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PASSIVE TREATMENT TO MEET THE EPA TURBIDITY LIMIT

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ABSTRACT

Rock check dams are commonly installed in construction site ditches to reduce the potential erosion that can occur during runoff events. Recent tests at field sites have suggested that check dams constructed of fiber materials, such as coir, straw, and excelsior may outperform rock in reducing ditch erosion, and adding polyacrylamide (PAM) can significantly reduce turbidity. This paper describes tests of three check dam types for turbidity reduction under controlled conditions. These included standard rock, rock wrapped in an excelsior blanket, and excelsior wattles. A series of three check dams were installed in a 24 m, lined ditch with a 5-7% slope. A simulated storm was introduced to the ditch for 20 minutes, with sediment added and a peak flow of 56 liter s^{-1} (2 cfs). Samples were taken on the downhill side of each check dam and analyzed for turbidity. The excelsior wattles with PAM produced significantly lower turbidity than the rock check dam, although adding PAM to that greatly reduced turbidity as well. When compared to untreated check dams, PAM reduced turbidity by 61-93%, down from a range of 350-1300 nephelometric turbidity units (NTU) to 47 – 229 NTU. The rock + excelsior and excelsior wattle dams maintained substantial flocculation potential after three events, but the rock dam did not. The maximum potential concentration of PAM was 5 mg L^{-1}, well below levels known to be non-toxic, but an indirect measurement indicated concentrations more than 100 fold lower after mixing with suspended sediment.

KEYWORDS. Turbidity, polyacrylamide, check dam, runoff, storm water.

INTRODUCTION

Check dams are designed to pond water in channels and as a result, reduce the velocity of water flowing through the channel. They are often constructed of rock, gravel bags, sandbags, fiber rolls, or other reusable products (California Stormwater Quality Association, 2003). When polyacrylamide (PAM) is incorporated into the dams, the settling rate of clay-sized particles increases due to flocculation, which can significantly reduce turbidity (McLaughlin et al., 2009)

Leib et al. (2005) showed that wooden check dams in a tailwater ditch ponded water and decreased flow velocity in a vineyard in Washington. Check dams caused the water to back up almost into the furrows, which decreased erosion in the transition area where the furrows met the ditch. This was due to water coming from the furrows and flowing into deeper pooled water rather than on the soil surface. McLaughlin et al. (2009) showed that fiber check dams considerably reduced erosion in ditches when compared to rock dams and the addition of PAM to the fiber check dams further reduced turbidity in runoff. Polyacrylamide is a synthetic polymer that causes soil particles to flocculate and settle which contributed to the decreased sediment losses in this study. A review of PAM uses for erosion and turbidity control has been published (Sojka et al., 2007).

Check dam location is also another important management decision that will determine the effectiveness of sediment trapping. Hassanli et al. (2009) showed that rock check dams placed in dry stream channels trapped increasingly smaller particles further downstream in the Droodzan watershed in Southern Iran. While they suggested the downstream dams were more efficient,

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many other factors could have led to this result, such as trapping of heavier fractions in upstream dams, changes in source sediment, or greater pooling due to increased dam width.

The efficiency of rock and fiber check dams at reducing erosion and controlling turbidity has not yet been well documented under controlled conditions. While field studies suggest than fiber check dams may be more effective at retaining sediment than rock check dam, this study evaluated turbidity reduction under identical conditions.

MATERIALS AND METHODS

A 24 m (80 ft) ditch was constructed on a 5-7% natural slope and lined with plastic tarps (Fig. 1). It was 0.9 m (3 ft) wide and 0.9 m (3 ft) deep with a 0.46 m (1.5 ft) H-flume installed at the lower end to measure flow. At three points in the ditch, check dams were installed so that the top of the lower one was even with the bottom of the upper one. Rock dams, composed of Class B stone (0.13-0.30 m; 5-12" diameter), were installed with a weir at 0.45 m in the middle and a "tail" extending 0.75 m downslope. The fabric used during this experiment was a single-net excelsior erosion control blanket from American Excelsior Company (Rice Lake, WI, USA). For the fabric-covered rock dams, the fabric was laid on the bottom of the ditch, the rocks piled on top as with the standard rock dam, and the fabric was pulled back over the rocks and anchored with rock on the downhill side. The excelsior wattles were received in 3 m (10') rolls, cut into sections to fit snugly into the sides of the ditch, and stapled down using 0.2 m (8") landscape staples. The excelsior wattles were nominally 0.45 m (18") in diameter, but they were loosely packed and tended to compact down 3-6" during installation and testing. Instead of installing wood stakes on the downhill side as would be the normal practice, we placed several large rocks below each device to avoid compromising the tarps.

Treatments included in this experiment were: rock only, rock with PAM, rock wrapped with excelsior, rock wrapped with excelsior with PAM, excelsior wattle, and excelsior wattle with PAM. The PAM used was Applied Polymer Systems 705 (Woodstock, GA, USA) and was applied by hand on each of the check dams at 60 grams per dam. After adding the PAM, dams were sprinkled with water to ensure that the PAM was wet prior to flow initiation, simulating the rainfall which would occur on an actual site prior to flow in a ditch.

A test consisted of three consecutive runs. For each run, water was introduced from our uphill storage pond through a 0.25 m pipe at the rates of 14, 28, and 56 liters per second (lps; 0.5, 1.0, and 2.0 cubic feet per second). A run consisted of 4 minutes of each flow in sequence followed by 4 min of 28 and 14 lps to simulate a storm event. Soil was added to the water at a rate to maintain a constant concentration of approximately 6,000 mg L^{-1}. It was added through an inlet approximately 6 m (20') from the outlet of the pipe. The soils used were subsoils excavated from local construction sites. After three consecutive runs, the check dams were removed and all residual sediment was washed out of the ditch, then the next set of check dams were installed for the next three runs. On the downhill side of each dam, an ISCO 6712 water sampler intake was anchored with a rock and the sampler was programmed to obtain a sample every minute, with four samples composited into one bottle to represent that flow period. Flow was measured in an H-flume at the ditch outlet using a fourth ISCO sampler with a bubble module (no samples taken, just flow). Samples were analyzed for turbidity, using an Analite turbidity meter (McVan Instruments, Victoria, Australia) and total suspended solids (TSS) following the Standard Methods for the Examination of Water and Wastewater (Clesceri et al. 1998). An estimate of the PAM concentration was determined on 58 of the water samples in the PAM tests using the filtration method of Jungreis (1981).

Figure 1. Example of rock check dam test at peak flow.

RESULTS

Turbidity was reduced significantly more with the excelsior wattles compared to rock, with the rock covered with excelsior blanket intermediate in performance (Fig. 2). One explanation is that the wattles have more surface area for the PAM to both attach to and dissolve from as the water flowed through and over them. Rock has the least surface area for both PAM attachment and dissolution, so it was the least effective.

The effect of each system of three dams on turbidity with and without PAM was measured in the samples taken after the third dam. The rock check dam system had much higher turbidity after the first run, indicating a reduction in effectiveness as sediment built up behind it (Fig. 3). The rock wrapped in excelsior and the excelsior wattle systems were less affected by successive simulated storms. Adding PAM to the check dams reduced turbidity as much as 93%, even for the rock dams. These values are lower than those in Fig. 2 because they reflect turbidity after all three dams, instead of an average for each individual dam. There was no large increase in turbidity in successive runs in the PAM treatments, suggesting it was still providing substantial flocculation. A more detailed look at the excelsior wattle tests suggests that there was some loss of effectiveness in the third run, but turbidity was still reduced substantially compared to the untreated wattles (Fig. 4). Total suspended solids were generally reduced when PAM was added, but to a lesser degree than turbidity because the flocculated sediment is included in the TSS measurement (data not shown). This also suggests the importance of a settling or filtration step prior to discharge from a site.

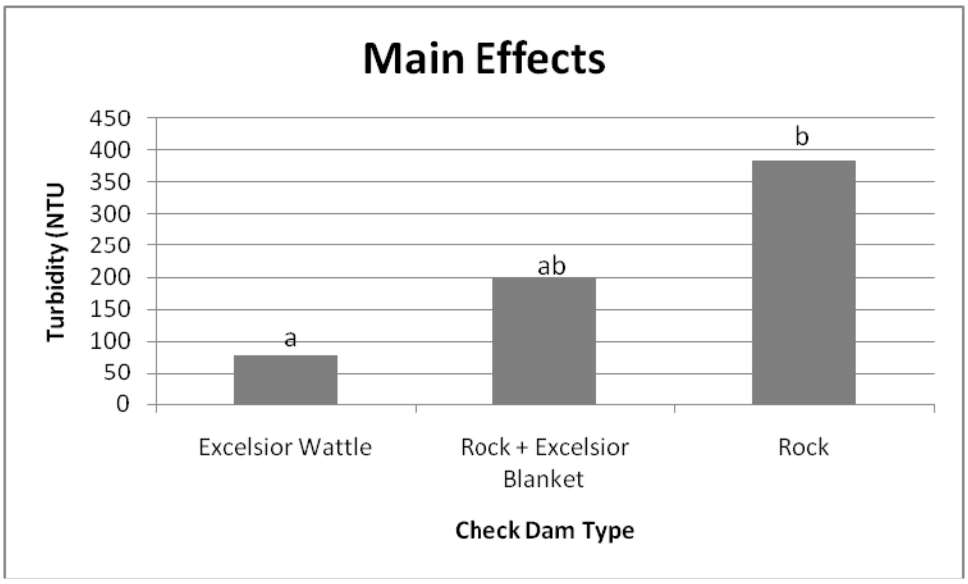

Figure 2. Average turbidity in simulated storm water passing three types of check dams. The average is for samples from all three check dams in the ditch test. Values with different letters are significantly different at α = 0.05.

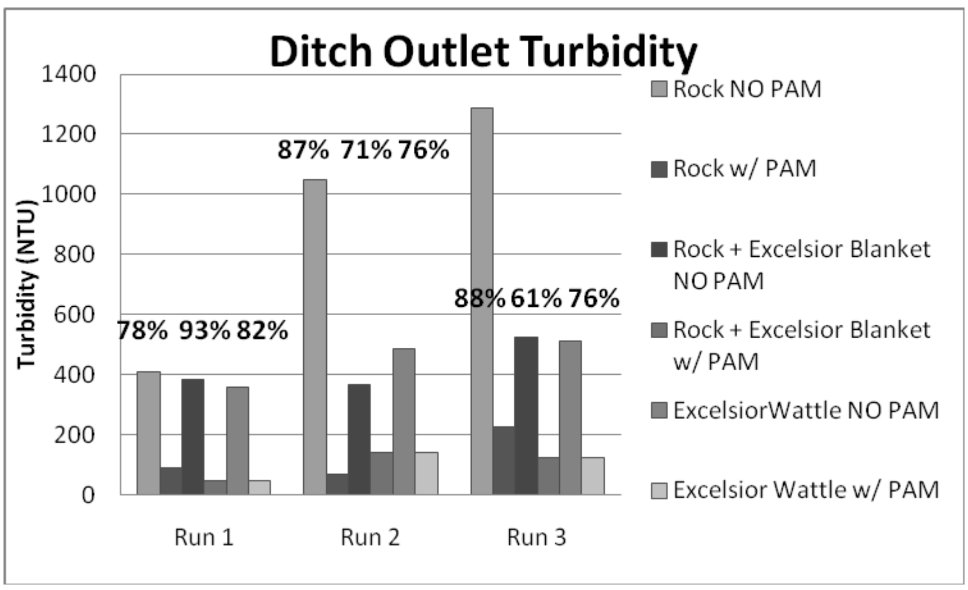

Figure 3. Turbidity in simulated storm water after passing three check dams alone or treated with PAM. The numbers above each pair of bars reflects the reduction in turbidity by adding PAM.

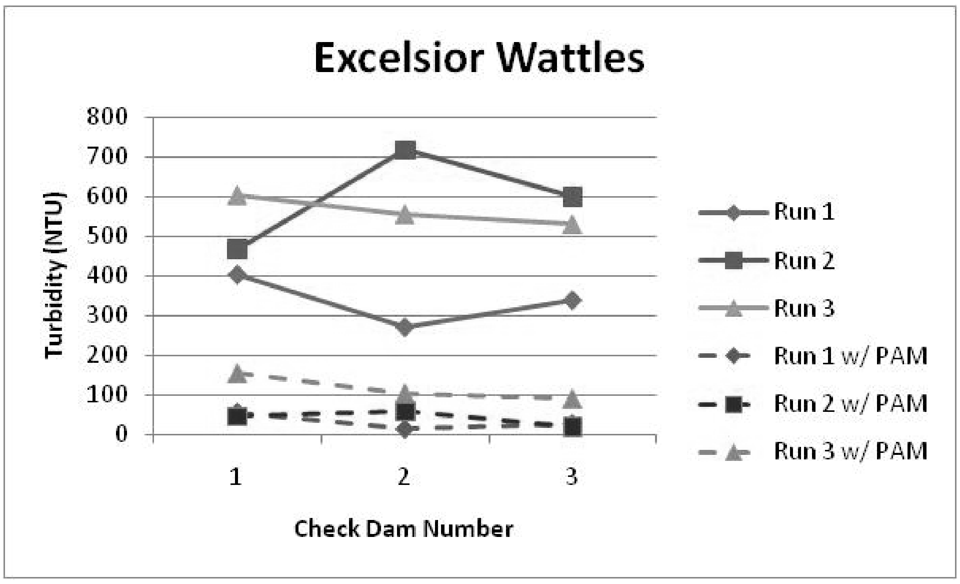

Figure 4. Turbidity in simulated storm water passing each excelsior wattle in series, with or without PAM added.

If all of the applied PAM had dissolved in the first run, the average concentration would have been approximately 5 mg L^{-1}, or in all three runs it would have been 1.7 mg L^{-1}, prior to reacting with the suspended sediment. These values are at least 5-10 times lower than the no observable effect concentration for chronic toxicity for this product as reported by the supplier (Applied Polymer Systems, 2010). The concentration of PAM in the water after reacting with the sediment was determined for selected samples at various points in the ditch and in the grass below the flume discharge. These samples all had estimated concentrations of 0.01 mg L^{-1} or less, indicating the rapid and complete reaction the PAM had with the suspended sediment.

CONCLUSION

These results suggest that the standard rock check dam can be treated with a flocculant to reduce turbidity, but that excelsior wattles were superior. In locations where rock is still preferred, wrapping the rocks in an excelsior blanket appeared to provide better turbidity reduction with the flocculant. The high surface area of the wattle may have been the reason for better flocculation due to greater PAM-water contact during each run. Turbidity was reduced by 61-93% when PAM was applied to the check dams compared to identical tests with no PAM. Only the rock check dam appeared to lose substantial flocculation potential by the third run, possibly due to the much lower surface area for the PAM to adhere to and dissolve from. The theoretical concentrations had a large (5-10X) safety margin and the estimated concentration after mixing with sediment was more than 100 times lower. This suggests that this can be an effective and safe method of reducing turbidity in runoff from disturbed areas.

Acknowledgements

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