WATER RESEARCH 45 (2011) 3075–3084

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Method for quantitative analysis of flocculation performance

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ARTICLE INFO

Article history:
Received 18 November 2010
Accepted 13 March 2011
Available online 21 March 2011

Keywords:
Tube flocculator
Sedimentation velocity
Residual turbidity

ABSTRACT

The sedimentation rate and the post-sedimentation residual turbidity of flocculated suspensions are properties central to the design and operation of unit processes following flocculation in a water treatment plant. A method for comparing flocculation performance based on these two properties is described. The flocculation residual turbidity analyzer (FReTA) records the turbidity of flocculent suspensions undergoing quiescent settling. The fixed distance across which flocs must travel to clear the measurement volume allows sedimentation velocity distributions of the flocculent suspension to be calculated from the raw turbidity data. By fitting the transformed turbidity data with a modified gamma distribution, the mean and variance of sedimentation velocity can be obtained along with the residual turbidity after a period of settling. This new analysis method can be used to quantitatively compare how differences in flocculator operating conditions affect the sedimentation velocity distribution of flocs as well as the post-sedimentation residual turbidity.

1. Introduction

The sedimentation velocity (V_s) of colloidal aggregates (flocs) formed in flocculation with hydrolyzing metal salts and their precipitates is an important parameter to consider in the design and operation of water treatment plants. V_s determines the design of sedimentation clarifiers and plate settlers. The V_s of a floc has been shown to increase with floc size (Tambo and Watanabe, 1979; Adachi and Tanaka, 1997). An ideal flocculator would produce flocs with high V_s and settled water with low residual turbidity after subsequent sedimentation processes. Floc V_s is typically measured in the laboratory using a settling column test (Metcalf and Eddy, 2003). In water treatment plants, coagulant doses are often determined by observing the residual turbidity of jar test samples to identify the dose that produces the most efficient floc sedimentation. Because of floc breakup and the formation of gelatinous precipitates, optical measurement techniques are preferred over particle counters to determine floc size distributions (Ching et al., 1994). Gregory (1985) developed an optical technique based on measurement of turbidity fluctuations in flowing suspensions to monitor floc suspensions, and demonstrated that the ratio of the root mean square of the fluctuating turbidity signal to the mean value is roughly proportional to the size of the aggregates flowing through the detector and to the square root of their concentration.

Two of the most informative parameters for plant designers and operators are floc sedimentation rates and residual turbidity after a period of settling. Thus, an apparatus capable of optically quantifying both V_s and residual turbidity as a method for comparing the performance of different flocculation conditions would be an extremely useful tool for researchers and plant operators alike. The following sections describe an experimental measurement apparatus and process for data analysis that is capable of providing the desired information. An analysis of flocs formed under different conditions is provided as an example application.

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doi:10.1016/j.watres.2011.03.021

2. Apparatus

2.1. FReTA

The flocculation residual turbidity analyzer (FReTA) is a measurement apparatus designed at Cornell University that measures both the sedimentation velocity and the residual turbidity of the effluent from a flocculator (see Figs. 1 and 2). FReTA is capable of measuring floc V_s without affecting the structure of flocs that have been formed. FReTA consists of three primary components: an inline turbidimeter, a transparent glass column, and an electrically actuated ball valve. The interaction of these components, as well as the acquisition and the analysis of data were automated using Process Controller software created using LabVIEW by Weber-Shirk (2008). A modified HF Scientific MicroTOL 2 infrared inline nephelometric turbidimeter was used in the apparatus. The plastic housing of the turbidimeter was altered to allow a 2.54 cm (1″) outer diameter, 2.06 cm (0.812″) inner diameter glass tube to fit vertically through the entire turbidimeter housing and through the measurement area. The glass column provided a quiescent chamber for flocs to settle as turbidity was measured over time. The glass column replaced the factory-standard measurement cuvette because the standard measurement cuvette had a restrictive inlet that disrupted flocs entering the chamber. A small diameter-settling column was used to accommodate the diameter of the turbidimeter sample cell. Calculations using methods described in McNown and Malaika (1950) were performed to ensure that errors produced by wall effects were not significant. Wall effect errors were estimated to be much less than 1% in all cases.

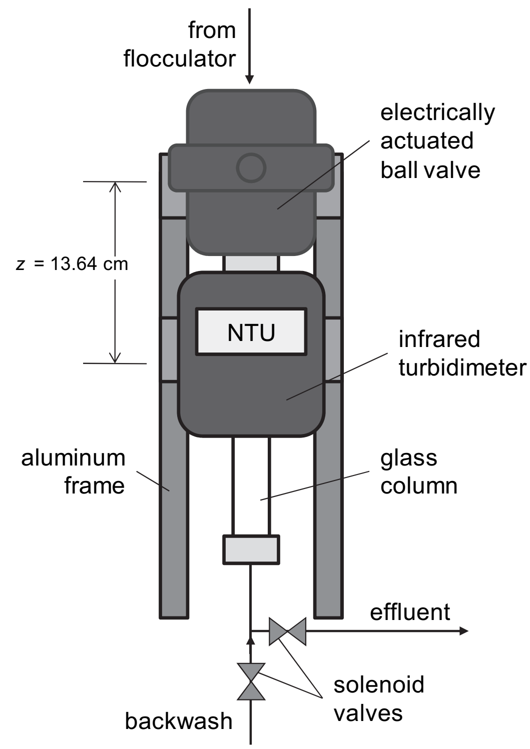

Fig. 2 – FReTA consists of an electrically actuated ball valve at the top and an IR nephelometric turbidimeter fitted with a glass tube and connected by fittings to an effluent line.

It was important that fluid motion inside the glass column be minimized once measurements had begun. A version of the MicroTOL 2 turbidimeter using a LED infrared light source

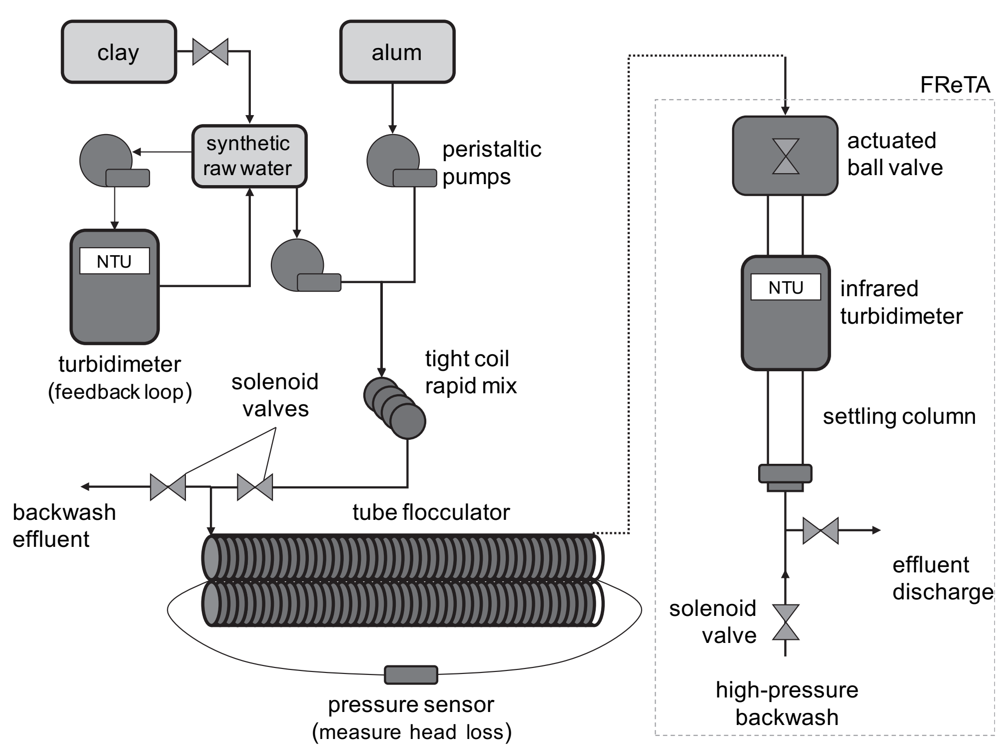

Fig. 1 – Schematic of the complete experimental assembly.