ISSN 1009－3095 *Journal of Zhejiang University SCIENCE* V.3，No.3，P.268－271，July－Aug.，2002
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SC response characteristics of two kinds of coagulant*

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Received Apr.5，2001；revision accepted Aug.2，2001

Abstract: Automatic coagulant dosage control with streaming current (SC) technique is introduced in this paper. Aluminum and ferric coagulants are widely used in surface water treatment. The SC response characteristics of P-$AlCl_3$ aluminum coagulant and P-$FeCl_3$ ferric coagulant were investigated in this work. Bench-scale water treatment results were obtained from jar tests including rapid mixing, flocculation and undisturbed sedimentation. Results showed that aluminum coagulant is more sensitive than ferric coagulant to SC response.

Keywords: Streaming current(SC)，SC response，Coagulant，Water treatment，Automatic control
Document code: A **CLC number:** TU991

INTRODUCTION

Automatic control of water treatment plants has become increasingly important and advanced worldwide. Coagulant dosage control is the key step in the water treatment plant. Therefore a large number of researchers in China are engaged in studies on coagulant automatic dosage control. Among all the control methods，streaming current (SC) technique is being used more and more in water supply plants in China (Cui et al.，1991). Recent advances in monitoring instrumentation (Lin et al.，1996)，enabling on-line detection of the SC value of floc and of the surface electrical properties of colloids，creates great opportunities for better control of coagulation reactions (Wu，1993；Zhang，2000). The on-line monitoring instrument selected for the current study was the streaming current detector (SCD) which has been widely and successfully utilized in water treatment plants (Detel，et al.，1989；1993；Barron，et al.，1994).

In general，two types of inorganic coagulants，aluminum coagulant and ferric coagulant，are widely used as the coagulant for surface water treatment in China. However，coagulation with different coagulants usually results in different SC values. Consequently，the proper analysis and comparison of SC characteristics，which is the major objective of the current work，will play an important role in actual application.

PRINCIPLE

As originally developed，SC measurement utilizes a capillary passage or porous plug of the material of concern，through which the bulk fluid can be forced by applied pressure. Counter ions in the diffuse layer surrounding the material then migrate with the fluid，creating a measurable electrical potential or current called SC，which can be mathematically related to the electrical potential at the shear surface between stationary and mobile portions of the fluid (zeta potential). The relationship is expressed as

$$I = \varepsilon p r^2 \xi / 4 \mu l \qquad (1)$$

Where I is streaming current；p is applied pressure；r is passage radius；ξ is zeta potential；ε is dielectric constant of water；μ is viscosity of water；and l is length of passage.

* Project (No 96－909－03－04) supported by the Key Science and Technology Project of the Ninth-Five Years Plan of China

The type of SCD being considered for use in water treatment differs somewhat from the original apparatus, essentially consists of a sampling chamber, a sensor comprising a reciprocating piston in a cylinder, and a signal amplifier (Fig. 1). A continuous sample, taken from a point immediately downstream of coagulant addition, flows through the sampling chamber. Colloids in the chamber momentarily adhere to the piston and cylinder surfaces. Because one end of the cylinder is closed, the piston acts as a displacement pump, imparting motion to fluid in the gap between itself and the cylinder, otherwise known as the annulus. This causes counter irons motion relative to the attached colloids. Movement of charge is equivalent to an electrical current, and although this current is quite low in magnitude, it can be detected by ring-shaped electrodes at opposite ends of the annulus and then amplified. Because the current is sinusoidal as a result of the cyclical motion of the piston, it must be rectified and time-smoothed to give a useful output. The rectifier circuit must be phase-sensitive in order to sense the polarity of the resulting DC output.

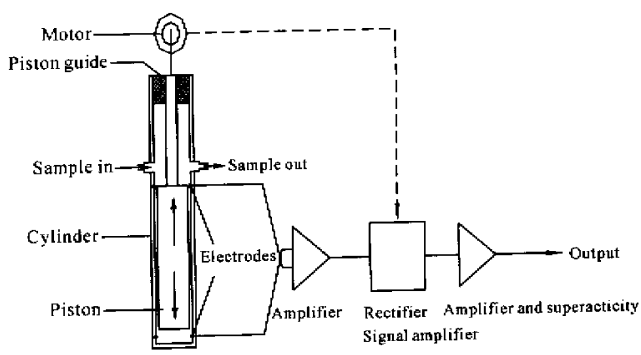

Fig. 1 Components of a streaming current detector

The resulting SC reading, or SC value, indicates the electrical charge on the colloids. If destabilization is associated with charge effects, the SCD also indicates the extent of destabilization in a manner similar to zeta potential. However, there are also some important differences between SC and zeta potential. For example, Eq. (1) is not directly applicable to the SCD, although the measured current is generally proportional to the average particle zeta potential in an analogous fashion. An approximate equation applicable to the SCD can be derived (Dentel et al., 1989; Bernazeau et al., 1992), which shows the linear proportionality between zeta potential and SCD output, and can be used for automatic coagulant dosage control of surface water treatment.

The final objective of adding coagulant was to obtain satisfactory water quality. In general, the sedimentation tank effluent's turbidity is used as the performance index of coagulation. Similarly, SC coagulation control aims at the same index.

EXPERIMENTAL DETAILS

According to the analyses above, the sedimentation effluent's residual turbidity was first measured; then the bound of coagulant dose corresponding to close residual turbidity was selected (Gergory, 1985). After that, through two times of repeated operation, the curve of residual turbidity after sedimentation was obtained.

On the condition of the same residual turbidity, the follow-up operation was to measure the SC values of the water with two kinds of coagulant corresponding to different dose. SC value is non-dimensional and its relative value can characterize the coagulation effect. For this reason, by eliminating the errors caused by apparatus and raw water, ΔSC value, the SC value of water after coagulating minus the SC value of raw water, was obtained to determine the influence extent of coagulants in treatment.

APPARATUS AND MATERIALS

Songhuajiang River water used as raw water samples had initial turbidity of 8.5 NTU, temperature of 10.0℃, and pH of 7.0. P-$AlCl_3$ (Anshan, 29.3% Al_2O_3) was used as aluminum coagulant, and liquid P-$FeCl_3$ (Harbin, 4.6% Fe_2O_3) was used as ferric coagulant. Coagulation effect was determined by jar test with stirrer induced mixing. After 1 minute fast stirring at 60 rev/min, 8 minutes, slow stirring at 10 rev/min, and 10 minutes undisturbed sedimentation, the residual turbidity of the upper clear water was measured. The SC value was measured for 5 minutes with an SC-3000 sensor installed in the tank (Harbin Modern Water Technology & Development Company, precision is 0.5%), and with the mean of several measurements taken as the needed SC value.

RESULTS AND DISCUSSION

Fig. 2 shows the relationship between residual turbidity and P-$AlCl_3$ concentration; Fig. 3 shows the relationship between residual turbidity and P-$FeCl_3$ concentration; Fig. 4 shows the effect of P-$AlCl_3$ concentration on the SC value; andFig. 5 shows the effect of P-$FeCl_3$ concentration on the SC value. Comparing Fig. 2, Fig. 3, Fig. 4 and Fig. 5, and removing coagulant dose, the obtained relationship between residual turbidity and SC value is as shown in Fig. 6.

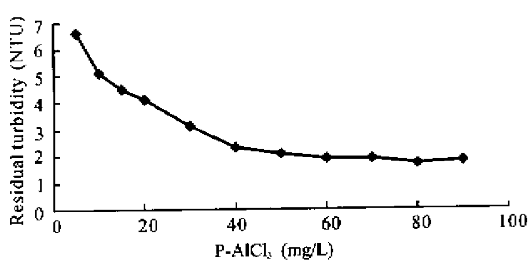

Fig. 2 Relationship between residual turbidity and P-$AlCl_3$ concentration

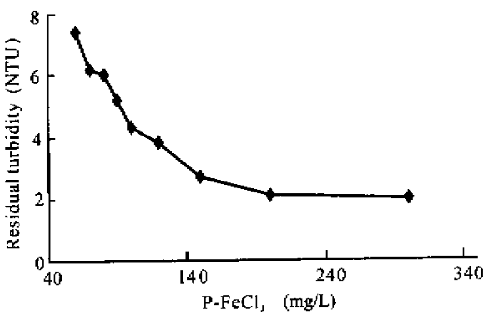

Fig. 3 Relationship between residual turbidity and P-$FeCl_3$ concentration

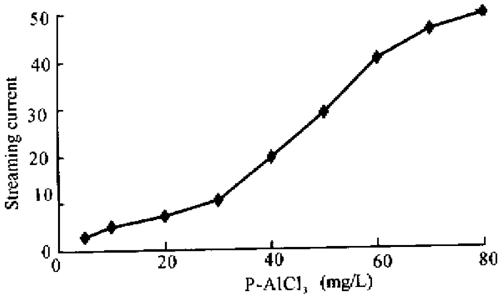

Fig. 4 Effect of P-$AlCl_3$ concentration on the SC value

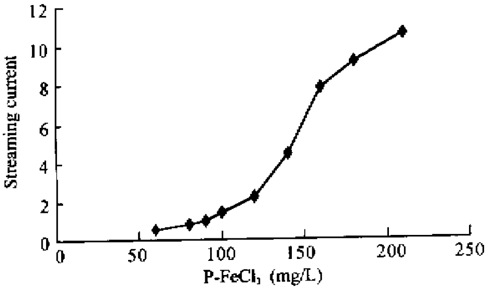

Fig. 5 Effect of P-$FeCl_3$ concentration on the SC value

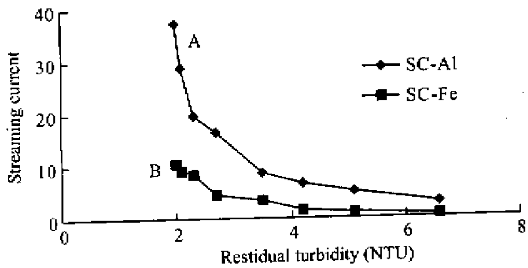

Fig. 6 Relationship between residual turbidity and SC value

Fig. 6 shows that curve A is steeper than curve B, or has the larger slope. If we let $y' = dSC/dt$, the slope of curve A may be y_A', the slope of curve B may be y_B', then

$$y_A' > y_B' \tag{2}$$

Eq. (2) shows that when residual turbidity changes by one unit, the SC variation, which is called SC response, of curve A is larger than that of curve B. Generally, the amount of the SC value variation caused by residual turbidity changes is defined as the sensitivity of such type of coagulant to the SC response; then Curve A shows the influence of aluminum coagulant, and curve B shows the influence of ferric coagulant. Therefore, aluminum coagulant is more sensitive than ferric coagulant.

Based on the same coagulantion result, the change of the colloid particles caused by aluminum coagulant is larger than that caused by ferric coagulant because the radius of hydrated aluminum ion is smaller than that of hydrated ferric ion which may be why aluminum coagulant is more sensitive from the viewpoint of the colloid chemistry.

CONCLUSIONS

The influence of different coagulants on SC can be determined through comparison experiments. Results showed that aluminum coagulant is more sensitive to SC response as compared with ferric coagulant. Therefore, in practical application, the process parameter of SC coagulaion control system can be derived from the SC characteristics obtained. For example, the multiple frequency of SC measurement should be larger for ferric salt used as coagulant than that for aluminum coagulant. Meanwhile, the control parameters should be adjusted to higher sensitivity.

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