

SOME PROVEN BENEFITS OF POLYMER USE IN THE TREATMENT OF SEDIMENTS IN RECENT DREDGING PROJECTS

ABSTRACT

For several decades, polymers have been used in the treatment of sediments for improving the dewatering step and reaching high solid content along with clear-water release. In order to show the main benefits of polymer use in the dredging industry, two projects started in the last three years have been selected for presentation in this article to demonstrate the main benefits of their use in the dredging industry.

Port-La-Forêt harbour in La Forêt-Fouesnant, France has not had any form of maintenance dredging in over 30 years. For the harbour's cleaning, 40,000 cubic metres of polluted sediment needed to be flocculated and pumped into geotextile tubes on a dewatering site located four kilometres away. The turbidity of the water released has been constantly monitored and kept below the authorised level throughout the project. The benefits of polymer use in conjunction with dewatering tubes are a shorter drying time and higher quality of released water.

The Kishon River project, contaminated by chemicals from both industrial effluents and municipal wastewater,

aimed at cleaning seven kilometres downstream of Haifa, Israel. Over a period of 20 months, some 400,000 cubic metres of material are expected to be removed from the river bottom and treated. Bioremediation is used after sediment dewatering. The benefits of polymer use in conjunction with dewatering equipment are a higher level of dryness in the final solid waste and higher quality release water.

With increasing pressure from local communities and authorities on project timeframe, worksite footprint and water quality, the use of polymers will be prevalent in dredging projects, especially those located in heavily populated areas or dealing with contaminated sediment.

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Above: For more than 30 years, maintenance dredging had not been done at the Port-La-Forêt harbour – and it was in need of cleaning. Photo CCPF, courtesy of Office de Tourisme de La Forêt Fouesnant

INTRODUCTION

Today, more than one million tonnes of synthetic organic polymers are produced annually worldwide for use as coagulants and flocculants, mainly for use in water treatment and the oil and mining industries. The main benefits associated with polymer use are improved solid-liquid separation, faster settling rate and reduced land surface for the treatment.

Improved solid-liquid separation during sediment treatment is now commonly requested by local legislation, including permanent monitoring of the turbidity of released water. In fact, higher turbidity in released water negatively impacts aquatic life and puts the project in jeopardy. Another side benefit is reduced sludge volume.

In dredging projects, specific equipment can either be common equipment from the water treatment industry, like a belt filter press or centrifuge, or more specific to sediments such as geotextile tubes or dewatering tables. Whatever the equipment, the high processing rate results in a shorter dewatering time ranging from several hours to several weeks.

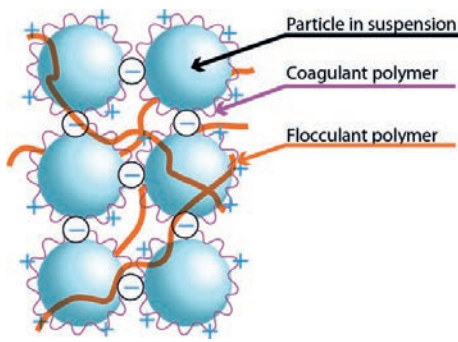


Figure 1. In floc's structure, suspended particles are surrounded by coagulant polymers and flocculant polymers.

When a project takes place in a harbour or in an urban or industrial area, reduced land surface available for sediment treatment is a key issue. In the past, some dredging contractors had to build several successive settling ponds to improve the overflow quality, but local agitation at the overflow point led to permanent re-suspension of fine particles. Polymers have solved this problem, at least halving the settling pond's surface area and accelerating drying time. This process is now widely used and its application has been extended to the dredging of lakes, canals, ports and rivers.

WHAT ARE POLYMERS?

The polymers used by the water treatment industry are known as coagulants and flocculants. Their main property is to create small aggregates, known as 'flocs' (see Figure 1), with the insoluble colloidal particles contained in the water to be treated. Flocs settle down fine particulates, thus leaving clear water.

Most water treatment programs include one coagulation step and one flocculation step. Coagulants are inorganic, such as ferric chloride, or organic such as polyamines and polyDadmacs. Flocculants are only organic in origin and have been used for more than 50 years. Organic chemistry is a very powerful to provide tailor-made polymers, like organic coagulants which are 10 times more effective than mineral

coagulants given their charge density and chain length.

Organic water-soluble polymers, also named synthetic polyelectrolytes, have adjustable charge density, chain length, structure and monomer composition. The main flocculants' backbone is made of acrylamide monomer which does not bear any charge. Some co-monomers are generally added to bring cationic or anionic charges into the polymer backbone. Acrylic acid is for example the most frequent monomer to build anionic polyelectrolytes whereas the cationic charge is generally brought by quaternised aminoalkyl acrylates.

When required by the application, cross-linking agents are used to provide branching between the polymer chains. Specific monomers are requested to build comb-like polymers. In these cases, they are called 'structured' polymers, to differentiate them from the linear ones.

Synthetic polymers are provided under different forms: solid, liquid or emulsion.

SEVERAL FACTORS AFFECT POLYMER CHOICE

Water Composition

Water may carry mineral particles made of clays that have not been removed by the previous separation steps and clays may carry some absorbed pollutants. In addition, some organic compounds resulting from human activities or natural processes – for example, humic acid – may also be carried by water. The organic to mineral ratio is the key parameter that will determine the nature of the polymer and the charge density

required. Other aspects such as like salt or iron levels may influence the polymer's effect and therefore its selection. In some cases, specific monomers which are salt or iron-resistant can be used.

Dewatering Equipment

During the preparation step, mechanical effects appear (for example shearing in pumps) which may break the polymer structure, reducing its efficiency. Shearing may also appear after the flocs have formed. Flocs should be resistant enough to keep their structure and their ability to settle quickly. Each type of dewatering equipment has its own mechanical effect which affects the polymer's selection, for example a centrifuge and geotextile bags present very different mechanical effects. In general, structured polymers will be preferred to linear ones when mechanical stress is induced by the process.

Water Available on Site for Polymer Preparation

Polymers are long molecules that need to uncoil in water to make them fully active during the flocculation step. While polymers are available commercially in several forms including powders, emulsions and liquids, powders and emulsions (see Figure 2) are typically chosen for use in large projects as the cost-effective solution. Powders need to be dissolved before use and emulsions must be diluted in water. Polymers are prepared at a relatively low concentration of water, from one to ten grams per litre. Therefore, the quality of the water used for preparation is so important. Sea water may affect the polymer choice



Figure 2. Polymers are commercially available in many forms including emulsion (left) and powder (right).

because of the presence of salt, reducing some polymers' ability to uncoil, making them less efficient. In the same way, hard tap water with high amounts of divalent ions will have a negative effect on polymer preparation and can lead to choosing specific grades. Water temperature is another key parameter as cold water increases the time required for polymer preparation.

Emulsions versus Powders

Factors like a project's size, environmental considerations or required polymer structure may influence the chosen polymer form. Emulsions are easy to prepare and to use. They contain oil and provide a very high degree of branching since very strong flocs with high polymer consumption increase efficiency.

Powders are 100 per cent active, contain no oil, and are generally effective at lower consumption than emulsions (see Figure 2). Alternatively, they can only provide a small level of branching and require a dissolution unit with a maturation time of approximately one hour.



Figure 3. A jar test is used to determine the best polymer to treat sediment samples collected from a project's site.

In small-scale projects – typically below 100,000 cubic metres – emulsions are preferred because they require simple equipment for the polymer preparation, unlike powders. This is a situation where emulsions are advantageous over powders. On the other hand, emulsions may not be suitable in some specific fauna protected areas where oil containing chemicals are prohibited, even if they are fully biodegradable.

When geotextile bags are used, specific structured polymers might be required. Their branched structure maintains good water release whatever the cake

thickness on the inner side of the bag. This specific branching rate is available from the emulsion range and not from the powder range because of polymer production technology which leads to the selection of one polymer under emulsion form.

Required Results

Each project has its own specificities that need to be discussed with operators before the polymer type is selected. In addition to the parameters previously listed, some process parameters may be required by the operators that will affect the polymer choice.

In most cases, the product selected by jar testing (see Figure 3) is the one that will be used industrially. Wastewaters from traditional industries like pulp and paper, textile, and mining industries have a relatively constant composition.

However, in the dredging industry, some factors may lead to an incorrect polymer selection. Specimens from the sampling campaign may have too many variations in their composition, making a one-size-fits-all product an impossibility. Working on a composite sample composed of all different samples may also lead to choosing the wrong polymer.

Additionally, in projects where sediments are pumped hydraulically and directly sent to treatment without holding tanks, the way the dredge manager operates its equipment may lead to high fluctuations in the sediment composition due to factors such as the water content. This may require specialised monitoring equipment to adjust the polymer dosage to the sediment slurry composition.

POLYMER SELECTION FOR THE DREDGING INDUSTRY

The main drivers for use of polymer in dredging projects are lack of space or time for sediment dewatering, as well as stricter regulations on discharged water. Polymer use results in lower turbidity in the released water, reduced land surface for the treatment and a shorter drying time. The polyelectrolytes which can be



Figure 4. Port-La-Fôret harbour before its much-needed sediment remediation project. A plan conceived by between port authorities, engineering and design departments, France's EPA equivalent and local communities involved pumping 40,000 cubic metres of sediment to a dewatering site located four kilometres inland from the harbour. Photo Ronan Quemere, courtesy of Office de Tourisme de La Forêt Fouesnant



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Figure 5. A dredger pumps the sediment at Port-La-Fôret harbour into a floating pipeline.

used in dredging applications are anionic polyacrylamide flocculants usually intended for the removal of clays, low cationic polyacrylamide flocculants typically for fine sand, or highly cationic coagulants for bio-solids and very fine clays. They are selected from the existing polymer range already developed for the municipal and industrial water treatment, which comprises thousands of different polymer compositions.

Selective testing, called a jar test, is necessary to find the right combination of coagulants and flocculants. It can be done in the lab or on site with portable equipment. The selection is done after identifying the following characteristics: nature of the polymer (cationic/anionic/non-ionic/amphoteric), nature of constitutive monomers and charge density required, and the molecular weight (chain length) and structure.

PORT-LA-FORÊT HARBOUR

For more than 30 years, maintenance dredging had not been done at the Port-La-Forêt harbour – and it was in need of cleaning (see Figure 4). After a discussion between port authorities, engineering and design departments, France's EPA equivalent and local communities, the

preferred option involved the creation of inland disposal facilities which would later be turned into a soccer stadium. The plan involved pumping 40,000 cubic metres of sediment into geotextile tubes on a dewatering site located four kilometres inland from the harbour (see Figure 6).

Selecting the polymer

First, the jar test and filtration pressure tests were performed on a representative sample of sediment. They allowed the selection of the best polymer in terms of anionic or cationic charges, charge density, chain length, structure and dosage optimisation. Following field tests gave more data about final results such



Figure 6. For the project at Port-La-Forêt harbour, the sludge treatment area includes a dewatering area with tubes (left) and water retention area (right).

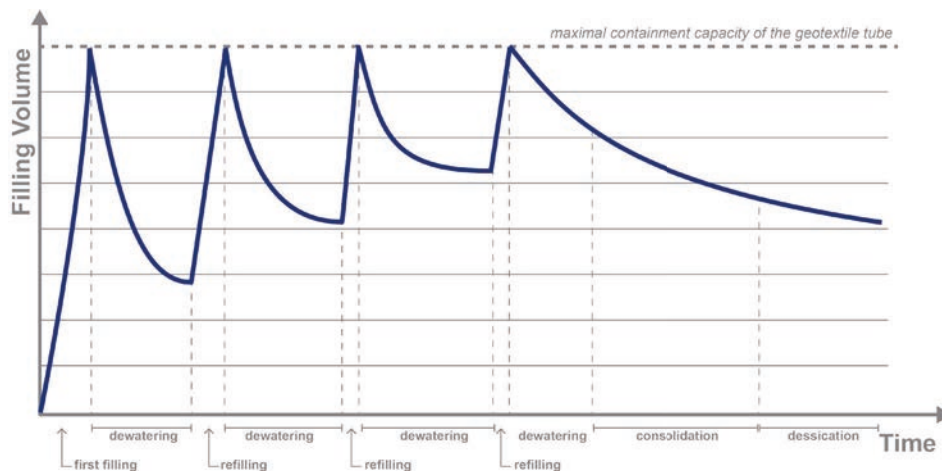


Figure 7. The cyclical filling method of the geotextile tubes includes pumping of sediment during the day followed by the nightly release of clean water.

as released water quality, dryness of dewatering sludge, polymer consumption and so on.

Finally, the polymer expert recommended a cationic polymer to treat this sediment which was made of sand with high organic content. For a dredging project of this size (smaller than 50,000 cubic metres), polymer in emulsion form would have been recommended, but, at the request of local authorities, powder was used.

Making the Retention Area

The ground was excavated and the removed soil was used to build a retention area for the released water. This area was necessary because only one pipe was used to pump the sediment

during daytime and to release clean water during the night (Figure 8). Geotextile tubes were then placed on a synthetic membrane to optimise the filtration and prevent water leakage into the ground. Dredged sediment was pumped directly into a global tubes layout designed by the tubes supplier.

With an automatic dissolution unit, a cationic powder polymer solution was prepared at two grams per litre. The polymer makeup equipment is a self-contained, split-tank design with an automated polymer dilution and solution-feed system for application of dry polymer. The polymer mixing tank is equipped with a dry polymer feeder and wetting system. The solution is agitated until the polymer is dissolved and then it is transferred to

the application tank. The application pump is variable in speed and delivers the prepared solution continuously.

The polymer solution was carried to the dewatering area by a specific line and was directly injected in the sediment sludge before inlet of the dewatering tube. Due to the high sediment pumping rate, the mixing of polymer solution and sediment sludge was satisfactory, although it is recommended to inject the polymer solution a few metres prior to the dewatering tube's inlet.

To obtain the recommended dosage, flowrate of the polymer solution was calculated in function of flowrate and solid content of sediment sludge. Sampling between the polymer injection point and dewatering tube's inlet was possible to check the flocculation mechanism.

The sediment sludge pipe was placed around the retention area to fill easily all dewatering tubes. Dewatering by means of geotextile tubes comprises a cyclic process. The tube is initially filled to the given maximum height and the filling is then stopped. The static drainage of sludge starts as soon as the filling process starts and following a degree of dewatering, the tube can be re-filled.

This process is repeated until the tube is completely filled. In the case of multiple tubes, it is possible to continuously pump sediment sludge by alternating filling and



Figure 8. Water exited the dewatering tubes and flowed by gravity to the low point, and was then pumped to a retention area where turbidity was continuously monitored.



Figure 9. During construction, the soccer stadium (white area) can be seen from the entry of the parking area.

dewatering steps from one tube to another. While only one layer of dewatering tubes was used for the Port-La-Forêt project, it is possible to stack several layers of geotextile tube to reduce the footprint for a dewatering area. Released water from all dewatering tubes flowed – by gravity – to a low point as shown in Figure 7, and was then pumped to a retention area where turbidity was permanently monitored. Every night, the clean water was pumped back to the harbour. During the 6-month-long project, 15 metric tonnes of polymer were used.

After Dewatering

After several weeks of dewatering, the geotextile tubes were covered over with stones and gravel. The soccer stadium and parking lot were then built on top (see Figure 9). In addition to the desired result of the cleaned Port-la-Fôret harbour, this project both increased the harbour's water level for boaters and removed contaminated sediment to a safe area. Managed locally, the 4-km-long landline saved the use of around 3,000 truckloads. Without polymer, dewatering by geotextile tubes would not have been possible because of the risks of releasing fine particles and organic matter into the effluent matter, and the plugging the geotextile's pores which would block the release of water and thus the possibility of building a soccer stadium.

KISHON RIVER

Originating from the Gilboa mountains, Israel's Kishon River flows for 70 kilometres in a west-northwesterly direction through the Jezreel Valley, until it flows into Haifa Bay and eventually the Mediterranean Sea. Before traveling through the heart of the Haifa metropolitan area, the Kishon River drains an area of 1,100 square kilometres, which includes much of Jezreel Valley and Western Galilee. As a result of the contamination of its last seven kilometres by industrial effluents and municipal wastewater released upstream, the Kishon River was considered to be the most polluted river in Israel.

In 1994 the Minister of Environmental Protection established a Kishon River Authority with the aim of rehabilitating and transforming the waterway into a regional attraction. Towards the end of the 1990s, the Minister of Environmental Protection required the polluting industries and the Haifa wastewater treatment plant to apply for waste discharge permits under the Prevention of Sea Pollution by Land-Based Sources Law and to comply with the stringent conditions stipulated in the permits. The requirement was accompanied by an enforcement campaign against seven major industrial plants in the environs of the river. The plants could no longer discharge their effluents to the Kishon River with impunity.

Treating the Contaminated Sediment

While good results were obtained on the front of stopping the release of polluted discharge, the problem of toxic sediments remained. In a first step, the Kishon River Authority conducted a survey of the riverbed that confirmed the seven downstream kilometres were polluted with TPH and heavy metals, especially cadmium and chromium. According to the calculations, some 400,000 cubic metres of material needed to be removed from the river. In a second step, sediment treatment options were studied. Bioremediation was preferred in comparison to disposal, incineration, chemical stabilisation or thermal treatment. Therefore in April 2014, the Kishon River project was inaugurated.

An area of five hectares was reserved to pre-treat slurry from the river before the biological treatment phase. The preparation included dewatering the slurry to 40 per cent solids. The supernatant was treated and then returned to the river. Sand was not separated from the sediment – comprised of approximately 60 per cent clay – since it helps with the dewatering process. The mixing of sediment with bulking agents such as straw, bark or shredded green cuttings composes a pile amenable for aerobic biological treatment. The sediment was collected into piles which stand 3-m-high and enable aeration.



Figure 10. After pumping, the sediments are first mixed in a homogenisation tank to reduce concentration fluctuations of the sludge. In a second step, a thickening tank is used to increase dryness of the sludge while centrifuges obtain the targeted dryness.

Dewatering in Steps

The dewatering step is divided into three parts. After pumping, the sediments are first mixed in a homogenisation tank to reduce concentration fluctuations of the sludge. In a second step, a thickening tank is used to increase dryness of the sludge. In the final step of dewatering, centrifuges are used to obtain the targeted dryness. The main difficulty for polymer selection is the sediment composition variation, due to a wide dredging area. After several tests on a lot of sediment samples, the polymer expert has recommended anionic polymer with a high molecular weight. Furthermore, to optimise polymer efficiency and decrease polymer consumption, this expert has advised a multiple polymer injection: one prior to the thickening tank and one prior to the centrifuge. Over the project's duration, the sediment composition changed and after jar testing, a change of the type of polymer was necessary. This dredging project is still underway today.

CONCLUSIONS

Overall, polymers are better known today within the dredging industry, but still need a higher profile. A large number of players involved in dredging projects, including and not limited to local authorities and communities, environmentalists, dredging contractors and maritime engineering companies. To increase knowledge of polymers, quality suppliers have developed a dedicated package of equipment and services which includes: aid with a polymer's selection, supply and/or training, make up equipment for polymer injection, technical assistance at the start-up of projects, regulatory information as required by authorities, field support to check flocculation parameters and final compliance with local legislation. With this package ready for use, a contractor – and its project – can benefit from polymers and adequate dewatering equipment, ultimately saving time, money, land and the environment.

Overall, polymers are now better known within the dredging industry, but still need a higher profile, given the large number of players involved in dredging projects – typically, local authorities and communities, environmentalists, dredging contractors, maritime engineering companies, et al. That's why some polymer suppliers have developed a dedicated package of equipment and services, that could consist of:

- Polymer selection, supply and training
- Make up equipment for polymer injection
- Technical assistance at the start up
- Regulatory information as required by authorities
- Field support to check flocculation parameters, and
- Final compliance with local legislation.

With this package ready, a contractor can benefit quickly from polymers and adequate dewatering equipment – saving time, money, land, and the environment.