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Research article

Simple systems for treating pumped, turbid water with flocculants and a geotextile dewatering bag

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ABSTRACT

Pumping sediment-laden water from excavations is often necessary on construction sites. This water is often treated by pumping it through geotextile dewatering bags. The bags are not designed to filter the fine sediments that create high turbidity, but dosing with a flocculant prior to the bag could result in greater turbidity control. This study compared two systems for introducing flocculant: passive dosing of commercial solid biopolymer (chitosan) and injection of dissolved polyacrylamide (PAM) in a length of corrugated pipe connected to the bag. The biopolymer system consisted of sequential porous socks containing a "charging agent" followed by chitosan in the corrugated pipe with two levels of dosing. The dissolved PAM was injected into turbid water at a flow-weighted concentration at 1 mg L^{-1}. For each treatment, sediment-laden turbid water in the range of 2000 to 3500 nephelometric turbidity units (NTU) was pumped into the upstream of corrugated pipe and samples were taken from pipe entrance, pipe exit, and dewatering bag exit. Without flocculant treatment, the dewatering bag reduced turbidity by 70% but the addition of flocculant increased the turbidity reduction up to 97% relative to influent. At the pipe exit, the low-dose biopolymer was less effective in reducing turbidity (37%) but it was equally effective as the high-dose biopolymer or PAM injection after the bag. Our results suggest that a relatively simple treatment with flocculants, either passively or actively, can be very effective in reducing turbidity for pumped water on construction sites.

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1. Introduction

Sediment is recognized as the most common pollutant in rivers, streams, lakes and reservoirs in the United States (US), causing $ 16 billion in environmental damage annually (Clark, 1985; USEPA, 2009a). The greatest sediment losses on an area basis result from construction activities, with erosion rates an order of magnitude higher than farming and several orders higher than undisturbed areas (Owen, 1975; Pitt et al., 2007). This can result in high sediment concentrations within aquatic environments which can have detrimental impacts for fish health, light penetration, water quality and aesthetics (Newcombe and MacDonald, 1991; Newcombe, 2003).

Many construction site managers find it difficult to control turbidity to meet local and state turbidity standards (USEPA, 2009b). For instance, the State of North Carolina (NC) in US enacted the Sedimentation Pollution Control act in 1973, requiring that any construction site that disturbs more than 1 acre shall have an approved erosion and sedimentation control plan (NCDENR, 2002). In addition, Fresh Surface Water Quality Standards in NC (Administrative code 15A NCAC 02B .0211) limits turbidity of discharged water to non-trout streams to 50 nephelometric turbidity units (NTU), 10 NTU for trout waters, and 25 NTU for lakes and reservoirs not designated as trout waters. Even with diligent attention to the design, implementation, and maintenance of erosion and sediment control measures, the turbidity in construction site discharges often remains quite high because silt- and clay-sized fine particles are not easily settled using gravity-based sediment control measures (Przepiora et al., 1998; Line and White, 2001; McCaleb and McLaughlin, 2008).

One promising approach to treat sediment-laden turbid water is to introduce chemical flocculants into the turbid water, causing the suspended solids to flocculate. The most common flocculant is polyacrylamide (PAM), but chitosan-based biopolymer has potential to be used for the turbidity control (Orts et al., 2000; Sojka et al., 2007). PAM is a water-soluble, synthetic polymer made of

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repeating acrylamide and acrylate monomers. Commercially available PAMs vary in physical formulation (granule, solid block, emulsion) with a range of charge densities and molecular weights (Barvenik, 1994). High molecular weight, linear, moderately anionic PAMs have been found to be effective as a soil conditioner for erosion control in irrigation furrows and construction sites (Sojka et al., 2007). For instance, Kang et al. (2014a) found that both dissolved and powder forms of PAM were effective in stabilizing soil surface and reducing runoff turbidity by 97% with groundcover compared to untreated bare soil. PAM can be added to hydroseeding mix and applied over a slope, which may help to stabilize the slope (Hayes et al., 2005).

There is growing interest in developing alternative flocculant to synthetic PAMs. A range of bioflocculants (e.g., starches, chitosan, alginates) have been studied (Orts et al., 2000; Renault et al., 2009) and chitosan-based flocculant has been commercialized for stormwater applications (HaloKlear, 2016). Chitosan is a modified, carbohydrate polymer derived from the chitin component of the exoskeleton of crustaceans such as shrimp, crab, and crawfish (Renault et al., 2009). It has characteristics of high cationic charge density, bridging of aggregates and precipitation, and long polymer chains. No and Meyers (1989) found that the total suspended solids (TSS) present in water discharged from seafood processing streams could be reduced by 97% compared to influent TSS (>5 g L^{-1}). The use of chitosan in the flocculation of river silt reduced the turbidity to below 5 NTU without filtration with influent turbidity up to 150 NTU (Divakaran and Pillai, 2002).

Construction site runoff can be dosed either passively or actively (USEPA, 2009b). Active dosing involves the use of external power to introduce the flocculant, usually involving pumping a liquid form of PAM into the flow in a controlled system. In general, active dosing produces very reliable turbidity reduction but the costs associated with setup and maintenance limit its widespread use for construction site runoff. Passive dosing requires no external energy and involves the introduction of flocculant by placing solid or powder form into the stormwater flow, thereby "passively" dissolving it into the water. There are several places to introduce flocculant into the water passively such as on check dams, channel liners, or in slope drains leading to sediment basins (Bhardwaj and McLaughlin, 2008; Kang et al., 2013, 2014b,c).

Geotextile dewatering bags are often used to contain sediment in dewatering applications where sediment-laden water is being pumped (Muthukumaran and Ilamparuthi, 2006). They are commonly used in situations where no space is available to install sediment basins. Because chemical flocculation prior to sediment basins has been shown to be very effective at reducing turbidity (Kang et al., 2014b,c), following the same approach prior to discharge into a dewatering bag could also reduce effluent turbidity. To our knowledge, there have been no published studies evaluating the effect of flocculants on water quality in the dewatering bag applications. The objective of this study was to determine the effectiveness of flocculants for turbidity reduction in discharges from the dewatering bags using a simple, pumped system.

2. Materials and methods

For most construction site projects, dewatering operations that remove ground water or accumulated runoff must be pumped through a treatment practice (Caltrans, 2001). This often involves either a sediment basin or a geotextile bag to remove heavy sediment. Our experimental setup (Fig. 1) added a chemical treatment step before the geotextile bag to determine the potential for removing substantially more sediment and turbidity through flocculation. This system could be adapted for any pumping operation in which sediment removal and turbidity reduction are the goals.

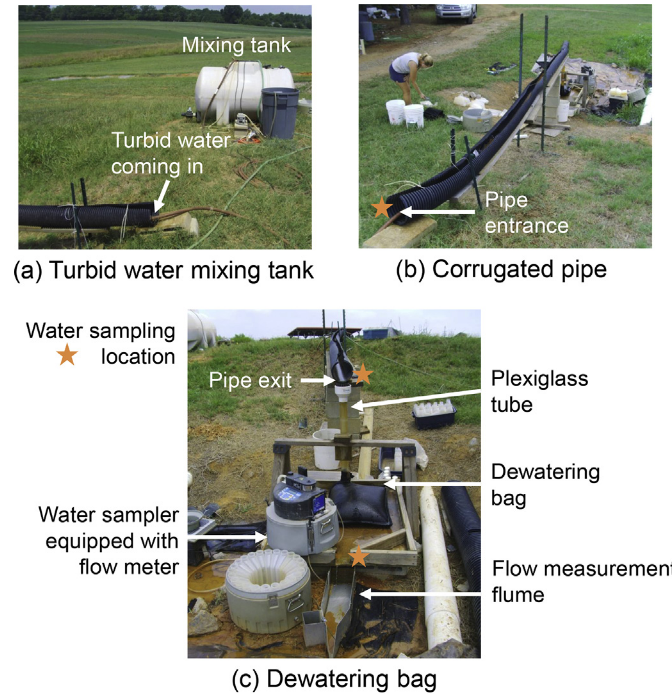

Fig. 1. Experimental setup for the dewatering bag test.

Experimental pumped water test was conducted at the Sediment and Erosion Control Research and Education Facility (SECREF) at the Lake Wheeler Field Laboratory in North Carolina State University, Raleigh, NC, USA. Turbid water was generated by adding a local fill soil (52% sand, 20% silt, and 28% clay) into a water tank at a sediment loading of 5000 mg L^{-1} and stirring it manually (Fig. 2a). The treatment system consisted of corrugated pipe, plastic funnel and pipe, and the dewatering bag (Fig. 2b). A 3.6-m long corrugated pipe (20-cm in diameter) cut in half was installed on a supporting frame. Corrugated pipe was selected as a way to introduce turbulence and mixing into the flow prior to the bag. Turbid water in the water tank was fed into the corrugated pipe using a sump pump approximately at 57 L min^{-1}. The funnel and pipe directed the discharge from the corrugated pipe into a dewatering bag (Fig. 1c). A 61 × 61 cm dewatering bag, constructed for this study using the same material used for commercial geotextile bags (Dirtbag™, ACF Environmental Inc., Richmond, VA, USA), was fastened with a built-in strap at the bottom of plexiglass tube. The bag lays on a tray which collected the discharge and directed it into a 15-cm H-flume, where effluent flow was measured and samples were taken automatically (Teledyne ISCO 6712 sampler with 640 bubbler module, Lincoln, NE, USA). The technical specifications of the dewatering bag are presented in Table 1 (ACF Environmental, 2016). For each test, turbid water was fed into the corrugated pipe until the flow backed up 58 cm up in the tube, equivalent to metric measurement for 0.8 pound-per-inch (psi).

The passive treatment consisted of a Dual Polymer System (DPS; HaloSource Inc., Bothell, WA, USA) biopolymer product consisting of two different chemicals, a "charging agent" (HaloKlear DBP-2100) followed by a chitosan flocculant (HaloKlear GelFloc). The charging agent is formulated from proprietary natural biopolymers and is reported to form highly stable, strong bonds with chitosan (HaloKlear, 2016). Both chemicals were deployed in porous socks parallel to flow (Fig. 3). In this study, the charging agent sock

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