

THE POSITIVE IMPACT OF POLYMERS ON SEDIMENT TREATMENT AND HANDLING

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ABSTRACT

Several factors are taken into consideration when a sediment handling operation for a dredging project is designed or implemented by a contractor. These factors – including operational efficiency, regulatory climate, project economics, etc. - sometimes require adoption of solutions that go beyond the capability of conventional material containment practices. One such solution is the use of polymers to improve the efficiency and cost-effectiveness of an operation. Of significant importance is the selection of the proper chemistry to employ for a given substrate, the appropriate equipment for chemical preparation and dosing, as well as working with competent vendors that possess the know-how and experience with dredging applications, including the ability to work with the local and regional regulatory agencies. This paper presents five examples where benefits from that sort of enhanced solutions approach were realized. When polymers are considered in this way, they can go from improving the quality of effluent produced, increasing the sedimentation and/or dewatering rate of dredged material, to positive impacts on the overall profitability of a dredging project.

Keywords: Polyelectrolytes, coagulants/coagulation, flocculants/flocculation, polyacrylamide

INTRODUCTION

Polymers, which are more commonly known by water chemists as synthetic organic polyelectrolytes, have been used in dredging in the United States for more than 30 years (Seagren 2003). However, their use over time has been rather limited when compared to the total amount of sediments dredged annually. In contrast, polymers have also been used to a much greater extent, and with a wider spectrum of applications, in the potable water and wastewater markets since the 1950's. The U.S. Army Corps of Engineers (USACE) has investigated, quite extensively, the use of polymers with confined dredged material disposal projects. These are documented in technical reports (Wang and Chen 1977), (Jones et al. 1978), (Schroeder 1983), (Wade 1988), (Bailey, et al. 2005), in which polymer evaluations were conducted and testing protocols were used and/or established. Additionally, the USACE has included information about the use of polymers and recommended testing methods within some of their engineering manuals such as, Confined Disposal of Dredged Material (USACE 1987) and Design of Small Water Systems (USACE 1999).

In spite of the body of information available, there still seems to be a need to fill some of the gaps with an explanation of what polymers actually are, how they work, how to make the correct selection for a particular substrate, and exactly how -and in what instances - one can benefit from their use. Perhaps, armed with this information and shown some recent examples of where they have been used successfully, project owners and key stakeholders may have a higher degree of comfort and confidence in considering the use of polymers in the early planning stages.

Most polymer usage in dredging takes place within upland disposal operations or solids dewatering operations in which enhanced solids/liquid separation and/or consolidation is desired. This occurs with freshwater or marine substrates (either contaminated or non-contaminated), but can also take place in a myriad of commercial,

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industrial, municipal, or public dredging applications, as well (Seagren 2003). Table 1 shows a partial list of these types of projects and /or substrates in which polymer treatment can be considered.

Table 1. List of potential dredging substrates for polymer usage.

Metal Industry Wastes	Petrochemical Wastes	Power Plant (fly ash)
Textile Wastes	Chemical Process Wastes	Storm Water Run-Off
Construction (Erosion)	High Water Table Excavation	Paper Mill Wastes
River Silt, Muck, & Clay	Lake Silt, Muck, & Clay	Marina/Dock Silt, Muck, & Clay
Inland Canals Silt, Muck, & Clay	Lock/Dam Silt, Muck & Clay	Aggregate Washing
Acid Mine Drainage	Coal Washing	Water Supply Reservoirs
Mineral Tailings	Municipal Wastewater Lagoons	Cooling Water Ponds
Cannery Wastes	Leather and Tanning Wastes	Sugar Processing Wastes
Atomic Wastes	Contaminated Sediments	Combined Sewage Outfall

From the list shown in Table 1, the following is a partial list of some of the characteristics those substrates exhibit, either individually or in combination, which make them amenable to polymer treatment:

- Fine-grained sediments (i.e., organic and inorganic silts and clays, fine sand)
- Highly organic soils or substrates
- Grain size below No. 200 mesh (0.075 mm or 75 microns)
- High surface area-to-mass ratio of particles

GENERAL DESCRIPTION OF POLYMERS

Polymers, in the sense we will be dealing with, are synthetic, in that they are not naturally occurring, but rather are man-made substances based primarily on water soluble polymer chemistry. They are organic because they are composed of carbon-based molecules that link together to form long chained compounds (i.e., macromolecules) of repeating single monomer units. The length of the chain formed for a particular polymer is an indication of its relative molecular weight, typically shown in units of 10^6 amu (atomic mass units), or on a relative scale of low-high. In other words, the longer the chain, the higher its relative molecular weight. The chains are reacted with various types of charge monomers, which give the chain either a predominance of positive charge, negative charge, or a neutral charge. The units of measure used for charge density is meq/g (milli-equivalents per gram), or it can just be shown on a relative scale of 0-100%. These types of polymers are referred to as polyelectrolytes because when they are dissolved in water, they exhibit electrolytic charge based on the charge monomers they were reacted with during the manufacturing (or polymerization) process. Figure 1 illustrates how polymers can range in both molecular weight and in charge density by the information just described.

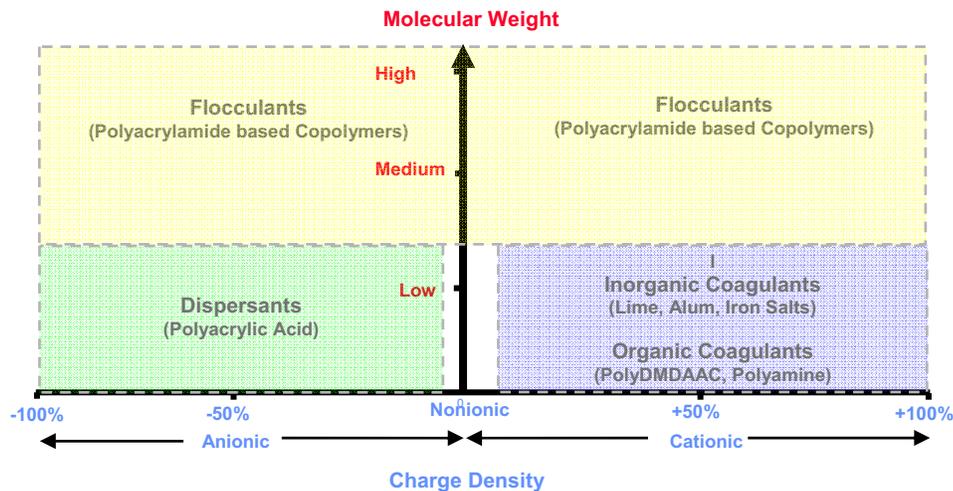


Figure 1. Chemical characteristics of polymers.

Coagulants and Coagulation

Due to their high surface area-to-mass ratio, fine-grained (i.e., below No. 200 mesh or approx. <75 microns) sediments and soils in water have the tendency to attract and display electrical charge properties. This means that most of those particles will have a similar charge and repel one another, as well as resist the natural influences of gravity to settle. In other words, they can form a stable colloidal suspension. Water treatment coagulants are chemicals that induce instability and agglomeration into a water based colloidal suspension that would otherwise only settle out over a long period of time. Hence, the primary function of the coagulant is to destabilize the suspension by neutralizing the surface charge upon the suspended particle, thereby, removing the electrostatic repulsion between the particles and allowing the particles to get close enough for forces of attraction to act and agglomerate the material. Inorganic coagulants employ metal cations (positive charge) for their effectiveness and, therefore, salts of iron and aluminum are commonly used. These may be applied as simple salt solutions of materials such as ferric chloride, ferric sulphate, aluminum sulphate or aluminum chloride, or the more complex poly-aluminum ion solutions, such as polyaluminum chloride and aluminum chlorohydrate.

Due to difficulties experienced with product handling issues, pH limitations, and additional solids generation inherent with the use of inorganic coagulants, synthetic organic coagulants were developed and became a viable alternative or supplement. Coagulation may also be achieved using synthetic organic polymer coagulants of high cationic (positive) charge. Standard, synthetic organic coagulants (as seen below in Figure 2) are poly-DADMAC, a homopolymer (repeating units of the same monomer) produced by addition polymerization, of diallyldimethyl ammonium chloride, and poly-amine (a condensation polymer prepared from epichlorohydrin and dimethyl amine). To function as a coagulant these polyelectrolytes have a low molecular weight, $1 \times 10^5 - 1 \times 10^6$ amu, and a very high charge density of 6-7 meq/g.

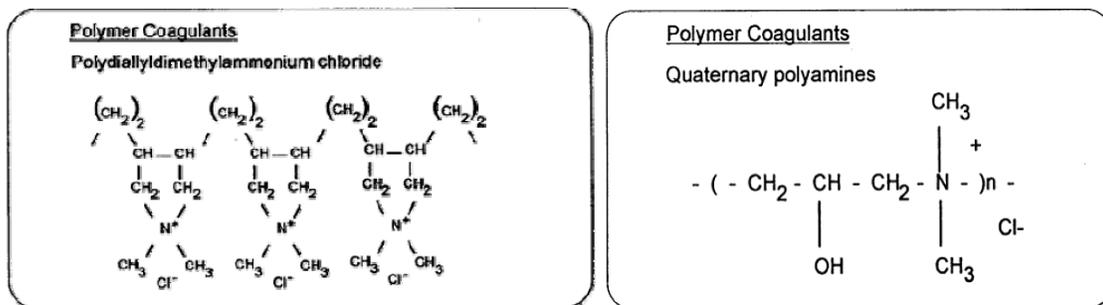


Figure 2. Synthetic organic coagulants: poly-DADMAC and poly-amine.

Synthetic organic coagulants are capable of patch coagulation, in which the cationic (positively charged) polymer chains become attached to the oppositely charged particle surfaces and act as an electrostatic adhesive to bring other particles into close contact with one another and allow forces of attraction between the particles to bind them (Figure 3). For that reason, synthetic organic coagulants bring about a faster aggregation rate than coagulation with simple electrolytes like inorganic coagulants.

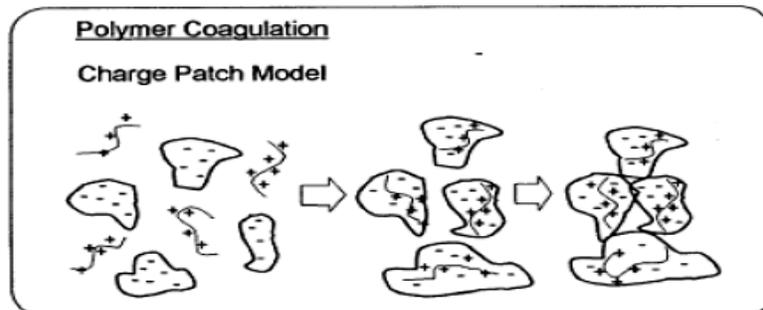


Figure 3. Charge patch coagulation model.

Flocculants and Flocculation

Flocculant polymers are very high molecular weight (long chain length), synthetic polyelectrolytes composed of a polyacrylamide backbone, and may be anionic (negatively charged), non-ionic (neutrally charged), or cationic (positively charged) in nature. Molecular weights are typically in the range of 3×10^6 to 15×10^6 amu. Flocculant polymers are supplied in dry (granular or micro-bead) or liquid (oil dispersion or inverse emulsion) form. These flocculant polymers are dissolved in water to form very viscous, low concentration (0.2 – 1.0%) solutions of the polyelectrolytes. Their primary function is to form large masses of particle solids from aggregating much smaller suspended particles to form “flocs” which readily separate from the water. A non-ionic flocculant is prepared by the homo-polymerization (to form repeating units of a single monomer) of acrylamide. If, in turn, acrylamide is co-polymerized with acrylic acid monomer, an anionic (negatively charged) flocculant is produced. When acrylamide is co-polymerized with acroxyethyltrimethylammonium chloride monomer, a cationic (positively charged) flocculant results (Figure 4). Variation in the ratio of these monomers to acrylamide during the polymerization process allows for the creation of polyelectrolytes of varying charge density levels.

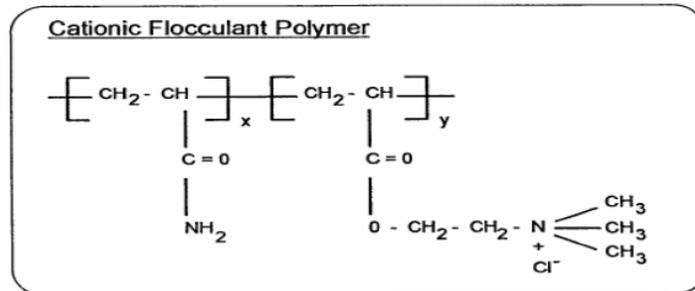


Figure 4. Basic cationic flocculant structure.

The destabilization of a colloidal suspension by flocculation is accomplished with these high molecular weight polyelectrolyte flocculants by attracting oppositely charged particles to its charged sites along the length of its long chain. This leads to the formation of large flocs as these long thread-like structures form bridge links between the suspended particles, as shown below in Figure 5.

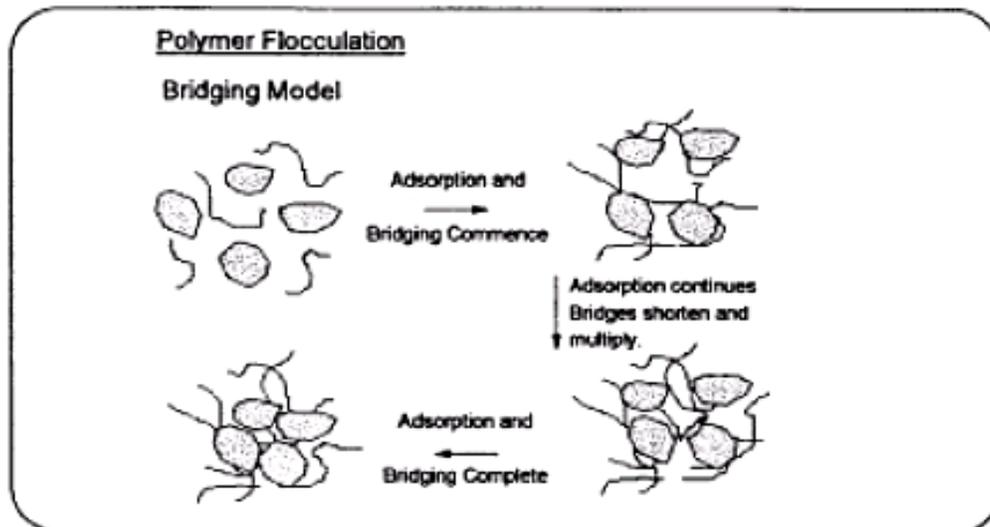


Figure 5. Flocculation bridging model.

General Polymer Treatment – Tying Coagulation and Flocculation Together

As you can see from the information presented above, coagulants and flocculants are different in chemical composition from one another, just as coagulation and flocculation are essentially different processes. However, in many cases, the terms and the processes are erroneously interchanged. Coagulants, both inorganic and organic, generally possess very high charge densities but lack the molecular weight to flocculate effectively. Flocculants can come in a full range of charge densities and molecular weights, and in most cases can coagulate as well as flocculate, but as the molecular weight of the flocculant increases, it tends to become less effective in its ability to coagulate. In those cases, one may opt to use a treatment program comprised of adding a coagulant (either inorganic, organic, or both) followed by the addition of a flocculant. Depending upon the specific substrate you may be wanting to test and what you are trying to remove, Table 2 shows some of the possible chemical combinations that could be used (not all-inclusive).

Table 2. Common chemical combinations dependent upon substrate.

Treatment Option	Chemical Addition #1	Chemical Addition #2	Chemical Addition #3
1	Cationic Organic Coagulant	N/A	N/A
2	Cationic Inorganic Coagulant	N/A	N/A
3	Cationic Flocculant	N/A	N/A
4	Anionic Flocculant	N/A	N/A
5	Cationic Organic Coagulant	Anionic Flocculant	N/A
6	Cationic Inorganic Coagulant	Anionic Flocculant	N/A
7	Anionic Flocculant	Cationic Flocculant	N/A
8	Cationic Inorganic Coagulant	Cationic Organic Coagulant	Anionic Flocculant

As can be seen, there are numerous ways and combinations in which treatment can be accomplished. However, the characteristics of the substrate (i.e., dredged solids) greatly influence which of these treatment options shown above would even be viable. More will be said on this in the Selection Process section below.

POLYMERS FOR DREDGING

Applications

Polymer treatment, of course, is not for all dredging applications. Since polymers mainly react with dredge slurry particles below No. 200 mesh (< 75 microns), which are typically referred to as “fines,” only those sediments or soils at or below the particle size of very fine sands, silts, clays, and organic materials are likely to be influenced by their coagulation and/or flocculation properties. All other larger particles are more capable of being acted upon by gravitational forces, and will settle (or separate readily from the water phase) without the aid of chemical addition. That larger fraction can be allowed to settle on its own, or can be separated from the water phase by screening or hydrocycloning, or other types of mechanical separation processes. So, any insitu material to be dredged with a high fraction of “fines” or organic material is a good candidate for polymer treatment, especially if the fines are to be contained within an upland or confined disposal site, or separated out and treated at an on-shore dewatering operation. Feasibility of chemical treatment versus the design of the upland or confined disposal site will have to be determined. USACE documents previously mentioned, such as Schroeder (1983), EM1110-2-5027 (1987), and Wade (1988) address this issue with testing methodologies that help determine if the new or existing disposal site design is adequate, or if polymer addition(s) could provide benefits.

Table 3 below, identifies the sediments or soils most amenable to polymer treatment (highlighted in **red**), and how they compare to the other soil types. These are the dredging “fines,” which pass through a No. 200 mesh sieve (<75 microns). This would also include many cohesive sediments (< 62.5 microns), suspended solids (< 45 microns), and even very hard to settle colloidal particles (0.001-1.0 microns).

Table 3. PIANC classification of soils by sieve size and 10⁻⁶ meters.

Soil Type	Particle Size – microns (10 ⁻⁶ meters)	Sieve Size
Boulders	> 200,000	6 in
Cobbles	60,000 – 200,000	3 – 6 in
Gravels - Coarse	20,000 – 60,000	¾ - 3 in
- Medium	6,000 – 20,000	¼ - ¾ in
- Fine	2,000 – 6,000	# 7 Sieve – ¼ in
Sands - Coarse	600 – 2,000	# 25 - # 7
- Medium	200 – 600	# 72 - # 25
- Fine	60 – 200	# 200 - # 72
Silts - Coarse	20 – 60	Passing # 200
- Medium	6 – 20	“
- Fine	2 – 6	“
Clays	< 2	“

Some of the benefits realized, which result in improved process efficiencies, when using polymer treatment are:

- 1) more rapid solids settling rates and resistance to re-suspension
- 2) cleaner supernatant or effluent discharge water due to TSS (Total Suspended Solids) removal
- 3) improved cake solids generation (i.e., volume reduction) and solids throughput – for dewatering

When dealing with contaminated sediments, these benefits become even more important. Process efficiency improvements are desirable under just about any conditions. However, being able to remove 99.99% of the contaminated solids so they do not re-enter the waterway with the effluent discharge, while significantly reducing the volume of sediment to be disposed of, and being able to pass a paint filter test (for leachability) for landfill final disposal are all concerns that polymers can influence in a positive manner.

Selection Process

The early planning stage of a project, including any feasibility studies that may be conducted, is the best time to begin thinking about polymer treatment. There are many factors that need to either be considered or decided on for a particular dredging project. The following is a breakdown of some of those factors that go beyond just selecting the correct polymer for the project, to help you make more informed decisions related to the use of polymers:

Reputable, Full-Service Supplier/Vendor

It is important to deal with suppliers that have experience in the application of polymers in, and understand the unique needs of dredging applications. Dealing directly with manufacturers, as opposed to resellers or distributors, has distinct advantages in terms of product availability, quality and consistency, as well as potential access to new product development or launches. Look for a supplier with a broad portfolio of services with a strong customer focus. The supplier’s Sales/Marketing department is the common point of most contact and is vital throughout the life of the project, but success will involve having a more comprehensive organization and resources to draw upon. Equipment Services is very important, especially one that can provide a variety of related polymer storage, makedown, dosing (conventional and automated dose control), and monitoring equipment. Equally as important are Laboratory Testing Services and Technical Support that offer a wide range of testing capabilities including sediment characterizations and standardized or customized testing methodologies for various types of processes that may be engineered into the project, under consideration, or just in need of optimizing. Additionally, other related support services are critical. Regulatory Services help interface with the USACE and

with various local and regional water districts, environmental agencies, and advocacy groups. For routine order placement and to help deal with any unexpected disruptions in product supply or quality, Customer Services can play a vital role in seeking out root cause, resolving the situations, and preventing them from reoccurrence. Last, but certainly not least, is the necessity for Field Support that entails work that may need to be performed before, during, and after the project has been completed. A low price from a local supplier for just polymer, alone, is rarely a good ingredient for a successful project. It is advisable to obtain all pricing up front, rather than allowing for subsequent, unaccounted for charges to mount up as the project gets under way. Due to polymer pricing being tied to the price of oil and to global shortages of related raw materials (used in polymer manufacture) that may exist as a result, longer term project contracts (> 1 year) should include some provision for price escalation or adjustment based on the Chemical Price Index.

Project and Treatment Objectives

Know early on, based on the type(s) of sediments likely to be encountered, whether polymer(s) should or could be considered. As previously stated, that would depend, in large part, upon the concentration of fine-grained material expected from any insitu analyses conducted, and upon whether or not the sediments are considered contaminated or not. Timing and duration of the project will also be important factors to consider. These, of course, influence the engineering of the disposal area or the treatment process, but from a polymer perspective, could affect the flow rates and necessary equipment sizing, as well as seasonal considerations (e.g., shelter, winterization, down-time, etc...). Effluent discharge limits for a particular project may also be a reason to consider the use of polymer treatment, and/or if dewatering of the solids is to be done. If the dewatered materials are to be hauled away any kind of distance, and depending upon how the hauling contract or the contract with the final disposal site (e.g., landfill) is structured, cake dry solids content may need to be maximized (usually by the use of polymers) in order to maximize the tonnage of actual dredged solids being loaded out per truckload, or to improve acceptability of the consolidated sludge cake at the landfill.

Polymer Selection

When trying to select the proper polymer treatment, the following items are inter-related and will need to go into the decision-making process for the most cost-effective and workable solution to satisfy the project, treatment, and timing objectives:

- Physical form: Dry, liquid solution, liquid inverse emulsion, or liquid dispersion
- Ionicity and molecular weight demand: Appropriate charge density and molecular weight needs to be determined by the polymer supplier from laboratory studies. This is best accomplished by the supplier since they will have access to a full range of products, including new product introductions or even experimental products nearing commercialization, they can include in their test work.
- Treatment combination: With the various chemical combinations that may be possible for a particular substrate, as shown in Table 2 and mentioned earlier, laboratory studies can help narrow down the available chemical combinations so that the efficacy of those remaining options can be compared for a particular substrate.
- Dosage requirement: Since it is well established now that polymers react with the fine solids in a given substrate, the dosage requirement is estimated by laboratory tests designed to best simulate the process or processes that will be utilized. Polymer dosage is usually expressed in a weight-to-weight ratio of, pounds of polymer in its as-supplied form per dry ton of dredged slurry dry solids. Suppliers experienced in dredging will be able to readily relate this information to a dosage per cubic yard insitu.
- Polymer make-down equipment: This is also where a supplier's experience with dredging applications can be a tremendous benefit. Polymers require to be made-down, or dispersed and diluted, into water to form a solution before it is introduced to the substrate to be treated. The physical form selected, anticipated volumes of product required, and the available area on site will determine the type, size, and possibly the sophistication of the equipment required. Accommodations need to be made for having adequate shelter, power, and water supply for make-down. In some cases mobile shelter, generator

power, and resident water may have to be considered. The polymer supplier needs to have the necessary resources to assess the equipment needs of the project, perform a site audit (if possible), and be able to present viable recommendations for equipment as a part of their overall proposal package.

- **Storage, Handling, and Safety:** The physical form of polymer selected and the anticipated volumes of product required will help to dictate the type of packaging and/or on-site storage that may be required. Check with your supplier to see what packaging options they may provide. Dry polymers can be packaged in small bags (~25 kg (~ 55 lb)), various tay bags (~ 544 - 907 kg (~ 1,200 – 2,000 lb)), stainless steel returnable tote bins (~907 kg (~ 2,000 lb)), or it can even be supplied in bulk (approx. 18,144 kg (40,000 lb)) into a silo system, if necessary. Liquids are typically supplied in drums (~188 – 208 liters (~50-55 gallons)), tote bins (~946 liters (~250 gallons)), or in bulk (~18,925 liters (~5,000 gallons)). Information should be provided from your supplier and on the MSDS regarding specific storage, handling, and safety guidelines.
- **Environmental:** The physical form of polymer (i.e., dry polymer, water based liquid coagulant, oil based inverse emulsion, or oil based liquid dispersion) and the Ionicity (charge density relative to whether it is anionic, cationic, or nonionic) will help determine its estimated ecotoxicity, and a specific product decision could be made based on that information.

Examples and Benefits

The following are examples of dredging projects that have taken place over the last five years (2002 – present), in which upland disposal or treatment of sediments took place, all involving the use of polymer. They are also examples in which polymers played a significant role in the accomplishment of the overall project and treatment objectives, as well as examples of how the Selection Process detailed above can be instrumental in improving your chances for success. Five different projects are shown below in Table 4. Three of the five projects had previously failed attempts at treatment. However, when the Selection Process was introduced and followed, coupled with the appointment of a new general contractor as well, a turn-around in results occurred. In all five of these cases, the projects ran well from the first day of treatment until completion, which resulted in minimal down-time, and positively influenced dredge production. Therefore, the projects experienced little to no costs associated with loss of dredging production due to poor or improper polymer treatment. Four of the five projects utilized automated polymer dosage control to help adjust for fluctuations that are usually experienced with incoming slurry concentration. This allowed for the minimization of polymer dosages, which, in turn, minimized residual polymer from being discharged back into the waterway.

Table 4. Successful Dredging Projects Utilizing Polymer

	Olmsted Locks & Dam	Murrells Inlet	Conner Creek	Fox River	Miami River
Year	2002	2003	2003-2004	2005-	2005-
Location	Olmsted, IL	Murrells Inlet, SC	Detroit, MI	Neenah, WI	Miami, FL
Sediment Type	Non-Contaminated	Non-Contaminated	Contaminated	Contaminated	Contaminated
Dredge Type	Hydraulic	Hydraulic	Hydraulic	Hydraulic	Mechanical Back Hoe
Process	3-Tiered Containment Area	Screening; RDS® Thickening; Belt Press Dewatering	Screening; Geotube® Dewatering	Gravity Thickening; Geotube® Dewatering	MSWP®; 3 Stage Screening/Separation; Gravity Thickening; Belt Press Dewatering
Polymer Type and Form	Cationic Liquid Coagulant	Anionic Liquid Flocculant + Cationic Liquid Flocculant	Cationic Dry Flocculant	Cationic Dry Flocculant; Cationic Dry Flocculant	Cationic Liquid Emulsion; Cationic Liquid Dispersion

Olmsted Locks & Dam (Figures 6-9)

High concentrations of kaolinite caused settleability problems and high TSS (Total Suspended Solids) in the discharge back into the waterway. Process consisted of primary, secondary, and tertiary containment areas. The addition of a cationic liquid polymer at a very low dosage resulted in rapid settling of the solids and TSS consistently below discharge permit limits.



Figure 6. Polymer injection



Figure 7. Slurry pipeline discharge into primary containment area



Figure 8. Primary containment area effluent



Figure 9. View of secondary containment area

Murrells Inlet (Figures 10-13)

Very fine-grained “fluff mud” treated with a dry cationic flocculant, made-down in solution (with an Alcotech®DWU system) allowed for a single dosage (via Alcotech®DS automated dosage control) prior to RDS®thickening, producing good thickening and subsequent belt filter press dewatering results. Anionic needed to be added when recirculation of solids occurred. Cake solids from belt filter press dewatering met or exceeded the target %TS (Total Solids by weight) and were successfully transported and landfilled. TSS for discharge was consistently below permit limits.



Figure 10. Polymer injection prior to RDS® thickeners



Figure 11. Thickened solids coming off the RDS® thickener



Figure 12. Cake solids coming off 1 of 2 belt filter presses



Figure 13. Effluent discharge returning back to the marina

Conner Creek (Figures 14-17)

PCB and mercury contaminated sediment was treated with made-down solution of a cationic dry flocculant (with an Alcotech®DWU system) prior to entering Geotubes® for dewatering. Automated dose control (Alcotech®DS) was set and never changed for the duration of the project. Cake solids generated were at or above %TS target and acceptable to the landfill. Discharge was consistently below discharge permit limits on TSS, PCBs, and mercury.



Figure 14. Polymer injection into pipeline



Figure 15. Alcotech®DWU dry polymer make-down system



Figure 16. Geotubes being filled with flocculated solids and draining



Figure 17. Geotube® weep being returned back to the waterway

Fox River (Figures 18-21)

For the 2005 dredging season, PCB contaminated sediment was treated with made-down solution of a cationic dry flocculant (with an Alcotech®DWU system) prior to gravity thickening (2006), followed by Geotube® dewatering. Automated dose control (Alcotech®DS) worked well when used and when solids were “in-range” for the system to function. Cake solids ranged from slightly below to above the %TS target when automated dosage control was used. Discharge was consistently below permit limits on TSS and PCBs.



Figure 18. Polymer addition point into 2 slurry pipelines



Figure 19. Alcotech®DWU dry polymer make-down system



Figure 20. Alcotech®DS polymer dosage control system



Figure 21. Geotubes filled with flocculated solids and draining

Miami River (Figures 22-25)

During 2005, MSWP® (Mobile Soil Washing Plant) was used to separate, wash, and remove all oversized materials. Fines were gravity thickened with the use of a very low dosage of a made-down cationic liquid inverse emulsion. The underflow sludge from the thickener was then treated with a made-down solution of cationic liquid dispersion before undergoing belt filter press dewatering. Cake solids %TS exceeded target, and discharge water was consistently below permit limits.



Figure 22. Flocculated fines entering gravity thickener



Figure 23. Gravity thickener overflow weir



Figure 24. Belt filter presses for dewatering thickened solids from thickener underflow



Figure 25. Sludge cake from belt filter press dewatering

It is worth noting that in all five examples shown above, that the proposed package price and budget for polymer, equipment, and all related support services was only slightly exceeded in 1 of these projects. That was only at the Murrells Inlet project and was due to the unexpected addition of anionic liquid dispersion used to help offset the residual cationic polymer being recirculated back through the process. All in all, the proper selection, application, and dosing of polymers in these 5 examples confirmed how polymers, equipment, and the related support services can definitely influence a positive project outcome.

Issues Raised

The most common issues for dredging applications revolve around permitting to the local regulatory agencies, which can vary greatly. Since polyelectrolyte use in some dredging applications may be fairly novel, the issue facing the industry is lack of knowledge about this chemistry. Anytime chemicals are considered anywhere near a waterway, watershed, or environmentally sensitive estuary, it tends to trigger the caution or warning flags. All industrial chemicals must comply with local, state and federal regulations. Dealing with a reputable supplier is crucial, and can dramatically increase your chances of proper compliance. The best piece of information to begin

with is the supplier-provided Material Safety Data Sheet or MSDS (sometimes referred to as SDS or Safety Data Sheet). A good MSDS will contain a tremendous amount of vital information.

Health Concerns

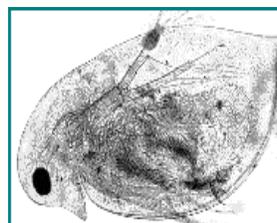
The MSDS identifies any OSHA (Occupational Safety and Health Administration) workplace health or physical hazards associated with each specific polymer. Some individuals may experience irritation to their eyes, skin, or respiratory system when handling certain types of polymers, and proper exposure controls and PPE (personal protective equipment), as spelled out in the MSDS, should be followed. The main physical hazards associated with polymers are the slip hazard potential when any polymer becomes wet, and a dust explosion potential for dry polymers. Avoiding and cleaning up polymer spills right away, in addition to following the guidelines within the product-specific MSDS will ensure safe and effective use of that particular polymer.

Environmental Concerns

Toxicity and Ecotoxicity information is usually documented in later sections of the MSDS depending on the formatting. In those sections acute (short term) and chronic (longer term) toxicity and ecotoxicity information is usually detailed. For dredging, the concern for customers and regulating agencies is the direct impact to the environment, i.e., ecotoxicity. Ecotoxicity values are typically reported in terms of LC50 or EC50 which is the lethal concentration (LC) or effective concentration (EC) at which 50% of the test subjects died or were adversely affected by the test substance. These tests are conducted on various species. The most common are vertebrate fish species from freshwater and/or marine water environments and invertebrate species from freshwater or marine environments. There are many methods and time frames utilized for executing these types of studies. The most common time frames range from 48 – 96 hours in duration for short term (acute) and 7 – 21 days and beyond for longer term (chronic) studies. The choice of test species is critical for certain governing bodies as well as the methods used for testing. An example of a typical freshwater vertebrate species is the Rainbow trout and a typical freshwater invertebrate is the water flea or *Daphnia magna* (depicted below in Figure 26).



Rainbow Trout



Water flea

Figure 26. Species for freshwater ecotoxicity testing: rainbow trout and water flea (*Daphnia magna*)

A typical vertebrate marine species is the tide water silverside and a typical invertebrate species is the tidal shrimp or mysid. The best resources for decision making in this area is the US Environmental Protection Agency (EPA). The following link is a great resource (<http://www.epa.gov/OST/WET>). The graphs below (Figure 27) demonstrate a few examples of various polymer types and anticipated ecotoxicity values in vertebrate and invertebrate freshwater species.

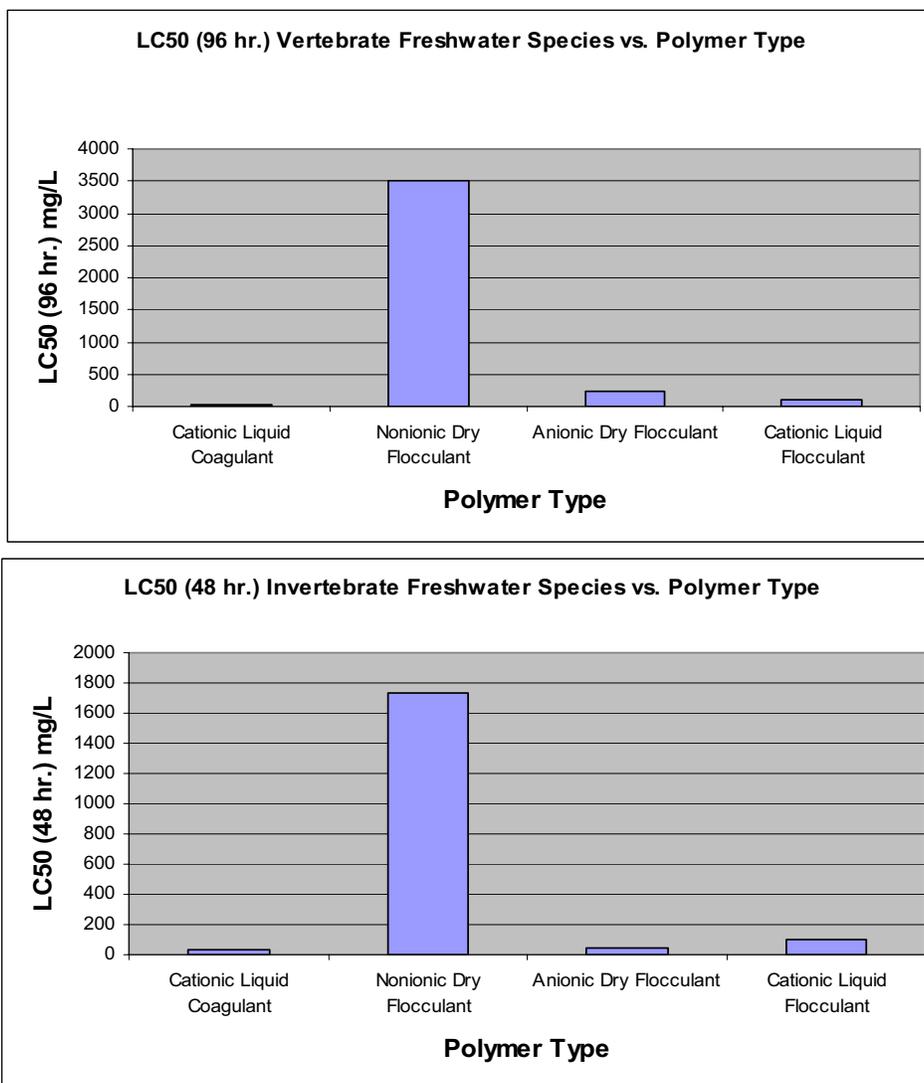


Figure 27. LC50 data for freshwater vertebrates (96 hr.) and invertebrates (48 hr.) vs. polymer type.

Other values that may appear under ecotoxicity on the MSDS often relate to bacterial or algal ecotoxicity. These reported ecotoxicity values can be used to assess environment impact or risk. In general materials that report low LC50 or EC50 values (< 1 mg/L) should be approached with a great deal of caution. Materials that report higher LC50 or EC50 values (>100 mg/L) are generally regarded as having little to no ecotoxicity potential, but assessing risk is still necessary.

Risk Assessment

Risk assessment is really the key. Determining the amount of risk associated with the use of certain chemicals in various applications has been a tool widely used within agencies like the EPA. For tools and information the EPA website is a valuable resource (www.epa.gov). One tool that can be very valuable is the EPA’s PBT Profiler which assesses materials in regards to their persistence, bioaccumulation, and toxicity. This tool can also found on the web (<http://www.pbtprofiler.net>). This is a search engine type tool that allows the user to “profile” either by the structure of chemical abstract services number (CAS#) the chemical of interest. The profile generated estimates if the material meets the EPA’s criteria of being persistent, bioaccumulative, or toxic in the environment. In general, substances that meet these criteria should be avoided due to their potential environmental impact.

Biodegradation

Biodegradation questions are common with the use of polyelectrolytes in dredging applications in which treated discharge waters are to be released back into the waterway. Biodegradation is the process in which materials degrade in the environment. There are several sources in the literature that discuss the process as it relates to other applications and this chemistry. Simply put, these polymers are classified as high molecular weight polymers and degradation is not a rapid process, however, it is documented to occur.

In 1995, the Dutch water authority or STOWA (Stichting, et al., 1995) investigated the environmental impact of polyelectrolytes in waste water treatment plants. The data collated showed that cationic ester-type polyelectrolytes are converted within 24-48 hours to an anionic polymer by hydrolysis (simple reaction with water). Research into the impact of anionic polyelectrolytes has indicated that they are effective in stabilizing soil aggregates, adsorbing readily to clay fractions (Letey, 1994), reducing soil erosion, increasing water infiltration and also have a significant but indirect and positive impact upon crop growth and yield. Earlier research by Grula & Huang (1981), concluded that certain polyelectrolytes can stimulate the growth of populations of soil bacteria when found as a sole organic compound in a chemically defined medium, where they are believed to act as a nitrogen source.

CONCLUSION

Although it may be a bit difficult for most to completely understand the chemistry associated with polymers, or to fully comprehend the mechanisms for how they function, it should not prevent their use from being considered as early in a project as possible. This is especially important when a project may entail dealing with fine-grained and/or contaminated sediments. The use of polymers offers many significant benefits, not the least of which are, increased dredging productivity due to enhanced solids-liquid separation, as well as, lower overall project costs as a result of fewer processing delays, additional capital expenditures, and non-compliance sanctions. These are all confirmed in the examples provided. However, it is essential to select a competent and experienced polymer supplier not only to select the proper chemistry, but to partner with you and help you achieve your project objectives and address related issues that may arise.

ACKNOWLEDGEMENTS

The following companies and entities are recognized for providing permission for the use of information contained within this document: Bean Environmental, LLC; Black & Veatch; Boskalis Dolman bv; J.F. Brennan Co., Inc.; CH2M Hill Constructors, Inc.; Genesis Fluid Solutions; G.W. Partners; Infrastructure Alternatives; Luhr Bros. Inc.; Walsh Construction; and Weston Solutions, Inc.

The following individuals are colleagues within Ciba Specialty Chemicals Corporation and recognized for their much appreciated information, input, and feedback during the process of putting this manuscript together: co-authors Karin Baron and Dr. Michael Heard. Others involved in review and editing were Matthew Englis, Jeffrey Griffiths, and Steve Meyers.

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