Sediment and Runoff Control on Construction Sites Using Four Application Methods of Polyacrylamide Mix

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Abstract

Fifteen small bare plots (1 meter x 1 meter) on a 10% slope were analyzed for runoff and sediment yield on a construction site. A rainfall simulator applied 6.32 centimeters of rainfall per hour to each plot after a polyacrylamide mix (PAM-mix CFM 2000*) treatment was applied. The following treatments: No PAM-mix applied to dry soil (control), PAM-mix in solution applied to dry soil, dry PAM-mix application to dry soil, PAM-mix in solution with mulch/seeding applied to dry soil, and PAM-mix in solution applied to moist soil. Each treatment was repeated on three plots. When a solution of PAM-mix with mulch/seeding was applied to dry soil and compared with the control (no PAM-mix application to dry soil), we found an average reduction of 93% in sediment yield. An average reduction of 77% in sediment yield was the worst performing PAM treatment, and occurred when PAM-mix in solution was applied to moist soil. The application of dry PAM-mix to dry soil reduced sediment by 83% and decreased runoff by 16% when compared to the control. Our results show that regardless of the application method, PAM-mix was effective in reducing sediment yield in the test plots. The ease of application, low maintenance, and relatively low cost associated with PAM make it a practical solution to the costly methods being implemented today

Keywords:

Soil binders, soil erosion, polyacrylamides, flocculation, infiltration, water retention.

*Use of a product name is for the convenience of the reader and does not imply endorsement by the authors, Dane County Land Conservation, or the University of Wisconsin.

Introduction

One effect of rainfall is the initiation of the erosion process where individual raindrops fall and impact the soil surface. Soil detachment and particle transport by raindrop splash can lead to serious soil deterioration. Once soil is eroded and transported by surface runoff to lakes, rivers, and streams, a degradation of the aquatic habitat occurs. Sediment is the largest pollutant, by volume, in the State of Wisconsin (WDNR, 1994). In order to maintain a healthy watershed, it is critical to control erosion and sediment yield.

Maintaining soil structure and aggregate stability helps control erosion by increasing infiltration and maintaining less erodible-sized aggregates. Stable soil structures also help maintain a healthy environment. The use of polyacrylamides

and polyacrilamide mixes (PAMs and PAM-mix) is a new tool to help maintain soil aggregate stability and reduce erosion caused by surface runoff. Such materials can be applied at a rate of 20 to 30 Ibs per acre on construction sites, to stabilize such sites against erosion until they can be permanently protected through vegetation.

Water-soluble polymers and water polymer mixes do not create aggregates when applied to soil. However, they can stabilize existing aggregates when the aggregates are saturated with a solution of water soluble polymer mix. Increasing the aggregate stability with polymers reduces the effect of raindrop impact on the soil, thereby reducing erosion. Polymer application to the soil may also retard surface sealing, reduce particle soil detachment, reduce sediment in suspension, and compensate for low residue.

Objectives

The objectives of this study are to determine the optimum application methods and the effectiveness of the PAM-mix under moist and dry soil conditions. The different application methods were applied to a construction site in Middleton, WI. Data were collected to determine the most effective method of application and the effectiveness of the PAM-mix on construction sites.

Literature Review

The use of polymers as soil conditioners has been studied for decades. The most conclusive studies, done by Lentz et al. (1992), determined that negatively charged PAM is an excellent soil erosion deterrent for furrow irrigated fields. It was found to be a cost-effective and safe technology. Sojka and Lentz (1994) found that PAM, when applied in irrigation waters at rates greater than 0.7 kg/ha, reduced furrow erosion by an average of 80 to 90% and increased infiltration on Portneuf silt loam by an average of 15%. Trout et al. (1995) reported a 30 to 110% increase in cumulative infiltration. Roa et al. (1996) found that soils treated with PAM had infiltration volumes more than double that of untreated soils over a two-hour period. The infiltration volumes for the untreated soils averaged 231 ml/38.5 square centimeters while those for treated soils averaged 490 ml/38.5 square centimeters, or 98% of the volume of water to be infiltrated. Roa et al. (1996) also found that the high infiltration rate of the treated sample was associated with low concentration of sediment in the effluent or infiltrated water.

Nadler et al. (1994) found that PAM mobility in sandy loam, as well as clay loam soils, was limited to the top 25 cm 10 months after application. Clays were attached to anionic polymers more easily when salts were present in solution. With anionic polymers, flocculation was easier and more complete. When polysaccharides are present with anionic polymers in solution, fixation was also easier and more complete. Khamraev et al. (1983) reported that clay fixation is best achieved for PAMs with 30% anionic charges. The cementation provided by the clay flocculation stabilizes the aggregate at the surface. Roa et al. (1997) found that using polysaccharides, a calcium source with anionic polymers orpolysaccharides with calcium nitrate and anionic PAM, increased the infiltration rate in saturated cores 5 times greater than with no soil treatment.

PAM use for erosion control provides a potent environmental benefit by halting furrow erosion by about half a ton of soil per ounce of PAM used. PAMs remove most sediment, phosphorus, and pesticides from return flows, and greatly reduce return flow BOD (Sojka and Lentz, 1996). The consequences of reducing sediment and nutrient loading of construction areas can ultimately be expected to reduce the frequency and intensity of algae blooms and reduce turbidity and sedimentation of stream channels.

Lentz et al (1992) in Kimberly, Idaho, reported that when applied at 10 ppm, PAM provided a 94% reduction in runoff-sediment in three years of testing. When used properly, PAM has no measurable toxicity to humans, plants, or aquatic organisms. Molash et al. (1997) state that the Polyacrylamide Allocation Standard for Reduction of Soil Loss is necessary because other best management practices (BMPs) are available and have varying degrees of effectiveness.

Sojka and Lentz (1996) summarized several advantages of PAMs over other erosion control BMPs: (1) PAM can be applied using irrigation equipment and can be effective for controlling erosion over large areas, as demonstrated in eastern Washington and Idaho; (2) PAM is very effective on fine silt/clay soils; (3) preliminary research conducted in

Kansas and California has indicated that PAM is effective at abating wind erosion; (4) PAM enhances precipitation of fine silts and clay particles, providing water quantity benefits; (5) PAM increases soil infiltration capacity that reduces runoff volumes; and (6) high benefit to cost ratio.

The types of PAM used for erosion control should have an approximate molecular weight of 12-l 5 Mg/mole, with an 8-35% negative charge density, and contain no greater than 0.05% Acrylamide monomer (Sojka and Lentz 1996).

A recent study done by King et al. (1996) focused on comparing the uses of polyacrylamides and straw mulch on dry bean yields. It was shown that the sediment loss was reduced for both straw mulch and the PAM treatment.

In three years of studies in construction sites using PAM for controlling soil loss, PAM has provided a 60-97% reduction in runoff-sediment (Roa et al. 1997).

Method

Five treatments were applied to soil test plots: (1) No PAM-mix application to dry soil [control], (2) PAM-mix in solution applied to dry soil, (3) Dry PAM-mix application to dry soil, (4) PAM-mix in solution with mulch/seeding applied to dry soil, and (5) PAM-mix in solution applied to moist soil. Three replications of each treatment were performed using a randomized block design on 1 m x 1 m non-vegetated plots in the Middleton Hills Development, Middleton, WI. The soil was a Dodge silt loam. The average slope of the test site was 10%.

Plot preparations included large boulder, cobble, and excess debris removal. The surface was raked prior to testing. Soil moisture prior to testing was about 9%.

The PAM-mix is a high molecular weight anionic granular polymer. The PAM-mix (2.25 g of PAM-mix added to 5 liters of water) was applied at a rate of 22.5 kg/ha, to the appropriate plots using a garden sprinkler. For the dry PAM-mix application, 2.25 grams of the PAM-mix was applied using a sifter. For the PAM-mix applied to moist soil treatment, the soil was pre-moistened by a 6.4 cm rainfall six hours before testing.

The sprinkler infiltrometer (Bubenzer and Patterson, 1982) was used to collect data for this study. A rainfall simulator was used that produces 6.4 cm per hour. Actual rainfall depths were recorded using eight rain gauges for each replication. Runoff from each plot was collected into a tank where the depth of the water was recorded at approximately 2-minute intervals during each test. The average trial time was 40-50 minutes or until the runoff collection tankwasfilled.

Runoff samples were extracted at approximately 1 O-minute intervals by diverting runoff into a collection container during each replication to determine sediment yield. A representative sample was also taken at the end of each replication from the tank. The samples were dried at 11 0°C for 24 hours and weighed to determine an average sediment load for each trial.

Results and Discussion

Mean sediment yield, infiltration, and runoff depth for the three replications and the controls are presented in Tables 1, 2, 3 and 4. For Replication 1, the PAM-mix solution was prepared the evening before field testing. It was noted that the viscosity of the solution decreased throughout the day. This change may have been due to UV light, reaction with the mix, and/or oxidative and photolytic interaction. Thereafter, the solution was prepared immediately before the rainfall simulation. After analyzing the results, a lower viscosity of the PAM-mix solution was determined to be less effective in controlling sediment yield. This difference is presented in Table 4. Future recommendationsforcommercial applications may need to take into account the time of preparation of the solution and handling before application.

During the first replication of testing, the largest sediment reduction occurred when PAM-mix in solution was applied to moist soil. The control yielded 184.4 grams per square meter and the PAM-mix in solution applied to moist soil yielded 36.4 grams per square meter resulting in a reduction of 80% in sediment yield (Table 1). The sediment yield reduction for the dry PAM-mix application to dry soil and PAM-mix in solution with mulch/seedling applied to dry soil were

Table 1. Summary of rainfall, infiltration runoff, and sediment yield for Replication #1 .

Treatment	Rainfall (cm)	Infiltration (cm)	Runoff (cm)	Sediment (gm)	Soil Loss % of Control	Runoff Rainfall % of rainfall
Control	5.64	1.70	4.01	184.4	100%	71%
Dry PAM-mix/Dry Soil	5.79	1.91	3.89	68.3	37%	67%
Solution PAM-mix/Dry Soil	5.64	1.60	4.11	103.7	56%	73%
Solution PAM-mix/Moist Soil	5.72	0.05	5.66	36.4	20%	99%
Solution PAM-mix/Mulch/Dry Soil	5.72	1.57	4.14	67.3	36%	72%

approximately 64%. The sediment yield for PAM-mix in solution applied to dry soil was reduced by 44% when compared to the control.

In Replications #2 and #3, the lowest sediment yield occurred for the treatment of PAM-mix in solution with mulch/seeding applied to dry soil. A sediment reduction of 97% and 89% occurred, respectively. A sediment reduction for the treatment of PAM-mix in solution applied to dry soil was 87% and 57% respectively (Table 2 and 3).

Table 2. Summary of rainfall, infiltration runoff, and sediment yield for Replication # 2.

Treatment	Rainfall (cm)	Infiltration (cm)	Runoff (cm)	Sediment (gm)	Soil Loss % of Control	Runoff Rainfall % of rainfall
Control	4.57	0.51	4.06	377.67	100%	88%
Dry PAM-mix/Dry Soil	5.72	1.57	4.14	178.36	47%	73%
Solution PAM-mix/Dry Soil	4.72	0.61	4.11	48.77	13%	87%
Solution PAM-mix/Moist Soil	4.14	0.13	4.01	242.4	64%	97%
Solution PAM-mix/Mulch/Dry Soil	4.55	0.38	4.17	12.04	3%	92%

Table 3. Summary of rainfall, infiltration runoff, and sediment yield for Replication # 3.

Treatment	Rainfall (cm)	Infiltration (cm)	Runoff (cm)	Sediment (gm)	Soil Loss % of Control	Runoff Rainfall % of rainfall
Control	5.05	1.12	3.94	231.34	100%	78%
Dry PAM-mix/Dry Soil	5.38	1.96	3.43	43.29	19%	64%
Solution PAM-mix/Dry Soil	4.50	0.61	3.89	98.59	43%	86%
Solution PAM-mix/Moist Soil	4.42	0.28	4.14	47.65	21%	94%
Solution PAM-mix/Mulch/Dry Soil	4.39	0.38	4.01	26.58	11%	92%

When Replication #1 is excluded from the results, the average sediment reduction for PAM-mix in solution with mulch/seeding applied to dry soil increased from 87% to 94% (Table 4). The sediment reduction for PAM-mix in solution applied to dry soil was 76%. For dry PAM-mix applied to dry soil, the sediment reduction was 17%, and the sediment reduction of PAM-mix in solution applied to moist soil was 77%.

Conclusion

Our results show that, regardless of the application method, PAM-mix was effective in reducing sediment yield in the test plots. The most effective method of soil treatment throughout this study in reducing sediment yield is PAM-mix in solution with mulch/seeding applied to dry soil. The ease of application, low maintenance, and relatively low cost

associated with PAM-mix makes it a practical solution to costly existing methods being implemented. The evidence from the field application in this study reflects that PAM-mix is a tool to reduce soil loss on bare soil until vegetation cover is established.

Table 4. Average summary of rainfall, infiltration runoff, and sediment yield for Replications 1, 2, and 3 and Replications 2 and 3, excluding Replication 1.

Treatment	Runoff (cm)	Sediment (gm)	Soil Loss % Replication 1, 2, and 3	Sediment (Gm) Excluding Replication 1	Soil Loss % Replication 2 And 3	% of Rainfall
Control	4.01	264.51	100%	304.51	100%	79%
Dry PAM-mix/Dry Soil	3.81	96.65	37%	110.83	36%	66%
Solution PAM-mix/Dry Soil	4.04	83.71	32%	73.68	24%	81%
Solution PAM-mix/Moist Soil	4.60	108.82	41%	145.03	48%	97%
Solution PAM-mix/Mulch/Dry Soil	4.11	35.32	13%	19.31	6%	84%

The primary factor that must be considered in future studies is the time of polymer solution preparation and application. It was noted that the optimal application procedure is to prepare the solution immediately prior to application. This procedure is necessary in order to limit the amount of degradation and maximize the performance of the PAM-mix.

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