Anionic Polyacrylamide Application Guide for Urban Construction in Ontario

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Sustainable Technologies Evaluation Program

Toronto and Region Conservation *for* The Living City®

THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

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- assess barriers and opportunities for implementing technologies;
- develop supporting tools, guidelines and policies; and
- promote broader use of effective technologies through research, education and advocacy.

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FOREWARD

This guide is intended for use by persons involved in the design, application, inspection and maintenance of erosion and sediment control (ESC) measures that incorporate anionic polyacrylamide (PAM). It provides a foundation of information for the use of anionic PAM, but does not substitute for the need for ESC professionals to undertake practical training specific to the use and application of these products.

The use of anionic PAM does not replace the need for an effective ESC plan that starts with erosion control, and incorporates a multi-barrier approach to mitigating sediment releases from the site. This guide should be used in conjunction with the Greater Golden Horseshoe Area Conservation Authorities Erosion and Sediment Control Guideline, completed in 2006, which offers direction on the type and appropriate use of ESC practices. Guidance in this document is superseded by specific direction from governing agency representatives.

Products that employ anionic PAM as their active ingredient have shown promising performance and low toxicity in studies completed to date. The guidance provided herein is limited to applications of anionic PAM on construction sites. While other types of polymers are currently available on the market, this guide does not promote, endorse, or provide guidance on, the use of any other polymers for ESC applications.

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1.0 Introduction

Polyacrylamides (PAMs) used for construction site erosion and sediment control (ESC) applications are a group of high molecular weight, water soluble molecules formed by polymerization of the monomer acrylamide. Anionic PAM is produced when acrylamide is polymerized with an anionic co-monomer. Water soluble PAMs have been used for decades to facilitate solid-liquid separations in wastewater and drinking water treatment, the pulp and paper industry, aquaculture, and many other industrial processes.

Although polymer-based water clarification is a technique that is well established in industrial applications, treatment of construction runoff is a newer and less established use of this technology. Today there are several anionic PAM-based products marketed for use in construction site sediment management. These products can be applied for erosion control, clarification of sediment laden runoff, and de-mucking of wet sediment during pond cleanouts. They are designed to be used in conjunction with other best management practices, as part of a multi-barrier approach, to minimize soil loss and improve settling of suspended sediments.

While products containing other polymers are currently available on the market, and are being used for ESC applications, the usage guidance provided herein is limited to anionic polyacrylamide and is only intended to govern the use of this polymer in the construction applications described. The guide does not promote, endorse, or provide guidance on the use of any other polymer types for ESC applications.

For additional information on polyacrylamide and other polymers, please refer to the companion background document entitled Polymer Backgrounder: The Nature, Efficacy and Safety of Polymers used for Construction Sediment Control (TRCA, 2013a).

2.0 General Requirements

2.1 Product Selection

Any anionic PAM product used for erosion and sediment control on a construction site should adhere to the following criteria.

- **Anionic PAM is the active ingredient.** Only products using water soluble anionic PAM as the active polymer ingredient should be used. Products containing a synthetic cationic polymer or chitosan should not be used due to their higher toxicity to aquatic organisms.

- **Site Specific Performance Testing.** The manufacturers of anionic PAM-based products typically offer more than one formulation of a given product, with different formulations varying in the relative amounts of PAM and other additives. Different formulations are designed to bind different soil types. Samples of water to be treated and sediment from the site should be tested with the various products and formulations available to determine which will be most effective for the desired application. This testing may be done by the manufacturer or by another party, based on guidance received from the manufacturer. The testing should demonstrate that the selected formulation can remove solids to a concentration suitable for discharge to receiving waters, as specified in local regulations or guidance documents. Written documentation of this performance testing should be retained by the proponent.

- **Safe based on expected release rates, toxicity reports and product Material Safety Data Sheets (MSDS).** An MSDS should be available for the specific anionic PAM product to be used, and should indicate that the product is safe at the anticipated concentration (calculated from product release rate) and based on the intended use. As a minimum, acute and chronic toxicity test data should also be available from the manufacturer or a third party organization for the following aquatic organisms: fathead minnow (Pimephales promelas), rainbow trout (Oncorhynchus mykiss) and water flea (Daphnia magna). On sites draining to more sensitive coldwater streams, toxicity testing for additional aquatic organisms of local ecological interest may be required. Relevant species for coldwater streams in the Toronto region would include brook trout (Salvelinus fontinalis), rainbow darter (Etheostoma caeruleum), mayfly (Ephemeroptera sp.), stonefly (Trichoptera sp.) and caddisfly (Trichoptera sp). The LC-50 concentrations (the concentration of polymer that is lethal to 50% of the sample population) listed in toxicity reports should exceed the maximum possible product release rate, for which documentation should be provided.

- **Moderate charge density.** The anionic PAM used in the product should have a charge density in the range of 8 to 35% by weight, however this is a general guideline. The primary factor in the selection of an anionic PAM product is the extent to which it is proven effective during site-specific soil testing.

- **High molecular weight.** The anionic PAM used in the product should have a molecular weight between 6 and 24 mg/mol, with 12 to 15 mg/mol preferred.

- **Emulsion forms of anionic PAM should be avoided.** Both independent studies (Hall and Mirenda, 1991; Weston et al., 2009) and manufacturer tests (Applied Polymer Systems Inc., 2010) have revealed that some anionic PAM emulsions are more toxic than granular and water-based liquid forms. This is mainly the result of the higher toxicity of additives, such as emulsifiers and surfactants, in the emulsions. Where an emulsion must be used, the product selected must be non-toxic based on comprehensive toxicity testing, which should include the species of local ecological interest, as described in requirement #3 above.

- **Residual acrylamide content less than 0.05%.** Acrylamide, the monomer from which PAM is synthesized, is currently classified as a likely human carcinogen and neurotoxin (U.S. EPA, 2010). While it is present to some extent in all PAM products, the amount can vary substantially depending on the manufacturing process. The U.S. Environmental Protection Agency currently regulates the levels of residual acrylamide monomer to 0.05% in PAMs used to treat potable water, and many PAM based products on the market already meet this criteria.

- **Product is distributed with appropriate labels and use instructions.** Package labels should always include a product expiry date, and the product should only be used prior to the specified date. The product should also be packaged and/or labeled with use instructions, including application rates, mixing methods (if applicable), maintenance requirements, safe handling, storage and disposal methods, and any other product details relevant to those who will be applying it.

2.2 Qualifications of Professionals

The components of ESC plans that specify the use of anionic PAM should be designed, installed and inspected by professionals qualified in the use of polymers for ESC applications. In this context, an individual will be considered 'qualified' if they can demonstrate sufficient knowledge of the use of polymers in construction applications based on previously completed training and field experience. Any other on-site staff working with the polymer should work under the direct supervision of the qualified person.

2.3 Documentation

Any application of an anionic PAM product on a construction site should be documented by the environmental monitor, inspector or equivalent. This may be done as part of the regular process for ESC documentation and reporting that is carried out on all construction projects. More detailed guidance on ESC inspection reporting is provided in the *Greater Golden Horseshoe Area Conservation Authorities Erosion and Sediment Control Guideline for Urban Construction (*GGHA Conservation Authorities, 2006).

As a minimum the following information about an anionic PAM application should be recorded and retained with other ESC documentation for the site:

- Product details (i.e. physical form, product name, expiry date and any other identifiers)
- Quantity used
- Application rate
- Site specific performance testing (as described in Section 2.1)
- Location on the site where the product is used
- Date of application
- Name and qualification of installer
- Method of application
- Weather conditions during application
- Brief description of the intended function of the product
- Any other site conditions or observations relevant to the functioning of the product.

Documentation should include any drawings, photographs or other visual aids necessary to provide sufficient detail on the application. Follow-up documentation should also be carried out in the event of any modifications, additions or re-applications.

2.4 Safe Handling and Disposal

Any persons involved in mixing, applying or otherwise handling an anionic PAM product should follow health and safety guidance provided by the manufacturer. The following measures are typically taken to ensure the product is handled safely:

- A dust mask should be worn at all times when handling granular forms of anionic PAM. The manufacturer's recommendation on the appropriate type of dust mask to be used should be solicited if it is not provided in the usage instructions.

- Eye protection such as safety goggles should be worn when granular or liquid forms of PAM are being mixed or applied, or otherwise used in a way that could generate a dust or mist. In the event of accidental eye contact, thorough rinsing for several minutes is recommended.

- Plastic, rubber or leather gloves should be worn during handling to protect hands from direct contact with the product or surfaces that have been treated with the product. In the event of skin contact, wash thoroughly with water and soap.

- Anionic PAM and the surfaces to which it has been applied can be very slippery when wet. Skid protection should be employed during wet conditions if vehicle or foot traffic is expected on a PAM treated area.

- In general, the use of water for cleaning PAM spills is discouraged. If the spilled product is dry, clean up should be done by simple sweeping or another method of removal without water. If the spilled product is wet, an absorbent material (e.g. sawdust) can help to dry it out so that it can be safely collected and removed (USDA, 2002).

Settled sediment collected in an anionic PAM based treatment system must be tested to determine appropriate disposal options. Test results from the dredged material are compared to the threshold limits specified in local policy documents, if available. PAMs are not typically classified as hazardous waste. Therefore, where PAMs have been utilized for water clarification or to facilitate stormwater pond clean outs, sediment disposal options are limited to reuse on site, with no off-site impacts, or disposal at a regulated landfill site, provided that there are no other contaminants present in the material that would dictate hazardous waste disposal. Reuse of the dredged material off-site would only be permitted where it has been clearly demonstrated that the PAM, and any other substance contained in the material, will not cause undue impacts to human health and the environment for the intended use off-site.

Wash water from rinsing of PAM application equipment should not be discharged directly to natural features, as this water may still contain unreacted PAM. The most appropriate use of rinse water would be application as an erosion control to any unstabilized areas of the site.

Disposal of expired or otherwise compromised anionic PAM products should be carried out in accordance with guidance from the product manufacturer or distributor, but typically they are not classified as hazardous wastes and are suitable for landfilling.

2.5 Spill Response

A procedure for containment and clean-up of accidental anionic PAM spills should be in place prior to application, and should be developed according to manufacturer guidance.

Any minor anionic PAM spill into a natural water feature should be immediately contained and removed. In this context, a minor spill into a natural body of water is defined as a spill that has no adverse effect on the quality of the water, the substrate, or the aquatic organisms. In the case of anionic PAM, a visible increase in the viscosity of the receiving water would be a key telltale sign of adverse impact. Spills of granular or liquid forms of anionic PAM are more

likely to cause a rapid increase in receiving water viscosity than gel block forms, which have a much slower release rate.

Significant spills of anionic PAM (i.e. those resulting in an adverse impact) should immediately be reported to the Ontario Ministry of Environment's Spills Action Centre (1-800-268-6060), the conservation authority enforcement officer for the site, the municipality, and the landowner. Monitoring efforts and documentation of incident details and containment/clean-up procedures should be initiated immediately upon detection of the spill.

3.0 Appplication for Erosion Control

When used as an erosion control on construction sites, PAM is applied by broadcast of granules, sprayed as a liquid by a construction site watering vehicle, or included in a hydroseeding mixture to provide additional erosion protection during seed establishment. In addition to reducing soil erosion, the application of anionic PAM to exposed soils has also been shown, in certain conditions, to prevent surface sealing while maintaining the capacity to infiltrate water (Shainberg et al., 1990). It is best suited to stabilization of soils containing high proportions of silt and clay and very little organic content.
It should be noted that the use of anionic PAM as an erosion control measure is only one method of protection. PAM applications should be used in conjunction with other best management practices, including sediment controls, as part of a larger comprehensive ESC plan.
Some of the main areas of a construction site that can benefit from stabilization with anionic PAM include:

- soil stockpiles
- low traffic sloped areas
- stripped areas left inactive for extended periods of time
- cut-off swales/ditches
- any other stripped areas of the site where dust control is needed

The following guidelines should be applied for any use of anionic PAM as an erosion control on construction sites.

- Granular anionic PAM applied to a soil surface for erosion control should be applied at least 15 metres away from any watercourse, wetland, well, etc. or other natural water feature. It should never be applied directly to natural features (e.g. woodlots, wetlands, streams).

- When not used in combination with other ground covers, anionic PAM should only be applied to protect against erosion in areas receiving non-concentrated sheet flows.

- Prior to PAM application, rills and/or gullies should be filled in and/or the surface should be prepped according to the manufacturer's specifications.

- Application of anionic PAM with seed (through hydroseeding or a similar method), or some sort of cover, is preferable to the use of the polymer alone on bare soil. The roots will help to anchor the soil in place and the PAM helps to stabilize soil early on before the seed has germinated.

- Accepted application methods include (i) broadcast of granular PAM, by hand or with a seed/fertilizer spreader, (ii) application of PAM solution with a construction site watering vehicle, and (iii) addition to hydroseeding mixture, followed by normal hydroseed application.



Figure 3.1: Methods of applying anionic PAM for erosion control

- Application rates used should be determined based on manufacturer guidance to ensure that coverage will be adequate to provide erosion control without excess that may be washed away during a rainfall event. Coverage should also be as even as possible.

- During application of granular PAM, surface wetting required for the final step should be done actively through controlled watering rather than passively by waiting for a rainfall event. Rainfall intensity is unpredictable and granules are more likely to be transported away (by runoff or wind) before they have bound to the soil particles. This increases the risk of PAM entering downstream natural features, and reduces effectiveness, since the polymer it is not being used where it is needed.

- Re-application of PAM to areas requiring stabilization should occur based on the manufacturer's recommended frequency, or sooner if erosion is observed. A six-week interval between applications is generally recommended, but this may vary according to soil type, precipitation frequency and slope characteristics. If PAM was applied with seed, and the seed is well established, no re-application is needed.

- The condition of the PAM-stabilized surface should be inspected weekly and before and after any rainfall event.

- Any deficiencies observed during the inspection of an anionic PAM treated surface should be rectified within 48 hours or sooner if critical environmental receptors are at imminent and foreseeable risk of adverse impact (e.g. sediment and/or polymer release to natural features).

4.0 Construction Stormwater Clarification

Treatment of turbid construction runoff prior to discharge to receiving waters is a common challenge on construction projects. Controls that promote sediment settling, like construction sediment control ponds, are the most popular treatment methods, but effluent turbidity levels from these controls are often still above thresholds for receiving water protection.

In some instances, an anionic PAM based treatment system may be a desirable means of promoting greater sediment removal. These systems can be particularly useful while dewatering an area with highly turbid water, in situations where conveyance of turbid water to a sediment control pond is not possible, or when the available sediment retention measure will not allow for adequate settling time because incoming flows are too high. They are best suited to the treatment of runoff with suspended solids levels of at least 100 mg/L. Guidance on the maximum suspended solids concentrations that can be effectively treated should be obtained from the product manufacturer.

4.1 System Design

Anionic PAM applied for the clarification of sediment-laden construction runoff should be used as part of a system designed to provide opportunity for dosing, mixing, settling, and final filtration. Designing a system that will do all these things effectively will ensure optimal polymer performance.

For any open systems like ditches or swales (Figure 4.1), care should be taken to prevent unintended sediment laden runoff from entering the system during wet weather. When constructing a ditch or swale it is almost always recommended to line the ditch with plastic or a jute/coconut matting to prevent scouring of the ground that might introduce new sediment into the system. Any water that flows into the system from somewhere other than the inlet(s) should be carefully monitored or controlled to ensure that these flows are not exceeding the capacity of the system to provide the intended level of treatment. Further, any water that flows out of the system from somewhere other than the outlet, where there is final filtration, should also be controlled to ensure that polymer-dosed water is not released without being subject to adequate settling time or final filtration.

Figure 4.1: Anionic PAM treatment system in a ditch

Dosing

During dosing, the anionic PAM product is dissolved into the stormwater being treated. In sediment removal applications, a solid block or tablet form of the product is often used. The success of dosing depends on several factors, including: (i) polymer product formulation, (ii) polymer product amount, (iii) the flow rate of water through the system, and (iv) the physical structure of the system.

As described in Section 2.1, site specific soil and water testing will allow for determination of which formulation best promotes flocculation and settling of suspended sediment. Once this is established, determining the anticipated flow rate through the system will allow for calculation of the amount of product that will be needed for adequate dosing. The optimal range of flow rates is calculated based on the dimensions of the flow path and the amount of reaction and mixing time required. The flow rate should be slow enough to allow adequate time for reaction between the product and the water, but fast enough to encourage vigorous mixing of the dosed water. Flow rates are typically determined in consultation with the product manufacturer/ distributor, with consideration for the intended use, system design, and any site-specific restrictions (e.g. space). Upon establishing the flow rate, the total amount of product required can be calculated based on a standard 'quantity per unit flow rate' value provided by the manufacturer.

Lastly, the physical structure of the system, and particularly the position of the product within the system, can also have a substantial impact on dosing efficiency. Where the solid blocks are used, they should be appropriately positioned to promote good contact with the water to allow for adequate dosing. Proper positioning maximizes the dissolution of PAM into the water and minimizes the amount of turbid water that will short-circuit the dosing area. Dissolution will also tend to be lower in colder temperatures. This should be taken into consideration if a PAM-based treatment system is intended for use during the cold season. An in-situ performance test should be done to determine if the system is still removing sediment. If it is determined that dosing is compromised due to the cold, more product may be needed. If it is still ineffective, the system should be temporarily decommissioned and replaced with alternative treatment measures.

Mixing

Once water has been dosed, physical mixing will increase opportunity for sediment particles to react with the PAM to form larger particles. Mixing, like dosing, is often passive and can be accomplished by allowing the water to flow through barriers that will create turbulence (e.g. rock check dams, baffles)

The mixing area should be constructed so that it provides at least the minimum required amount of mixing/reaction time. The length of the mixing zone depends partly on the flow rate, with a faster flow rate requiring a longer flow path through the mixing zone than a slower flow rate would. The total amount of mixing time required should be determined based on manufacturer guidance. In a TRCA evaluation of an anionic PAM-based treatment ditch, it was demonstrated that turbidity decreased with longer mixing times (TRCA, 2010).

Settling

All PAM-based treatment systems should be designed with a settling/ sediment retention area in which large flocs that have formed will settle out of suspension due to gravity. Some systems may also be designed to include a natural fibre like jute or coir netting in the settling area. The natural fibre can also be coated with a granular form of the anionic PAM product, creating an electrostatic affinity for flocculated sediment particles that will help enhance settling. Provision of a high surface area of fibre with soft fibre will provide the best particulate attachment potential when used with the correct PAM.

The settling area should be large enough to hold a significant amount of sediment without requiring excessively frequent clean out. Accumulated sediment should be removed when it has reached 30% of the height of the sediment retention barrier, or sooner if there is evidence that previously settled sediment is being re-suspended.

Filtration

Any effluent discharged from an anionic PAM-based treatment system should be filtered, after settling, to remove flocculated sediment remaining in suspension. Suitable filters are those rated for filtering particle sizes of 150 microns or less (apparent opening size 0.15 mm or smaller). Acceptable filtration methods include:

- non-woven geotextile filter bags;
- non-woven geotextile particle curtains;
- non-woven geotextile fabric in another configuration (e.g. covering an inlet or outlet); and
- sand filters (with backflush capability).

Filtered effluent should be discharged using a method that will not cause any erosion downstream of the outlet. If the flow path downstream of the outlet is susceptible to erosion, measures should be taken to stabilize the flow path and/or encourage sheet flow rather than concentrated flow leaving the system.

4.2 System Siting

Anionic PAM-based clarification systems should never be sited in natural areas, including woodlots and water features (e.g. streams, lakes, wetlands). Where effluent from the system will be discharged to a natural water feature, the distance between the system outlet and the water feature should be at least 10 metres. In addition, some form of flow spreading device should be implemented at the outlet to prevent concentrated flows.

In determining the best location for the construction of the treatment system, it is important to consider susceptibility to vandalism, or damage related to extreme weather or construction activities. Designs that are more protected from the elements and vandalism are preferable to exposed systems that may require excessive maintenance to ensure safety and functionality.

4.3 Inspection, Monitoring and Maintenance

The frequency of inspection of a PAM-based water clarification system will vary based on system design and how often it is actively used. Inspections should take place every day that the system is operational. When the system is not operational, inspection may still be required before and after wet weather events to ensure the system is still intact. The monitoring and maintenance program should include the following elements:

- **Inspection of filters.** Regular inspection is required to ensure filters remain effective. Where geotextile bags are used for final filtration, close monitoring is required to ensure that bags are replaced as needed (e.g. when outflow rate slows down and/or effluent turbidity increases). Because they can

fill up quickly when used as part of a polymer system, caution should be exercised to prevent rupture. Filter inspection frequency will depend on how much the system is used. If it is operated continuously and/or the influent turbidity is high, inspection should occur daily.

- **Sediment inspection and clean out.** Accumulated sediment should be removed when it has reached 30% of the height of the sediment retention barrier, or sooner if there is evidence that previously settled sediment is being re-suspended. Regular effluent turbidity monitoring will allow for identification of any decline in performance over time that may be associated with sediment re-suspension.

- **Maintenance of anionic PAM blocks.** Keeping the blocks in good condition is essential to maintaining the dosing function of the system. Blocks may over time become coated with a layer of sediment and associated contaminants, which will compromise their ability to dissolve into the water. When this occurs, the sediment should be wiped off of the blocks so that their surface is again exposed. The blocks can be used until there is no product remaining, provided that the expiry date has not passed and that they have been stored properly, in accordance with manufacturer guidance. If the system in which the blocks are installed is subject to a long inactive period, care should be taken to ensure the blocks are being stored in a way that will not compromise their functionality (e.g. avoidance of extended exposure to sunlight). Manufacturer guidance on proper storage should be referenced. Safe handling of the blocks should be carried out in accordance with Section 2.4 of this document. In some instances, PAM tablets may also be used in place of blocks to reduce the tendency of gel blocking.

- **General maintenance of system components.** As the system is used, over time it will likely require other maintenance to keep its functions intact. Block position may require adjustment if they have moved since initial installation or if it

5.0 Appplication for Stormwater Pond Demucking

Various forms of anionic PAM may be used to facilitate sediment pond demucking, or pond clean outs. The form of PAM used depends largely on the type of excavation methodology being employed to remove the captured sediment. Granular PAM products may be directly applied to the captured wet sediment, most often when traditional excavation techniques are used, while liquid forms are often used in conjunction with hydraulic dredge technology. Some of the potential advantages associated with using anionic PAM to facilitate pond cleanouts include:

- the consolidation or thickening of saturated soils that are otherwise difficult to handle and remove;
- a reduction in land area required to accommodate sediment drying;
- continued pond operation while clean out occurs; and
- a reduction in environmental impacts; and
- a reduction in off-site impacts.

The following guidelines should be applied where the use of a granular anionic PAM product is proposed to aid in pond demucking.

- Site specific sediment and water samples should be taken at each site and sent to the polymer manufacturer for lab testing. Multiple samples may be required from various locations within the pond to ensure any variability in sediment composition is identified and treated with the appropriate polymer. Sediment samples should also be tested using a manufacturer supplied test kit to compare with the lab results and confirm that the appropriate polymer is selected.

- Proponents should follow the manufacturer's recommended application rate.

- Standing water should be removed to the extent feasible prior to PAM application for consolidation of wet sediment, as moisture content will affect performance. Proponents should discuss treatment options with the manufacturer where it is not possible to dewater the pond prior to clean out.

- When using a granular anionic PAM product directly applied to the captured sediment, the product should be mixed into the sediment as per the manufacturer's recommendations. This will provide more opportunity for the polymer to react with the sediment and thereby improve performance. Extending the contact time will also help to improve overall performance.

- Pond demucking activities that require anionic PAM should be carried out during warm weather. During a lab-scale study completed by TRCA (2013b), the effectiveness of a granular anionic PAM product improved at temperatures above 11˚C, with the optimal performance observed at 21˚C. A manufacturer supplied test kit can be used to confirm polymer effectiveness at a specific outdoor temperature when needed.

TRCA is continuing to carry out research on polymer assisted pond demucking. It is anticipated that this research will inform the development of additional guidance on this practice, which will be included in future updates to this guide.

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