Separation Science and Technology

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713708471

Treatment of low-turbidity water by sweep coagulation using clay

Yun-Hwei Shen[a]

[a] Department of Resources Engineering, National Cheng Kung University, Tainan, Taiwan, R.O.C.

Online publication date: 07 October 2002

SEPARATION SCIENCE AND TECHNOLOGY, 37(11), 2739–2744 (2002)

TECHNICAL NOTE

TREATMENT OF LOW-TURBIDITY WATER BY SWEEP COAGULATION USING CLAY

Yun-Hwei Shen

Department of Resources Engineering, National Cheng Kung University, Tainan, Taiwan, R.O.C.

ABSTRACT

A novel strategy of sweep coagulation to treat low-turbidity water is presented herein. Preliminary study findings demonstrate the feasibility of employing flocs formed by coagulation of montmorillonite suspension with cationic polyelectrolyte as a surrogate to the amorphous $Al(OH)_3$ precipitated in sweep coagulation. Excellent efficiency of turbidity removal is attained via physical entrapment of TiO_2 particles within the flocculating montmorillonite flocs.

Key Words: Sweep coagulation; Turbidity; Montmorillonite

INTRODUCTION

Treatment of low-turbidity water is essential to several industries, such as drinking water supply, electronic manufacturing, fine polishing, and pure chemical manufacturing. Owing to the low concentration of particles in water, the rate at which interparticle contacts are produced limits the overall process of aggregation (1). Effective coagulation is generally accomplished by sweep coagulation, which is performed with alum (2). In such a process, high alum dose results in amorphous $Al(OH)_3$ precipitation, which increases the interparticle collision rate, enmeshes the particles, and then removes them via sedimentation. However, in addition to the large amount of waste sludge produced by sweep coagulation using alum, high levels of aluminum remained in the treated water, which raised public health concerns (3). McLachlan (4) discovered that an intake of large quantity of alum salt may cause Alzheimer's disease. In this study, a novel strategy of sweep coagulation to treat low-turbidity water is explored. This strategy uses flocs formed by coagulation of clay suspension with cationic polyelectrolyte as a surrogate to the amorphous $Al(OH)_3$, which is precipitated during sweep coagulation. Due to layer delimination, swelling clay with high cation exchanged capacity (CEC), such as montmorillonite, forms a colloidal dispersion with extremely fine subdivision states dispersing in water (5). Adding cationic polyelectrolyte causes charge neutralization of the montmorillonite and subsequent formation of flocs from all the particles in the solution. The turbidity causing particles may well be entrapped within the flocculating montmorillonite, and is removed from the solution by sedimentation. The treatment efficiency of this new sweep coagulation strategy is illustrated in the following section. Hence, experimental results focus on the treatment of dilute dispersion of nanometer titanium dioxide (TiO_2).

MATERIALS AND METHODS

The TiO_2 powder used herein was purchased from Degussa Corp (Germany). It was 50 nm in size and a point of zero charge (pzc) at a pH of 6.2. Kaolinite and montmorillonite with a CEC of 8 and 71 meq/100 g, obtained from Aldrich Chemical Co. (USA) were also used. The cationic polyelectrolyte used was polydiallydimethylammonium chloride (medium molecular weight, 20% by weight in water). Low-turbidity water sample was prepared by mixing 0.25 mg TiO_2 in 400 mL distilled water with a final pH of 10.5 that was adjusted by NaOH.

For the clay coagulation test, a weighed sample was stirred in 400 mL of distilled water contained in a 500 mL beaker, fitted with four 0.25 in. wide baffle plates and 1 in. diameter propeller, for 10 min. The suspension was then adjusted to pH 10.5 and further conditioned for 2 min. After conditioning, different amounts of cationic polyelectrolyte were then added to the suspension, while the propeller was rotated at 100 rev/min. After 3 min of rapid mixing, the sample was stirred for further 10 min at 20 rev/min, then left to settle for 1 hr. The clay concentration in the suspension was estimated by absorbance measurements taken with a Shimazdu UV-160A spectrophotometer (Japan) using 10-mm cuvattes at a wavelength of 650 nm. A calibration curve of the absorbance vs. clay concentration was obtained. Samples were taken before and after coagulation, and the absorbance was determined. The percentage of clay removal was calculated as usual. For the sweep coagulation test, a pre-weighed amount of clay was added to 400 mL of low-turbidity water and varying amounts of cationic polyelectrolyte were then added to the suspension followed by procedures described in clay coagulation test. Supernatant turbidity was measured with a HACH 2100A turbidimeter (USA) and expressed in Nephelometric Turbidity Units (NTU).

RESULTS AND DISCUSSION

Figure 1 presents a comparison of the coagulation of kaolinite and montmorillonite (nonswelling and swelling clay, respectively) suspension with cationic polyelectrolyte. The optimum coagulant dosage for montmorillonite (5 ppm) was considerably higher than that of kaolinite (0.5 ppm), due to the higher CEC value of montmorillonite. Over- and under-dosing were observed in both cases and the cationic polyelectrolyte dosage range for good coagulation was wider within the montmorillonite suspension. At the optimum dose, apparent solid removal was almost 100 and 98% for montmorillonite and kaolinite,

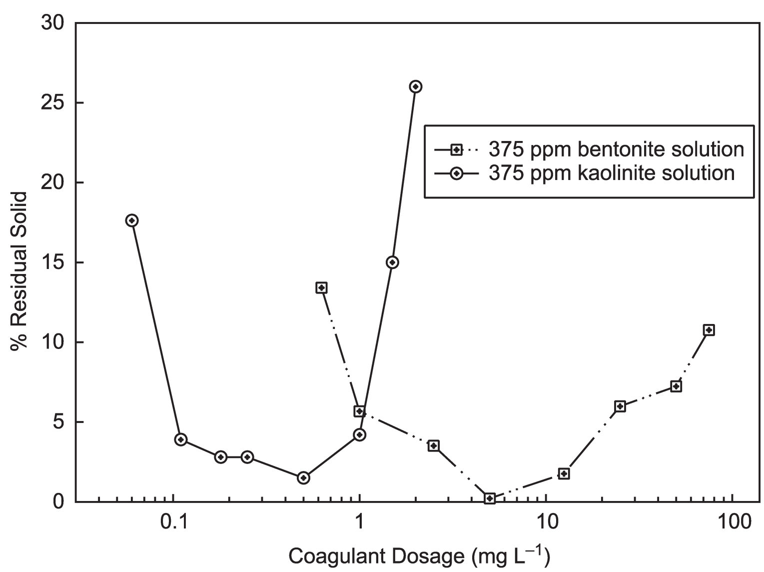

Figure 1. The coagulation of kaolinite and montmorillonite suspension with cationic polyelectrolyte as a function of polyelectrolyte dosage.

respectively. Furthermore, visual inspection of the sediments indicated the formation of small flocs with a compact structure within the kaolinite suspension and large flocs with a fluffy structure within the montmorillonite one. This can be explained as follows: the delminated state of montmorillonite particles within the suspension resulted in numerous particles that favored coagulation. In addition, the swelling characteristic and intense edge-to-face coagulation of these particles formed large flocs that were removed easily by sedimentation. The above observations verify that swelling clay, such as montmorillonite is preferred for sweep coagulation. Figure 2 shows the effects of increase in the montmorillonite concentration on the coagulation process. Notably, a higher montmorillonite concentration is difficult to restabilize by overdosing of cationic polyelectrolyte. The region of destabilization by charge neutralization widens with increasing montmorillonite concentration.

Figure 3 compares the coagulation of low-turbidity water (with a turbidity of 8 NTU) with only cationic polyelectrolyte addition and sweep coagulation via kaolinite and montmorillonite, in terms of supernatant turbidity vs. dosage. As expected, coagulation was not effective over a wide range of cationic polyelectrolyte dosages because of the low rate of interparticle contact and

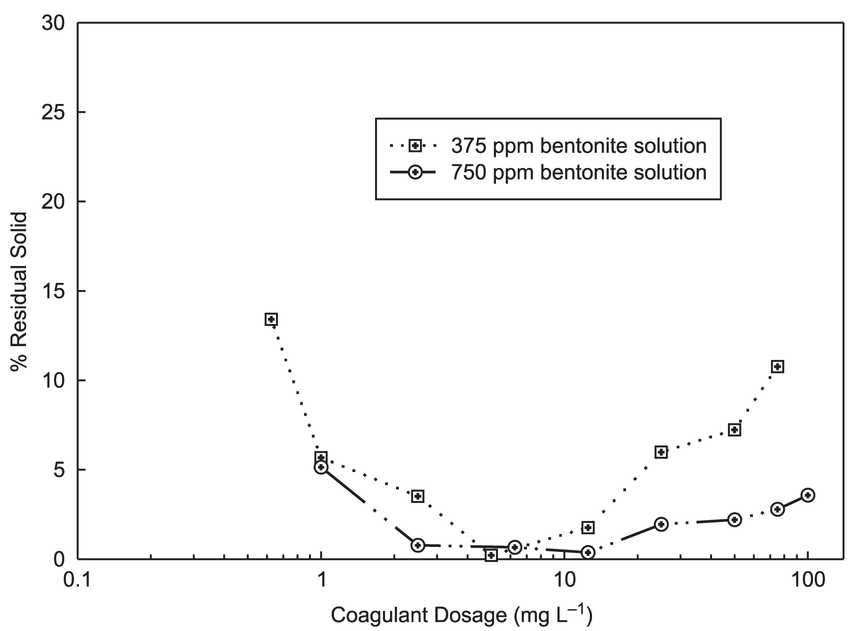

Figure 2. Coagulation of montmorillonite suspensions with cationic polyelectrolyte as a function of polyelectrolyte dosage.

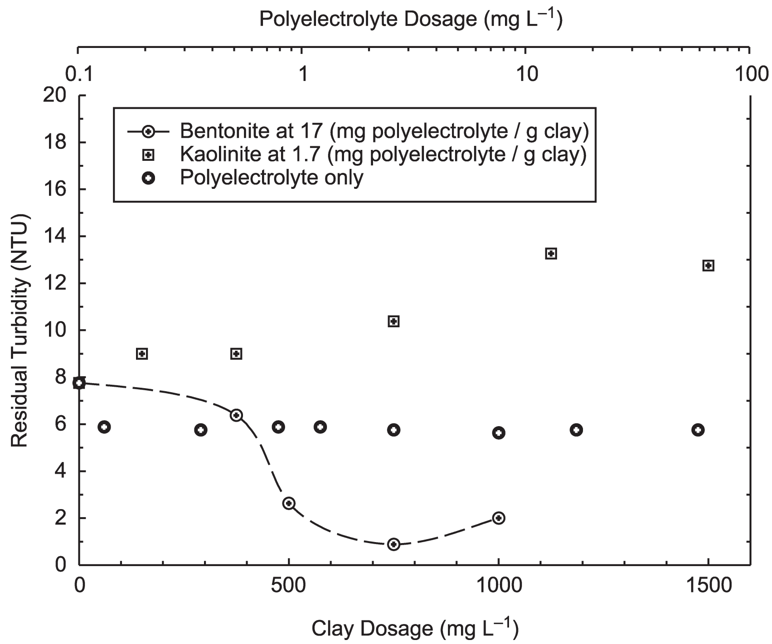

Figure 3. Coagulation of low-turbidity water with cationic polyelectrolyte, kaolinite, and montmorillonite as a function of dosage.

fineness of dispersed TiO_2 particles. The cationic polyelectrolyte dosages applied (1.7 and 17 mg/g of clay for kaolinite and montmorillonite, respectively) herein were obtained from Fig. 1. Figure 3 shows that kaolinite causes very poor turbidity removal, that is, the residual turbidity exceeds that of untreated water due to incomplete coagulation of kaolinite particles. In contrast, significant turbidity removal was achieved by sweep coagulation using montmorillonite (a residual turbidity of 1 NTU at a montmorillonite dose of 750 mg/L) (Fig. 3). Notably, excellent sweep coagulation occurred even when both montmorillonite and TiO_2 particles carry significant negative charge (10.5 pH). This suggests that the physical entrapment of TiO_2 particles within the flocculating montmorillonite flocs may be the primary mechanism responsible for TiO_2 removal.

CONCLUSION

This preliminary study considered the treatment of low-turbidity water by sweep coagulation, which employed clay. The feasibility of using flocs formed by montmorillonite suspension coagulation with cationic polyelectrolyte as a surrogate to the amorphous $Al(OH)_3$, which precipitated in sweep coagulation has been demonstrated. Excellent turbidity removal was attained due to the physical entrapment of TiO_2 particles within the flocculating montmorillonite flocs. Furthermore, montmorillonite may function as a recyclable material for sweep coagulation and subsequent combustion of adsorbed cationic polyelectrolyte. In addition, coagulation is usually an integral part of water treatment, therefore, when coupled with the general water treatment process, it is advantageous.

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Received March 2001
Revised December 2001