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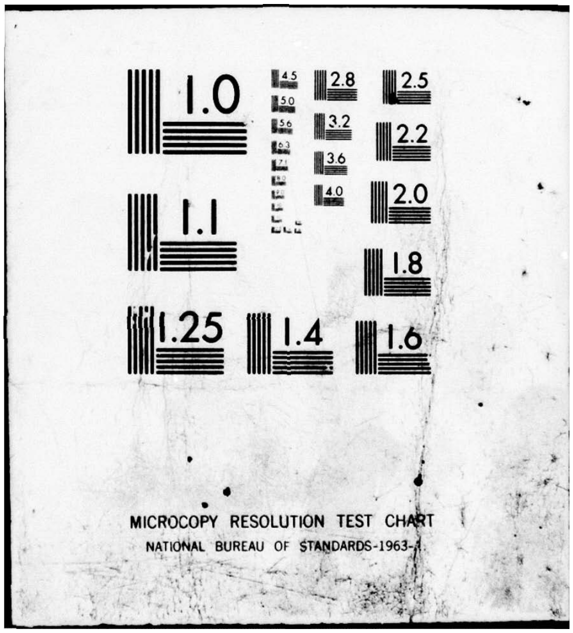

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SYNTHESIS OF RESEARCH RESULTS

DREDGED MATERIAL RESEARCH PROGRAM

LEVEL II

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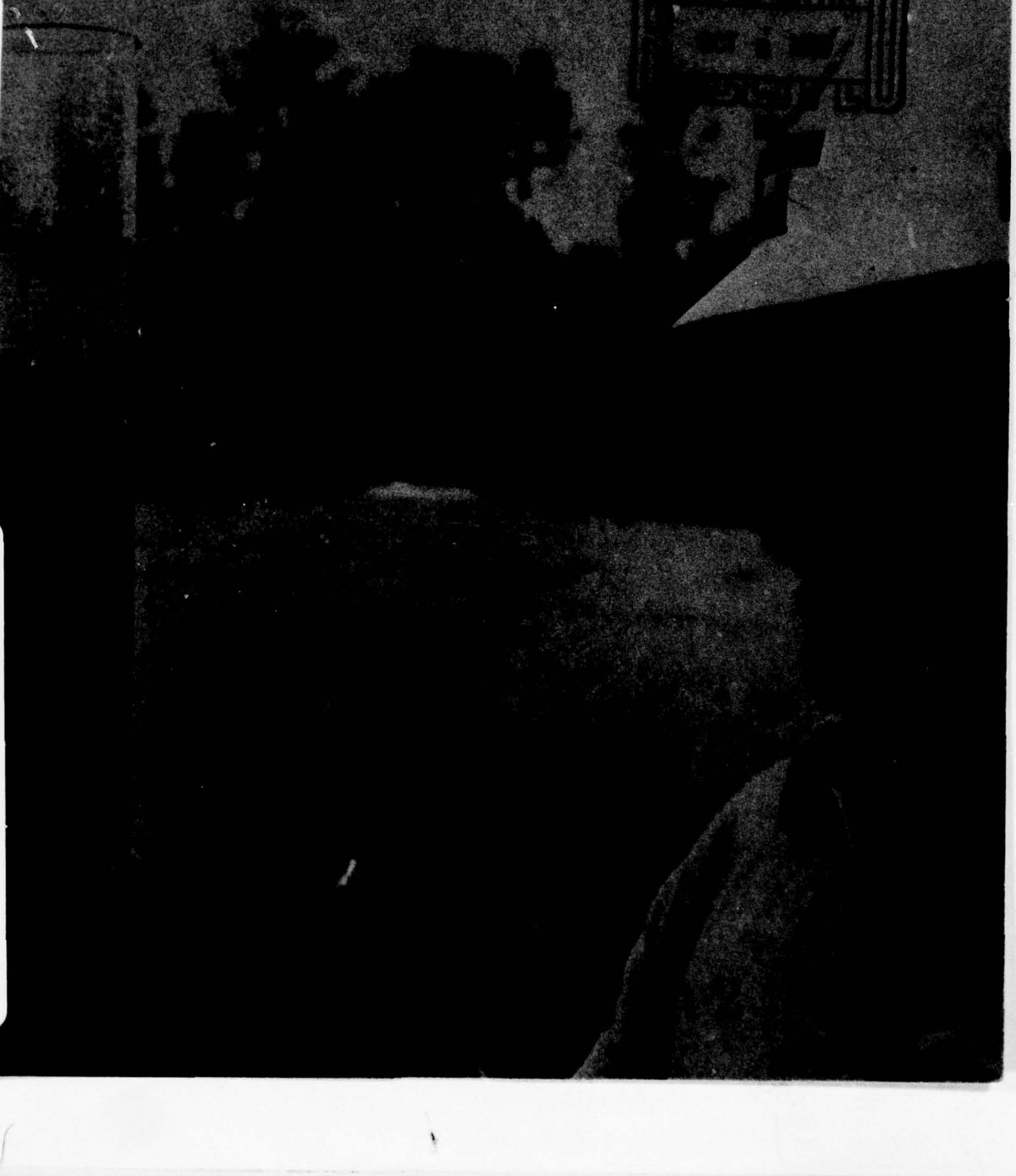
TECHNICAL REPORT DS-78-14

TREATMENT OF CONTAMINATED DREDGED MATERIAL



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DS-78-16	Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation
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Task 6B of the Dredged Material Research Program (DMRP) was established to evaluate physical, chemical, and/or biological processes for treating contaminated dredged material to minimize the environmental impact of open-water and confined disposal operations. Although the majority of the sediments dredged in the United States are not contaminated by significantly high levels of harmful chemical constituents, in some cases treatment may be a necessary → Con't

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part of the dredging or disposal operation. This report synthesizes the results of seven contract research studies and provides an overview of the problems associated with treating dredged material slurries generated by hydraulic dredging operations.

Since the levels of chemical constituents in the effluent water from a containment area are directly related to the amount of fine-grained material suspended in the effluent, retention of fine-grained solids in the containment area results in a maximum degree of retention of potentially toxic chemical constituents. Although the effluent from a properly designed and operated containment area will usually not require further treatment, in certain cases the levels of suspended solids and/or chemical constituents in the effluent water may be in excess of those levels specified by existing criteria. One method for reducing the levels of fine-grained suspended solids levels in the effluent involves treating the containment area effluent or the dredged material slurry with chemical flocculants to enhance the formation of flocs that settle more rapidly than the individual particles. In some situations, direct injection of polymers into the dredge pipeline before the slurry is discharged into the containment area may enhance the sedimentation of the slurry in the containment area enough to achieve acceptable effluent quality.

An alternative mechanism for reducing the suspended solids levels in containment area effluent may involve filtration. The systems that show the most potential applicability for effluent filtering are pervious dikes, sandfill weirs, and granular media cartridges. Discharging containment area effluent through raceways containing certain plant species is another technique that can be used to filter suspended solids from the effluent; however, this technique cannot be endorsed at this time. In some cases, the use of vacuum filters to directly dewater dredged material slurry may be a technically feasible process. Unfortunately, vacuum filtration for most dredged material applications cannot be used economically. On certain operations, it may be necessary to further treat the effluent to remove dissolved chemical constituents and colloidal matter. In these cases, the treatment system must be tailored to the composition and concentration of the constituents to be removed.

During some open-water disposal operations, there may be a need for mitigating the depression of dissolved oxygen levels in the water column in the immediate vicinity of the discharge point. Saturation of the slurry carrier water with dissolved oxygen accomplished through injection of oxygen into the pipeline can marginally reduce the depression of dissolved oxygen levels in the water column. However, the oxygen injection technique is not considered necessary or practical except under environmentally sensitive circumstances. Oxygenation of the dredged material slurry using air injection and injection of chemical oxidants is either ineffective, impractical, or would have adverse effects and is therefore not recommended.

Site-specific treatment problems may be encountered on some operations where a process that was not evaluated in this program may appear to be applicable. In these cases, the advice of consultants specializing in process design should be obtained. Regardless of the nature and magnitude of the treatment problem, it is imperative to consider the compatibility of all the components of the dredging operation, including excavation, transportation, and disposal/treatment, as a total integrated system and not as separate components.

SUMMARY

In response to the increasing concern about the potential adverse environmental impact associated with the dredging and disposal of contaminated bottom sediment, Task 6B of the Dredged Material Research Program (DMRP) was established to evaluate physical, chemical, and/or biological processes for treating contaminated dredged material. Although the majority of the sediments dredged in the United States are not contaminated by significantly high levels of harmful chemical constituents, in some cases treatment may be a necessary part of the dredging or disposal operation. This report synthesizes the results of seven contract research studies under Task 6B and provides an overview of the problems associated with treating dredged material slurries generated by hydraulic dredging operations. The scope of Task 6B research was limited to the treatment of dredged material during disposal operations as a means of improving the quality of effluent from confined disposal areas and minimizing potentially adverse impacts associated with open-water pipeline disposal operations.

In most cases, conventional treatment processes rely on a certain degree of uniformity in the flow and the character of the material being treated in order to maximize the effectiveness of the treatment process and minimize the cost of the operation. Although the chemical constituents present in dredged material are for the most part the same as those found in domestic and industrial wastes, it is often difficult or impossible to apply conventional treatment technology. This is primarily due to the fact that disposal operations are generally not performed continuously at central locations. In addition, relative to typical waste treatment schemes, flow rates generated by hydraulic dredges are high, the solids concentrations in the pipeline are highly variable with time, and the organic content of the slurry is generally low. The large variability in sediment characteristics at dredging sites and the differing environmental conditions present at confined and open-water disposal areas also complicates the application of treatment processes to dredging operations. In all cases, treatment, if deemed necessary, must be evaluated on a site-specific basis.

When dealing with polluted sediment, the primary objective of confined disposal is to isolate the material as completely as possible and to minimize the migration of toxic chemical constituents into the environment. When dredged material slurry is disposed in a well-designed and operated containment area, the vast majority of the solids will settle out of suspension and be retained within the basin. Since the levels of chemical constituents in the effluent water are directly related to the amount of fine-grained material suspended in the effluent, retention of fine-grained solids in the containment area results in a maximum degree of retention of potentially toxic chemical constituents. In most cases, the effluent from a properly designed and operated containment area will not require further treatment. However, in certain instances, the levels of suspended solids and/or chemical constituents in the effluent water may be in excess of those levels specified by existing criteria.

One method for reducing the levels of fine-grained suspended solids levels in the effluent from containment areas involves treating the containment area effluent or the dredged material slurry with chemical flocculants to enhance the formation of flocs that settle more rapidly than the individual particles. Ideally, treatment of containment area effluent requires a polymer feed system, rapid-mix facility, slow-mix facility, and a settling basin or clarifier with an adequate detention time to allow the flocced material to settle. However, in many cases the level of treatment required may not necessitate a sophisticated treatment system. In other words, a system that does not provide optimal feeding, mixing, and clarification conditions but which provides acceptable effluent quality may be adequate.

During some operations, the suspended solids levels in the effluent may only slightly exceed water quality criteria. In these situations, direct injection of flocculants into the dredge pipeline before the slurry is discharged into the containment area may enhance the sedimentation of the slurry in the basin enough to achieve acceptable effluent quality.

Unfortunately, the degree of improvement in effluent quality using pipeline injection is totally unpredictable.

An alternative mechanism for reducing the suspended solids levels in containment area effluent may involve filtration of the effluent. Based on an evaluation of most types of mechanized and non-mechanized surface and depth filters composed of various media, the systems that show the most potential applicability for effluent filtering are pervious dikes, sandfill weirs, and granular media cartridges. Discharging containment area effluent through raceways containing certain plant species is another technique that can be used to filter suspended solids from the effluent. However, this technique cannot be endorsed at this time due to the ecological importance of and political sensitivity surrounding wetlands and marshes. In some cases, the use of vacuum filters to directly dewater dredged material slurry may be a technically feasible process. Unfortunately, vacuum filtration for most dredged material applications cannot be used economically.

On certain operations, it may be necessary not only to remove the suspended material from the effluent, but also to further treat the effluent to remove dissolved chemical constituents and colloidal matter, if their levels exceed those set forth in existing criteria. In these cases, the treatment system must be tailored to the composition and concentration of the constituents to be removed. The design of the treatment system should be accomplished through consultation with specialists in treatment process design and with representatives of companies that produce specific chemical constituents that must be removed. Specific unit processes that may play a prominent role in removing dissolved chemical constituents from containment areas effluent include activated charcoal adsorption, ion exchange, chemical precipitation and air stripping, breakpoint chlorination, and biological nitrification. These processes mentioned above may be used separately or in combination depending upon the settling properties of the material, characteristics of the disposal operation, the dredged material or effluent being treated, and the water quality criteria that must be satisfied.

If prescribed tests and evaluations indicate that the dredged material will have an insignificant adverse effect on the aquatic environment, open-water disposal may be an acceptable alternative. In some cases, there may be a need for mitigating the depression of dissolved oxygen levels in the water column in the immediate vicinity of an open-water pipeline disposal operation or for controlling the generation of turbidity. This latter problem of turbidity control is addressed in Technical Report DS-78-13 entitled "Prediction and Control of Dredged Material Dispersion Around Dredging and Open-Water Pipeline Disposal Operations." Saturation of the slurry carrier water with dissolved oxygen by injecting oxygen into the pipeline can marginally reduce the depression of dissolved oxygen levels in the water column. Since low dissolved oxygen levels are primarily restricted to the fluid mud layer, the oxygen injection technique is not considered necessary or practical except under environmentally sensitive circumstances. Oxygenation of the dredged material slurry using air injection and injection of chemical oxidants is either ineffective, impractical, or would have adverse environmental effects and is therefore not recommended.

The use of flocculants, filtration techniques, and in-line oxygenation may be applicable for treating dredged material slurry at certain disposal operations. However, site-specific treatment problems may be encountered on some operations where processes that were not evaluated in this program may appear to be applicable. In these cases, the advice of consultants specializing in process design should be obtained. Regardless of the nature and magnitude of the treatment problem, it is imperative to consider the compatibility of all the components of the dredging operation, including excavation, transportation, and disposal/treatment, as a total integrated system and not as separate components.

PREFACE

This report synthesizes the results of seven research studies within Task 6B "Treatment of Contaminated Dredged Material" of the Disposal Operations Project (DOP), Dredged Material Research Program (DMRP) and other related work.

Planning and management of Task 6B was performed by Mr. Thomas K. Moore under the general supervision of Mr. Charles C. Calhoun, Jr., Manager of the DOP; Dr. Roger T. Saucier, Special Assistant for Dredged Material Research; and Dr. John Harrison, Chief, Environmental Laboratory. This report was prepared by Dr. William D. Barnard and MAJ Terry D. Hand, CE. This report is also being published as Engineer Manual 1110-2-5021.

The research synthesized in this report was performed by various laboratory groups at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., as well as engineering firms and universities under contract to WES.

Commander and Director of WES during the preparation of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic yards per hour	0.7645549	cubic metres per hour
feet	0.3048	metres
feet per second	0.3048	metres per second
gallons per minute	3.785412	cubic decimetres per minute
gallons (U. S. liquid)	3.785412	cubic decimetres
inches	25.4	millimetres
tons (2,000 lb., mass)	907.1847	kilograms

TREATMENT OF CONTAMINATED DREDGED MATERIAL

PART I: INTRODUTION

Background

1. Although domestic and industrial wastes have been treated for many decades, the recent recognition of potentially toxic chemical constituents associated with some sediments and the concern over the environmental effects of dredging operations have necessitated the consideration of dredged material treatment as a means of reducing the potential adverse impacts of certain dredging and disposal operations. Fortunately, the vast majority of the sediment that is dredged from harbors and waterways in the United States is not grossly contaminated. However, in some instances treatment may be a necessary part of the disposal operation.

Task 6B Research

2. Task 6B of the Dredged Material Research Program (DMRP),[1] entitled "Treatment of Contaminated Dredged Material," was established to evaluate possible physical, chemical, and biological processes for treating dredged material in order to minimize the environmental impact of open-water and confined disposal operations. Ideally, treatment methods should be evaluated after the effects of various contaminants on the ecosystem are known and meaningful criteria for treatment have been established. Because of the time constraints placed on the DMRP, studies within Task 6B were conducted concurrently with other DMRP research addressing the potential adverse impacts of contaminants that are often found in dredged material. Moreover, Task 6B was conducted during the time when standards and criteria were being developed, but did not exist. Therefore, to provide meaningful results, Task 6B goals and objectives were developed in close coordination with those research studies in other related tasks concerned with the environmental impact

of contaminants in dredged material.[2,3] As water-quality criteria and standards evolved during the DMRP,[4] Task 6B research plans were modified and/or redirected. The seven studies actually performed within Task 6B are listed in Table 1.

3. The scope of Task 6B research was limited to the treatment of dredged material during disposal operations as a means of improving the quality of effluent from confined disposal areas and minimizing any adverse impacts associated with open-water pipeline disposal operations. These studies did not address treatment of dredged material already placed in existing disposal areas. Short- and long-term leaching of chemical constituents were addressed in related Task 2D.[3] The information presented in this report includes not only the results of Task 6B, but also incorporates pertinent research results from other related tasks.

Dredged Material Slurry Characterization

4. Dredged material slurry generated by hydraulic pipeline dredges averages approximately 15 percent solids and 85 percent water by weight.[5] The size distribution of the solids may range from clay to sizes larger than gravel depending on the sediment being dredged; the organic content of the sediment usually ranges from 1 to 10 percent by weight.[6] Since the chemical constituents associated with the dredged material are usually in a reduced state, an immediate oxygen demand will be exerted such that the dissolved oxygen level in the slurry water will be essentially zero.[7] The vast majority of any potentially toxic chemical constituents present in bottom sediments is closely associated with the fine-grained material (i.e., the clays) or the organics;[8] consequently, in most cases there are no biologically significant releases of heavy metals or chlorinated and petroleum[9] hydrocarbons to the carrier water over the short term. Nutrients may be released, but usually not at toxic levels.[2] Regardless of the levels of release, containment area effluents and open-water pipeline discharges are usually rapidly diluted

Table 1

Task 6B Research Studies

Research Study	Contractor	Objective
Assessment of the Chemical, Physical, and Biological Processes for Treating Dredged Material	JBF Scinetific Corp. Wilmington, MA (Mr. Edward E. Johanson and Dr. Stewart P. Bowen)	To review the literature on dredged material properties and dredging operations and equipment; assess the suitability of available physical, chemical, and biological treatment processes for treating chemically contaminated dredged material.
Laboratory Treatability of Dredged Material	Waterways Experiment Station Vicksburg, MS (Mr. Thomas K. Moore and Mr. Brooks W. Newbry)	To determine the amenability of various types of contaminated dredged material to physical, chemical, or biological treatment processes through bench-scale treatability studies.
An Evaluation of Oil and Grease Contamination Associated with Dredged Material Containment Areas	Engineering Sciences, Inc. Austin, TX (Dr. Lial F. Tischler)	To examine the oil and grease problem associated with dredged material and to evaluate different processes for removing oil and grease from the effluent from upland containment areas.
Oxygenation of Dredged Material by Direct Injection of Oxygen and Air During Open-Water Pipeline Disposal Operations	JBF Scientific Corp. Wilmington, MA (Mr. Robert W. Neal, Dr. Robert B. Pojasek, and Mr. J. C. Johnson)	To evaluate the feasibility of using in-line injection of oxygen and air to satisfy the oxygen demand of dredged material slurry at open-water pipeline disposal operations through laboratory and field testing.
Laboratory Study of Chemical Coagulation As a Means of Treatment for Dredged Material	University of Southern California Los Angeles, CA (Dr. Chun-Ching Wang and Dr. Kenneth Y. Chen)	To evaluate the effectiveness of flocculants in increasing the settleability of dredged material slurry and removing fine-grained suspended material from containment area effluent.
Development and Application of Design and Operational Procedures for Coagulation and Clarification of Dredged Material Slurry and Effluents from Upland Containment Areas	Jones, Edmonds & Assoc. Gainsville, FL (Dr. Richard H. Jones)	To develop procedure for selecting flocculants and designing application systems for treating dredged material slurry and effluent from containment areas.
Ability of Salt Marshes to Remove Nutrients and Heavy Metals from Dredged Material Disposal Area Effluents	Dr. Herbert L. Windom	To evaluate the efficiency of a marsh system to extract selected trace metals and nutrients from the effluent from a dredged material containment area.

at the discharge site to levels that are not significantly different from background.

Preliminary Evaluation of Conventional Treatment Processes

5. A preliminary evaluation of conventional water and wastewater treatment processes[10] was made based on potential rather than proven effectiveness, since at the time of the study no process had been designed or previously used in the United States for treating dredged material slurry or containment area effluent. Although the chemical constituents present in dredged material are, for the most part, the same as those found in domestic and industrial wastes, it is often difficult or impossible to apply conventional treatment technology to dredged material disposal operations because of several complicating factors:

a. Disposal operations are generally not performed continuously at central locations.

b. Flow rates generated by hydraulic dredges are high [e.g., approximately 32,000 gpm* (46 mgd) for a 30-in. dredge] relative to those flow rates accommodated by most conventional treatment facilities.

c. The solids concentration in the pipeline is highly variable with time. Although the solids concentrations may average approximately 15 percent by weight, the concentration may erratically and rapidly vary from 0 to 40 percent.

d. The organic content of the slurry is generally low relative to domestic wastes.

e. The complex physical and chemical characteristics of the sediment being dredged as well as the environmental and operational conditions usually vary considerably within any particular dredging site.

f. Because dredged material slurry may be disposed in open-water or confined disposal areas, treatment processes must be tailored to the particular mode of disposal.

6. In most cases conventional treatment processes rely on a certain degree of uniformity in the flow and the character of the material

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* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 9.

being treated in order to maximize the effectiveness and minimize the cost of operation. When dealing with dredging and disposal operations, variability is the rule rather than the exception. In addition, the applicability of conventional treatment systems is difficult to assess because of the nonuniformity and/or total absence of treatment standards and rational criteria for evaluating the pollution potential of dredged material. Therefore, the degree to which dredged material slurry must be treated is not always known. In all cases, treatment, if deemed necessary, must be evaluated on a site-specific basis.

7. To provide a framework for discussion, major conventional treatment processes considered in the preliminary evaluation of possible treatment alternatives[10] have been grouped into categories depending on their primary application to conventional treatment. The degree to which dredged material slurry can be treated and the treatment method(s) used depend to a large extent on whether the slurry is disposed in open water or in a containment area. Applicable treatment processes in Table 2 are discussed briefly in light of these two disposal alternatives.

Confined disposal operations

8. When dredged material slurry is disposed in a well-designed and managed containment area, the vast majority of the solids will settle out of suspension and be retained within the settling basin. However, any fine-grained material suspended in the ponded water above the settled solids will be discharged in the effluent water.[11] In addition to the physical presence of suspended solids, the levels of chemical constituents in the effluent water are directly related to the amount of fine-grained material suspended in the effluent.[12] Therefore, retention of fine-grained solids in the containment area results in a maximum degree of retention of potentially toxic chemical constituents.

9. Of the treatment processes shown in Table 2, several in the fine separations category (i.e., plain sedimentation, coagulation-sedimentation, flotation, and filtration) initially appeared to offer the most potential for economically and effectively maximizing the retention of fine-grained solids. Subsequent laboratory experimentation indicated that flotation was generally ineffective.[13] Based on further

Table 2
Conventional Treatment Processes

		Organics	Oil and Grease	Heavy Metals	Organo-halogens	IOD	Suspended Solids	Algal Nutrients	
Simple Separations	Bar Screen						●		
	Coarse Screen						●		
	Classifier						●		
	Hydrocyclone						●		
Fine Separations	Plain Sedimentation	/ ●	●	/ ●	/ ●		●	/ ●	
	Coagulation-Sedimentation	/ ●	●	● / ●	/ ●		●	● / ●	Dissolved P only, not N
	Flotation	/ ●	●	/ ●	/ ●		●	/ ●	
	Fine Screening	/ ●		/ ●	/ ●		●	/ ●	
	Filtration	/ ●	○	/ ●	/ ●		●	/ ●	
	Centrifugation	/ ●	○	/ ●	/ ●		●	/ ●	
	Hydrocyclone	/ ○	○	/ ○	/ ○		○	/ ○	
Treatment of Water Phase	Bio-treatment	○ / ○	○			●	●	● / ●	Adaptations available to separate soluble N and P
	Precipitation	/ ●	●	● / ●	/ ●		●	● / ●	Dissolved P only, not N
	Disinfection								Destroys Pathogen
Solids Pretreatment	Thickening						●		
	Flotation						●		
	Digestion								
	Chemical Conditioning						●		
	Heat Conditioning						●		Solubilizes organics
	Freeze Conditioning						●		
	Chemical Conversion						●		
Solids Dewatering	Vacuum Filtration						○		
	Centrifugation						●		
	Drying Beds						●		
	Heat Drying						●		
Pollutant Oxidation	Multiple Hearth Furnace	●	●		●				
	Fluidized Bed Incinerator	●	●		●				
	Wet Oxidation	●	●		○				
In-Pipe Treatment	Oxygenation					●			
	Precipitation			●				○	

Dissolved / Particulate

Blank	No effect
●	Significant effect
○	Possible effect

laboratory and field observations, plain sedimentation appeared to be the simplest and most effective process for retaining the majority of the dredged material solids in the containment area. However, in some cases the suspended solids/contaminant levels in the effluent from containment areas (after sedimentation) may still exceed applicable criteria. Therefore, additional laboratory and field research was performed to evaluate (1) several techniques for filtering the effluent[14] and (2) the ability of flocculants to increase the rate and extent of settling of the fine-grained suspended solids.[15,16] After solids removal has been accomplished, if any dissolved contaminants remain in the effluent at concentrations exceeding existing discharge limitations or water-quality standards, then further treatment of the effluent may be necessary before it is finally discharged. The most promising methods for treating dredged material slurry at upland disposal operations are described in more detail in Part II.

Open-water pipeline disposal operations

10. If required tests and evaluations indicate that the dredged material will have an insignificant adverse effect on the aquatic environment, open-water disposal may be the most acceptable and economic alternative. One of the major concerns about open-water pipeline disposal operations involves the impact resulting from the release of chemical constitutents from the dredged material slurry. However, there are now ample research results indicating that the traditional fears of water-quality degradation resulting from the release of potentially toxic chemical constituents from dredged material are for the most part unfounded.[2] In the immediate vicinity of open-water pipeline disposal operations, levels of manganese, iron, ammonium nitrogen, orthophosphate, and reactive silica may be increased somewhat, but because of dilution there are no well-defined plumes of dissolved metals or nutrients at levels significantly greater than background conditions.[17]

11. In some cases there may be a need for mitigating the depression of dissolved oxygen levels in the water column in the immediate vicinity of the discharge point or for controlling the generation of turbidity. Task 6C of the DMRP, entitled "Turbidity Prediction and

Control,"[18] was established to investigate the latter problem of turbidity and to develop the capability for predicting turbidity plume characteristics downcurrent from dredging and disposal operations. In addition, measures for controlling turbidity generation were also evaluated in some detail within this task. With respect to reducing the degree of dissolved oxygen depletion in the water column in the vicinity of open-water pipeline disposal operations, laboratory studies indicated that oxygenation of dredged material slurry provided a treatment alternative[13] that warranted further field testing.[7] The effectiveness of in-line oxygenation of dredged material slurry will be discussed in Part III.

Site-Specific Treatment Problems

12. The use of flocculants, filtration techniques, and in-line oxygentation was evaluated in the field because of the potential applicability to the typical disposal operation. However, site-specific treatment problems may be encountered on some operations where a process that was not tested in this program may appear to be applicable. In this case, the advice of consultants specializing in process design should be obtained. The capabilities and limitations of each process listed in Table 2 are discussed in more detail by Johanson and Bowen.[10]

PART II: TREATMENT DURING CONFINED DISPOSAL OPERATIONS

Introduction

13. If open-water disposal sites are not available or if the prescribed test procedures indicate that the sediment is polluted, the dredged material will probably be confined in a containment area. When dealing with polluted sediment, the primary objective of confined disposal is to isolate the material as completely as possible and minimize the migration of toxic chemical constituents into the environment.

14. Sediment destined for confined disposal can be removed from the dredging site with a mechanical dredge (e.g., clamshell or dipper) at nearly its in situ density and transported to the containment area on a barge. Unfortunately, production rates are low and levels of turbidity in the water column at the dredging site are relatively high. For these reasons hydraulic dredges are more often used to excavate and transport the material to the disposal area as a slurry. Although hydraulic dredge production rates are relatively high, the slurry contains large quantities of dredging site water (i.e., approximately 85 percent by weight) that can either be (1) permanently stored in the containment area or (2) temporarily contained to allow settling of most of the fine-grained suspended solids before the ponded water is discharged. Since complete retention of the water would require prohibitively large containment areas, it is usually discharged over a weir located as far from the dredge's discharge pipe as possible to maximize retention of the solids.

Primary treatment: settling of the solids

15. The primary treatment for dredged material slurry disposed in diked containment areas involves settling of the solids. Although most of the solids readily settle, some fine-grained particulate and colloidal material may remain suspended in the ponded water causing the containment area effluent to be excessively turbid or to have an objectionably high suspended solids concentration. Moreover, since most of

the chemical contaminants in polluted sediments are closely associated with the fine-grained inorganic components of the sediment and are not readily released to solution, a high level of suspended solids in the containment area effluent will generally indicate a high level of chemical contaminants. This fact underscores the immense importance of solids removal, particularly fine-grained solids, in any system for treating dredged material.

Determining the need for additional treatment

16. In most cases the effluent from a properly designed and operated containment area will not require further treatment. However, in certain instances the levels of suspended solids and/or chemical constituents in the effluent water may be in excess of those levels specified by existing criteria. In those cases, further treatment of the slurry or containment area effluent for additional removal of the fine-grained material may be necessary to prevent potentially harmful contaminants from being discharged with the effluent water.

17. Presently there are no uniform national criteria for determining the contamination potential associated with the effluent from containment areas. Qualitative indications of a potential need for additional treatment of an effluent can be obtained by evaluating existing information derived from procedures such as bulk sediment analysis, elutriate tests, and bioassays, and also by considering existing sources of contamination, such as industrial discharges and background conditions in the area to be dredged. Unfortunately, it is very difficult to accurately and quantitatively predict the quality of an effluent that may be discharged from a containment area. In some cases data from similar past operations may indicate potential treatment needs. Based on the results of settling tests, the suspended solids levels in the effluent can be estimated knowing the dredge discharge rate, the type of dredged material, and the existing or planned design of the containment area.[11] Suspended solids levels for an effluent from a properly designed and operated containment area will normally be approximately 1 to 2 g/ℓ.[11] With respect to water chemistry, the elutriate test will

qualitatively indicate those chemical constituents (such as iron, manganese, ammonia, and orthophosphate) that may be released to solution; however, there is at this time no standard procedure for quantitatively predicting the chemical composition of the effluent water.

18. If applicable environmental policies require prediction of effluent composition, an unverified, but logical, approach for obtaining a quantitative estimate might involve preparation of a sediment slurry with a solids content of 15 percent by weight using samples of sediment and near-bottom water from the dredging site. The slurry is then allowed to settle for a time period that may be equal to the average detention time of the containment area. The water and suspended material overlying the settled slurry can be thought of as a simulated containment area effluent and analyzed to quantitatively determine its physical and chemical composition. This estimate can then be compared to existing water-quality standards and the characteristics of the water into which the effluent will be discharged to determine the necessity for additional treatment. The type and degree of treatment that may be necessary will of course be dependent on the character and concentration of the contaminants of concern.

Levels of treatment

19. If the results of the settling tests used for the design of the containment areas[5,11] and/or the results of the above-suggested test indicate that levels of suspended solids or chemical constituents may exceed the applicable criteria, a system for treating the effluent can be designed and incorporated into the disposal operation. In the absence of a fully engineered treatment system, several expedient measures can be employed to enhance retention of the suspended solids within a containment area of a given size prior to effluent discharge. They include: intermittent pumping, increasing the depth of ponded water,[11] increasing the effective length of the weir, discontinuing the operations, or decreasing the size of the dredge.

Treatment Processes

20. If applicable water-quality criteria or effluent limitations cannot be satisfied through proper containment area sizing, design, operation, and management, the treatment processes evaluated under the DMRP and described below may be incorporated into the containment area design to reduce the levels of suspended solids in the effluent. These procedures may be used separately or in combination, depending on the settling properties of the material, the characteristics of the disposal operations, the dredged material or effluent being treated, and the water-quality criteria that must be satisfied. In other words, the system should be designed based on the degree of anticipated treatment. To maximize the effectiveness of the operation, any proposed treatment processes should be tested on a pilot scale using the dredged material or a simulated effluent.

Chemical coagulation of containment area effluent and dredged material slurry[15,16]

21. One method for reducing the levels of fine-grained (clay-sized) suspended solids levels in the effluent involves treating the containment area effluent or the dredged material slurry with chemical flocculants to enhance the formation of flocs (i.e., particle agglomerates) that settle more rapidly than the individual particles. This agglomeration or coagulation process is accomplished by alteration of the electrochemical properties of the clay particles and/or the bridging of particles and small flocs by long polymer chains.

22. Flocculant types. There are two basic types of flocculants that may be used to treat dredged material suspensions: (1) inorganic compounds, such as aluminum sulfate, hydrated lime, ferric chloride or ferric sulfate, and (2) synthetic organic polymers or polyelectrolytes.

a. Inorganic flocculants are used extensively in the treatment of industrial and domestic wastewater as well as drinking water, but are not generally recommended for treating suspensions with high solids concentrations due to the large doses that are usually required. In addition, the pH of the suspension must be closely controlled to obtain optimum flocculation. Inorganic flocculants may be effective where solids concentrations are relatively low or when used in combination with polyelectrolytes. To obtain effective coagulation of suspensions, inorganic flocculants require initial flash-mixing into the suspension for 15 to 30 sec followed by a period of slow mixing for 5 to 10 min.

b. Organic polyelectrolytes, long-chained polymers, are classified as cationic, anionic, or nonionic, depending on the character of the net charge of the chemical groups arranged along the polymer chain. Molecular weights may range from a few hundred to several million. Cationic polyelectrolytes appear to possess the most potential for coagulating freshwater dredged material; in saltwater environments, anionic and nonionic as well as cationic polyelectrolytes are potentially effective. Although polyelectrolytes are more expensive than the inorganic flocculants, their optimum doses are usually much smaller; thus, they are usually more cost effective. Polyelectrolytes are sold either as a liquid or in dry powder or granular form. The range of physical/chemical characteristics (i.e., density, viscosity, toxicity, molecular weight, etc.) of the several thousand available polymers is extremely broad. A list of major manufacturers is given by Jones, Moore, and Williams.[16] To obtain optimum flocculation, polyelectrolytes must be added to the suspension and mixed rapidly for approximately 5 to 15 min to fully disperse and extend the individual polymer molecules. The treated suspension is then slow mixed for 10 to 30 min to allow complete floc formation before the suspension is finally allowed to settle under quiescent conditions in a basin or clarifier.

23. For both inorganic flocculants and polyelectrolytes the slow-mix period must be followed by a period of relatively quiescent settling in a basin or clarifier.

24. Polyelectrolyte selection. Based on the disadvantages associated with using inorganic flocculants, polyelectrolytes are considered to have a greater potential for coagulating dredged material.[15] Unfortunately, theories concerned with coagulation of dredged material have not been sufficiently developed to allow the selection of the "best" flocculant or dosage without screening and testing. Because of the large number of manufacturers and types of polyelectrolytes available, preliminary screening of flocculants should be accomplished by technical representatives from selected chemical manufacturing companies. Each company should be able to provide its best candidate

flocculant based on laboratory tests using samples of both the sediment and near-bottom water from the dredging site to produce a slurry or a suspension simulating the effluent that might be released from a containment area. Further evaluation and determination of the optimum dose of several nontoxic polymers may be accomplished using jar-testing procedures.[16] These procedures will indicate the most cost-effective polymer, the optimum polymer dosage relative to the suspended solids levels in the suspension, the optimum concentration of the polymer solution used to treat the suspensions, as well as the optimum mixing intensities and durations for both rapid- and slow-mixing stages. Optimum detention times and surface overflow rates for clarifying the flocced suspensions and a general indication of the volume of flocced material that must be stored or rehandled can be determined from various settling tests.[5,11,16]

25. Although the variability in flow rates and solids concentrations expected during an actual dredging operation will seldom precisely match the conditions of the jar test, this laboratory testing is nevertheless essential to ensure that approximate dosages, detention times, etc., correspond to average conditions. If existing basins, pipelines, etc., are to be used in the treatment operation, the mixing intensities and durations in the jar tests should as closely as possible duplicate those conditions expected in the field, and the optimum dose should be determined for those field conditions. This dose may be significantly different from the optimum dose that would correspond to optimum mixing intensities and durations.

26. Final selection of a suitable flocculant should be based on its cost, chemical form, handling properties, mode of application, and its potential effectiveness for a given operation. Because of effectiveness of a given polymer depends on the characteristics of the sediment, the solids concentration of the suspension, the salinity and pH of the water, and the characteristics of the proposed treatment operation (i.e., mixing conditions, settling basin retention time, etc.), there is no universal flocculant that works best on all types of dredged

material under all conditions. One flocculant that works best for one operation may not work for another.

27. Effluent treatment. Sedimentation of fine-grained material suspended in the effluent from a containment area can be enhanced by treating the effluent with flocculant(s). Relative to chemical coagulation of the dredged material slurry prior to discharge into the containment area, this method is both more effective and more efficient because the flow rates over the weir can be better controlled and the suspended solids levels in a containment area effluent are relatively constant and much lower than in a pipeline slurry. Ideally, polyelectrolyte treatment of containment area effluent requires (1) a carefully controlled polymer feed system, (2) a facility to rapidly mix the suspension at a specified optimum intensity, (3) a slow-mix facility to allow effective coagulation of particles, and (4) a settling basin or a clarifier with an adequate detention time and surface overflow rate to allow the flocced material to settle. Depending on the storage capacity of this latter basin/clarifier, additional facilities for rehandling and disposal of the settled material may also be required.

28. A well-designed and fully engineered system such as that described above should provide the most effective and consistently reliable treatment possible. However, because of the large volumes of water that must be treated (approximately equivalent to the discharge rate of the dredge), such a system will also be quite expensive in terms of both capital costs as well as operation and maintenance costs. Each component of the system (i.e., polymer feed, rapid-mix, slow-mix, clarification, and sludge handling/storage facilities) will have to be constructed in-place or purchased off-the-shelf depending on the flow rates of the operation. As an example, the estimated capital and operational/maintenance costs of a fully engineered system designed to handle 25 mgd (roughly equivalent to a 20-in. dredge production rate of 5144 cu yd/hr), 365 days a year, would be approximately $1.5 million and $2.2 million, respectively. These figures do not include sludge handling or disposal costs. More detailed cost estimates for each component of the treatment system for various size operations are also available.[16]

29. A small pilot plan was used in the field to test the effectiveness of flocculants in clarifying the effluent from a containment area being filled with a freshwater dredged material slurry. Although the tests were conducted with nonoptimum doses under variable rapid-/slow-mix conditions, effluent suspended solids levels of 2 to 5 g/ℓ were consistently reduced to less than 50 mg/ℓ. In addition, there was a significant reduction in the levels of chemical constituents in the effluent. However, because of the many variables that can affect treatment processes, the results of these tests should not be used to predict the results of any other treatment operation.

30. In many cases, the leael of treatment required may not necessitate a sophisticated treatment system. In other words, a system that does not provide optimal feeding, mixing, and clarification conditions, but which does provide an acceptable effluent quality, may be adequate. Figure 1 illustrates a number of possible schemes for treating containment area effluents with polyelectrolytes. They are arranged in decreasing order of probable effluent quality, sophistication, and cost. Detailed design guidelines that can be applied to the site-specific problems and conditions of each operation are also available.[16] The system ultimately chosen should be the one with the least complexity that will satisfy effluent requirements. Regardless of the treatment system, the laboratory jar-test procedures for determining the needed design parameters for a polymer coagulation treatment system must: (1) use a simulated basin effluent produced from sediment and near-bottom water from the dredging site, and (2) reproduce as closely as possible the mixing conditions to be experienced in the field.

31. Pipeline injection.[16] Ideally, if the predicted effluent quality greatly exceeds those levels outlined in applicable criteria, a chemical coagulation system should be designed for treating the effluent from the containment area. However, during some operations the effluent quality may only slightly exceed water-quality criteria. In this situation, direct injection of polymers into the dredge pipeline before the slurry is discharged into the containment area may enhance the in-basin sedimentation of the slurry enough to achieve acceptable effluent quality.

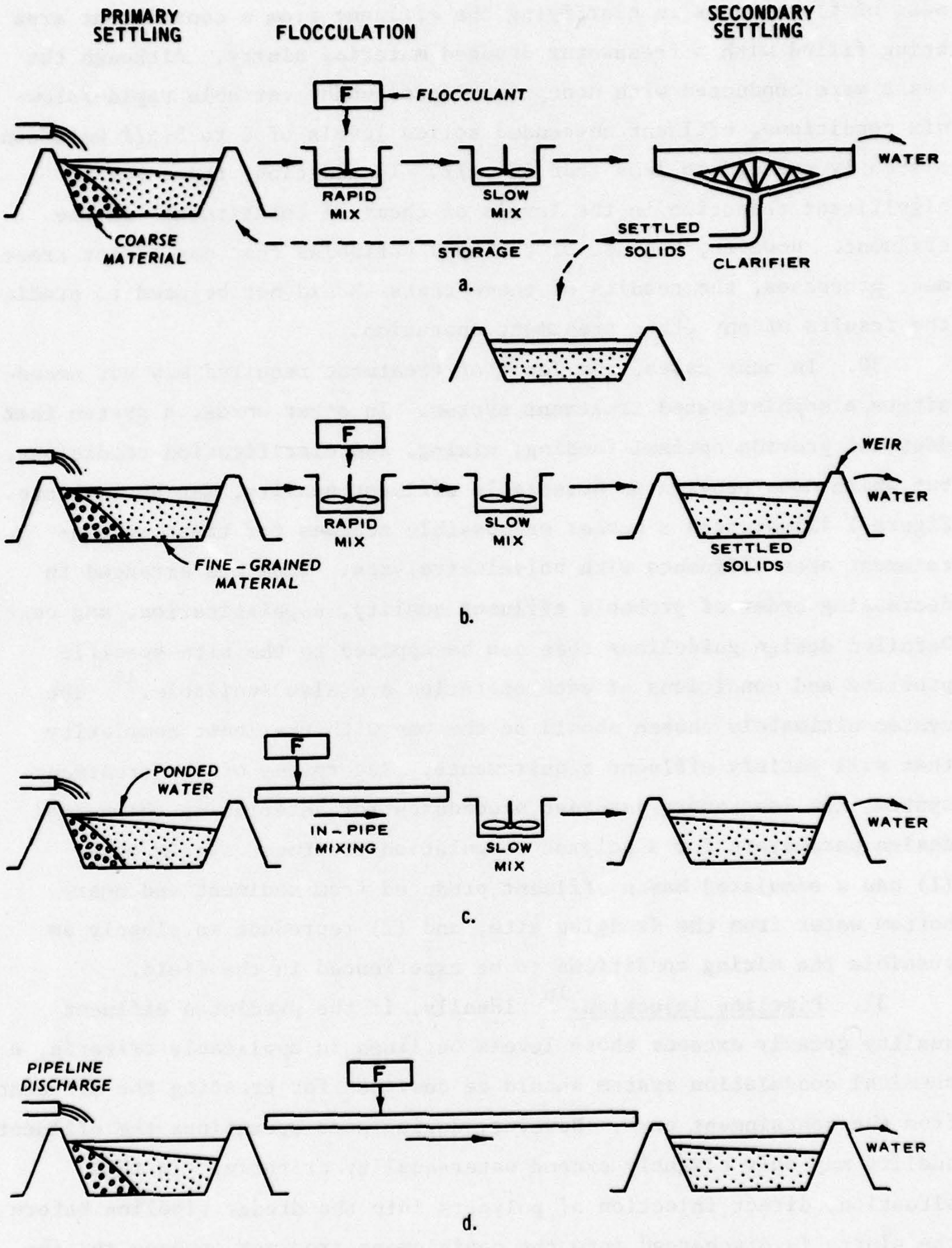


Figure 1. Various schemes for chemical coagulation of containment area effluent

32. In theory, to achieve the desired optimum dose, the flocculant is injected into the pipeline at a rate that depends on the solids concentration of the slurry in the pipeline. Mixing and flocculation occur in the pipeline; the mixing time is governed by the pipeline flow velocity and distance of the injection point from the discharge point. Additional flocculation and improved sedimentation occur in the diked containment area, resulting in a reduction in the amount of fine-grained material suspended in the effluent.

33. In practice, these various processes will occur generally as described; however, the degree of improvement in the effluent quality is totally unpredictable. During full-scale field testing of polymer injection, the floc size in an 18-in. pipeline was limited because of excessively high mixing intensities. However, large flocs formed rapidly after samples of the slurry had been collected and allowed to settle in graduated cylinders. Although a direct comparison of treated and untreated slurry was not made, pipeline injection of a polymer appeared to increase the settling rates of the treated slurry and decrease the suspended solids levels in the water above the settled solids.

34. The unpredictability of this treatment technique can be traced primarily to the high degree of variability in the solids content of the slurry, types of bottom material, and flow rate in the pipeline. As mentioned previously, the optimum polymer dose for a given suspension depends to a large extent on the concentration of suspended solids; as the solids concentration increases, so does the optimum polymer dose. Although the solids concentration of dredged material slurry in the pipeline averages 15 percent by weight, it may rapidly vary from 0 to as much as 40 percent by weight. In an ideal situation the flow rate and solids content of the slurry could be monitored instantaneously with a flow meter and density gauge and the rate of flocculant injection automatically controlled. Although technically feasible, this arrangement would demand rather sophisticated and expensive equipment. Without solids monitoring equipment, the flocculant should be metered into the pipeline at a dose that would be appropriate for a slurry with an average solids content of 15 percent by weight.

Since the slurry will be continually underdosed or overdosed as the solids concentration fluctuates above and below this average, the most suitable flocculant would be one with a high degree of effectiveness over a wide range of suspended solids concentrations.

35. The effectiveness of a flocculant also depends largely on the characteristics of the sediment in the suspension. As the dredge swings back and forth across its cut and advances down the channel, the composition of the dredged sediment may change markedly. This is especially true when dredging new material. In addition, although the flow velocity usually ranges from 15 to 20 ft/sec, it may vary from 0 to 25 ft/sec, resulting in rapid changes in both the appropriate polymer dose and the mixing intensity within the pipeline. These latter variations make it impossible to feed an optimum dose into the pipeline, even if that dose could be determined.

36. Although the degree of effluent improvement that can be obtained from pipeline injection is quite unpredictable, this treatment technique is easy to implement, inexpensive relative to effluent treatment, and may provide an expedient means for improving an existing situation without necessarily optimizing the settling/clarification process. When selecting a flocculant for this type of operation, the jar-test procedure should be modified to simulate the mixing conditions in the pipeline.[16]

37. <u>Clarification of the treated suspension.</u> Regardless of the degree of sophistication of the flocculant treatment system, an adequate settling basin must be provided for clarification of the treated dredged material suspension. For pipeline injection, the primary containment area may satisfy this requirement. However, if the effluent from the containment area is to be treated, a secondary settling basin or clarifier will be required for clarification and temporary or long-term storage of the flocculated material.

38. <u>Properties of the settled dredged material.</u> The dredged material that has been treated with polyelectrolytes will probably have a very low bulk density and may occupy a relatively large volume. Although polymer treatment may result in a slight increase in the

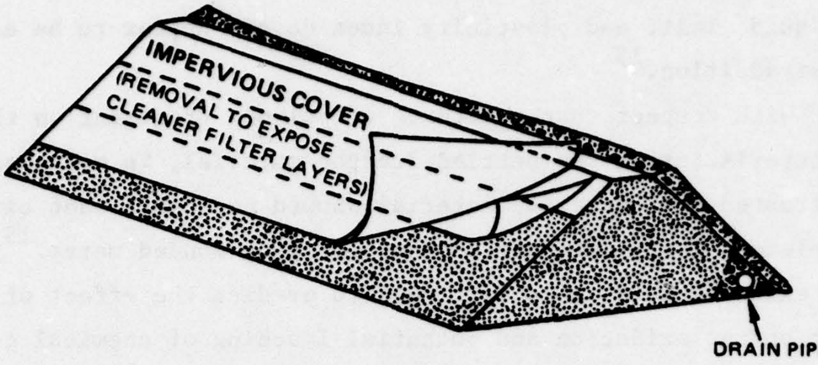
coefficient of permeability of the settled dredged material, the plastic limit, liquid limit, and plasticity index do not appear to be affected by polymer addition.[15]

39. With respect to the effects of polymer treatment on the chemical characteristics of the settled dredged material, in most cases the polymer-treated and untreated material showed no significant differences in the release of contaminants to the overlying ponded water.[15] However, based on existing data it is difficult to predict the effect of polymer treatment on the oxidation and potential leaching of chemical constituents when surface trenching techniques are used to dewater and densify the dredged material.[19]

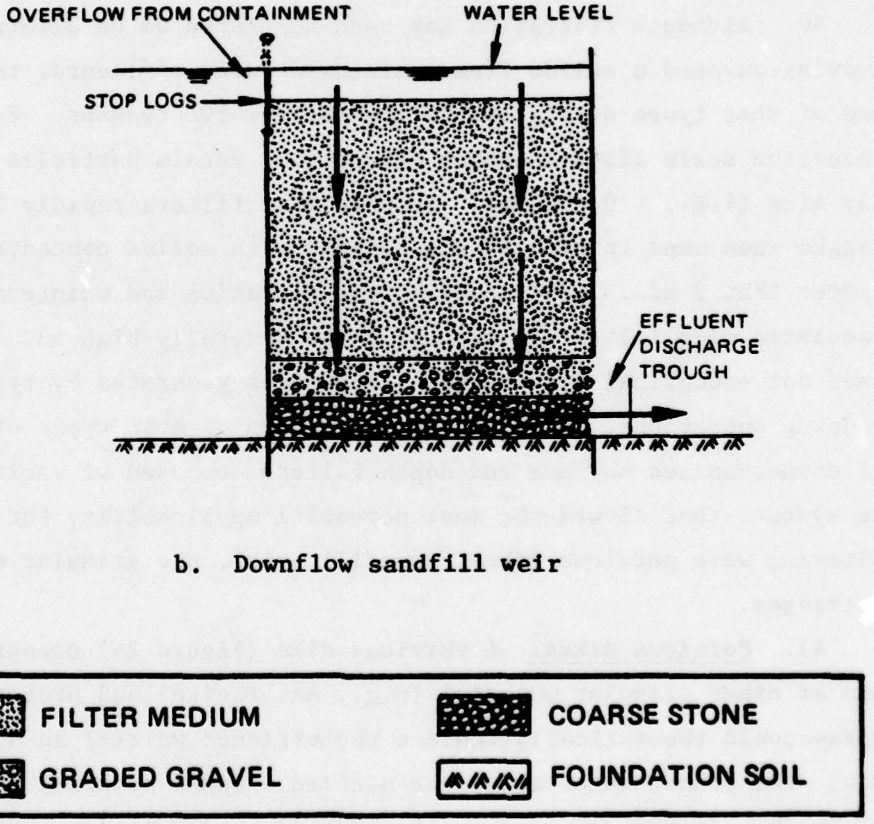
Filtration of containment area effluent[14]

40. Although filtration has been suggested as an alternative for removing suspended solids from containment area effluents, the effectiveness of most types of filters is limited for two reasons. First, many production scale filters cannot effectively retain particles that are clay size (i.e., $\leq$ 0.002 mm). Second, most filters rapidly become clogged when used to process suspensions with solids concentrations greater than 2 g/ℓ. Additionally, the operation and maintenance costs associated with filtration processes are generally high and in many cases not econorical for the high flow rates generated by typical dredging operations. Based on an evaluation of most types of mechanized and nonmechanized surface and depth filters composed of various media, the systems that showed the most potential applicability for effluent filtering were pervious dikes, sandfill weirs, and granular media cartridges.

41. Pervious dikes. A pervious dike (Figure 2a) constructed of sand or other granular material (e.g., anthracite) and protected with riprap could theoretically replace the effluent weir(s) in a containment area. The ponded water above the settled dredged material would percolate through the dike and collect outside the containment area in a drainage tile located at the toe of the dike. The dike could theoretically be designed to remove as much as 99 percent of the suspended



a. Pervious dike with multilayered impervious cover



b. Downflow sandfill weir

Figure 2. Techniques for filtering fine-grained suspended sediments from effluents (Reference 14)

solids[14] (in return for a very short filter life). In addition, various configurations such as removable impervious covers, could be used to control flowthrough rates as well as extend the life of the filter before it becomes completely clogged (Figura 2a). Lab tests indicate that pervious dikes may be practical for filtering effluent water with solids concentrations as high as 1 g/ℓ for periods of about 1 year before clogging.[14]

42. Sandfill weirs. Sandfill weirs (Figure 2b) consisting of one or more sand-filled cylindrical or rectangular cells could also be used to filter the effluent from containment areas.[14] Although their capabilities and solids loading/clogging limitations are similar to those of pervious dikes, sandfill weirs do offer several advantages over pervious dikes. First, clogged cells can be taken off line and refilled with fresh sand or another media, thereby allowing continuous or repeated use of the containment area. Second, they offer more economy of space than a pervious dike, and if several sandfill weirs are built into a containment area they will allow flexible operation. Lastly, because they operate under a higher hydraulic head, higher flow rates can be processed with similar filtering performance. For high concentration suspensions, however, clogging will be pronounced and backwashing schemes may be necessary.

43. The Chicago District has successfully used sand-filled filter cells to process effluent with solids concentrations of a few grams per litre. Depending on the design of the filter, the nature of the dredged material, and the loading rate experienced by the weir, a sand-filled weir may effectively remove most of the suspended solids in the effluent for several dredging operations before it becomes clogged.*

44. Granular media cartridges.[14] Granular media cartridges are comparable to sandfill weirs in their function and performance capability, but are considerably more versatile due to their modular configuration. Since cartridges can be easily replaced as they become

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* Personal communication, 2 July 1978, Paul Mohrhardt, Civil Engineer, U. S. Army Engineer District, Chicago, Chicago, Ill.

clogged, a cartridge system could effectively treat containment area effluents with solids concentrations of 5 to 10 g/ℓ. Once clogged, cartridges could be removed and washed for later reuse. Cartridge media and configuration could be varied depending on the flow rates, solids concentration in the suspension, and other conditions present at a particular containment area.

45. Vegetative filtering. Discharging containment area effluent through raceways or areas containing certain plant species is another technique that can be used to filter suspended solids from the effluent. By effectively reducing the water flow, the settling of the fine-grained suspended material is enhanced. In addition, the same plants may take up dissolved nutrients in the effluent during their growing season;[20] however, the same nutrients may be subsequently released at other times of the year when plants are not actively growing. Since many disposal areas are located near low-lying wetlands, simply discharging the effluent from the containment area through the marsh grass may effectively remove most of the suspended solids and associated adsorbed heavy metals and dissolved nutrients from the effluent.

46. *One research study*[21] *of the ability of a salt marsh to filter* containment area effluent indicated some removal of both heavy metals (15 to 32 percent) and nitrogen and phosphorus (30 percent). This reduction was probably due primarily to deposition of the fine-grained suspended solids. Although the nutrients in the effluent may be taken up by the plants, laboratory and field studies have indicated that movement of the heavy metals from the settled dredged material into the leaves and stems of the marsh plants seldom occurs in significant amounts.[22] While vegetative filtering by wetlands and marshes may be a viable treatment technique, it cannot be endorsed at this time due to the ecological importance of and political sensitivity surrounding wetlands and marshes.

Vacuum filtration of dredged material slurry[23]

47. Vacuum filters may, under certain circumstances, lend themselves to the direct dewatering of dredged material slurry. Their

potential performance depends on many factors, including: concentration and grain size of solids in the slurry, vacuum pressure, drying time, type of filter fabric, and tendency of the dried cake to crack. Additionally, vacuum filters usually require chemical preconditioning of the influent with flocculants to reduce the number of fine particles in the slurry. Vacuum filters are commonly used to densify sludges and industrial slurries with a solids contents ranging from 1.4 to 7 percent by weight, but could process fine-grained dredged material with a solids content of 8 to 20 percent solids by weight. Processes filter cakes may have a solids content of 40 to 60 percent by weight depending on the factors stated previously; the filtrate quality may have a solids concentration as low as 500 mg/ℓ.

48. Unfortunately, vacuum filtration, for most dredged material applications, cannot be used economically. For example, to process a dredged material slurry from a 10-in. dredge (i.e., approximately 25,000 cu yd/day) would require approximately 25 rotary drum filters, with a total surface area of 1735 m^2. The capital cost alone for these filters would be greater than $6 million. Operation and maintenance costs vary from $5 to $30 per ton of dry solids. These factors indicate that vacuum filtration would be extremely expensive to use on any dredging operation. However, there may be instances where the use of this technically feasible process may be justified.

Final treatment of dissolved chemical constituents

49. On certain operations it may be necessary not only to remove the suspended material from the effluent, but also to further treat the effluent to remove dissolved chemical constituents and colloidal matter that have not been removed by chemical flocculation, if their levels exceed those set forth in existing criteria. In many cases where dissolved contaminants are of concern, their source may have been the ambient water used to hydraulically transport the sediment. In such cases a rationally formulated effluent standard should not require treatment to below receiving water background levels; however, should removal of dissolved and colloidal constituents be required after

optimum solids separation has been accomplished, a treatment system must be tailored to the composition and concentration of the constituents to be removed. The design of the treatment system should be accomplished through consultation with specialists in treatment process design and with representatives of companies that manufacture the specific chemical constituents that must be removed. Full-scale implementation will, in many cases, have to be preceeded by laboratory treatability tests and/or pilot plant operations.

50. Specific unit processes that will most likely play a prominent role in removing dissolved chemical constituents from the effluent include: activated carbon adsorption (effective against most organics); ion exchange (possibly effective against certain dissolved heavy metal ions); chemical precipitation (effective against phosphorus, iron, manganese, and other heavy metals under certain conditions); and air stripping, breakpoint chlorination, and biological nitrification (for removal of ammonia).[24] These processes are generally quite expensive with expected operating costs in the range of $0.50 per 1000 gal and up; capital costs may be on the order of several hundred to several thousand dollars per thousand gallon of plant capacity.[10] Other treatment processes capable of purifying waters to a very high degree (depending on the contaminant identity and concentration) include reverse osmosis and distillation. These are all low-rate processes and would seldom, if ever, be practical on the scale necessary to handle dredged material.[25]

51. For some smaller operations it may be feasible to use a mobile treatment plant, such as the unit built by Industrial Environmental Research Laboratory, Edison, New Jersey. This unit consists of mixed media pressure filters and activated carbon adsorption columns capable of processing about 200 gpm (0.288 mgd). This unit was used as a final treatment of the effluent from the containment area used for the disposal of PCB-contaminated (polychlorinated biphenyl) sediment dredged with the Pneuma system from the Duwamish River, Seattle, Washington.[26] This unit may be available from the Environmental Protection Agency on a limited basis.

"Hot Spot" Treatment

52. In some situations it may be necessary for environmental reasons to remove sediments that are grossly contaminated by toxic chemicals released from a spill or long-term industrial discharge. Such grossly polluted areas are referred to as "hot spots." Dredging for the sole purpose of removing the polluted sediment from the aquatic environment is referred to as "hot spot" dredging. Depending on the particular contaminants involved, the location of the proposed disposal site, and the prevailing political constraints, it may be necessary to totally contain all the material dredged from the hot spot and treat the ponded water to those levels specified in the applicable standards. To isolate the contaminated material, the containment area will probably have to be sealed with clay or another type of impervious liner. An additional measure may involve chemical fixation of the residual solids[27] to prevent any long-term leaching and migration of the chemical contaminants back into the environment. Some types of contaminants that may be encountered in hot spot situations are persistent pesticides (e.g., DDT, DDE, aldrin, Myrex, etc.), chlorinated hydrocarbons (e.g., PCB's, Kepone, carbon tetrachloride, etc.), as well as various chemical forms of highly toxic heavy metals (e.g., mercury, cadmium, lead, arsenic, etc.).

53. Unfortunately there are no standard procedures for treating extremely contaminated dredged material; each case must be evaluated on a site-specific basis. However, since most toxic chemical constituents are strongly adsorbed to the fine-grained portion of the sediments, the majority of the contaminants can be isolated within the containment area by retention of the solids in the dredged material slurry. Consequently, solids removal remains the key first step in any treatment system. The dissolved or colloidal fraction that remains suspended in the ponded water may then require additional treatment by one or more of the methods discussed in the previous sections.

54. Regardless of the nature and magnitude of the treatment problem, it is imperative to consider the compatability of all the components of the dredging operation including excavation, transportation,

and disposal/treatment as a total integrated system and not as separate components. In other words, the best dredging system may not be compatible with the best treatment system.

PART III: TREATMENT OF DREDGED MATERIAL SLURRY AT OPEN-WATER PIPELINE DISPOSAL OPERATIONS

Introduction

Dredged material dispersion

55. During open-water pipeline disposal operations any coarse-grained material in the slurry will accumulate directly beneath the discharge point. Ninety-five to ninety-nine percent of the fine-grained material also descends rapidly to the bottom where it forms a low-gradient fluid mud mound with solids concentrations ranging from 10 g/ℓ at the surface of the mound to as high as 500 g/ℓ at the base of the mound. The remaining 1 to 5 percent of the material remains suspended in the water column above the fluid mud mound in the form of a turbidity plume at solids concentrations ranging from a few tens to a few hundred milligrams per litre.[18]

Chemical treatment

56. Although most of the heavy metals, nutrients, and petroleum and chlorinated hydrocarbons are usually associated with the fine-grained and organic components of the sediment[3] present in turbidity plumes, water chemistry data collected around dredging and disposal operations indicate that there is no biologically significant long-term release of these chemical constituents from typical dredged material to the water column. Levels of manganese, iron, ammonia, orthophosphate, and reactive silica may be increased somewhat over background conditions; however, there are no well-defined plumes of dissolved metals or nutrients at levels significantly greater than background concentrations.[2,3,17] Since there does not appear to be any significant impact associated with the release of chemical constituents from uncontaminated dredged material slurry disposed in open-water environments, chemical treatment does not appear to be necessary or advisable.

Oxygen Injection

57. When anaerobic sediments are dredged hydraulically, several chemical constituents (i.e., ferrous iron, sulfides, and manganous manganese) associated with the fine-grained particles in the slurry will undergo an oxidation process that reduces the dissolved oxygen levels in the slurry to zero. Due to the very high immediate oxygen demand associated with the slurry, levels of dissolved oxygen in the water column in the immediate vicinity of a pipeline discharge may be somewhat depressed.[7,13,17] For example, dissolved oxygen levels measured in the center of the turbidity plume 120 ft from the discharge point of a typical (untreated), open-water (16-in.) pipeline disposal operation were depressed to approximate levels of 7 to 8 mg/ℓ at the surface, 4 to 6 mg/ℓ at middepth, and 2 to 3 mg/ℓ in near-bottom waters (above the fluid mud layer), relative to background concentrations of approximately 9 to 10 mg/ℓ throughout the water column. This tendency for dissolved oxygen levels to decrease with increasing water depth merely reflects the increase in suspended solids concentration with increasing depth. Dissolved oxygen levels in the upper water column increased toward ambient levels with increasing distance from the discharge point due to dilution and settling of the suspended material.[7,17] Dissolved oxygen levels within the fluid mud layer will probably be very close to zero.

58. Levels of dissolved oxygen in the water column, especially in the near-bottom water, can be increased by injecting pure oxygen ineo the pipeline. With an injection point 1000 to 2000 ft from the discharge point, the oxygen demand associated with the sediment cannot be completely satisfied; however, the carrier water can be saturated so that the degree of dissolved oxygen depletion in the water column can be reduced. For example, when pure oxygen generated by the vaporization of liquid oxygen was injected through eight nozzles into the discharge line of the 16-in. dredge (Figure 3) mentioned above, dissolved oxygen levels measured 120 ft from the discharge point in the center of the turbidity plume were approximately 7 to 8 mg/ℓ at the surface, 5 to 7 mg/ℓ at middepth, and 5 to 6 mg/ℓ in near-bottom waters. From these

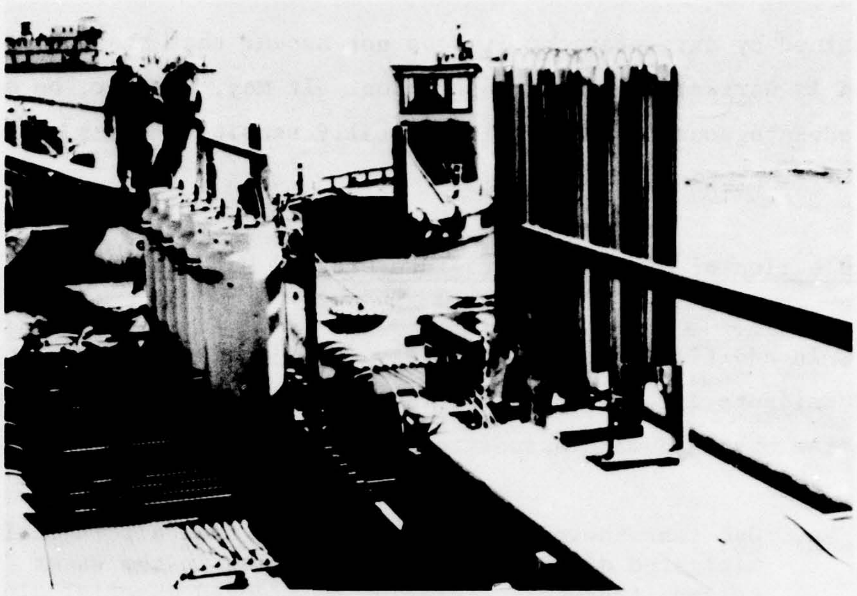

Figure 3. Oxygen injection system

data there appears to be a marginal improvement in the dissolved oxygen levels in the upper water column due primarily to the already high dissolved oxygen levels and the relatively low suspended solids levels present. However, dissolved oxygen levels in near-bottom waters may be temporarily increased by as much as 3 to 4 mg/ℓ.

59. Because there is not enough excess oxygen in the slurry water to completely satisfy the oxygen demand associated with the sediment, the dissolved oxygen levels within the oxygenated slurry will be reduced to near zero within several minutes as the oxidation of chemical constituents and the biochemical oxidation of organic matter within the fluid mud continue. Field observations indicate that oxygenation has no effect on the levels of suspended solids observed in the turbidity plume. Laboratory testa also indicate that it is very unlikely that oxygenation of dredged material slurry would significantly increase the release of toxic metals and/or nutrients to the water column. The cost of continuous oxygen injection would probably increase the total cost of the dredging operation by 1 to 4 percent.

60. The field tests of an oxygen-injection system indicate that oxygentation of dredged material slurry is feasible.[7] However, considering the degree and short-lived nature of any increases in dissolved

oxygen gained by oxygentation, it does not appear that the use of oxygen injection is warranted at every operation. It may, however, be marginally advantageous in some environmentally sensitive areas or situations.

Injection of Other Oxidants into Dredged Material Slurry[7]

61. In addition to testing the oxygen-injection concept, injection of other oxidants into the pipeline was considered as a means of decreasing the oxygen demand associated with typical dredged material slurry.

a. One test showed only weak evidence that air injection mitigated dissolved oxygen depletion in the water column; therefore, aeration of dredged material slurry is not recommended.

b. Oxidation of reduced chemical constituents in dredged material slurry by injecting potassium permanganate, chlorine, or nitrates is also not recommended due to potentially harmful effects on the aquatic environment.

c. It is not technically feasible to use ozone as an oxidant primarily because ozone is unstable at pressures necessary for pipeline injection.

d. The use of hydrogen peroxide may prove to be the best alternative oxidant, if the goal is simply to oxygenate the carrier water in the pipeline. In addition, hydrogen peroxide injection may increase the cost of the dredging operation by a prohibitive amount.

PART IV: SUMMARY AND CONCLUSIONS

62. Although the majority of the sediments dredged in the United States are not contaminated by significantly high levels of harmful chemical constituents, recent environmental trends and increasingly stringent discharge standards often cause dredged material to be viewed as a potential pollutant of the Nation's waters. Open-water disposal of highly polluted dredged material is not recommended due to the possible release of harmful chemical contaminants to the receiving water. In addition, open-water disposal may cause aesthetically displeasing turbidity plumes accompanied by marginal decreases in the dissolved oxygen levels in the water column. For these reasons, confined disposal of dredged material, although usually more costly than open-water disposal, may be the only viable alternative for disposing of highly polluted bottom sediments.

63. The aim of this report has been to examine, in the content of both open-water and confined disposal, processes and techniques for treating dredged material or the effluent from confined areas to minimize the impact of receiving waters. Generalizations are difficult to make since each operation must be analyzed based on such site-specific circumstances as sediment characteristics, salinity of the carrier water, containment area effluent restrictions, size of the job, location of the disposal site, etc. Nonetheless, a number of general findings have emerged from the various studies associated with Task 6B. They are briefly summarized below.

64. For confined disposal operations the following findings and conclusions have been made:

a. Sedimentation in a containment area should be regarded as the primary treatment of the dredged material. In most cases the solids and associated chemical contaminants that can be removed through plain sedimentation in a properly designed and operated containment area will yield an environmentally acceptable effluent.

b. Existing containment areas will function more efficiently as settling basins through one or more of the following expedient measures: reducing the size of the dredge, intermittent pumping, increasing the weir length, and increasing the depth of ponded water by raising the weir.

c. Organic polymer flocculants can be effectively used to coagulate and clarify effluents from containment areas containing unacceptably high solids concentrations. Inorganic flocculants such as alum and lime may be efffective as well, but very large doses will probably be required.

d. For polymers to perform effectively, their full-scale use must as a minimum be preceded by laboratory jar tests using an actual or simulated effluent made from a suspension of the material to be dredged.

e. Flow schemes and equipment needed for treating containment area effluents with flocculants may range from fully mechanized rapid-mix, slow-mix, and clarification facilities to the expedient use of existing pipes, channels, and basins. The type of system selected should be the simplest and least expensive one that will yield an acceptable effluent.

f. Injection of organic polymers into the dredge pipeline prior to discharge into the containment area may enhance the sedimentation process in the basin, thus improving the effluent quality. Though operationally quite simple, this technique is difficult to control and produces unpredictable results.

g. Filtration of containment area supernatants through the use of pervious dikes, sandfill weirs, and filter cartridges is technically feasible and can produce very high-quality effluents. Unfortunately, such devices are operationally intensive and may not be cost effective.

h. Regardless of its effectiveness, vegetative filtering cannot be endorsed at this time.

i. Posttreatment (after solids removal) of the liquid phase of dredged material effluents may be necessary in cases of highly contaminated sediments (hot spots), especially where a significant concentration of harmful chemical contaminants exists in solution. Depending on the type of constituents to be removed, such processes as carbon adsorption, ion exchange, chemical precipitation, and others may be appropriate. Process designs should be tailored to the site-specific circumstances and be accomplished in conjunction with consultants who are experts in the field.

65. For open-water disposal operations the following findings and conclusions have been made:

a. Saturation of the slurry carrier water with dissolved oxygen accomplished through injection of oxygen into the pipeline can marginally reduce the depression of dissolved oxygen levels in the water column. Since low dissolved oxygen levels are primarily restricted to the fluid mud layer, the oxygen injection technique is not considered necessary or practical except under environmentally sensitive circumstances.

b. Oxygentation of the slurry, using air injection, and injection of chemical oxidants are either ineffective, impractical, or would have adverse effects; therefore, they are not recommended.

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