Performance Evaluation of an Anionic Polymer for Treatment of Construction Runoff

Vaughan, Ontario

Prepared by: Toronto and Region Conservation

Final Report 2010

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NOTICE

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies;
- 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.

Technologies evaluated under STEP are not limited to physical structures; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and liveable communities.

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EXECUTIVE SUMMARY

The impacts of a construction project on the natural features that surround it can be substantial. Large areas stripped of their vegetative cover during construction are susceptible to erosion, resulting in high turbidity runoff that can be detrimental to aquatic organisms in receiving waters. Sediment control measures like detention ponds have proven effective in removing the majority of suspended sediment, however the levels in construction effluent from most sites in the Greater Golden Horseshoe Area are still above thresholds required for the protection of aquatic habitat.

The use of flocculation polymers for the clarification of construction runoff has recently garnered a great deal of attention. Their effectiveness lies in their ability to enhance coagulation and/or flocculation of fine particles, allowing for more rapid settling in downstream detention practices. Polymer-based water clarification has been used in wastewater and drinking water treatment for decades, but treatment of construction runoff is a newer and less established application of the technology.

This study evaluates the performance of the polymer *anionic polyacrylamide* (PAM) for treatment of construction runoff in two potential dewatering applications. PAMs are a group of high molecular weight, water soluble molecules formed by polymerization of the monomer acrylamide. It was selected as the subject of this evaluation based on promising performance and low toxicity findings in studies completed to date. A literature review was also completed to provide a context for the field study, and improve overall understanding of the nature, performance, and safety of PAM and some of its polymer alternatives.

Study site

Field monitoring activities completed as part of this study were carried out at the construction site for a 77 ha residential development in the City of Vaughan, near the intersection of Pine Valley Drive and Major Mackenzie Drive. The site drains to Marigold Creek within the East Humber River subwatershed. Field monitoring focused on evaluation of two applications of anionic PAM products to treat stormwater being pumped out of a construction sediment control pond located on the development site. In the first application, PAM products were used in a roadside ditch, and in the second application the product was introduced via a mixing tank installed in series with a larger settling tank.

Approach

The primary PAM product used was the Floc Log®, a semi-solid block composed of drinking water treatment chemicals and anionic PAM, and manufactured by Applied Polymer Systems Inc. (APS) based in the U.S. state of Georgia. For the ditch application, an anionic PAM-based powder sold by APS under the proprietary name Silt Stop® was also used. The specific formulations of both products used were determined by APS based on laboratory analysis of sediment and water samples collected from the site. For each application a polymer-free control was also set up in order to quantify the added sediment removal benefit the polymer provided over and above that of the same measures applied without polymers.

Ditch application

A portion of the roadside ditch on Pine Valley Drive, bordering the construction site, was converted into a polymer-based system for the clarification of water being pumped from the sediment control pond. A south-draining stretch of the ditch was retrofitted with a polyethylene liner, rock check dams, Floc Logs®, and jute netting coated with Silt Stop®. A control for the experiment was installed on a north-draining portion of the ditch, and was retrofitted with all the same components with the exception of the PAM products.

The amounts of Floc Log® and Silt Stop® to be used, the placement of the logs and check dams in the ditch, and the optimal water flow rate were all determined based on consultation with Clearflow Enviro Systems Group and APS. Their recommendation was to use 8 Floc Logs® and pump water into the ditch at a rate between 9 and 13 litres per second. The ditch was designed to provide adequate space for polymer dosing (dissolution of logs into water), mixing, and settling.

Sampling of ditch influents and effluents was planned during periods of elevated pond turbidity, as dry weather pond turbidity was too low (< 10 FTU) to allow for an accurate assessment of polymer performance. Two separate experiments were undertaken to characterize the effectiveness of the ditches. In the first experiment, water was pumped into the ditch at 11 L/s and automated water samplers set up at the beginning and end of each ditch collected hourly samples for 20 hours following a 60 mm rainfall event on August 20, 2009.

Prior to the second experiment the position of the logs was reassessed due to the minimal turbidity reduction observed in the first experiment. The logs were re-positioned to better channelize the flow, encourage contact between the logs and water, and minimize water short-circuiting the dosing area. During the second experiment, carried out on September 9, 2009, influent turbidity was elevated through manual disturbance of pond bottom sediments near the pump intake. Rather than continuous sampling, grab samples were taken at different points along the ditches to measure the progressive decline in turbidity through the flow path. Samples were taken at two pump flow rates (8 L/s and 11 L/s) and at different influent turbidity levels to assess the extent to which these factors would influence performance.

Tank application

In the second application, the anionic PAM product was introduced through a polymer mixing tank in series with a large settling tank downstream and a sediment bag at the end of the system for final filtration and flow dispersion. A control for the experiment consisted of a settling tank with a sediment bag downstream. The 1.8 m^3 mixing tank used contains three separate horizontal compartments; the top to hold the Floc Logs®, and the bottom two forcing mixing of the water and the dissolved PAM. A total of eight large Floc Logs® - equivalent to double the mass of those used in the ditch experiment - were placed in the mixing tank. Water was pumped from the pond to the mixing tank (polymer side) or directly to the settling tank (control side) at a rate of 12.6 L/s.

Field monitoring of the polymer and control tank systems occurred in December 2009. Samples were collected on two occasions: the first set during a rainfall event on December 2, and the second set during manual disturbance of pond sediments on December 4. For samples from the December 2 rainfall event, handheld turbidity measurement of influent during the event showed that it was too clear for the test (less than 80 FTU). As a result, these samples were not submitted for laboratory analysis, and instead only turbidity levels were measured using a handheld turbidimeter.

During the December 4 experiment, it was observed that freezing conditions overnight had resulted in the freezing of Floc Logs® in the mixing tank. A few test samples taken when the logs were frozen indicated that effluent turbidity was similar to influent turbidity and that the logs were not dosing effectively in that condition. The logs were subsequently defrosted gradually by water that was pumped through the tank and the warmer daytime temperatures before it was determined that sampling could be initiated.

Samples collected from both the ditch and tank applications were submitted to the Ontario Ministry of Environment Laboratory for analysis of turbidity and suspended solids concentrations. Select samples were also analyzed for particle size distribution.

Findings

Performance results

Despite a wide variation in performance among different experiments, the systems in which polymer products were used were consistently more effective at reducing TSS than their corresponding control systems for both applications (Figure 1).

The Aug. 20 ditch experiment was the only one for which the average effluent TSS concentration was higher for the polymer system. Reasons for the poor performance of the polymer ditch during that experiment include the less than optimal orientation of the logs and the finer PSD of the polymer ditch influent. The modest reduction in turbidity observed for both the polymer and control tanks on Dec. 2 (16.2% and -1.5%, respectively) is also likely attributable to a finer influent particle size distribution compared to the Dec. 4 test. The naturally turbid runoff from the Dec. 2 rainfall event would be expected contain finer particles than influent from Dec. 4, which was turbid as a result of manual agitation.

The polymer systems yielded the best results during the Sept. 9 and Dec. 4 experiments, both with respect to effluent TSS concentration and percent TSS reduction. Percent TSS reductions in the polymer systems during these two tests – 88% for the ditch and 92% for the tank – would seem to indicate that the tank was slightly more effective than the ditch, however the ditch resulted in a substantially lower TSS effluent, averaging 20 mg/L, compared to the tank average of 42 mg/L.

Based on the experiments conducted, neither application (ditch or tank) was demonstrated to perform more effectively than the other with respect to reducing suspended solids levels. While the largest TSS reduction was observed on Dec. 4, this is largely a function of the greatly elevated influent TSS concentration during that experiment. Ultimately, the system that achieved the largest TSS reduction (95%) and lowest effluent TSS concentration (13 mg/L) was the polymer tank system with the sediment bag. If the ditch system was also applied with a similar type of final filtration measure, it is conceivable that effluent TSS concentrations would have been closer to the low levels discharged from the tank system with the sediment bag.

Experiment date	Application	Average TSS concentration (mg/L)				Average % TSS reduction		Comments
		Control influent	Control effluent	Polymer influent	Polymer effluent	Control	Polymer	
Aug. 20	ditch	78.0	73.7	115.3	106.5	5.4	7.7	Before correction of Floc Log® positions
Sept. 9	ditch	148	108	171	20.4	22.3	87.7	After correction of Floc Log® positions
Dec. 2	tank	TSS data not collected				-1.5*	16.2*	* No TSS data available; values represent turbidity reduction
Dec. 4	tank	706	126	706	41.6	82.2	94.1	Tank effluent prior to sediment bag filtration
Dec. 4	tank + bag	564 **	153 **	564 **	13.3 **	58.6 **	94.9 **	Tank effluent after sediment bag filtration **Average of only 4 samples; other results for Dec. 4 represent 16 samples.

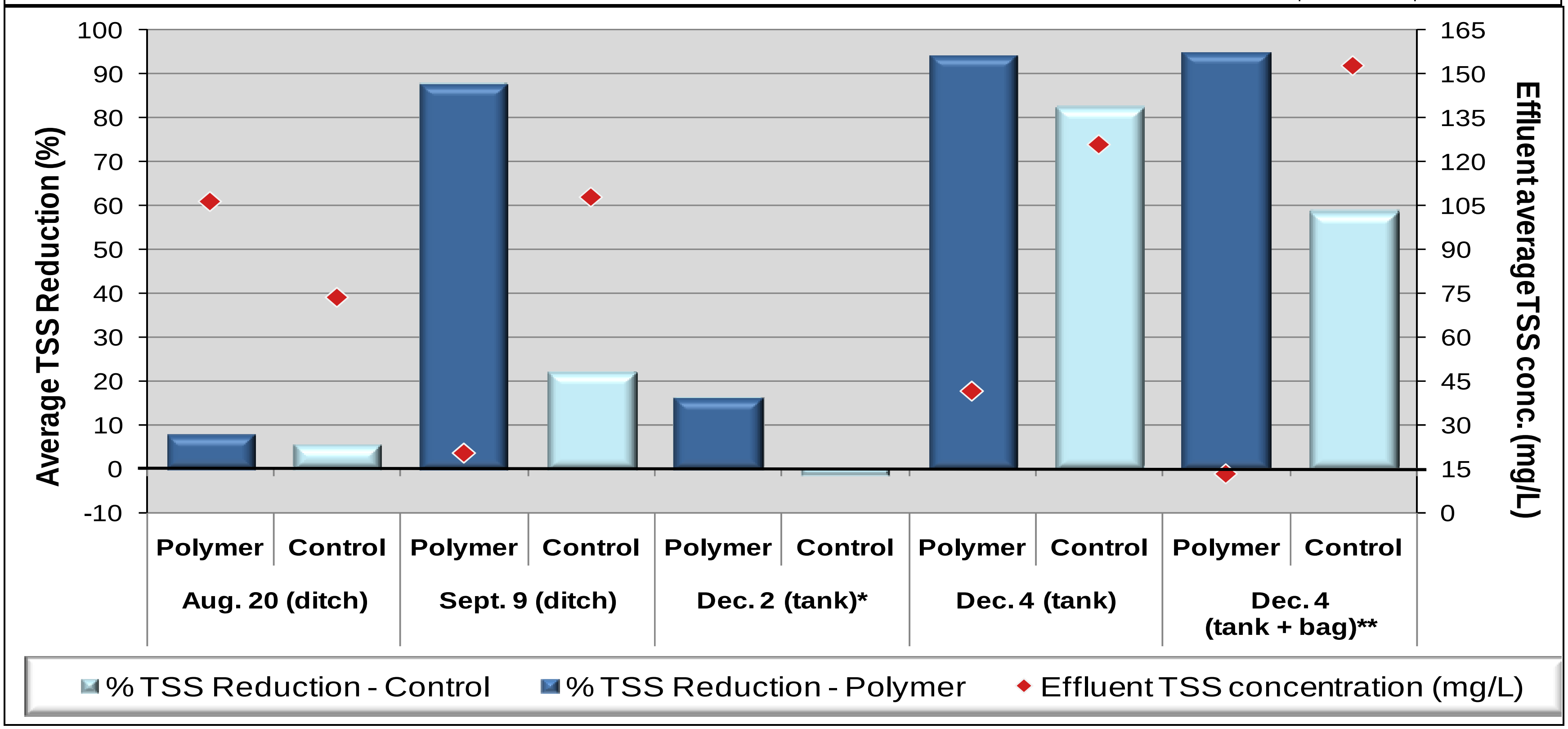

Figure 1: Average percent TSS reductions and effluent concentrations for all experiments. Data table also includes influent TSS concentrations.

TSS levels in effluents from the both control systems were consistently greater than 100 mg/L with the exception of the Aug. 20 event, for which influent was only 78 mg/L and thus the effluent was 74 mg/L. While TSS reduction was sometimes substantial in these systems (82% on Dec. 4), these effluent TSS concentrations are not low enough to prevent impacts to aquatic habitat. Because settling is the primary mechanism of sediment removal in the control systems, and detention time provided during dewatering was relatively short, fine particles could not be settled out of suspension using the ditch or tank as they were applied during these experiments. Modifications to the design and/or method of application of these practices could help to optimize settling and yield better results.

Factors influencing performance

The three main steps in the polymer-based systems were dosing, mixing and final filtration. Polymer-based flocculation systems for stormwater clarification are designed to optimize performance of these three functions, and the experiments conducted demonstrated the importance of each, as described below.

- Re-positioning of the Floc Logs® after the first ditch test resulted in more opportunity for contact between the water and the logs during the second test, and a therefore a substantial improvement in ditch performance (from 7.7% to 87.7% TSS reduction).
- The importance of adequate opportunity for mixing/reaction of the polymer and the water was most apparent during the Sept 9 ditch test, during which TSS levels progressively decreased through the polymer ditch from the inlet to the outlet. Optimization of flow rate, and system length and structure are essential to proper mixing.
- While no filtration was provided at the end of the ditches, the effect of filtration in the tank experiment was substantial. The polymer tank effluent TSS concentration decreased from 42 mg/L to 13 mg/L after filtration through the sediment bag.

For the control systems, factors affecting the gravitational settling of suspended particles, such as flow rate and particle size distribution, were expected to be the most important determinants of sediment removal performance. During the Sept. 9 ditch test, a lower flow rate and coarser influent particle size distribution resulted in the greatest TSS removal for the control ditch system.

Sediment accumulation in detention type measures can also reduce performance over time due to re-suspension. This is widely accepted as a factor impacting the performance of settling tanks, or any other measure that promotes settling through detention (*e.g.,* basins). During the Dec. 4 experiment, effluent TSS concentrations increased over the course of sampling as sediment accumulated in the polymer and control tanks. The TSS increase was greater for the control tank, which is line with polymer manufacturer claims that polymer-based flocculation results in settled sediment that resists re-suspension. This effect was less apparent in the ditches, likely because they were used for a shorter period and accumulated less sediment than the tanks.

Recommendations

Anionic PAM has the potential to be a highly effective aid in clarifying construction site runoff when the delivery system is properly designed and maintained. The following recommendations are based on study results and the need to fill existing knowledge gaps with respect to polymers.

Polymer system design and monitoring

- Anionic PAM-based delivery systems must be designed to ensure that they provide for proper dosing, adequate mixing, and a final filtration to prevent flocs from entering receiving waters. The intended installation location and the expected flow rate are important considerations in determining the physical structure of the system.
- The chemistry of water to be treated and sediment from the site are the primary data used to determine the type and quantity of polymer and mixing time required. Data provided to the polymer product supplier must be true to field conditions.
- During PAM-based construction runoff clarification, the system should be continuously monitored to ensure that no PAM is released to adjacent natural features. Designs that are protected from the elements and vandalism are preferable.
- Risk of accidental polymer release to the environment can be minimized by (i) increasing redundancy in the system by installing protection surrounding a ditch application or extra filtration at the end of the system, (ii) ensuring calculations of the amount of polymer used are accurate and (iii) educating construction staff about the polymer being used.
- Where geotextile bags are used for final filtration, close monitoring is required to ensure that bags are replaced as needed Because they can fill up quickly when used as part of a polymer system, extra caution should be exercised to ensure the bag does not rupture.
- For ditch systems, the impact of wet weather flows in the ditch must be considered. Any water that flows into the ditch from somewhere other than the inlet, or flows out from somewhere other than the outlet (where there is a final filtration) should be monitored to ensure that polymer-dosed water is not released to areas outside the treatment system.

Control systems – dewatering ditch and settling tank

- Settling tanks like the one tested, used without polymers, should not be applied in the clarification of sediment-laden construction runoff consisting of a large proportion of fine particles, as the mechanism of sediment removal in the tank does not allow for reduction of TSS to levels low enough to meet thresholds for aquatic habitat protection.
- The control ditch tested, as designed in this study, should not be applied for the purpose of clarifying construction runoff if used as a standalone measure. The ditch was ineffective at reducing TSS to acceptable levels, particularly for fine particles. Using a permeable and/or natural cover (*e.g.,* vegetation, erosion control mats) to stabilize the ditch would improve both infiltration and evaporation.

Research needs

Further study in the following areas will help to provide information needed in order to inform the establishment of effective policy and guidance documents governing anionic PAM use.

- Physical impact of reacted and unreacted anionic PAM deposition in aquatic habitats.
- Safety of anionic PAM to other, more sensitive benthic invertebrates, particularly those commonly found in southern Ontario *e.g.,* mussels, caddisflies, stoneflies, mayflies

- Performance of other viable applications of anionic PAM for treatment of construction runoff as well as stormwater from other urban developments.
- Quantification of the extent to which re-suspension is reduced for settled sediment that contains anionic PAM (*e.g.,* where PAM was used as a flocculant).
- Cost assessment of different anionic PAM applications; design, installation, maintenance and decommissioning should all be included to ensure that the real costs of the applications are being compared.
- Performance of PAM-based applications for reducing real turbidity levels resulting from dewatering during early construction stages before ponds are in place (*e.g.,* earthworks).
- Performance of anionic PAM for preventing erosion and increasing stormwater infiltration on construction sites in southern Ontario.
- Identification and evaluation of viable non-polymer alternatives for clarification of sediment-laden construction runoff during early stages of construction.
- Residual acrylamide content in existing PAM products; research in support of development of a local (Canada or Ontario) policy governing residual levels.
- The extent to which PAM in the environment can degrade to AMD, including identification of which if any conditions in the natural environment can catalyze the reaction.
- Research in support of development of a local certification or verification program for PAM products, to ensure consumers are receiving accurate information about their safety and performance.