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Understanding Interactions Between Clay Mineralogy and Polyacrylamide for Turbidity and Flocculation Control in Discharged Waters from Construction Sites

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ACADEMICS ▲ RESEARCH ▲ EXTENSION

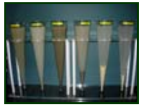
Introduction

Suspended sediment in surface waters is a serious water quality problem detrimentally affecting aquatic biota, transportation of pollutants, and decrease the aesthetic value of lakes and rivers. Increased turbidity reduce the amount of light penetrating water, reduce photosynthesis and overall productivity of the community. Suspended sediments clog fish gills, reduce resistance to disease, lower growth rates, and affecting egg and larval development. High turbidity increases water temperatures and alters water chemistry.

Discharges from construction sites are major contributors to turbidity of rivers and streams with contributions from 100 to 15000 NTU (Przepiora et al., 1998; Line and White, 2001). Federal and state regulations require developers to design sediment and turbidity control programs for construction sites and that the turbidity in the receiving waters adjacent to sites must not exceed 50 NTU for non trout waters and 10 NTU for trout waters (USEPA, 1992; NCDEHNR, 1995). Turbidity is difficult to control with increased detention time and gravity based settling because it is primarily due to suspended clay and fine silt particles. Polyacrylamide (PAM) has been found to be a very effective flocculant for turbidity control without any toxic effects within desired concentrations. In spite of defined flocculation mechanisms, mineralogical composition of suspended clay and other characteristics such as cationic composition, sediment sizes have strong influence on the flocculation performance. In this perspective, understanding of these interactions is critical for chemical treatment and control of turbidity in discharged waters.

Objectives

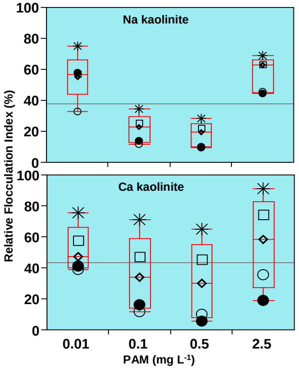
- To investigate the effects of clay mineralogy and exchangeable cations on flocculation by PAM.
- To evaluate PAM treatment of turbidity from different soil sources using simulated stilling basins.



Materials and Methods

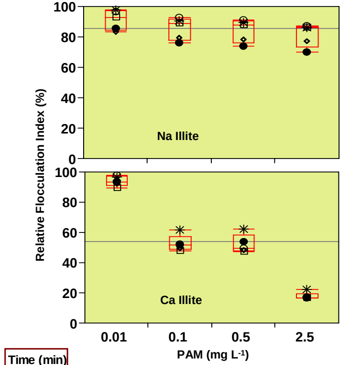
- **Clays and Soils**: Three reference clays were used: Montmorillonite, illite and kaolinite. Homoionic Na and Ca clays were prepared by saturating them with NaCl or $CaCl_2$ 0.5 N solution. Clays were centrifuged and washed with water and water/ethanol mixtures several times to remove Cl^- and thereafter freeze dried. For stilling basin studies two soils: Plymouth, NC (Loamy Sand ; Dominant clay minerals: Kaolinite- 55%, Vermiculite- 25%, Smectite- 20%) and Raleigh, NC(Sandy Clay Loam; Dominant clay minerals: Kaolinite- 82%, Vermiculite- 12%, Smectite- 6%) were used.
- **Laboratory Studies**: In these experiments the effects of an anionic PAM (A110, Cytec Inc., North Andover, MA) with high molecular weight and 15% hydrolysis were studied on clay flocculation. A stock solution of 1000 mg L^{-1} PAM was prepared. 5 g L^{-1} suspensions of montmorillonite, illite and kaolinite clays were made with deionized water. PAM solutions were added by pipette to 200 ml portions of clay suspensions that were placed in 330 ml Nalgene containers for final PAM concentrations of 0, 0.01, 0.1, 0.5, 2.5, 5, and 10 mg L^{-1}; suspensions were then hand shaken for 10 sec. Thereafter a nephelometer (Analite 152, McVan Instruments, Australia) probe was inserted into the suspensions to a depth of 25 mm and turbidity was recorded after 0.5, 1, 5, 10 and 20 min. Relative flocculation index (RFI) was calculated from the turbidity data using the equation: RFI = (Ti/To)*100; where Ti is the turbidity of suspensions with PAM and To is the turbidity of suspensions without PAM, but otherwise under the same conditions. Same experiments were repeated with the soils. Soil amounts used for turbidity generation were equivalent to 5 g L^{-1} clay.
- **Stilling Basin Studies**: Stilling basin studies consisted of a simulated borrow pit operation. Water from a source pond (300 m^2) was delivered to a mixing pond (80 m^3) at a fixed rate of 20 L s^{-1} while adding soil at a controlled rate for 0.5 h. Turbid water from the mixing pond was pumped to a stilling basin (22 m^3) at the rate of 4L s^{-1} to test PAM dosing treatments. PAM dosing treatments were tested in the stilling basin for 130 min. Active and passive dosing in turbid waters due to Raleigh sandy clay loam was tested with APS 705 (Applied Polymer Systems Inc.) solution (4 mg L^{-1}) and APS 706b (Applied Polymer Systems Inc.) Floc Log with PAM release rate of 2.1 mg L^{-1}.

Results

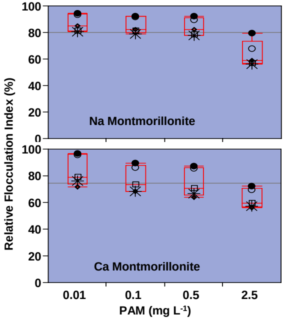


- Anionic PAM was more effective in flocculating Na- Kaolinite than Ca-Kaolinite (at pH 6.6) due to interactions between PAM and aluminol groups present on the edges of kaolinite particles.

Time (min)
● 0.5
○ 1
◇ 5
□ 10
✳ 20



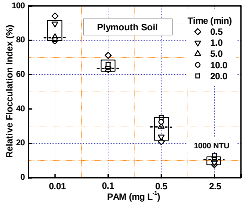
- Anionic PAM had higher efficiency of flocculating Ca-Illite than Na-Illite indicating that cation bridging was the main mechanism bonding the anionic PAM and negatively charged illite clay particles

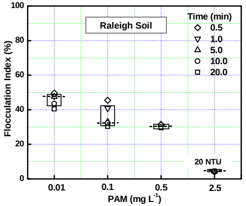


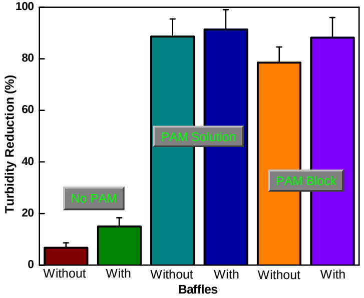
- Anionic PAM was more effective in flocculating Ca-Montmorillonite than Na-Montmorillonite at lower concentrations while opposite was true for higher PAM concentrations.

Turbidities from Plymouth soil ranged from 5000-6000 NTU while Raleigh soil had turbidities in range of 200-1000 NTU with the same amount of soil.

- The two different soils (clay mineralogy) had similar RFIs, but the actual turbidity was still very high for the Plymouth soil (>1000 NTU).







- Turbidity reduction of 80-90 % achieved with anionic PAM (both active and passive dosing) as compared to 5-15 % with no PAM.

Conclusions

- PAM induced flocculation of clay minerals is affected by both clay mineralogy and exchangeable cations.
- Smectitic and illitic clays are more dispersive than kaolinitic clays and therefore the former produce higher turbidities than the latter.
- Higher smectitic clay in Plymouth loamy sand than Raleigh sandy clay Loam provided greater turbidities in the former than the latter.
- PAM dosing in pumped waters from construction sites can effectively control turbidities to <50 NTU (required for pumped discharge) irrespective of physical controls employed.
- Understanding the clay mineralogy of soil on the construction sites is important for selection of appropriate PAM product to control turbidity.

References

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Acknowledgements

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