CHEMICAL CONDITIONING OPTIMIZATION FOR GEOTEXTILE TUBE DEWATERING

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ABSTRACT

Hydraulic dredging project sites are generally remote, require major site preparation time, lack utilities (i.e., power and water), and are only temporary construction sites, thus mechanical dewatering techniques are logistically and economically prohibitive. Large-diameter geotextile tubes have been used to contain and dewater hydraulically dredged sand from river channels, lakes, and harbors for decades. Technological advances in the use and application of polymers and other chemical conditioning agents for the expedient separation of contaminated solids from water have facilitated the use of geotextile tubes for containment, dewatering, and consolidation of hydraulically excavated fine-grained materials. Geotextile tube containment and dewatering technology is a high volume, high flow containment option. It provides dredging contractors an efficient on-site, cost effective dewatering option that requires no special equipment or permitting, low operations and maintenance costs, and residuals excavation and disposal may be deferred to subsequent fiscal quarters. With the addition of a chemical conditioning agent(s) (e.g., coagulants and/or flocculents), excess water drains from the container through the geotextile resulting in effluent that is clear and safe enough to be returned to a receiving system. Volume reduction within the container allows for repeated filling of the Geotextile container. After the final cycle of filling and dewatering, retained fine grain materials continue to consolidate by desiccation because residual water vapor escapes through the geotextile. Excavation of the dried materials and subsequent disposal occur when retained solids meet dryness goals or excavation and disposal may be deferred to a more economically feasible time. The objective of this study was to optimize chemical conditioning programs for geotextile tube dewatering of hydraulic dredging residuals. Polymers were evaluated based on water release rate, water clarity, flocculent appearance, water volume, and constituent(s) break-through. In addition, online optimization, including polymer make-down concentration, activation, feed equipment, mixing energy, shear energy, and contact time were evaluated during these hydraulic dredging projects to increase filtrate quality and decrease time to attain desired cake solids within the geotextile containers.

Keywords: Chemical conditioning, dewatering, geotextile container, polymers, hydraulic dredging.

INTRODUCTION

Large-diameter geotextile tubes have been used to contain and dewater dredge materials from river channels and harbors for decades (Fowler et al. 1995). In these applications, coarse-grain sediments pumped into the geotextile tube settle rapidly and slurry water is discharged through ports in the top of the tube. Geotextile tubes deployed in such settings have been used to form berms and alternative disposal sites to contain additional dredge materials. Sand-filled geotextile tubes are also used to stabilize dunes on beaches, as levees, and as manmade peninsulas to establish harbors. In these applications, confinement of the geotextile fabric adds shear strength to the sediment fill, resulting in a structure that is stable and resistant to erosion. Use of geotextile tubes to thicken and dewater fine grained sediments is a developing field and has had limited application in the municipal, industrial, and environmental dredging markets (Miratech 2005). Technological advances in the use and application of polymers and other chemical conditioning agents for the expedient separation of contaminated solids from water have facilitated the use of geotextile tubes for containment, dewatering, and consolidation of hydraulically excavated materials (Mastin and Lebster 2006, 2007, Mastin et al. 2008a, Mastin et al. 2008b). This new and innovative technology has been successfully used to dewater fine-grained, contaminated material that contained dioxins, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), pesticides, metals (with a lithic biogeochemical cycle), and other hydrophobic materials (Fowler et al. 19996, Mastin and Lebster 2006, 2007, Mastin et al. 2008a, Mastin et al. 2008b, Taylor et al. 2000).

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Geotextile Containment and Dewatering Technology is a high volume, high flow containment option. It provides dredging contractors an efficient on-site, cost effective dewatering option that requires no special equipment or permitting, low operations and maintenance costs, and residuals excavation and disposal may be deferred to subsequent fiscal quarters. Geotextile containers, which are manufactured from high strength polypropylene fabric, are designed to allow effluent water to escape through the pores of the fabric while retaining the fine-grain, flocculated solids. With the addition of a chemical conditioning agent(s) (e.g., coagulants and/or flocculents), excess water drains from the container through the geotextile resulting in effluent that is clear and safe enough to be returned to a receiving system. Volume reduction within the container allows for repeated filling of the geotextile container. After the final cycle of filling and dewatering, retained fine grain materials continue to consolidate by desiccation because residual water vapor escapes through the geotextile. Excavation of the dried materials and subsequent disposal occur when retained solids meet dryness goals (e.g., 20 to 80-percent cake solids, sufficient to pass a paint filter test) or excavation and disposal may be deferred to a more economically feasible time.

Online chemical conditioning optimization of dredged sediments dewatered with geotextile dewatering technology was evaluated at a number of space-limited, contaminated project sites. Due to local industrial inputs that resulted in PAH, metals (i.e., Ag, As, Cd, Cu, Hg, Pb, and Zn), and suspended solids (TSS) contamination (preventing alternative containment options), sediments were designated to be dewatered and transported to local licensed and approved landfills. An alternative method for containment and dewatering of contaminated sediments was sought by the project engineers and environmental scientists that not only reduced costs associated with solids processing but required less facility resources to operate. WaterSolve, LLC recommended geotextile containment and dewatering technology to project engineers, environmental contractors, and other stakeholders as a cost effective, safe, and efficient method for handling contaminated sediments in the shortest amount of processing time. The objective of this study was to optimize chemical conditioning programs for geotextile tube dewatering of hydraulic dredging residuals. Polymers were evaluated based on water release rate, water clarity, flocculent appearance, water volume, and constituent(s) break-through. In addition, online optimization, including polymer make-down concentration, activation, feed equipment, mixing energy, shear energy, and contact time were evaluated during these hydraulic dredging projects to increase filtrate quality and decrease time to attain desired cake solids within the geotextile containers.

METHODOLOGY

Chemical Conditioning

The objective of dewatering performance trials was to develop chemical conditioning programs for each potential geotextile tube dewatering application. Polymers were evaluated based on water release rate, water clarity, flocculent appearance, water volume, and targeted constituent(s) break-through after passing through a geotextile filter. In addition, dosing rate(s) were determined during these bench-top dewatering experiments and recommendations were provided as a part of these trials. Hanging Bag Performance Evaluations should be performed with the recommended chemical conditioning program to evaluate filtrate quality, potential requirements for filtrate treatment, and time to attain desired cake solids within the geotextile container.

A representative 11.5 to 19.25-L (3 to 5-gal) sample of sediments was collected from each potential dredge reach within a project site. Sediments were homogenized with overlying site-water and 150-mL (0.04-gal) test samples were placed in graduated, glass jars. Polymers were "made-down" (200 mL or 0.05 gal) at a 0.5-percent concentration for these dewatering trials. Polymer(s) was added to a sample with a 10-mL plastic syringe and moderately tumbled five to ten times. Observations of water release rate, water clarity, and flocculent appearance were recorded on appropriate data sheets. Polymer(s) that flocculated and dewatered these sediments most effectively were re-evaluated with lower doses in order to isolate the most efficient flocculating and dewatering polymer(s).
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Two to three polymer conditioning programs were typically observed to flocculate and dewater these sediment slurries most effectively compared to the other products. In all cases, water release rate and clarity were excellent. Re-evaluation with lower polymer doses or make-down concentrations were used to select one to two products as the recommended chemistry conditioning program for dewatering these potential dredge sediments. Once a recommended chemical conditioning program was identified, other chemical application variables were evaluated for potential full-scale operations including:

- Use of more than one chemistry during dredging operations as sediment character changes with depth, debris, organic matter, and density
- Simultaneous or sequential application of more than one chemistry,
- Application of an inorganic chemistry in combination with an organic chemistry,
- Effects of mixing energy and shear energy during introduction of flocculating chemistry inline to a dredge slurry pipeline to evaluate injection distance from the geotextile tubes, and
- Use of pre- and post-dilution to meet project objectives of geotextile tube sediment dryness and/or filtrate "quality

Hanging Bag and Geotextile Dewatering Trial (GDT) Performance

Objectives

This test method was used to measure 1) percent dry weight solids in a geotextile container used for dredged material and 2) measure the concentration of suspended solids and other targeted constituents that may pass through a geotextile container used to contain contaminated dredge material. Results of sediment that passed through the geotextile container were shown as percent total suspended solids in milligrams per liter or parts per million.

This test method required several pieces of specified pieces of equipment, such as an analytical balance, a geotextile container, a metal frame or scaffold to hold the geotextile container, clean containers to collect the dredged material sediment, and a representative sample of dredged material from each proposed dredge reach. This standard did not purport to address all of material and site safety problems, if any, associated with its use. It was the responsibility of the user of this standard to establish appropriate safety and health practices for contaminated dredged materials and determine the applicability of regulatory limitations prior to use.

Summary of Test Method

A geotextile hanging bag container was constructed by sewing one or more layers of geotextile together to form a container that supported and contained a measured amount of saturated dredged material. The time and amount of sediment that flowed through the geotextile container collected at given time intervals and was measured. The amount of sediment passing the geotextile container was determined as the total suspended solids. Dredged material from each different area to be dredged was used in this test method. A chemical conditioning program was identified for each dredge material sample.

Significance and Use

This test method was used to determine percent and concentration of total suspended solids and other constituents of oil-contaminated sediment passing through a geotextile container over a specified time period.

This test method was used to design geotextile container systems that contain fine-grained dredged materials to meet special environmental requirements of regulatory agencies and determined the amount of dredged material sediment passing a geotextile and the flow rate for specific dredged material conditions. This test method was used to determine the quantity and percent dry weight solids of fine grained dredged material sediment that was contained in the geotextile container. The designer used this test method to determine the quantity of contaminated, fine grained dredged material sediment that passed through the geotextile container into the environment.

This test method was intended as an index test for performance evaluation, as the results depended on the specific dredged materials evaluated and the location of the geotextile container below or above water.

This test method provided a means of evaluating geotextile containers with different dredged materials under various conditions that simulated the conditions that exist with geotextile contained dredged material. The number of times this test was repeated depends on the users and the site conditions. This test method evaluated the identified chemical conditioning program(s) for performance (e.g., water release, water clarity, and flock appearance) and dose on a field application scale.

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Procedure

1. Geotextile containers provided by the manufacturer are constructed by sewing one or more geotextile layers of geotextile together to form a container 114-cm (45-inch) inside circumference and 163-cm (64-inch) long as shown in Figure 1A. A selvedge edge is provided along the circumference of the container opening. Eight 1.3-cm (0.5-inch) diameter metal grommets are evenly spaced about 2.5-cm (1.0-inch) from the selvedge edge. Fabric seams are constructed by two double lock stitches to contain the dredged material, as it would be in the prototype

2. Attach the geotextile container to the sheet metal pipe with 1-cm (0.39-inch) galvanized bolts, washers and nuts through the eight evenly spaced metal grommets. The bottom of the container should have a clearance of about 15 to 20-cm (6 to 8-inch) above the floor of the platform to accommodate removal the collection pans as they fill with sediment and water

Figure 1. A) Geotextile hanging bag dewatering performance trial. B) Sediments were collected for analytical testing (e.g., contaminants, percent dry weight solids).

3. After the geotextile container is suspended from the scaffolding, a collector pan is placed under the geotextile container to collect water and sediment by gravity flow (Figure 1A).

4. Obtain about 150 to 190 L (40 to 50 gal) of the site specific dredged material in a 208-L container (55-gal) (Figure 1B). Thoroughly agitate the dredged materials with the stirrer for one minute to mix in free decant water to obtain a uniform consistency that would be representative of dredged material after excavation and placement. Blend in previously identified chemical conditioning program until material is thoroughly mixed and flocculation is observed. Immediately pour this mix to the geotextile container (Figure 2).

5. As the filtrate collection containers are about half full with water and sediment they should be removed and the time and quantity recorded. The water and sediment sample should then be carefully placed, with all visible sediment, in approved clean glass containers marked with the time, quantity and order in which they were collected and recorded (Figure 3).

6. Water and sediment should be collected from the drainage of the dredged material in the collection containers for about one week or until drainage has slowed to less than one inch depth in the pan per day or 24 hours. This completes the filtrate sample collection phase of the test (Figure 3C).

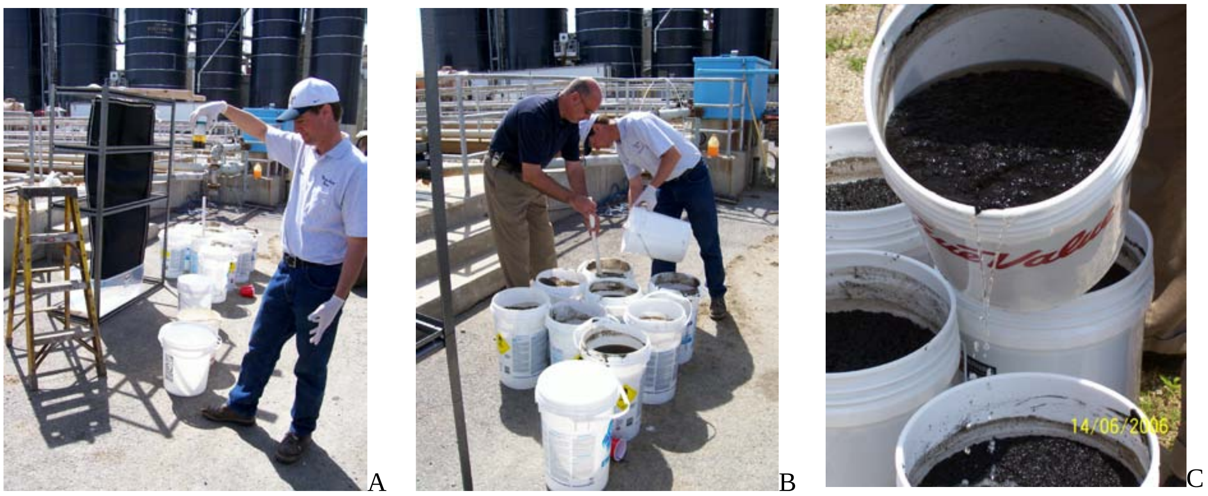

Figure 2. A) Identified chemical conditioning polymer is "made-down" at 0.5-percent concentration and confirmatory bench test performed to verify dose. B) The calculated dose of made-down polymer is added to each five gallon pail and stirred to achieve a sufficient flock and release of free water (C).

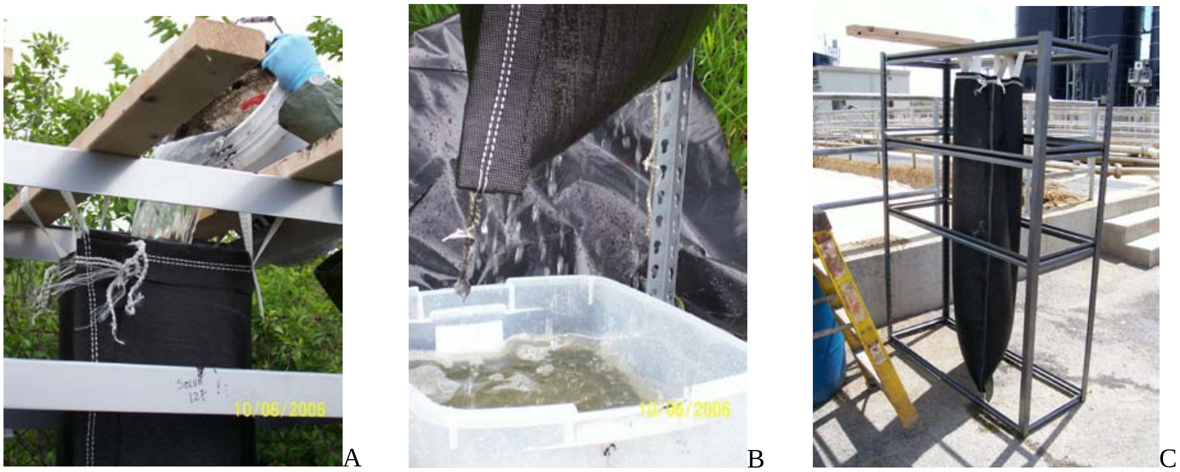

Figure 3. A) Flocked sludge is poured into the hanging bag and filtrate collected (B) in a lexan-container for analyses (e.g., TSS, contaminants, and volume released). C) Total solids were measured daily/weekly by site personnel over time in order to predict the timeline expected for consolidation and expected footprint required for geotextile containers.

7. At the completion of the sample collection, agitate the collected filtrate in each container with a stirrer until the mixture is uniformly mixed. After one minute of mixing, obtain a depth-integrated suspended solids sample from the mixture while continuing the agitation
8. Place a glass fiber filter disk either on a membrane filter apparatus or in the bottom of a suitable Gooch crucible. Apply a vacuum and wash the disk with three successive 20-mL (0.005-gal) portion of distilled water. Continue suction to remove all traces of water from the disk
9. Carefully remove the filter disk from the membrane filter apparatus and transfer to an aluminum or stainless steel planchet. If a Gooch crucible is used, remove the crucible and filter disk combination
10. Dry the filter disk for at least 1 hour in an oven at 103 to 105^{o}C (217.4 to 221.0^{o}F).
11. Store in a desiccator until cooled to room temperature.
12. Weigh the filter disk to an accuracy of 0.00001 g.

13. Place the filter disk in the membrane filter apparatus and return it or the Gooch crucible to the vacuuming and filtering apparatus
14. Under the vacuum, filter the sample of water collected in 8.7
15. Repeat 9 through 12.

CASE STUDY #1 – COPPER MINE SEDIMENTATION LAGOON

Objective

This copper mine had a sediment lagoon full of unconsolidated sediment from storm water runoff and site water reclamation (Figure 4). Previous attempts to remove the sediment from the pond resulted in damage to the pond liner and significant additional expense to repair the liner. Previous methods also resulted in the inconvenience of disrupting the day to day operations of the facility. Facility managers searched for alternative dewatering processes to remove the sediments from the pond as economical and efficient as possible without interruption of operations. The objective was to remove the material out of the pond and dewater it so the solids could be harvested and run back through the facility again. Dredging the pond would allow space for the coming year and capture the precious metals the pond contained. Dredging the sediment into geotextile containers was selected as the most efficient process for this project and dredging operations to remove the sediments were performed in the fall of 2008.

Geotextile® Container

Geotextile containers were manufactured from high strength polypropylene fabric and designed to allow water to escape through the pores of the fabric while retaining the chemically-conditioned solids. Sixty-foot circumference by 30.5- m (100-ft) long GT500D geotextile containers were selected for this operation. This 30.5- m (100-ft) length fit well in the containment area and provided approximately 405 cubic meters (530 cubic yards) of storage in each container.

Figure 4. Full lagoon prior to commencement of dredging operations.

Chemical Conditioning

A representative sample of the lagoon residual was collected and sent to the WaterSolve LLC laboratory for testing. Dewatering polymers were evaluated based on water release rate, water clarity, and flocculent appearance. In addition, the dosing rate was determined during bench-top dewatering experiments and recommendations provided to the facility during this phase of the program. Polymer(s) that flocculated and dewatered these residuals most effectively were re-evaluated with lower doses in order to isolate the most efficient dewatering and flocculating polymer. Solve 9330 was the recommended polymer for dewatering this residual in geotextile containers. We recommended using Solve 9330 at a rate of 50-ppm in order to achieve greater than 40-percent solids in geotextile containers for subsequent passing of a Paint Filter Test and excavation (Figure 5).

Results

WaterSolve was contracted to dewater residual dredged from the lagoon as it was being pumped into the 18.3 m (60 ft) circumference by 30.5 m (100 ft) long geotextile containers (Figure 6). Two-Model WSLP-2400 polymer make-down units were plumbed together to administer the proper dose of polymer during operations. An inch and a half water line from the make-down units injected the made-down polymer (Solve 9330) into the 8-inch pipeline line going to the geotextile containers. A sample port located on the eight-inch pipeline prior to the geotextile containers was used to draw samples for visual observations of the inline floc (Figure 7). Adjustments to Solve 9330 dose were made in response to visible observations of the inline samples, filtrate quality, and filtrate release volume from the geotextile container. The pumping rate to the geotextile containers was approximately 1,500-gpm. One containment area was constructed on-site with room for four geotextile containers on the bottom layer and three stacked on the second layer (Figure 8).

Figure 5. Dredge residual sample conditioned with 50-ppm Solve 9330 (left). A 150-mL conditioned sample was poured through a GT500D filter (center). Residual cake remaining on the filter after 60 minutes (right).

Figure 6. Geotextile containers were filled to the maximum height of 2.3 m (7.5 ft).

Figure 7. The raw dredged sample (left) was conditioned with 66-ppm of Solve 9330 (center). The filtrate collected from the geotextile containers is on the right.

Figure 8. Lagoon near the end of dredging operations (left). Geotextile containers were stacked to minimize the space requirement for containment and dewatering (right).

CASE STUDY #2 – STEEL MANUFACTURING FACILITY SETTLING BASIN

Objective

An eight-acre settling lagoon at this major steel manufacturing facility in northern Ohio required removal of solids which had accumulated over several years of operation to increase hydraulic retention time, reduce short-circuiting, and improve solids settling. Facility managers searched for alternative dewatering processes to remove the solids from the pond as economically and efficiently as possible. The objective was to remove the material from the lagoon and dewater it to pass a Paint Filter Test in order to effectively handle, excavate and haul off-site for economical disposal.

The Solution

Several alternative methods were evaluated and it was determined that dredging the material from the lagoon into geotextile containers with chemical conditioning to facilitate the solids/water separation was the most effective. Geotextile containers are manufactured from high strength polypropylene fabric and designed to allow effluent water to escape through the pores of the fabric while retaining the chemically-conditioned solids. The project was commenced and completed during the fall of 2008.

Chemical Conditioning

A representative composite sample of lagoon residual was collected and delivered to the WaterSolve, LLC laboratory for testing. Several dewatering polymers were evaluated based on water release rate, water clarity, and flocculent appearance. In addition, dosing rate(s) were determined during bench-top dewatering experiments and recommendations provided to the facility during this phase of the program. Polymers that flocculated and dewatered these residuals most effectively were re-evaluated with lower doses in order to isolate the most efficient dewatering and flocculating polymer. Solve 9248 was the recommended polymer for dewatering this residual in geotextile containers as a single polymer application (Figure 9).

The Result

WaterSolve was contracted to dewater residual dredged from the lagoon as it was being pumped into 80-ft circumference by 200-ft long geotextile containers. Two model WSLP-2400 polymer make-down units were plumbed together to administer the proper dose of polymer during operations (Figure 10). A three-inch trash pump transferred water from the lagoon to supply the make-down units with adequate water for the chemical feed systems. A two-inch hose from the make-down units injected the made-down polymer (Solve 9248) into the 8-inch pipeline line going to the geotextile containers. Sample ports located on the pipeline prior to the geotextile containers were used to draw samples for visual observations of the conditioned residuals. Adjustments to the polymer dose were

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made in response to visible observations of the inline flocculated samples collected periodically via these sample ports. Geotextile container filtrate quality and the filtrate release volume from the geotextile container were continuously observed during dredging operations. Neat (concentrated) polymer (Solve 9248) demand varied from 2 to 25-gallons per hour and was supplied to the site in 250 gallon totes. The pumping rate to the geotextile containers was approximately 2,000-gpm an inline booster pump to maintain pressure. Two containment areas were constructed; each holding five geotextile containers. Each container was supplied with an 8-inch shutoff valve coming off the manifold header and a 90-degree elbow connecting them via a flexible hose to allow for the containers to fill to their maximum height. Once each container reached the maximum height of 8-feet, the valve directing flow to the individual container was turned off and the container was allowed to dewater without additional flow. After the level in the container dropped, additional flow was directed to the container. The sequence of filling and dewatering varied based on several factors and was continuously monitored by WaterSolve personnel (Figure 11).

Figure 9. A 150-mL diluted test sample (1:2) conditioned with 233-ppm Solve 9248 was passed through a GT500D geotextile filter in comparison to a 150-mL test sample (1:1) conditioned with 333-ppm Solve 9248. Residuals remaining on geotextile filter after 12-h drying time (greater than 40-percent dry wt solids).

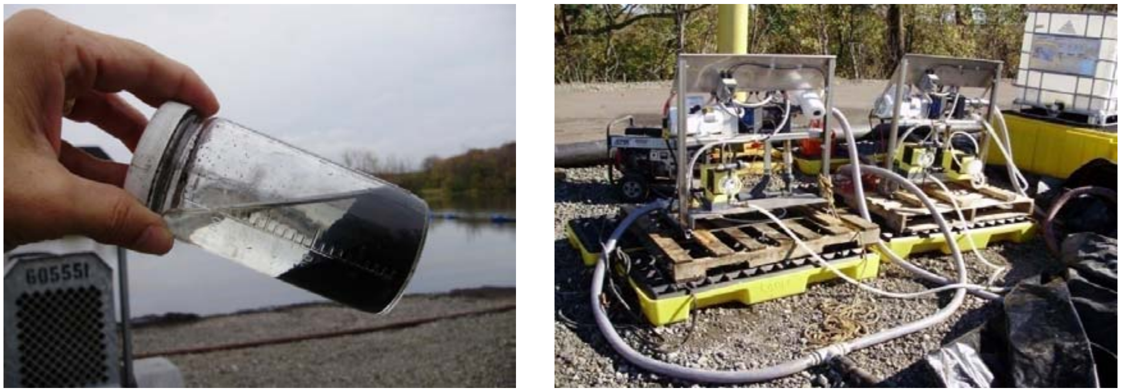

Figure 10. Lagoon residual conditioned with Solve 9248 at the project site (left). Two WSLP-2400 polymer make-down units used to deliver 20 to 30-gph of Solve 9248 (right).

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Figure 11. Geotextile containers were filled via flexible hoses connected to a valved-manifold. Supernatant from the geotextile containers was diverted and returned to the lagoon.

RESULTS AND DISCUSSION

Polymer Make-down Concentration and Activation

Recommended flocculent make-down concentration for dredge-slurry dewatering in geotextile containers is less than 0.5-percent. The inline conditioning and expedient separation of solids and water may be accomplished with lower polymer concentrations as long as inline solids and delivered polymer volume are mixed thoroughly inline prior to the geotextile containers. Greater than 0.5-percent make-down concentration is typically too viscous for inline mixing and loss of efficiency and overall performance are realized in the geotextile containers. In addition to wasting inactive polymer, break though of residual polymer may occur, contained solids may not dewater to project dry weight solids objectives, and containers may blind-off with unused polymer.

In both dredging applications previously described, single emulsion polymer conditioning programs were recommended. In order to facilitate an appropriate inline floc, make-down concentration was less than 0.5-percent. In both cases inline solids concentrations were greater than recommended thresholds for optimizing containment and consolidation. In order to help facilitate mixing and provide interstitial space for sufficient conditioning, polymer was made-down at less than 0.25-percent to add additional in-line water volume for dilution of dredge materials.

Mixing/Contact Time and Shear Energy

A fine balance between enough mixing energy/contact time and shear energy, too much mixing/contact time, exists while adding polymer(s) to a dredge residual pipeline. With insufficient mixing energy/contact time, polymer will flow in streams or ribbons with the residual into the geotextile containers and not facilitate the water release and subsequent consolidation expected over time. With delivery of the correct dose, evidence of insufficient mixing energy is realized with unused polymer in the geotextile tube filtrate. The filtrate will be slimy and foaming may be visible. In order to increase mixing energy/contact time, move the injection port(s) closer to the dredge; add bends

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(45 and 90 degree) or inline static mixers to the discharge line to disrupt laminar flow. Also, addition of polymer into several injection ports along the residual line may facilitate more proportional distribution of inline mixing.

Too much mixing/contact time or shear energy results in the conditioned residuals disassociating inline prior to the geotextile tube and potentially not dewatering and subsequently consolidating. In many cases, the recommended dose is delivered and an inline floc is facilitated only to fall apart. In many cases with the appropriate flocculent, the residual will re-form and dewatering in the tubes will occur. However in most cases of shear, the residual will not re-flocculate and consolidation will not occur in the geotextile tubes. Inline evidence of shearing is no visible floc observed in the sample port and no change observed after addition of more polymers to the residual. Typically, the geotextile tube filtrate is free of polymer and the release volume is diminished. In order to decrease shear, move the injection port(s) closer to the tubes and straighten out the flow line from the injection port to the geotextile tubes. In both examples, additional mixing energy/contact time was facilitated by adding a mixing manifold (45 degree bends) downstream of the injection ports.

Feed Equipment

Several options are available to make-down, activate, and deliver polymer to a dredge residual line (1,000 to 5,000-gpm flow rate) for subsequent dewatering in geotextile containers. Polymer may be made-down in batches, adding neat polymer to a tank of water, blending at high speed for 10 to 15 minutes, and allowing product to swell for an additional 30 minutes prior to injection/pumping into the residual line. Although batching is operationally time consuming and requires a large footprint for make-down tanks and equipment, polymer activation is effective and dewatering more efficient than many other options. In order to decrease operational time, batching may be automated for make-down of either dry or emulsion polymers, typically in a temporary building or other dry environment. A chemical feed pump with appropriate chemical resistance housings is subsequently used to deliver made-down polymer to the residual slurry inline.

Many dredging projects with subsequent dewatering components take place in sites with limited resources and utilities and/or in temporary construction zones. The footprint for full-scale operations is restrictive and alternatives to batching in tanks are imperative. One option is to add neat polymer with a chemical feed pump into a high flow, high pressure water line and pass the mixture through a series of static mixers to unravel and activate the chemistry. With adequate mixing time prior to introduction to the residual line, the polymer will provide effective dewatering performance. We typically recommend additional inline mixing downstream of the polymer injection port and prior to the geotextile containers to make-up for delinquencies in make-down and/or activation due to laminar flow and short-circuiting. Several manufacturers' have also designed equipment based on activation with static mixers and energy for mixing introduced through the water source. These compact systems were designed for low volumes of high solubility polymer (e.g., coagulants) introduced into low solids residuals. However, these systems are limited on delivery volume (less than 18.9 liters/hr, 5 gph) and are not suited for high viscosity emulsion flocculants.

An efficient and effective make-down technology for high volume polymer delivery in continuous, high flow residual streams uses a high-speed mixing chamber for activation. Neat polymer and water (high flow and pressure) are delivered to a mixing chamber with high-speed blenders for mixing, swelling, and activation prior to introduction to the residual line. These units are available with diaphragm, progressive cavity, or gear pumps for delivery of the neat polymer (0.15 to 227 liters/hr, 0.04 to 60 gph) with subsequent made-down volumes of 30.3 to 45,420 liters/hr (8 to 12,000 gph) delivered to a dredge slurry line. Many of these units run off 110V, single phase electricity and have a small bench-top footprint.

A single piece of equipment to manage large polymer demands is susceptible to breakdown, maintenance schedules, requires a dry footprint, and other unrealistic utility demands (large water volume and 480 V/3 phase) that are an operational and cost deterrent. In many cases a single unit is not sufficient to deliver enough made-down polymer, thus several units may be plumbed together or fed to an injection manifold separately.

In lieu of a single machine, we typically recommend plumbing several smaller units together, such as with the two previously described case studies. In both cases, two 37.85 liter/hr (10 gph) WSLP-2400s (diaphragm pumps) were used simultaneously to deliver enough made-down polymers for conditioning approximately 7570 liters/min (2,000 gpm) dredge discharge flows of 10 to 15% inline solids. The footprint required for two skid-mounted units is approximately 1.5 m x 3.05 m x 1.5 m (5ft x 10ft x 5ft) (W x L x H), each unit requiring 110V/single phase and water delivered at 189 to 379 liters/min (50 to 100 gpm) with 345 to 690 KPa (50 to 100 psi). The units are easy to move around, maintenance is minimal, and if a unit were to be offline for an extended period of time, the project would not be shut-down. If a unit would require maintenance unsuitable for facilitating in the field, a replacement is typically 24-hours for delivery and change-out.

CONCLUSIONS

Chemical conditioning optimization of geotextile containers used for dewatering contaminated solids and subsequent excavation operations at two project sites, including cost effectiveness, polymer make-down concentration and activation, mixing energy, contact time, and make-down equipment required to operate. Geotextile containers, with the aid of dewatering polymers, were recommended to and implemented by both contractors into which solids were dredged and pumped directly into geotextile containers. With optimization of chemical conditioning, geotextile dewatering reduced the volume and mass of residual solids and is expected to save the contractors 50-percent of the costs associated with hauling and disposal while allowing continual operations of the project sites.

Overall, containment and dewatering of contaminated solids with geotextile containers (including dewatering polymer and feed equipment) costs less than \$0.01/gal (greater than 2,000 yd^3 *in situ*), requires minimal technical assistance to install and operate, retained greater than 95-percent solids, solids were only handled once they were dried sufficiently for hauling and disposal (18 to 40-percent cake solids), did not interfere with site and facility operations, and the lay-down area for containment of 765 m^3 (1,000 yd^3) of solids production was 562 m^2 (6,050 ft^2).

ACKNOWLEDGEMENTS

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