaminants may be reduced, e.g., through phytoremediation and other natural methods, although specific data are lacking.

Sites for placement of the manufactured soil will be determined by criteria formulated by the states of New York and New Jersey. For example, comparison with residential and non-residential soil cleanup standards shows that the contaminants in the manufactured soil will exceed standards in several instances. There probably will be sediments that are less contaminated and where this approach could be useful in non-critical applications.

Under the WRDA Program, bench-scale testing was performed in a green house to determine whether the estuarine sediments could be formed into a viable soil. The results were positive and gave values for the relative amounts of the manufactured soil components that formed the most fertile soil. The suitability of the soil for growth of different plant species was tested for tomato, marigold, rye grass, and vinca. The soil was most suitable for the growth of rye grass.

The results of the initial testing showed that a viable soil was formed. The approach gave promise of being able to serve as an alternative for large volumes of dredged material at a potentially low cost. As a variation in this approach, the use of dredged material that had been treated to reduce contaminant levels could eliminate possible questions about placing large amounts of contaminated dredged material in the environment with a possible effect (even perceptual) on environmental and human health. It was therefore considered useful to proceed to carry out a pilot-scale test under actual seasonal weather conditions to be found in the harbor area. The question of salinity tolerance on the plants also needed to be considered.

With cooperation from the Port Authority of New York & New Jersey (PA), the pilot-scale demonstration was performed at a site in PA Port Newark Marine Terminal. A number of test cells were constructed so that the soil composition could be varied and growth of several different plant species could be evaluated. The test period covered two growing seasons. The overall results from the pilot testing corroborated and extended results from the bench-scale tests.

The overall results showed that a viable soil was formed and that, under carefully controlled conditions, use of manufactured soil could be considered for use on a larger-scale project. The advantages of this method include relatively low cost and easy implementation with no need for complex capital equipment or dewatering of the material. The disadvantage is that the degradation of the organic compounds and fate of the heavy metals proceed with unknown rate and pathways so that food chain transfer issues could restrict use as a topsoil. Since the removal and transport of these contaminants is an *in-situ* process that proceeds slowly and unpredictably, long-term monitoring will be required.

It was also concluded that a large-scale demonstration of manufactured soil, if performed under the WRDA program, should be done in conjunction with an actual decontamination technology to ensure creation of an environmentally-safe end product.

WES, International Technology Corporation (IT), Marcor, Metcalf & Eddy(M&E). Solidification/ stabilization (S/S) by addition of Portland cement, fly ash, lime and/or proprietary chemicals to create solid aggregates.

S/S is also a very simple method for treatment of contaminated sediments. The aim is to mix dredged material with cement and other additives to bind the small particles into larger aggregates with improved physical and chemical properties that qualify the treated sediments for use as aggregate in some types of construction projects. These can include landfill closure and brownfield remediation applications. There are several ways in which the S/S technique can be applied. It can be used with untreated sediments, with sediments that have gone through a cleaning process to remove contaminants, or with sediments that have been modified by addition of a chemically-active additive that changes the chemical form of the contaminants.

S/S has been applied in Japan to bottom sediments containing toxic substances and in the United States to industrial wastes as well as to dredged material from New York/New Jersey and Boston Harbors. Laboratory studies have been performed on dredged material from Indiana Harbor, Indiana; Everett Bay, Washington; and Buffalo River, New York.

Tests were performed by WES on untreated sediments. They measured the physical properties of the solidified and stabilized sediments for a number of different cement/fly ash/lime mixtures. It was shown that the physical properties were adequate to meet standards for several beneficial uses in the construction industry. M&E produced cleaned sediment using a solvent extraction technique (see below) which was then followed by S/S. The results of these tests showed that S/S procedures formed materials from the dredged material that had satisfactory physical and chemical properties and defined the optimum proportions of additives for use with the dredged material found in the New York/New Jersey Harbor region.

BioGenesis. Soil washing using a proprietary blend of biodegradable surfactants (detergents), chelating and oxidizing agents, and high pressure water jets (collisions) to remove both organic and inorganic contaminants.

The BioGenesis treatment technology has blended a mechanical scouring of the dredged material particles by high-pressure jets of water with application of oxidizing chemicals and sufactants to clean the particle surfaces. Chelating chemicals are used to render metals soluble so that they are transferred from the solid to the surrounding liquid. The contaminants that are removed from the dredged material are treated by producing bubbles that produce a local region of high temperature that destroys the organic compounds in the water (cavitation-oxidation). Floatable organic material is separated by surface skimming in a flotation tank and metals are precipitated in the form of a sludge which is disposed of at a landfill.

The results obtained during the bench-scale testing showed reductions of the organic compounds by approximately 90% and of inorganic compounds by about 70%. The specific reduction efficiency varied with the particular compound or element considered. The BioGenesis technology is simple in concept and in the type of equipment used, but it is also one that rests on a knowledge of surfactant and sediment chemistry as well as liquid-solid separation techniques for the silts and clays which make up at least 85% of the grain size fractions in the Harbor dredged material. For this reason, the sediment washing approach has great potential for improvement as the process is gradually optimized for the conditions found in the Harbor. The process produces an end material which can be combined with humates, lime, compost, and other materials to form a manufactured topsoil. Any contaminants left in the sediments are diluted by these additions. The overall reduction for organic compounds then becomes about 97% and for inorganic compounds about 90%. This magnitude of decontamination makes it possible to produce manufactured soil which meets the standards for residential soil. Revenue from the sale of this soil can be used to reduce the tipping fee charged for dredging and decontamination of the dredged material.

The BioGenesis approach is now being extended to a large-scale pilot demonstration. The details of the work are discussed below.

Metcalf & Eddy (M&E) Solvent extraction, this is similar in concept to soil washing, but uses organic chemicals such as solvents (alcohols) at an elevated temperature instead.

Solvent extraction procedures are similar to the sediment washing process of BioGenesis in the sense that a chemical solvent is used to remove the surface coatings of contaminated materials. Removal of volume contamination depends on the porosity of the material and the treatment time as well as on the details of the chemical interactions of the contaminants with the bulk material of the sediment. The extraction process operated at a temperature of 37.7-60.0°C and employed isopropyl alcohol and isopropyl acetate as the solvents. These conditions require more elaborate apparatus than the BioGenesis process and require more attention to operating conditions because of fire/explosion hazards.

Pilot-scale experiments were carried out using multiple passes through the system and in a continuous mode (Gasbarro et al., 1998). This particular experiment did not use a chelator, and the metal levels are not substantially reduced. The testing included production of stabilized materials from both untreated and treated dredged material by M&E and the U.S. Army Corps of Engineers Waterways Experiment Station. It was found that compressive strengths of over 100 lbs/in^2 could be achieved. These values are comparable to values reported for a project carried out on dredged material from the Port of Boston.

Battelle Memorial Institute. Base-catalyzed decomposition (BCD).

In work that began in 1978, the BCD process was developed by the EPA Office of Research and Development, Cincinnati. The research work that followed led to the design of a two-stage process. In the first stage of the process, materials containing halogenated contaminants (PCBs, dioxins, and furans) are mixed with sodium bicarbonate and heated to 340°C to vaporize and partially decompose the contaminants. This is a modified thermal desorption process related to the simpler version tested by IT. The vaporized contaminants in the resulting small volume of water and organic condensates then are dehalogenated using heat (340°C), a hydrogen-donor oil, sodium hydroxide, and a catalyst (stage 2). The volatile and semi-volatile organic compounds present in the contaminated dredged material will also be removed by the heat treatment as will inorganic compounds with high vapor pressure or solubility. The removal/destruction efficiency achieved for this application of BCD to estuarine dredged material has excellent success in handling chlorinated compounds (99.88% reduction efficiency). PAHs were not decomposed by the BDC process. It was found that the metals remaining in the treated sediment were not removed during standard leachability tests so that the sediments do not become a hazardous waste by reason of the BCD treatment.

Because the BCD process operates at elevated temperature, the water, volatile and semi-volatile organic compounds and potentially volatile metals will be evaporated and subsequently partitioned into various sidestreams (e.g., condensates and off-gas). Therefore, complex material handling and pollution control systems will be required to treat the various sidestreams to minimize environmental emissions.

Battelle estimated the cost of dredged material decontamination at a BCD treatment facility treating 150,000 cy/yr at $108/cy. The work also shows that there are many unknowns in the process parameters that will require further examination before the design of a full-scale plant would be prudent. The relatively high-cost of treatment, need for further research work, and a probable long time before a plant could be operational made the BCD technology unattractive for further consideration at this time.

International Technology Corporation (IT). Thermal desorption: uses heat to remove surface contaminants. The temperatures used are not high enough to destroy the organic compounds.

IT used thermal desorption to remove organic compounds from the surface of the sediments (Hall et al., 1998). Their laboratory testing was carried out with a small-scale rotary kiln. This is merely a tube containing the sediment that is rotated to mix the sediment while the tube is raised to a high temperature. The variables in the process are the temperature and the time the sediment spends at the elevated temperature.

The results of the bench-scale testing showed that the intermediate treatment temperature was effective in reducing contaminant levels. However, as a consequence of the approach, a side stream of hazardous material was produced that would require disposal at a hazardous waste treatment facility. Proposed beneficial uses for the end product were for applications such as construction fill and habitat restoration. Economic benefits from these applications would be low and this fact combined with a relatively high capital cost made it seem unlikely that a self-sustaining business could be created based on this technology.

Therefore, it was concluded that moving to a pilot-scale test level was not justified.

BioSafe. High-temperature treatment using a fluidized bed heating unit.

BioSafe used a fluidized bed treatment (FBT) to destroy the organic compounds in the dredged material. Metal contaminants are either retained in the treated material or are volatilized and removed from the gaseous side stream.

The FBT process uses fluidized bed steam cracking to totally destroy any organic materials such as dioxins, PCBs, and petroleum products present in the dredged material feed stock. It is a robust process, based on the application of fluid-bed technologies that have been in practice for more than 50 years. The process is not incineration or oxidation. It converts all organic materials to carbon monoxide, hydrogen, and methane--a clean, fuel gas that is recycled in the process. The remaining solids are free of organic material, and (depending on the metal content) may be disposed of without restriction.

Key to the process is the use of fluidized beds as reaction vessels. Fluidized bed operation depends on the fact that when the velocity of a gas flowing upward through a bed of small particles is increased sufficiently, the particles begin to float. At the threshold velocity for fluidization, the bed of material expands upward and behaves as if it were a viscous fluid. Further increasing the velocity of the gas causes the bed to expand by about 30% as bubbles form, and the bed begins to behave like a turbulent boiling fluid. It does not have a sharply defined free upper surface, rather, as the solid fraction decreases in the upper regions of the bed, the gas velocity also decreases and the particles making up the bed are no longer lifted. However, within this bubbling bed, the large gas bubbles that form move upward rapidly and in doing so displace bed material above it, and some circulates downward along the bubbles' upward path. This turbulence provides a significant agitation within the bed which provides a uniform distribution of hot material and temperature within the bed.

The most significant advantage of a fluid bed for thermal applications is the mixing of a large mass of material that is held at a constant temperature. This mass of material provides not only a high thermal inertia, but also a highly conductive heat transfer media. Each particle within the bed is hot (typically the entire bed is maintained within a 10°F range), and acts as a source of heat that transfers via conduction to the material that is introduced. Studies have shown that within fluid beds heat transfer coefficients are 5 to 25 times those for the combustion gas alone. This inherent efficiency is the basis of selection of the fluid bed for the FBT process.

This demonstration was conducted in a pilot-scale unit with a size sufficient to realistically demonstrate the most critical aspects of the process. Data that was indicative of process operation at a size sufficient to measure the effectiveness of the technology for dredged material decontamination and to identify any potential barriers to scale-up to commercial operation were obtained.

The results of the testing procedures showed that:

- The process can operate with a continuous feed of dredged material -
  can use the as-received dredged material (without dewatering), and
- can produce a contaminant-free solid product.
- The destruction efficiency is >99.99% Metals do not leach from the treated sediment.
- Beneficial use options for the treated dredged material include use as clean fill, concrete aggregate, cover material, agricultural material or beach nourishment.

The BioSafe FBT approach was very successful in treating the dredged material. It was deemed worthy of continuing the demonstration at the pilot-scale size. However, changes in the business directions of BioSafe after the conclusion of the bench-scale testing made it impossible to consider them as a candidate for a further demonstration.

Institute of Gas Technology (IGT)/ENDESCO. High-temperature thermal destruction.

The technology employed is that commonly in use at existing cement plants. This is encouraging since it means that existing manufacturing facilities could possibly be devoted to processing of dredged material. There is essentially complete destruction of organic compounds. The metals are reduced by dilution and by loss to the gaseous side-stream. Moreover, the metal values are in the range found for commercially-available cements. Strength tests have been carried out and show that the sediment-derived product meets compressive strength standards. The end product is a marketable, construction grade cement product for use in the concrete and construction industries.

Bench-scale testing was done to demonstrate that the organic contaminants could be destroyed by use of high temperatures and that a useable end product could be created. The particular aim of the demonstration was to show that it was possible to create cement that could be sold on the open market. These results verify that application of high temperatures can remove organic contamination. Blended cement was created by grinding the decontaminated material into a fine powder and adding Portland cement.

The bench-scale testing showed effective decontamination of the dredged material. Creation of a high-value end product, construction grade cement, was verified. It was also shown that the physical properties of the cement were acceptable in comparison with industry standards. Hence, pilot-scale testing was justified as the next step towards creation of an operational facility.

The pilot-scale testing was carried out with a small rotary kiln. In addition to measuring destruction effectiveness under conditions more nearly equivalent to a full scale facility it was also possible to assess the types of compounds that should be emitted to the atmosphere following an exhaust gas scrubbing. The pilot-scale test gives data to serve as the foundation for design of larger facilities. The important results of the pilot testing were:

- Essentially all of the organics contaminants originally present in the sediments were completely destroyed (>99.99% reduction efficiencies).
- The blended cement product readily passes TCLP test for priority metals.
- The blended cement product has a compressive strength that exceeds ASTM requirements for Portland cement.
- The flue gas was devoid of heavy metals, PCBs, chlorophenols, chlorobenzenes, and pesticides.
- The concentration of dioxins/furans in the flue gas were below detection limits on a Toxicty Equivalent Quotient (TEQ) basis.

Westinghouse Science and Technology Center. The Westinghouse Science and Technology Center demonstrated the use of a plasma torch for destruction of organic contaminants and immobilization of metals in a glassy matrix.

The plasma torch is an effective method for heating sediments to temperatures higher than can be achieved in a rotary kiln. Plasma, a high temperature (3,000 ^{o}C), ionized, conductive gas, is created within the plasma torch by the interaction of air with an electric arc. The sediment is melted in the plasma melter using fluxes to produce a target glass product. The molten glass can be quenched to produce a glass aggregate or directly fed to glass manufacturing equipment to produce a salable commercial product. In the plasma melter, all organics are dissociated into elemental species to form clean gasses (i.e., N_2, O_2, H_2O and CO_2). The metals are incorporated into a product glass.

Feeding of the dredged material into the plasma system is more complex since de-watering is necessary, and residence times in the high temperature regions are difficult to adjust. The end goal of the processing is not only to reduce contaminant concentrations, but also to produce a useful final product. Glass tiles and fiberglass materials were successfully produced during the pilot-scale test work. Glass production can, therefore, be considered as successful in reduction of contaminant levels and production of a valuable end product.

The bench-scale testing was carried out in an oven-heated crucible. The testing was designed to show that a useful glass product could be manufactured from the Harbor sediment by addition of chemicals to optimize the major element composition for glass production. The same approach is used by IGT where the composition is adjusted for the manufacture of cement.

The glass produced in the bench-scale tests showed destruction of the organic contaminants by 99.99%. Metals were incorporated in the glass matrix and were not leached out during the TCLP tests. Fiberglass and raw glass for glass tile production were successfully produced showing that there was potential for manufacture of an end product with high-resale value. The economic benefit derived from sale of the product can offset the cost of the energy needed to produce the glass and thus make the overall process economically viable. This is also the case for the IGT cement production.

The results of the bench-scale tests in terms of decontamination efficiency and beneficial reuse prospects were excellent. There was also a clear need for a technology of this type to use for highly contaminated sediments. Consideration of these factors led to a decision to proceed to a pilot-scale demonstration to test the operation of the plasma torch.

The pilot-scale testing was carried out at an operational facility used for demonstrations of the plasma torch. A single torch was used which operated at a power of 2 MW. A second test processed approximately 1000 gallons of sediments at rates up to 4 gallons per minute. The success of these runs showed that the sediment could be vitrified reliably over hours of operation to produce tons of glass product.

A summary of the main conclusions derived from the pilot-scale data is as follows:

- Demonstrated complete 99.9999% destruction of organics in test sediment.
- Demonstrated metal incorporation (80%) into product glass. Leaching tests on glass product show that the glasses passes TCLP by several orders of magnitude.
- Confirmed pre-treatment system design and the filtrate water stream composition. Sediment was successfully dewatered to 58% solids; the filtrate water composition meets discharge criteria.

- Established off-gas compositions, providing the basis for a commercial off-gas treatment system design for SO_x, NO_x, particulate, organic and metal compositions.
- 3,500 pounds of quenched glass products were produced. The glass product was used to demonstrate the feasibility of commercial construction of glass tile.

Summary of Bench- and Pilot-Scale Testing Results

High-temperature treatments were all successful in producing reductions in organic contaminant levels on the order of three or more orders of magnitude. Some reduction of metal concentrations occurred through emission into gaseous side streams and through dilution by additives used to produce cement or glass.

The main drawback of the high-temperature methods rests in the costs associated with the energy required for heating the dredged material to the temperatures above 1000°C used for the treatment. The advantages are the destruction of organics and incorporation of the inorganics in a glassy or cementitious matrix so that they are not likely to leach from the product material. The production of end products that have the potential for high-return beneficial reuse is essential to the economics of these high-temperature processes.

It was concluded from these tests that the high-temperature thermal technologies using temperatures higher than 750°C are extremely effective in destroying organic contamination. The lower temperature thermal desorption process is also effective, but has the disadvantage of creating a sidestream of materials which must then be treated or disposed of in a separate step.

Solidification/stabilization and sediment washing were found to have less effect on the sediments. Analysis of the results suggests that the treatments may, in some cases, change the chemistry of the contaminants and render them more susceptible to leaching. This could affect the contaminant analyses and also suggests the need for further experimentation with the specific chemicals used for the treatments to improve performance and for consideration of the testing procedures themselves. The separations technologies used can also lead to recontamination of the material in the final stages of the process.

The overall conclusions of the work are that it is possible to assemble a complete treatment train that can be used to process dredged material with a wide range of contaminant concentrations. A short discussion of technologies from the three temperature classes is given to indicate regions of application and to touch on some of the drawbacks.

Full-Scale Dredged-Material Decontamination Demonstration (WRDA 1996)

The tests carried out during the pilot-scale demonstrations were successful in defining the major elements of a sediment decontamination treatment train. The goal of the full-scale decontamination demonstration is the construction of one or more facilities capable of treating 500,000 cy/yr of dredged material with end disposal through beneficial use. The facility proper is thus, part of the overall treatment train.

Design of Treatment Train for Sediment Decontamination

Technologies tested during the bench and pilot-scale phases of the WRDA Program can be classified according to the temperature at which they operate: (1) ambient or at least low temperatures (<200°C), (2) intermediate temperatures (~300°C) that do not destroy the organic constituents, and (3) high temperatures above the decomposition point of the organic compounds (>1200°C).

The wide variety of contaminants and differing concentration levels make it plausible to search for technologies that can be applied to specific concentration levels. In addition, the low-temperature technologies may be more acceptable to the local and regulatory communities and they may be easier to permit. The higher temperature technologies may be more applicable to the most contaminated sediments that are found outside of navigational channel and depositional areas. These areas may lend themselves to "hot spot" remediation. High temperature technologies will produce beneficial use products that have higher resale values. Examples of the previously tested technologies that fit each sediment contamination category are:

- Low contamination. S/S, manufactured soil, and phytoremediation. *US Army Corps of Engineers, M&E, IT, Marcor*
- Low to medium contamination. Sediment washing and chemical extraction. *BioGenesis Enterprises Inc.*
- Medium contamination. Solvent extraction. *M&E*
- High contamination. High-temperature thermo-chemical / rotary kiln. *Institute of Gas Technology/ENDESCO*
- High contamination. High-temperature plasma-arc torch. *Westinghouse Science & Technology Center*

Taken together these technologies form the basis of an integrated treatment train for the management of contaminated dredged material from the Port of NY/NJ or other locations worldwide. In the next phase for commercial-scale applicability, the treatment train includes the BioGenesis low-temperature soil-washing method and the IGT/ENDESCO and Westinghouse high temperature methods.

Low Temperature Approach:

Sediment Washing of Untreated Sediment. Under the guidance of Brookhaven National Laboratory (BNL), EPA, WES, and Rensselaer Polytechnic Institute (RPI), BioGenesis conducted several treatability studies during 1997 demonstrating a proof-of-concept with encouraging results for continuation to the pilot-scale and full-scale/commercialization phases.

In the winter of 1998/99 BioGenesis Enterprises in cooperation with Roy F. Weston Inc. has installed advanced sediment-washing equipment at the Koppers Coke Seaboard site in Kearny, New Jersey. The Seaboard site is a former coal gasification, coke-processing facility that is presently undergoing environmental brownfield redevelopment using S/S. BioGenesis/Weston are now demonstrating an integrated treatment train that includes the following: physical separation of the sediments to remove oversize materials, sediment-washing, liquid-solid separation, and beneficial use of the post-treated material. This pilot test is conducted first to determine design engineering parameters, mass balance, economic costing analysis, and beneficial use of a making of manufactured topsoil prior to moving to a large-scale demonstration.

Dredging of 700 cy from a project location in the lower Passaic River/Upper Newark Bay, New Jersey took place in January 1999 for use in the pilot-scale demonstration. Recipes of different manufactured topsoil products will be tested for commercial beneficial use applications. The WRDA Program in partnership with private industry will work together in 1999 to produce a complete facility running at approximately 250,000 cy/yr by the end of 1999/2000. It is projected that a 500,000 cy/yr sediment-washing system can be in operation during fiscal year 2001. The sediment-washing treatment process shall capable of handling a high processing rate (40 cy/hr) of varying grain sizes at varying concentrations of a wide variety of chemical contaminants. The goal is for the treatment process to be performed in a cost-effective manner that identifies public-private partnership situations for funding of a commercial-scale treatment facility in order to fulfill the WRDA mandate.

High Temperature Approach:

IGT/ENDESCO. Natural gas-fired melter with cement-lock technology with beneficial use of post-treated sediment as blended cement. The Institute of Gas Technology (IGT)/ENDESCO will carry out a final design study for a construction grade cement manufacturing facility capable of processing 100,000 cy/yr of dredged material. A 30,000 cy/yr dredged material decontamination and cement manufacturing demonstration is planned for the summer of 1999 (Rehmat et al., 1999). The intention is to operate the facility at a profit through revenues derived from a reasonable tipping and sale of the blended cement.

In 1997-1998 IGT/Endesco started work on designing for commercial scale-up operations. The following tasks were completed:

(1) preliminary design and cost estimation for a 100,000 cy/year plant
(2) piping and instrumentation drawings
(3) equipment lists and descriptions, quotes and total equipment costs
(4) cost estimates for utilities and raw materials costs

The next step, the purchase and installation of a gas-fired melter (rotary kiln) that will process in excess of 30,000 cy/yr is now in progress. Purchase orders for a rotary kiln and ancillary equipment have been placed. Delivery and assembly of the plant by July 1999 is anticipated. The exact location of the demonstration is now being negotiated with the expectation that a decision will be made during the first quarter of 1999. Initial discussions with the State of New Jersey on the necessary permits have been held and permit applications are being prepared. The first step in the work will be a demonstration treating approximately 1,500 to 2,000 cy. This will be completed during the latter half of 1999. Work to treat approximately 30,000 cy will take place in the first quarter of 2000. As BioGenesis, IGT projects a 500,000 cy/yr manufacturing facility to be on-line during fiscal year 2001.

Westinghouse. Plasma-arc vitrification of untreated sediment. A design study for a vitrification facility capable of treating 100,000 cy has been carried out by the Westinghouse Science and Technology Center. The design basis for a 100,000 cy/yr plasma vitrification decontamination facility included the following:

(1) process flow diagrams for 100,000 cy/yr plant
(2) piping and instrumentation drawings
(3) material and energy balance showing the detail for all major process streams
(4) stream flow rates and enthalpies
(5) flow rates of individual solid, liquid, and gas compounds
(6) utility infrastructure
(7) sediment delivery systems
(8) environmental requirements (emission controls)

Westinghouse is presently engaged in a demonstration of the manufacturability of glass tile from the glass produced from the pilot-scale phase testing. Approximately 4,000 pounds of glass produced from treatment of dredged material was converted to glass tile at a tile manufacturing plant located in Wisconsin in early 1999. The WRDA Program team are working with the tile company and the private sector in an effort to commercialize the technology in the NY/NJ Harbor region.

Treatment Train Commercialization

The project was also organized so that it could serve as a general technical resource for the technology firms interested in commercialization of decontamination processes. Efforts have been made to provide assistance both to the firms funded through the project, and also to add firms so as to stimulate a wider technology base and to share knowledge gained with public agencies and the wider general public in the region. The WRDA Program Team routinely collected large volumes of sediments not only for the firms working on the WRDA program but for other firms that requested samples to conduct their own treatability analyses at their own cost.

This has been very rewarding since there have been several instances where contributions have been made to technical aspects of the tests and to the many questions involved in site selection and acquisition. In addition, efforts to expand the technology base have been rewarded by working with additional vendors who could provide existing infrastructure.

At all times it has been recognized that economics is a major driving force in the work. A technically elegant solution is needed, but overall operational costs must be competitive. Funding for the work must be obtained from several sources. While federal and state funds will be available, they will not be sufficient for construction and operation of major facilities. Therefore, private investments must be applied in a major way in the commercialization process.

Public-Private Partnerships

At the inception of the project, the WRDA Program Team introduced the concept of public-private partnerships for the decontamination program. It was evident from the beginning that this was a desirable approach because of the need to gain community support for siting of the decontamination facilities and because public funds were not intended by themselves to construct and operate a facility. This approach would interest private capital in providing funds for the creation of a new type of environmental business sector. The public sector's contribution would be "seeding" applied technology development with a corporate commitment for developing a long-term, sustainable, profitable enterprise. We have explored this approach with a number of technology developers and site owners both within and outside the WRDA program.

Preliminary Estimates for Decontamination Costs

Technologies that are environmentally safe and that effectively decontaminate dredged material are not enough. They must also be economically viable.

Most of the non-HARS dredged material in the NY/NJ Harbor region undergoes S/S with cement and fly ash. This material is used for beneficial use purposes in construction (sub-base for parking lots) and brownfield remediation cover at several locations in New Jersey. Currently, the total cost for dredging, treatment (S/S), and placement ranges from $45 to $55/cy.

Another alternative is placement in an aquatic confined disposal facility (CDF) in Newark Bay at a cost of approximately $32/cy (includes dredging).

We anticipate that the costs for sediment washing, cement production, and glass production will be competitive when full-scale operation is achieved and when the economic benefits of beneficial uses are considered. Preliminary estimates detailed by the private sector for the demonstration-scale level processing costs range from $55 to $90/cy. Larger scale demonstrations planned in 1999 will provide economic information for scale-up volumes as well as information on potential return for beneficial use. The target range of costs for full-scale/commercial-scale operations is to be at or below $35/cy.

There is good reason to believe that lower costs for decontamination can be achieved for the Port of NY/NJ to remain competitive. Competition from other East Coast ports also needs to be considered, in that environmental regulations from different states for handling of dredged material are not uniform and can be more or less stringent than the NY/NJ Harbor benchmark. If other ports attract deep water shipping away from the NY/NJ Harbor, then the entire transportation pattern in the region could change and completely alter the current needs for dredged material management in the Port. From an examination of two technologies undergoing the next phase of scale-up potential, it is believed that preliminary decontamination costs may be low enough to meet the market cost as it is currently projected for other options can be achieved. The actual costs for decontamination in the future will be determined by cost-competitive responses to requests for proposals from USACE, the Port Authority of NY/NJ, and private dredging clients. In the final analysis, decontamination as with any dredged material management option, will be evaluated for its costs with respect to its benefit to the environment and public health of the region.

Beneficial Use

To be used beneficially, treated material must meet applicable state and federal environmental and health and safety guidelines as well as engineering specifications for its proposed end-use. Since the states, and not the federal government, have jurisdiction of upland management of dredged material, the presiding state determines the end-use testing criteria and issues the acceptable/beneficial-use determination for the end product of any treatment process. New Jersey Department of Environmental Protection (NJDEP) recently issued its guidance manual on dredging activities and dredged material. The New York State Department of Environmental Conservation (NYSDEC) is still in the process of finalizing its guidance manual. The acceptability, and therefore the success, of treated dredged material will be based on the ability of a given process to meet these standards at an affordable price. Discussions have been held with the NJDEP and NYSDEC on whether processed dredged material will qualify for an alternate use determination (AUD) in New Jersey or a beneficial use determination (BUD) in New York. Informal reactions in both states have been positive for production and use of soil, cement, and glass. Formal applications will be submitted in 1999.

Technical Transfer/Cooperative Efforts

The WRDA Program in 1999 will continue efforts in its cooperative relationship with the states of New Jersey and New York. These state agencies include the NJ Commerce & Economic Growth Commission, the NJDEP, and the NYDEC. Of noted importance in regional decontamination efforts are five awards by the state of NJ for demonstrations at the pilot- through commercial-scale levels. BioGenesis/Roy F. Weston Inc. and the Institute of Gas Technology are two of the award recipients. WRDA Public Outreach efforts through Rutgers University will continue to build public support for the decontamination programs.

Technology development under the WRDA Program is also being transferred to other states and EPA regions, specifically the Great Lakes National Program Office in EPA Region 5 and the State of Michigan Department of Environmental Quality. They are also supporting sediment decontamination demonstrations by our WRDA Program contractors on fresh water sediments in problematic areas in the Great Lakes region.

SUMMARY

The development and status of a comprehensive treatment train for processing contaminated dredged material in the New York/New Jersey Harbor has been described. A number of different technologies producing different types of beneficial use products can be used to effect the decontamination of the material. The estimated treatment costs are competitive with existing disposal options. The diverse beneficial uses help to ensure that individual markets for the products are not seriously perturbed. At this time it seems that dredged material decontamination can be a cost-effective method and option for placement of dredged material in the Harbor region and that it will be able to process a meaningful fraction of the total dredged material produced per year in the very near future. There are, of course, many steps that are necessary to take to achieve this goal, but none seem to be insolvable. We expect to see a thriving decontamination industry arise by the end of 1999 with further growth expected in 2000/01.

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