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AIMS & SCOPE OF THE JOURNAL

The *Journal of Dredging* is published by the Western Dredging Association (WEDA) to provide dissemination of technical and project information on dredging engineering topics. The peer-reviewed papers in this practice-oriented journal will present engineering solutions to dredging and placement problems, which are not normally available from traditional journals. Topics of interest include, but are not limited to, dredging techniques, hydrographic surveys, dredge automation, dredge safety, instrumentation, design aspects of dredging projects, dredged material placement, environmental and beneficial uses, contaminated sediments, litigation, economic aspects and case studies.

A SPECIAL REPORT ON PIANC'S INNOVATIVE DREDGED SEDIMENT DECONTAMINATION AND TREATMENT TECHNOLOGIES SPECIALTY WORKSHOP

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ABSTRACT

During 1999, the U.S. Section of the Permanent International Association of Navigation Congresses recognized the need to address the state of the practice of innovative dredged sediment decontamination and treatment technologies. As a result, the U.S. Section held its first specialty Workshop on "Innovative Dredged Sediment Decontamination and Treatment Technologies" on May 2, 2000 in Oakland, CA as part of their annual meeting. Objectives of the workshop were to conduct a critical review of selected technologies demonstrated for decontamination and treatment of contaminated dredged sediments generated from large-scale navigation dredging projects and assess the beneficial use potential of the products generated by the technologies. A technical review panel consisted of experts and potential technology users from the navigation industry, private consulting firms, and academia. Invited speakers form a variety of technology development firms made presentations. Six formal presentations were made on technologies being used in the United States and two guest speakers provided additional information on technologies being used in Europe. This paper presents a summary of the dredged sediment decontamination and treatment technologies presented at the PIANC Specialty Conference.

INTRODUCTION

Background

Waterborne cargo alone contributes more than $742 billion to the U.S. gross domestic product and creates employment for more than 13 million citizens (U. S. Department of Transportation, 1999). Vessels of the future, though more cost-efficient transporters will need deeper waterways. Consequently, dredging requirements in the future will increase with this increased demand for navigable depth resulting in an increase in generation of dredged material, including contaminated dredged material (CDM). Please note that contaminated dredged sediments and contaminated dredged material are used interchangeably in this paper.

Estimates of the size of the contaminated sediment problem vary widely with a high degree of uncertainty associated with all the estimates. In 1997, the National Research Council's Marine Board stated that approximately 14 to 28 million cubic yards (MCY) of contaminated sediments out of an average of 283 MCY that are dredged each year have been identified as requiring

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special management (National Research Council, Marine Board 1997). Regardless of the size of the contaminated sediment problem, the Corps of Engineers and Ports must manage increasing amounts of CDM from maintenance dredging each year.

Increasing controversy over adequate management of CDM also adversely impacts the Nation's waterborne transportation infrastructure and commerce by stopping or delaying dredging projects. Notable examples include dredging projects in the New York-New Jersey area and the Great Lakes. In addition, the Nation is facing a monumental task in managing contaminated sediment outside navigation channels without the benefit of cost-effective sediment remediation technologies. Innovative management solutions for these sediments must include affordable decontamination, treatment, and beneficial uses of the residual end products.

Treatment is defined as a way of processing CDM with the aim of reducing the amount of contaminated material or reducing the contamination to meet regulatory standards and criteria. Treatment techniques are available for different types of contaminants in CDM. Some of these techniques are still in a demonstration stage, while others are approaching large-pilot scale or full-scale operations. Because the CDM may contain various mixtures of heavy metals, petroleum hydrocarbons, and organochlorine compounds, they present a formidable challenge to treatment or decontamination technologies. Therefore, significant innovation will be required to bring a viable treatment or decontamination scheme to solve CDM in navigation projects.

RELATED R&D PROGRAMS

Sediment treatment has received much attention in recent years. There are several research and demonstration programs aimed primarily at the need to develop technologies for handling and treatment of contaminated sediments from freshwater and marine ecosystems. Programs have been completed in the Netherlands, Belgium, Germany, Canada, Japan, and the United States (Averett, et. al., 1990; Permanent International Association of Navigation Congresses (PIANC), 1998; Tetra Tech and Averett, 1994). Two pertinent programs conducted in the United States are highlighted in the following sections.

Assessment and Remediation of Contaminated Sediments (ARCS)

The 1987 amendments to the Clean Water Act (CWA), particularly Section 118(c)(3), authorized the U.S. Environmental Protection Agency's (EPA) Great Lakes National Program Office (GLNPO) to coordinate and conduct a 5-year study and demonstration project relating to the appropriate treatment of toxic pollutants in bottom sediments. Five areas were specified in the Act as requiring priority consideration in conducting demonstration projects: Saginaw Bay, Michigan; Sheboygan Harbor, Wisconsin; Grand Calumet River, Indiana; Ashtabula River, Ohio; and Buffalo River, New York.

To fulfill the requirements of the CWA, GLNPO initiated the Assessment and Remediation of Contaminated Sediments (ARCS) Program. The ARCS program completed a number of studies describing alternative physical, chemical, and biological treatment processes and approaches for design and implementation of treatment (Averett, et. al., 1990; EPA, 1994; PIANC, 1996). The ARCS program concluded that there are many technologies available for treating CDM. It also concluded that treatment is generally the most costly component with the least amount of full-scale experience. Treatment processes require additional development for full-scale application. The level of experience in sediment remediation, particularly with treatment processes, is very limited, and there is a high degree of uncertainty with the estimates of costs and contaminant losses from most of these technologies. Reliable cost estimates are only developed through the experience that comes from the execution and observation of multiple full-scale remediation projects.

Water Resources Development Act (WRDA)

The Water Resources Development Acts of 1990, 1992, 1996 and 1999 authorized funding for the purpose of demonstrating on a commercial scale [up to 382,277 cubic meters (500,000 cu yd)] the capability to decontaminate CDM from the harbors of New York and New Jersey (NY/NJ). The goal of the WRDA Decontamination Program is the construction and implementation of one or more sediment decontamination facilities that result in a treatment process train capable of producing a viable end product for beneficial use applications such as construction or fill materials and agricultural grade topsoil (Jones, et. al, 1998). Many of the technologies evaluated for the NY/NJ harbor sediments were reviewed during the PIANC Specialty Workshop.

DESCRIPTION OF THE SPECIALTY WORKSHOP

The objectives of the workshop were to conduct a critical review of selected previously demonstrated technologies for decontamination and treatment of CDM generated from large-scale navigation dredging projects; and, assess the beneficial use potential of the products generated by the technologies. To achieve these objectives, the workshop planners convened a technical review panel consisting of experts and potential technology users from the navigation industry, private consulting firms, and academia; and, invited speakers from a variety of technology development firms (TDF's) to make presentations. Six formal presentations were made on technologies being used in the United States and two guest speakers provided additional information on technologies being used in Europe.

The invited TDF's were requested to focus their presentations on the ability of their technologies to handle the volumes of sediment and production rates typically associated with large-scale navigation dredging projects. They were requested to address the following topics:

(1) Technology Description and Technology Availability
- Description of the technology and its unique characteristics
- Marketable products produced
- Current availability and scale of demonstration
- TDF's capability to fully implement technology

(2) Applicability to Large-Scale Navigation Projects
- Quantity of dredged sediment (or other media) on which technology has been demonstrated
- Demonstrated ability to process dredged sediment (or other media) in excess of 35,000 cu yd per month

(3) Logistical and Regulatory Requirements
- Degree of incorporation of the technology in an overall sediment management program
- Amount of site preparation and required utilities for operation of technology plant
- Particular facility siting requirements including land area
- Environmental and/or regulatory barriers to implementation of the technology

(4) Net Cost
- Potential profit from sale of product resulting from applying technology to dredged sediment
- Estimated costs for ranges of dredged sediment production rates and project size/duration including production costs, delivery costs, and tipping fees
- Particular physical and/or chemical characteristics of dredged sediments that significantly impact costs

The TDF's were also requested to address the following factors where applicable, particularly for those technologies that have not been demonstrated on dredged sediments on a large scale:

- Current state of technology development and time required for commercialization
- Factors affecting technology performance when applied to dredged sediments
- Estimates of performance for application of the technology to dredged sediment remediation
- Factors affecting economics of the technology
- Estimates of the capital and operating costs for the technology for ranges of project sizes
- Examples of application of the technology to dredging projects or remediation of contaminated sediments
- Unknowns or potential problems associated with applications of the technology to dredged sediments
- Health, safety, and environmental risks or related areas of concern associated with application of the technology to dredged sediments

At the conclusion of the presentations, the technical review panel and the audience were invited to ask questions and provide comments. The review panel then provided a brief comparative analysis of each technology as a means of clarifying the information presented and stimulating further discussion between the presenters and the audience. After completion of the comparative analysis, the technology presenters and the review panel led an open discussion on barriers to implementation of the technologies on dredged sediments. Barriers from both the TDF's and potential users' perspective were identified. Possible solutions or ways to minimize the barriers were also discussed.

PRESENTATION OF TECHNOLOGIES

The technologies are categorized under two groups. The first category of technologies includes those that achieve contaminant destruction using thermal processes. The technologies presented, identified by their end product, include:

- Blended (construction-grade) cement
- Building bricks
- Glass aggregate
- Lightweight aggregate

The second category of technologies includes those that achieve contaminant extraction, partial removal, or containment using non-thermal processes. The technologies presented include:

- Flowable fill
- Electrochemical remediation
- Sediment washing
- Solidification/stabilization

The information presented by each TDF is summarized under six topic headings including:

- Technology Description – a description of the technology process, product produced, and unit processes incorporated in the technology.
- Demonstration Scale – the scale at which the technology has been demonstrated, pilot-scale and/or full-scale demonstration sites, and results of demonstrations.
- Commercial Availability – commercial-scale applications, availability of equipment required for commercial application, and actual or proposed applicability to large quantity dredged sediment operations (greater than 35,000 cu yd per month).
- Beneficial Use Applications – description and actual or proposed use of product produced by technology.
- Logistics and regulatory Requirements – amount of total sediment management program achieved by technology, sitting and utility requirements, regulatory requirements including permits based on unit operations and generated wastes or discharges.
- Estimated Costs – estimated capital and operating costs by range of processing rates, required tipping fees, marketability and potential price of produced product, and factors including dredged sediment characteristics affecting costs.

Not all TDF's provided all the information requested as noted in the particular technology discussions. Availability of information varied depending on the demonstration scale achieved for a particular technology. Although some of the information was incomplete, an attempt was made to develop a comparative summary of the information presented in a tabular format. This summary is presented and discussed later in the report. Please note that the information on the various technologies presented and discussed in this report was provided by the TDF's and has not been verified by PIANC or the authors.

In addition to the technology presentations, barriers to implementation of decontamination and treatment technologies, which were identified during the conference, are discussed including economic, logistical, political, and liability barriers. Possible solutions and opportunities to overcome or minimize the barriers are discussed, and conclusions presented.

Thermal Contaminant Destruction Technologies

Blended (Construction-Grade) Cement

The Cement-Lock^{SM} Technology is marketed by ENDESCO Services, Incorporated. Cement-Lock is an advanced thermo-chemical manufacturing process for decontaminating wastes including dredged sediments, soils, and sludges, and producing a marketable product. Using this technology, dredged sediment can be transformed into construction-grade cement that meets ASTM standards. During the process, organic contaminants are destroyed with destruction and removal efficiencies greater than 99% achieved. Heavy metals are immobilized in the cement matrix thus limiting their mobility and allowing for meeting Toxicity Characteristic Leaching Procedure (TCLP) regulatory criteria.

In operation, the water content of the dredged sediment (or other waste) is reduced using waste heat from the thermal process. The sediment is then transferred into a rotary kiln melter identified as an ECOMELT^{TM} Generator where fuel, air, and modifiers are introduced. A clinker-type material, produced in the ECOMELT^{TM} Quench Unit, is transferred to a pulverizer/mixer where additional additives are introduced and mixed resulting in the Cement-Lock construction-grade cement product. Modifiers and additives used in the process are formulated based on the chemical and physical characteristics of the sediment (or other waste) feed stream. Modifiers are inexpensive materials typically used in cement manufacturing. Off-gas from the kiln is treated in a secondary combustion chamber; heat from the gas is recovered for use in drying the feed stream; and, the gas stream is passed through a final cleanup process prior to discharge to the atmosphere.

The Cement-Lock technology has been evaluated on both bench and pilot scales (up to 1 ton per day) for dredged sediments from various sites in New York, New Jersey, and Michigan. A demonstration plant designed to treat 30,000 to 150,000 cu yd of sediment is under construction in New Jersey. Another demonstration will be conducted on 2,000 to 5,000 cu yd of sediment from the Detroit River in Michigan. Engineering has been completed on a 100,000 cu yd/ year process module and a 500,000 cu yd/year plant composed of five modules. The technology has not been demonstrated for large scale (greater than 1,000,000 cu yd) dredging projects.

During these demonstrations, numerous samples were collected for analysis. Analytical results are available on organic contaminant destruction, heavy metal immobilization, pilot-scale air emissions, and cement product quality. The results have shown that the process is effective in destroying organic contaminants, immobilizing metals and producing a quality product. Concentrations of trace metals in the Cement-Lock cement have been shown to be comparable with those reported for Portland cement.

Cement-Lock technology is not currently being used to treat CDM on a commercial scale; however, large-scale demonstration projects will be completed in the near future. All equipment required for commercial application is available. Much of the equipment used in the process is identical to, or similar to, that used in the commercial cement industry. Equipment required for off-gas treatment is routinely used in other industries and is readily available. Various vendors willing to provide turnkey production plants have been identified.

For a large quantity dredged sediment operation (greater than 35,000 cu yd per month) ENDESCO Services proposes to use four Cement-Lock modules, each with a capacity of 100,000 cu yd per year. The production rate would be in excess of 200,000 tons per year; less than 20% of a typical full-scale cement plant. Marketability for this volume of product should be good. Approximately 100 million metric tons of cement is used annually in the United States.

The Cement-Lock product has been tested and shown comparable in performance to commercial Portland cement. In addition to general commercial use, other markets identified by ENDESCO include; general construction for sediment processing stakeholders, grouting of underground storage tanks at Department of Energy/Department of Defense sites, soil conditioning at landfills, sediment stabilization processes, and, construction of retention walls in mines where sediment is used for backfilling.

The Cement-Lock process is only one component of the process train required to move dredged sediment from the channel to the end-use. Transportation and storage for raw and processed sediment must be designed and implemented on a site-specific basis. The processing plant requires a constructed site large enough for the equipment and material storage, with water, fuel, and power utilities. Storage of dredged sediment is required to provide a steady flow of raw sediment to the plant. No wastewater is generated during the process that requires disposal. This excludes wastewater from dewatering that is included in other processes. Debris from the screening process must be transported off site for disposal. No specific residue-requiring disposal was identified as being generated in the off-gas cleanup process.

Variability in the physical and chemical characteristics of the dredged sediments was deemed not to affect the technical performance of the process. Factors identified as affecting process costs are discussed in the "Estimated Cost" section.

With respect to regulatory requirements, the Cement-Lock processing plant requires permits similar to manufacturing process plants including an air permit. No wastewater discharge permit is required, since no wastewater is discharged. Specific permitting requirements will vary depending on the state in which the system is operated.

The capital cost for a 500,000 cu yd/year processing plant is estimated at $100 million. Operating costs were provided based on a dedicated 500,000 cu yd/year plant using a 20-year life span. Several scenarios were detailed including the use of different fuels (natural gas versus high-BTU-content waste slugs) and different market prices for the Cement-Lock product. A full market value for cement of $70.00/ton and a discounted value of $35.00/ton were used for illustrative purposes. The tipping fee required for the process to break even ranged from ($7.66) [profit] to $33.69/cu yd. The profitable scenario was based on use of a waste material as a fuel source for which a tipping fee was collected, and full market value for the cement product.

Favorable costs for the process require a steady and guaranteed supply of sediment or other waste material (i.e., soils, sludges, ash, etc.) and a guaranteed buyer and stable price for a period of at least 10 to 20 years. Several factors that would affect the overall cost were noted. Excessive moisture content would reduce the quantity of product. A non-steady supply of sediment would require larger storage capacity, thus increasing capital costs. Use of additional waste materials, particularly high-BTU materials, would reduce the treatment cost and would supplement and level the feed of raw materials to the process. Non-continuous processing of sediment would increase the product cost.

<u>Building Bricks</u>

Hanseaten-Stein Ziegelei GmbH in Hamburg, Germany manufactures building bricks from CDM. Using this technology, dewatered contaminated sediments from the Port of Hamburg are used in the production of regular bricks suitable for use in the building industry. During the drying and ceramization process, organic contaminants are oxidized and metal contaminants are converted to stable immobile compounds or are volatilized.

In operation, the fine grain portion of dewatered dredge sediments is used as the raw material for the bricks. The sediments dredged from the Port of Hamburg are dewatered and segregated in a system operated by the Port prior to being transported to the Hanseaten-Stein facility. Analytical data indicate that a large percentage of the contaminants are associated with the fine-grained fraction (less than 63 μm) of the sediment. At the manufacturing facility, the sediment is mixed with natural clay and ground brick in a pan mill. The mixture is dried from 30 percent moisture to below 2 percent moisture content using a steam dryer. The water removed (in the form of vapor) is condensed and treated using an activated carbon system. The mixture from the steam dryer is dry-pressed to form the bricks that are then placed in a kiln. The bricks are dried at a temperature of 1,115° F. The temperature is then increased to 1,950° F for the ceramization process. The bricks are cooled and prepared for shipment. Flue gas from the process is treated with calcium hydroxide and activated carbon, and passed through a fabric filter prior to discharge.

The building brick technology is in full-scale production producing 5 million bricks per year utilizing 35,000 metric tons per year of heavily contaminated, dewatered sediments from the Port of Hamburg. The bricks manufactured by the Hanseaten-Stein process have been thoroughly tested and found to be in full compliance with Germany's strict building material regulations. The bricks are being used commercially in Northern Germany's building industry.

Brick manufacturing technology is being used on a commercial scale to treat CDM. Typical brick manufacturing equipment is used. Flue gas is being treated using conventional air pollution treatment equipment.

Currently, approximately 100,000 cu yd of dredged sediment (prior to dewatering) are being used in the process. The capacity of the process could easily be scaled up to handle in excess of 35,000 cu yd/month if a market were developed for the produced bricks.

The bricks produced by the process are suitable for use in all types of commercial and residential building projects. Different sizes and styles of bricks can be manufactured based on market demands.

The Hanseaten-Stein brick manufacturing process is only one component of the process train required to move dredged sediment from the channel to the end use. Since only the fine-grained sediment is used in the process, dewatering and separation of the sediment is required. Transportation and storage or raw sediment and the final brick product are required. The processing plant requires extensive site preparation and facility construction along with water, fuel, and power utilities. Storage of dewatered dredged sediment is required to provide a steady flow of raw sediment to the plant. Storage for the natural clay used in the process is also required. Wastewater from the dewatering process requires treatment prior to discharge.

Debris from the screening and separation process must be managed and disposed of properly. Residue from the flue gas treatment process must also be managed and disposed of properly.

The impact of sediment variability on the technical and economic performance of the process was not discussed. However, the dredged sediment characteristics must be fairly consistent to ensure a quality product.

With respect to regulatory requirements, the Hanseaten-Stein processing plant requires permits for operations including an air permit. A permit for discharge of the wastewater from the dewatering process is required. Permits for disposal of debris and the remaining sediment fraction after screening also are required.

Cost estimates were presented based on a process capacity of 20 to 60 million bricks per year using 300,000 to 900,000 metric tons per year of dredged sediment. This represents an increase of four to twelve times the current production rate of the Hanseaten-Stein plant in Germany. A capital investment of $25 to $80 million would be required excluding the facility required to screen and separate the dredged sediment. The market value for the brick produced was assumed to range from $0.10 to $0.40 per brick. The tipping fee required for the process to break even ranged from $20.00 to $60.00 per metric ton.

Favorable costs for the process require a steady and guaranteed supply of sediment and a stable market for the bricks produced over the life of the plant. Specific factors affecting costs were not identified.

Glass Aggregate

Global Plasma Systems Corporation in partnership with Westinghouse Plasma Corporation, market the Plasma Vitrification Technology. Plasma vitrification is a high-temperature thermal process for converting waste to energy and decontaminating wastes including dredged sediments, wastewater sludge, and bio-solids. Using this technology, dredged sediments can be transformed into molten glass and cooled to form glass aggregate. The aggregate can be used as a raw material in the manufacture of architectural tile, glass fiber, sandblasting grit, roadbed aggregate, and roofing granules. During the process organic contaminants are destroyed by combustion, with destruction efficiencies greater than 99 percent achieved. Heavy metals, along with mineral phases, are fused into glass thus limiting their mobility and meeting TCLP regulatory criteria.

In operation, the dredged sediment is screened and partially dewatered using conventional techniques. The sediment is desalinated with a simple rinsing and dewatering process. The sediment is then injected in front of a plasma torch with temperatures in excess of 5,000° C. Fluxes are added to modify the properties of the final product. The molten material is collected in an associated chamber and passes through a quench chamber from which the vitrified product is collected. The glass aggregate is shipped off site to conventional manufacturing operations where the final products are produced.

The glass aggregate process marketed by Global Plasma Systems has been evaluated on both bench and pilot scales for dredged sediments from New York/New Jersey Harbor. Approximately 17 metric tons of contaminated New York/New Jersey Harbor sediment were converted into glass during several demonstration projects conducted at a demonstration facility operated by Westinghouse Plasma Company and monitored by the U.S. Department of Energy's Brookhaven National Laboratory. A preliminary design for a full-scale plant has been completed. The technology has not been demonstrated for large-scale dredging projects.

During the bench and pilot studies, samples were collected and analyzed. Analytical results are available on glass characteristics, heavy metal immobilization, and organic contaminant destruction. The results indicate that the process is effective in destroying organic contaminants, immobilizing metals, and producing a quality product.

The Global Plasma process is not currently being used on a commercial scale to treat CDM. Global Plasma Systems has signed contracts for full-scale plasma systems to treat waste materials other than sediments in several foreign countries. The equipment required for commercial application is unique to the plasma process and must be designed and fabricated for the application. Conventional screening and dewatering equipment is used for that portion of the process.

Preliminary information was presented on a plant capable of treating 500,000 cu yd per year of sediment. This information is discussed in the "Estimated Cost" section.

Global Plasma Systems has proposed that the glass aggregate produced from dredged sediments can be used as a raw material in a variety of manufacturing applications. As part of the pilot testing conducted, the glass aggregate product was used to produce finished Paver's Tile utilizing a manufacturing technology developed by Futuristic Tile. The tile has a potential high market value. The total market capacity was not quantified.

The Global Plasma process is only one component of the dredged sediment process train required to manage the sediment from generation to end use. Transportation and storage for raw and processed sediment must be designed and implemented on a site-specific basis. The processing plant requires a constructed facility to house the processing equipment and sediment storage with water, fuel, and power utilities. Storage of sediment is required to provide a steady flow of raw material to the plant. Wastewater from the dewatering and desalination processes may require treatment prior to discharge. Debris from the screening process must be managed and disposed of.

The impact of sediment variability on the technical and economic performance of the process was not discussed. However, the dredged sediment characteristics must be fairly consistent to insure a quality product.

With respect to regulatory requirements, a full-scale Global Plasma processing facility would require permits for operation including an air permit or waiver. Permits for discharge of wastewater and disposal of the debris from the screening process would be required.

Cost estimates were presented based on a process capacity of 500,000 cu yd/year generating 139,000 metric tons/year of glass slag that would be used to manufacture 196,000 metric tons/year of tiles. A capital investment of $80 to $90 million would be required. The market value for the tiles manufactured was assumed to range from $1.25 to $2.00 per square foot. The tipping fee required for the process to break even ranged from $25.00 to $29.00/cu yd.

Favorable costs for the process require a steady and guaranteed supply of sediment and a stable market for the glass aggregate produced over the life of the plant. Specific factors affecting costs were not identified. It was noted that additional waste materials could be processed if required to supplement and level raw material feed to the process.

Lightweight Aggregate

The HarborRock Technology is marketed by HarborRock Holdings. HarborRock is a rotary kiln based thermal process for the production of an ASTM-grade expanded clay lightweight aggregate, which is used worldwide in building material applications. Inherent to the high temperature process is the ability to effectively decontaminate dredged sediments. Organic contaminants are thermally destroyed with destruction efficiencies greater than 99 percent. Heavy metals are immobilized in the aggregate thus limiting their mobility and meeting TCLP regulatory criteria.

In operation, the dredged sediment is screened to remove large stones and debris, and then dewatered using mechanical and thermal processes. The dewatered sediment is then processed in a combined grinding and thermal drying process to achieve a uniform consistency. The material is mixed with water and extruded into pellets approximately 0.5 inches in diameter by 1 inch long. The pellets are then fed into a kiln for firing at a temperature in excess of 2,100° F where they expand to about 1.3 times their original size. The expanded clay aggregate is then cooled and stockpiled. Off-gas from the kiln is cooled, with the heat recovered, recycled, and used elsewhere in the process, and passed through a final cleanup process prior to discharge. Residue from screening is landfilled.

The HarborRock lightweight aggregate technology has been evaluated on a bench scale for sediments from various sites on both the East and West coasts. HarborRock is currently developing dredged sediment projects ranging from 500,000 to 3,000,000 cu yd/year. The specific projects were not identified and none are in full operation as yet.

No analytical testing results were presented for the lightweight aggregate product. Test results are reportedly available on ASTM-procedure testing conducted on samples of the product and TCLP testing conducted to determine metals mobility.

The HarborRock process is not currently being applied to dredged sediments on a commercial scale; however, several full-scale projects are under development. The equipment required for commercial application is available. Much of the equipment used in the process is identical to, or similar to, that used in the commercial aggregate manufacturing industry. The mixing and pelletizing equipment is commercially available. Equipment required for off-gas treatment is routinely used in other industries and is readily available. HarborRock has teamed with vendors in the mining industry willing to provide engineering, design, construction, and pyroprocessing equipment. Project specific pilot testing is required to obtain operational data and parameters for scale up to commercial production. This testing can be completed in about 2 months using about 10 cubic yards of material.

Specific information on a system capable of processing greater than 35,000 cu yd/month was not presented. Marketability of the product should be good if required product quality can be continuously met. HarborRock has estimated the national market for lightweight aggregate at

approximately 17 million tons per year with only 10 million tons per year currently being produced or imported.
The HarborRock product has been tested and shown comparable to, or better than, existing commercially available expanded clay, shale or slate lightweight aggregate. Potential applications identified include: geotechnical fill; ready-mix or structural concrete; masonry blocks; specialty concrete products; horticulture; and, road and bridge paving.

The HarborRock manufacturing process is only one component of the dredged sediment process train required to manage dredged sediment from generation to end use. Transportation and storage facilities for raw and processed sediment must be designed and implemented for the specific project. The processing plant requires a constructed site of approximately 15 acres excluding material storage areas. Required utilities include water, fuel, and electric power. Storage of dredged sediment is required to provide a steady flow of raw sediment to the plant. Wastewater from the dewatering process requires treatment prior to disposal. Debris from the screening process must be managed and disposed of.

The impact of sediment variability on the technical and economic performance of the process was not initially discussed. However, the dredged sediment characteristics must be fairly consistent to insure a quality product. During subsequent discussion, HarborRock personnel indicated that high sediment variability would result in a product of lesser quality if the input feed material were processed without screening or refinement.

With respect to regulatory requirements, a HarborRock processing plant would require permits for operation, including an air permit. Permits for discharge of the generated wastewater and disposal of the debris from the screening process would be required.

No project specific capital or operating costs was presented.

Non-Thermal Extractive/Containment Processes

Flowable Fill

Pohlman Materials Recovery markets a flowable-fill technology that consists of a non-thermal, mixing process using chemical additives to transform dredged sediments into a flowable construction fill product. During the process, contaminants are not destroyed, but their mobility is reduced due to chemical stabilization and incorporation in the physical matrix of the product. Reduction in mobility of two to three orders of magnitude is not unusual depending on the contaminant species.

In operation, the dredged sediment is screened to remove large debris and then transferred to a blending mixer. Some dewatering of the sediment may be required prior to processing. Proprietary silicate binders, fine aggregate waste material, and water are added to the mixer and the mixture is thoroughly blended. Once blended, the product is transferred directly to mixer vehicles for immediate transport to the place of use. The product requires immediate use and cannot be stored for any extended period of time. No off-gas requiring treatment is generated during the process.

The Pohlman Materials Recovery flowable fill technology has been evaluated on both bench and pilot scales (up to 30,000 cu yd) for dredged sediments from two sites in New York. Fixed and mobile production facilities have been developed with maximum daily outputs in excess of 6,000 cu yd/day. Production runs of up to 10,000 tons of dredged sediment have been completed. Debris up to sixteen inches in diameter has been successfully passed through the system. The technology has not been demonstrated for large scale dredging projects.

During the demonstrations, analytical testing was conducted but no specific chemical results were presented. Leach testing reportedly indicated a two to three order of magnitude reduction in contaminant mobility. Physical testing indicated strengths of approximately 200 psi after 28 days of curing with some degradation of strength noted after 2 months in a dry environment. Pilot-scale demonstrations have shown that the product characteristics are more than adequate for use as a commercial fill agent. The Port Authority of New York and New Jersey have approved flowable fill product with up to 75-percent dredged sediment content as structural fill.

Pohlman flowable fill technology has been used to process contaminated sediments on a commercial scale at materials processing rates exceeding 200,000 tons per year for a single urban market. Dredged sediment used in the commercial application was obtained from a confined disposal facility. A majority of the equipment required for commercial application is available since the process uses conventional concrete batch plant equipment. Conventional screening equipment is used to remove large debris.

No specific information was presented on a system capable of processing greater than 35,000 cu yd/month; however, sufficient operational data have been developed to allow scale up to that level of production. Such a production rate would require a market for the product in close enough proximity to allow for real time delivery to the site of use since the product cannot be stored.

The flowable fill product is used as a replacement for compacted fill in construction. The product is delivered on demand in a mixer truck to the construction site. It is self-leveling and self-compacting, thus achieving some economy over traditional solid fill material. The product must compete with other fill materials manufactured using waste such as coal ash and foundry sands.

The Pohlman flowable fill process provides several components of the dredged sediment process train required managing sediment from generation to end use. These components include treatment and transportation of the product to the final point of use. Raw sediment transportation and storage must be designed and implemented for the specific project. The processing plant requires a constructed site large enough for the concrete-type batch plant and raw sediment storage. Either a mobile or permanent plant can be set up on the site. Required utilities include water and power. Storage of dredged sediment is required to provide an immediate source of raw material for the on-demand process. Wastewater from any required dewatering requires treatment prior to discharge. Debris from the screening process must be managed and disposed of.

The impact of sediment variability on the technical and economic performance of the process was not discussed. However, the dredged sediment characteristics must be fairly consistent to insure a quality product.

With respect to regulatory requirements, environmental permitting will be required for the Pohlman flowable fill process plant depending on the jurisdiction governing the production facility and the classification of the sediments. Permits for discharge of any generated wastewater and disposal of debris from the screening process would be required.

The capital cost for a processing plant was not presented. Production and delivery costs are estimated to range from $12 to $20/cu yd. Required tipping fees range from $5 to $20/cu yd excluding sediment transportation and management costs. Specific operational factors affecting cost were not presented.

Favorable costs for the process require a steady and guaranteed supply of sediment and a market for the flowable fill product. The product value is variable depending on demand, but typically ranges from $10 to $40/cu yd delivered to the construction site. The product must be competitively priced with similar products available in the area manufactured from other waste materials.

<u>Electrochemical Remediation</u>

Weiss Associates under license to the European technology developer market ElectroChemical Remediation Technologies (ECRTS). There are two principal ECRT technologies: (1) ElectroChemical GeoOxidation (ECGO) which mineralizes organics to their inorganic components, and (2) Induced Complexation (IC) which enhances the mobilization of metals to be plated on electrodes. These technologies can be used as an ex-situ or as an in-situ process. The technologies are based on imposing a direct electrical current through the contaminated material with a superimposed alternating energy current using buried electrodes. The superimposed electrical field creates an induced polarization effect in the sediment that, in turn, induces redox reactions that decompose organic contaminants through ECGO and provide enhanced mobilization of metals through IC. Removal efficiency is contaminant specific and the treatment process treats clays and silts much faster than coarse-grained sands and gravels. The process does not produce a final marketable product, but rather affects a reduction in contaminant concentrations thus allowing: (1) the sediment to be left in place, (2) the sediment disposed as non-hazardous waste, or (3) reuse of the sediment as a soil-like product after further processing.

For application of the technology, the sediment is treated in situ or in a confined area. Electrodes are installed either through borings in the material or as "sheet" piles on approximately 10 meter centers. Local electrical power is passed through proprietary direct current/alternating current converters and then the current is applied to the sediment through electrodes emplaced in the sediment. Optimum remediation is generally achieved in less than 6 months.

The ECRTs have been used primarily to remediate soils in upland locations. The IC technology has been used on a demonstration scale to remediate 168 cubic yards of mercury-contaminated sediment at the Union Canal in Scotland. Additionally, the technology has been evaluated on a bench scale (26.4 gallons) for dredged sediments from the Port of Hamburg, Germany. This technology was developed in Europe and has primarily been applied to sites in Europe. No specific information was presented on pilot or full-scale demonstration of the technology on dredged sediments.

At the Union Canal demonstration project, average total mercury concentrations decreased from 243 mg/kg to 6 mg/kg after 26 days. Analytical results from the 14-day bench-scale test conducted on dredged sediment from the Port of Hamburg indicated an oxidation of organics resulting in the elimination of all color and odor and a marked decrease in metal concentrations. Reduction in metal concentrations ranged from 78 to 94 percent.

The ECRTs are not currently being applied on a commercial scale to treat CDM. Contaminated soil volumes in excess of 150,000 metric tons have been successfully treated in mostly upland applications in Europe. The equipment required for commercial application of the ECRTs is unique but not site specific. System layout must be designed and constructed specifically for each site depending on site characteristics. The equipment used (electrodes, wiring, and generators) is relatively small and easily transported from site to site. Procedures for installation of the electrodes vary depending on the physical characteristic of the material being treated. Specific information on a system capable of treating greater than 35,000 cu yd/month was not presented.

The ECRTs are contaminant treatment processes typically conducted without production of a marketable product as a primary goal. If concentrations of contaminants in dredged sediment can be sufficiently reduced, the treated sediment can be converted to a manufactured soil through addition of bulking materials. Marketability of such a final product was not discussed.

As previously discussed, the ECRTs can be applied either as an ex-situ or in-situ process. With respect to dredged sediment, the process could be applied to sediment previously dredged and managed in a confined disposal facility. The sediment must be trafficable to allow installation of the electrodes and associated wiring. Siting requirements for the equipment are minimal with electrical power being the only utility required for the process. Further processing of the sediment to produce a marketable manufactured soil would require additional equipment and would involve excavation of the sediment and mixing with bulking materials. The product produced would have to be packaged or transported in bulk to the point of sale or reuse. The primary waste stream produced from the application of the ECRTs consists of electrodes plated with metals. Metals can be recovered from the electrodes in a metallic form, which can be recycled.

The affect of sediment variability on the technical and economic performance of the technology was not discussed. Environmental permitting requirements were not discussed.

Capital costs for the equipment were not presented, however, since the technology is a turnkey treatment process, the cost of the equipment is included in the per unit treatment price. For sediment treatment, general preliminary engineering cost estimates for non-specific contaminated materials were estimated to range from $130/cu yd for treatment of 3,000 cu yd of material to less than $33/cu yd for treatment of greater than 100,000 cu yd of material. Specific operational factors affecting cost were reported as: type of contaminant, total physical depth of sediment to be treated, and physical location of the site containing the sediment.

Sediment Washing

Weston and BioGenesis market the BioGenesis Advanced Sediment Washing Technology jointly. This technology is a multi-staged sediment washing and organic oxidation process for decontaminating dredged sediments and producing a marketable fine-grained soil-like product for reuse after the addition of bulking materials. During the process, organic material is stripped from the solid particles. Removal efficiency is contaminant specific.

In operation, the dredged sediment is screened and then high-pressure water and chemical cleaners are used to strip the outer layers of organic material from the sediment particles. Organic material is removed using diffused air flotation. Organic and inorganic material is stripped from the sediment particles using high-pressure water and chemicals in a collision chamber. Organic material is oxidized by means of chemical oxidizer addition and processing in a cavitation unit. Reductions of strongly hydrophobic contaminants have been achieved. The treated sediment slurry is dewatered using a centrifuge and hydrocyclone. Bulking materials are added and mixed to produce a manufactured soil. Wastewater from the process is recycled into the process and/or treated and discharged.

The BioGenesis technology has been evaluated on both bench and pilot scales (up to 10 cu yd/per hour) for dredged sediments from upper Newark Bay. A full-scale system capable of processing 40 cu yd/hour (250,000 cu yd/year) is being designed and will be constructed starting in 2001. The full-scale facility will process contaminated sediment from dredging sites in New Jersey.

During the pilot-scale demonstration, numerous samples were collected for analysis. Analytical results are available on organic contaminant removal, heavy metal removal, air emissions, and physical characteristics.

Results from the testing indicated removal of individual polyaromatic hydrocarbons (PAHs) up to 78 percent and individual metals up to 92 percent, respectively, per washing cycle. Full-scale design data was developed including oxidant dosing requirement, process retention time, and quality requirements for recycled water.

The BioGenesis technology is not currently being used to treat contaminated sediment on a commercial scale. However, plans are in place to have a 250,000-cu-yd/year facility operational by 2002, and increase the capacity to 500,000 cu yd/year by the end of 2002. Some of the equipment required for commercial application of the technology is custom-designed and fabricated. Commercially available equipment is used for material handling and water treatment.

Specific uses and marketability of the treated sediment to be generated from these facilities were not identified. Potential beneficial uses of the treated sediment identified during the presentation are discussed in the next section.

A manufactured soil product was produced from the treated sediment. The treated sediment from the BioGenesis process is proposed for use as or for: manufactured top soil; manufactured potting soil; construction fill aggregate; wetlands restoration; landfill cover; and, Brownfields redevelopment.

The treated sediment from the process has the characteristics of a damp, fine-grained soil. Addition of bulking agents, potentially other waste materials, is generally required to produce a marketable product.

The BioGenesis technology is only one component of the dredged sediment process train required managing sediment from generation to end use. Transportation and storage facilities for raw and processed sediment must be designed and implemented. Barge transportation of dredged sediments is planned for the treatment plants to be constructed over the next 2 years. Site requirements for a 250,000-cu-yd/year facility were identified as 10 to 15 acres for the treatment facility and associated structures, and 5 to 10 acres for treated sediment storage. A 27-acre site has been acquired for construction of the proposed 500,000-cu-yd/year facility. Utility requirements include water and electrical power. Transportation infrastructure is required for transporting large volumes of the final product to the point of ultimate use. Debris from the screening process must be transported off site for disposal. Limited air emissions do not typically require off-gas treatment. Wastewater from the process is treated and recycled into the process with only limited discharge.

Physical and chemical characteristics of the dredged sediment identified as affecting technical and associated economic performance include particle size distribution, and type and concentration of contaminants. Factors affecting economic performance include volume of sediment to be treated and availability of a local market for the manufactured product.

With respect to the environmental regulatory requirements, a BioGenesis processing facility typically requires air discharge, wastewater discharge, and recycling permits. A variety of conventional permits are required for site construction depending on facility location.

A range of capital and operating costs were presented based on the proposed facility to be constructed over the next two years. Initial capital costs were estimated to range from $5 to $10 million with an additional $3 to $5 million required to boost the capacity to 500,000 cu yd/year. Operating costs were estimated to range from in excess of $160/cu yd at 30,000 cu yd/year, to less than $20/cu yd at a processing capacity of 500,000 cu yd/year. Specific elements included in the cost estimates were not identified. Favorable costs for the process require a steady supply of sediment to allow for continuous operation of the facility. Market value for the manufactured soil product and impact on operating costs were not presented.

Solidification/Stabilization

The solidification/stabilization technology presented was developed and used by the OENJ Cherokee Corporation to cap an old city landfill in Elizabeth, New Jersey, using dredged sediment. This technology is a non-thermal, mixing process using chemical additives to transform dredged sediments into a structural capping product. During the process, contaminants are not destroyed, but their mobility is reduced due to chemical stabilization and incorporation in the physical matrix of the product. Reduction in mobility is dependent on the contaminant and the type and amount of chemical additives used.

In operation, the dredged sediment is screened to remove large debris and then transferred to a pug mill. Solidification additives (Portland cement was used for this particular project) are added and mixed into the sediment. The resulting mixture is transported to the work site where it is allowed to dry and gain strength as a result of hydration of the additives. The material is then spread and compacted to provide a smooth, hard surface.

The solidification/stabilization of CDM has been repeatedly demonstrated on all scales. The OENJ Cherokee Elizabeth, New Jersey project was a full-scale commercial operation. A total of 750,000 cu yd of dredged sediment was processed and used as capping material at the site. OENJ Cherokee has initiated another capping project in Bayonne, New Jersey where approximately 4.5 million cu yd of dredged sediment from New York Harbor will be solidified/stabilized using Portland cement, and used to construct a structural cover over a 38-acre former municipal landfill and a 97-acre industrial site. No analytical results on the raw sediment or final product were presented.

The OENJ Cherokee processing plant incorporates conventional equipment including a pug mill, material storage silos, feeder belts, and construction machinery. Other suitable mixing equipment is also commercially available. This process can be readily applied on a commercial basis on sites where structural fill or structural cover is required and dredged sediment of sufficient quantity is conventionally available. The technology can be easily scaled up by increasing equipment size or by operating multiple plants in parallel.

With respect to product marketability, solidified/stabilized dredged sediment can be used as a replacement for compacted fill or capping material in construction, typically in the form of land recovery. The material must be finally placed shortly after processing due to the setting reaction that occurs due to hydration of the cement. Use of contaminated sediment in the process often requires engineering controls to minimize the potential for leaching of contaminants. The material must compete with other materials and processes primarily on an economic basis.

For the projects presented, OENJ Cherokee provided a complete process train for movement of the dredged sediment from the harbor to the end use. A dredging contractor dredged the sediment using a clamshell dredge and placed in barges. The barges were transferred to a docking area adjacent to the site where the sediment was off-loaded and transferred to the processing plant. After processing, the material was trucked to the working face of the capping area and deposited. After curing for a short period of time, the material was spread and compacted.

The processing plant requires a constructed site large enough for the equipment and additive storage. Electric power is the only required utility. The small quantity of water required for equipment washing can be trucked and tanked at the site. No large-scale storage of dredged sediment was required for the project presented due to the method of supply and near availability of the sediment. The process is also applicable to projects where sediment storage is required to maintain a continuous supply of raw sediment. No wastewater or off-gas stream requiring treatment or disposal is generated during the process. Debris from the gross screening process generally must be transported off site for disposal.

The impact of sediment variability on the technical and economic performance of this process was not discussed. However, the dredged sediment characteristics must be fairly consistent to insure a quality product.

With respect to regulatory requirements, the following environmental permitting and approvals are typically required for the process: closure and post-closure approvals (for landfills); remedial investigation and remedial action plan approval; erosion control plan; wetlands delineation; permit to accept recycled materials; acceptable use determination for dredged sediment; development permit; stormwater management plan; and, dredging permits.

No itemized capital or operating costs was presented. The Port Authority of NY/NJ paid OENJ Cherokee $56/cu yd for dredging, transporting, and treating the CDM at the Elizabeth, New Jersey site,

Summary Comparison of Processes and Technologies

A summary of the information presented by the TDF's is presented in Table 1 for comparison purposes. Some of the information is incomplete because it was not presented by the TDF's. In comparing technologies, it should be noted that the technologies vary in their maturity and scale of demonstration. Capital and operation and maintenance (O&M) costs are highly dependent on specific site conditions, dredged sediment characteristics, and the marketability of the product produced

Table 1
Comparison of Decontamination/Treatment Technologies

Evaluation Factors	Technologies							
	Blended (Construction-Grade) Cement	**Building Bricks**	**Glass Aggregate**	**Lightweight Aggregate**	**Flowable Fill**	**Electrochemical Remediation**	**Sediment Washing**	**Solidification/ Stabilization**
Demonstrated on sediments	Sites in New York, New Jersey, and Michigan	Port of Hamburg, Germany	New York Harbor	Various Sites	Sites in New York	Port of Hamburg, Germany and Union Canal, Scotland	Upper Newark Bay	New Jersey New York
Scale of demonstration	Pilot scale (1 ton/day)	Full scale (35,000 metric tons/yr)	Pilot scale (13.4 cu yd)	Bench scale	Full scale (200,000 tons/yr)	Bench scale (100 liters); field-scale (220 cu meters)	Bench and pilot scale (10 cu yd/hr)	Full scale (750,000 cu yd)
Effect on contaminants	Organics thermally oxidized; metals immobilized in cement matrix	Organics thermally oxidized; metals immobilized or volatilized	Organics thermally oxidized; metals immobilized in glass	Organics thermally oxidized; metals immobilized in aggregate	Reduced mobility due to stabilization and incorporatio n in physical matrix	Organics decomposed by redox reactions; metals mobilized to electrodes where they are deposited	Organics are oxidized; metals are removed	Incorporated in physical matrix of product
Commercial availability	Process not applied to sediments on commercial basis; equipment available	Process being conducted on commercial basis; equipment available	Process not applied to sediments on commercial basis; equipment unique to process	Process not applied to sediments on commercial basis; equipment available	Process commerciall y available	Process not applied to sediments on commercial basis; equipment configured specifically for each site	Process not applied to sediments on commercial basis; some of the equipment is custom designed and fabricated	Process commercially available

Table 1 (continued)

Evaluation Factors	Technologies							
	Blended (Construction-Grade) Cement	**Building Bricks**	**Glass Aggregate**	**Lightweight Aggregate**	**Flowable Fill**	**Electrochemical Remediation**	**Sediment Washing**	**Solidification/ Stabilization**
Beneficial uses	Cement for general construction, soil stabilization, and solidification	Commercial/ residential construction	Architectural tile; glass fiber; blasting grit; aggregate; glass cullet	Geotechnical fill; concrete/masonry aggregate; horticulture; road paving	Replacement for compacted fill	Manufactured soil by addition of bulking materials if sediment removed from site	Manufactured soil by addition of bulking materials	Compacted fill; capping
Siting requirements	Land area for melter and material storage; water, fuel, and power utilities	Land area for kiln and material storage; water, fuel, and power utilities	Land area for plasma arc facility; dewatering and desalination facilities; water, fuel, and power utilities	15 acres plus material storage; water, fuel, and power utilities	Land area for batch plant and material storage; water and power utilities	Process is conducted either ex situ or in situ; power utilities	15-25 acres for 250,000-cu yd/yr facility; water and power utilities	Land area for mixing equipment, additive storage; power utilities
Waste streams generated	Debris from screening; off-gas	Debris from screening; wastewater; off-gas	Debris from screening; wastewater	Debris from screening; wastewater; off-gas	Debris from screening; wastewater	Limited residues (sediment remains in place if conducted in situ); electrodes with deposited metals may require disposal or recycling	Debris from screening; limited air emissions; limited wastewater; non-hazardous sludge from water treatment system	Debris from screening

Table 1 (continued)

Evaluation Factors	Technologies							
	Blended (Construction-Grade) Cement	**Building Bricks**	**Glass Aggregate**	**Lightweight Aggregate**	**Flowable Fill**	**Electrochemical Remediation**	**Sediment Washing**	**Solidification/ Stabilization**
Permits required	Air; solid waste	Air; wastewater; solid waste	Air; wastewater; solid waste	Air; wastewater; solid waste	Wastewater; solid waste	None identified	Air and wastewater discharge; recycling	Recycling
Capital costs	\$100 million for 500,000 cu yd/yr	\$25-\$80 million (brick plant only; 300,000 - 900,000 metric tons/yr of sediment)	\$80-\$90 million (500,000 cu yd/yr of sediment)	Not provided	Not provided	Not provided	\$8-\$15 million (500,000 cu yd/yr of sediment)	Not provided
Processing costs	\$45-\$50/ cu yd	\$25-\$75/ metric ton	Not provided	Not provided	\$12-\$20/cu yd	\$130/cu yd for 3,000 cu yd to less than \$33/cu yd for volumes greater than100,000 cu yd	\$160/cu yd for 30,000 cu yd/yr to \$20/cu yd for 500,000 cu yd/yr	\$56/cu yd (includes sediment dredging, transporting, and treating)
Tipping fee required	\$0-\$35/ cu yd	\$20-\$60/ metric ton	\$25-\$29/cu yd	\$15-\$30/cu yd	\$5-\$20/cu yd	Included above	Included above	Included above

BARRIERS TO TECHNOLOGY IMPLEMENTATION

After the technology presentations were completed, an open discussion led by the technology industry representatives and the review panel resulted in the identification of a number of barriers to implementation of the innovative technologies. The barriers identified are briefly discussed below.

(1) The decontamination/treatment technology must be integrated into an overall dredged sediment management plan. A decontamination/treatment process is only one component of the total process train required to manage dredged sediment from generation to final use of the produced product. The decontamination/treatment process must be well integrated into this process train. Transportation, storage, and conditioning of the sediment both before and after treatment processing are other required components of the total process train and must be planned, designed, and implemented so as to optimize the complete process and minimize the total cost of dredged sediment management.

(2) Funding and dredging contracts are typically negotiated on a short-term basis. Federal and state funding for dredging activities is generally appropriated on an annual basis and may expire at the end of the fiscal year. As a result, contracts are written only for the period of time for which the money is available or may require annual appropriation for a longer-term contract. Without long-term contracts and a guarantee of income, it is difficult for TDFs to acquire to the capital required to construct the decontamination/treatment facilities. These types of facilities generally require a long operating period to amortize the initial investment to allow for reasonable unit costs. In addition, TDF's cannot negotiate long-term contracts with chemical, reagent, and material suppliers, which limits their ability to obtain the supplies at the lowest possible price.

(3) Competitive procurement processes discourage capital investment and cooperative agreements. Under current competitive procurement methods and typical single contractor awards, it is generally not economically feasible for TDFs to invest the capital required to construct a processing facility. There is no guarantee that the TDF will be the low bidder on future contract competitions and awards. The TDF must bear the cost of periodic proposal preparation that is passed on to the user as an indirect cost. Competitive procurement and single awards also discourages cooperative activities and agreements between TDFs where sharing of proprietary information is required since the TDFs may be competitors during future procurement actions. Such cooperation between TDFs may be highly beneficial to the agency responsible for dredged sediment management.

(4) Potential delays/work stoppages due to public agencies and/or representatives. The potential sensitivity of dredging projects, particularly those involving contaminated sediments, can result in the delay or stoppage of facility construction and/or operation. Project delay or stoppage represents a significant economic risk to the TDFs.

(5) There is a lack of consistency in, or in some cases an absence of, state regulations covering the marketing and use of recycled CDM. Regulations pertaining to acceptable levels of contamination in recycled sediment products often vary from state to state, making marketing of such products difficult. In some states, no such regulations exist. This represents a potential risk to TDFs trying to market the products since future regulations may result in the products being deemed unacceptable for certain, or all, uses.

(6) There is a poor public perception or fear of certain decontamination/treatment technologies. Certain technologies, i.e., thermal destruction, are poorly received by the public. They do not want such facilities constructed in their "backyard". Such opposition typically results in a lengthy, costly operating permit negotiation. In the worst case, operating permits are denied.

(7) The intermittent nature and variation in chemical and physical characteristics of a typical dredged sediment stream presents a problem with real time application of a decontamination/treatment process. The dredged sediment stream produced by a dredge can be highly variable in flow volume, solids content, particle size, and contaminant concentrations. These variables can significantly affect the successful application of a decontamination/treatment technology, resulting in a poor quality product.

(8) A market for recycled dredged sediment products must be developed. Favorable costs for application of decontamination/treatment technologies generally require that the recycled product produced have a market value. Such a market must generally be developed, which requires effort and time. In some cases, the product must replace other products already in the market place. In these cases, the product must be shown to be superior or less expensive than the existing product.

(9) Product buyers often have a poor perception of recycled product. Recycled products are often deemed to be inferior to virgin products. These perceptions must be overcome by demonstration or price differential to successfully market the product.

(10) Resistance from labor groups to displacement of traditional products and associated jobs. Introduction of a new product (such as a recycled dredged sediment product) into the market place can result in the displacement or replacement of a traditional product. This can result in the loss of jobs or, more typically, a shift in jobs. Labor groups tend to resist such changes that can affect the ability to market the new product.

(11) There are potential long-term product liability and legal responsibilities associated with a recycled product. The manufacturer of a recycled product that incorporates contaminated material is at risk for long-term product liability and the associated legal ramifications. The real or perceived potential public exposure to such contaminants and potential for migration of such contaminants into the environment presents a long-term risk of lawsuits and legal responsibility for cleanup with associated potentially high costs.

OVERCOMING THE BARRIERS TO TECHNOLOGY IMPLEMENTATION

The discussion on barriers to technology implementation led to a discussion of possible methods, activities, and procedural changes, to aid in overcoming or minimizing such barriers. Those identified are briefly discussed below.

(1) Long-term forecasting of dredging requirements and likelihood of funding. Information on long-term dredging requirements from the responsible agencies and estimates of potential funding levels would aid TDFs in preparing for and acquiring funding necessary for technology implementation including design of equipment and facilities. This information should include locations and estimates of volumes and contaminant concentrations.

(2) Public funding of centralized dredged sediment storage and management facilities. Most all of the decontamination/treatment technologies require a continuous supply of fairly homogenous dredged sediment that has been screened and partially dewatered. The agencies responsible for dredging can benefit from having a funded public entity operate a long-term centralized sediment storage and management facility. Sediment from various dredging projects in the area could be stored and conditioned at the facility. Space would be available for various TDFs to construct processing plants on, or adjacent to, the storage facility.

(3) Use of other waste streams to insure continuous feed stream to process. Other waste materials may be available in the area that can be incorporated in the process to minimize the impact of variability in dredge sediment flow to the process

(4) Processing of other waste streams to augment income. Substantial tipping fees may be generated from the treatment of other waste streams using the processing facility. This could help lower the per-unit cost for processing dredged sediment.

(5) Partnering between TDFs would increase the volume of recycled dredge sediment that can be marketed. The market demand for recycled dredge sediment products directly affects the sustainable production rate and the per-unit processing costs. The higher the volume of products sold, the more sediment that can be processed at a favorable per-unit cost to the responsible agency. Thus, the optimum scenario is to have multiple TDFs producing a variety of products, thus reducing the impact of market variability.

(6) Decouple product from the treatment process. With respect to public perception of a product, it is important to de-emphasize the fact that the product is generated from the treatment of CDM. The product should instead be promoted on the basis of its quality and cost advantage for a particular market.

(7) Mandate use of recycled dredged sediment products in public projects. Mandating the use of recycled products in public projects has been successful in creating a market for other waste materials. Such a mandate for recycled dredged sediment products would create and sustain a market for these products. Many of the dredged sediment products can be incorporated as construction materials in construction projects.

(8) Provide education on the benefits of using recycled dredged sediment products. Education of potential product users and the public is required to overcome the poor perception and/or fear of process technology and recycled dredged sediment products.

FINDINGS AND CONCLUSIONS

The focus of the PIANC Specialty Conference was on technologies that are generally applicable to contaminated sediments and that have the potential to process large amounts of sediments, that is, sediment quantities in excess of 1,000,000 cu yd. Essentially all dredged material decontamination/treatment technologies that are capable of processing this quantity of dredged sediment fall into one of two basic categories, thermal destruction technologies and non-thermal technologies that separate or stabilize contaminants. Destruction technologies are generally thermally based. Non-thermal processes often provide only slow or minimal destruction of organic contaminants. Sediment decontamination technologies that are capable of processing large volumes of dredged material are designed to avoid disposal costs for the treated residue by producing a saleable product material.

Thermally based treatment/destruction technologies have the advantage of significant destruction of at least the organic contaminants in the dredged material. Conventional incineration faces significant community acceptance issues despite the potential for achieving essentially complete destruction of the bulk of the contamination. There is a potential for greater community acceptance with the production of blended cement, lightweight aggregate or glass from the dredged material if contaminant migration issues can be resolved. However, the use of cement kilns raises air emissions permit and community acceptance issues similar to those for a conventional incinerator. The production of lightweight aggregate from dredged sediment employs rotary kiln technology for the destruction of contaminants and production of the aggregate. Similar air emission permitting and community acceptance issues can arise. The production of glassy products from dredged material employing a plasma torch has been tested on a demonstration scale. This process has relatively high energy and capital costs but produces a clean product. It is most likely to be used for small volumes of highly contaminated dredged material unless the costs can be offset by the value of the product produced.

Non-thermal separation and stabilization technologies that have been proposed for contaminated sediments include sediment washing and processes that seek to produce fill material in which the contaminants are effectively contained. Soil washing technologies serve to reduce contaminant levels by partial removal of fines and organic material containing contaminants. The net result is a reduction of the more soluble contaminants in the sediments by factors ranging from 2 to 10. Reductions in contaminant concentrations of less soluble components, such as PCBs or high molecular weight PAHs, are likely to be less than a factor of two. In many situations, this may be insufficient to allow significantly expanded uses of the treated material over the untreated dredged material. The goal of most soil washing technologies is production of a manufactured soil.

Stabilization technologies introduce additives to the dredged material to produce flowable or solid fill material. Contaminant levels are normally unchanged except for dilution due to the additives or the mixing with other fill components. The resulting stabilization, however, is expected to significantly reduce the potential for leaching of the contaminants. A significant barrier to use of the resulting material, however, is the lack of regulatory standards for the product. Fill-product criteria based upon total contaminant levels are not likely to significantly expand the potential uses of this material, while fill-product criteria based upon leachate tests such as the TCLP may not receive sufficient community acceptance.

The treatment of CDM becomes more attractive if alternate management options, such as disposal in a less secure (and less expensive) landfill are not available. Some benefit may be gained from partial decontamination, but if there is no potential for expanded use of the dredged material, it is unlikely that these processes can compete economically with direct disposal of the dredged material in a landfill. The products of each of the above processes have the potential to offset part of the cost of treatment, although introduction of these products in large volumes is likely to have a significant negative impact on their value in the marketplace. The costs of these processes are also likely to be high, except when a large-volume dredged sediment stream can be guaranteed to allow the economies of scale. It has been estimated, but not demonstrated, that all processes except the plasma torch technology can be applied for between \$30 and \$70/cu yd of dredged sediment if amounts greater than 100,000 cu yd/year for between 10 and 20 years can be guaranteed. The success of the various technologies and the products they produce currently depends upon community and regulatory acceptance of their respective operations and the proposed uses for the resulting products.

A number of barriers to technology implementation have been identified. These include integration of treatment technologies into overall dredged sediment management; conventional short-term, competitive procurement processes which hinder capital investment and limit the TDF's ability to procure required materials and supplies at the lowest possible price; lack of consistency between or total absence of applicable state regulations on acceptable uses of process products; residual levels of contaminants in products and process effluent streams; public concern about technologies/processes used to treat and manage sediments; intermittent nature and variations in sediment characteristics associated with typical dredging projects; required development of market and acceptance of products produced from dredged sediments; resistance from labor groups to displacement of traditional products and associated jobs; and, long term product liability and legal responsibilities associated with products.

Potential methods, activities, and procedural changes which may aid in overcoming or minimizing such barriers include long-term forecasting of dredging requirements and funding availability; public funding of centralized dredged sediment storage and management facilities; processing of other waste streams in treatment facilities to insure a continuous-feed stream and lower per-unit processing costs based on additional tipping fees; partnering between TDF's to increase overall product markets; decoupling a product from the treatment process; mandating use of recycled dredged sediment products in public projects; and, educating the public in the benefits associated with using recycled dredged sediment products. Some of these changes will probably be required to foster and stimulate the implementation of these innovative decontamination and treatment technologies. Regardless of the decontamination or treatment technology selected for a navigation project, the economic and environmental benefits must be clearly identified and articulated to project sponsors, the public, and other stakeholders.

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REFERENCES

Averett, D. E., B. D., Perry, E. J., Torrey, and J. A. Miller (1990), "*Review of Removal, Containment, and Treatment Technologies for Remediation of Contaminated Sediments in the Great Lakes.*" Miscellaneous Paper EL-90-25. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. (http://www.epa.gov/glnpo/arcs/EL-90-25.html)

Department of Transportation (September 1999). "*An Assessment of the U. S. Marine Transportation System - A Report to Congress.*" (http://www.dot.gov/mts/report/mtslinks.pdf)

Jones, K. W., A. J. Guadagni, E. A. Stern, K. R. Donato, and N. L. Clesceri, 1998. "*Commercialization of Dredged-Material Decontamination Technologies.*" Remediation, Special Issue: Innovative Remediation Technology, Vol. 8, 43-54.

National Research Council, Marine Board (1997). "*Contaminated Sediments in Ports and Waterways - Cleanup Strategies and Technologies*", Committee on Contaminated Marine Sediments, National Academy Press, Washington, D.C. ISBN 0-309-05493-1, TD878.C665. (http://www.nap.edu/order.html)

Permanent International Association of Navigation Congresses, PTC I - Working Group 17, 1996. "*Handling and Treatment of Contaminated Dredged Material from Ports and Inland Waterways- CDM*", Volume 1, PTC I, Report of Working Group no. 17, Supplement to Bulletin No. 89, PIANC General Secretariat, Brussels, Belgium. ISBN 2-87223-072-6.

Permanenet International Association of Navigation Congresses. (1998). "*Handling and Treatment of Contaminated Dredged Material from Ports and Inland Waterways- CDM*", Volume 1 and Volume 2, PTC I, Report of Working Group no. 17, Supplement to Bulletin No. 89, PIANC General Secretariat, Brussels, Belgium. (CD-ROM). (http://www.pianc-aipcn.org)

Tetra Tech, Inc., and D. E. Averett, (1994). "*Options for Treatment and Disposal of Contaminated Sediments from New York/New Jersey Harbor,*" Miscellaneous Paper EL-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Environmental Protection Agency (1994). "*ARCS Remediation Guidance Documents.*" EPA 905-B94-003, Great Lakes National Program Office, Chicago, IL. (http://www.epa.gov/glnpo/arcs/EPA-905-B94-003/EPA-905-B94-003-toc.html)

NOTES FOR CONTRIBUTORS

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$$y = a + b + cx^2 \qquad (1)$$

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Hunt, J.B. (1995). "*Environmental Dredging*". Smith & Son, Inc., New York, NY.

Donegan, T.M., and Dinicola, W.J. (1986). "*Turbidity Associated With Dredging Operations*". Technical Report, XYZ Consultants, Inc., Baltimore, MD., 60 p.

Jones, F., Doe, A., Hart, E.J.E., and Next, J.P.J. (1986). "*The Design of Dredged Material Disposal Sites.*" Proceedings XIVth World Dredging Congress, CEDA, Amsterdam, The Netherlands, pp. 350-368.

White, F.K. and Jones, J.M. (1991). "*The Analysis of Flow Fields Around Dragheads.*" Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, Vol. 121, No. 5, pp. 1-16.

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