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ASSESSMENT OF CLARIFICATION EFFICIENCY OF FLOCCULATED SUSPENSIONS ON THE BASIS OF FLOC SIZE MEASUREMENTS

BERNARD POŁEDNIK

Politechnika Lubelska, Katedra Ogrzewnictwa, Wentylacji i Automatyzacji, ul. Nadbystrzycka 38a, 20-618 Lublin.

Keywords: sedimentation process, flocculation, clarification efficiency.

COMMUNICATION

OCENA SKUTECZNOŚCI KLAROWANIA FLOKULOWANYCH ZAWIESIN NA PODSTAWIE POMIARÓW WIELKOŚCI FLOKUŁ

Podano teoretyczną zależność pomiędzy czasem sedymentacji flokulowanych zawiesin a efektywną wielkością flokuł. Wykazano jej dobrą zgodność z doświadczalną relacją czasu opadania 80% masy zawiesin i średniej efektywnej wielkości flokuł, wskazującą na możliwość opracowania nowej metody oceny efektywności klarowania zawiesin.

Summary

The theoretical dependence between flocculated suspension settling time and mass floc size has been presented. The good agreement with the experimental relation between settling time of 80% of suspension and mass median floc size was showed, which indicates the possibility of developing a new method for clarification efficiency estimation.

INTRODUCTION

Clarification of flocculated suspensions, commonly known as purification, is essential to natural aquatic ecosystems, wastewater treatment and to present-day, environmentally orientated, mineral processing technologies [6]. Clarification is characterized by decrease of suspension concentration in upper layers. Experimental tests are usually carried out in the settling columns for batch sedimentation. Processes occurring there are the same as in so-called Ideal Thickeners without feed and discharge and reflect processes in natural settling ponds and industrial sedimentation tanks [3]. Clarification efficiency could be estimated on the basis of fall of the interface, or mud line, between suspension and supernatant. The currently used methods are mostly founded on such supernatant-suspension interface settling rate measurements. These techniques, however, cannot be applied when interface is not visible or is weak-distinguished, what takes place for suspensions of wide floc size range or low initial concentrations.

The aim of this paper is to present the experimentally verified relation between settling time of 80% of suspension and mass median floc size, which could be the basis for the new method for clarification efficiency estimation of flocculated suspensions.

THEORY

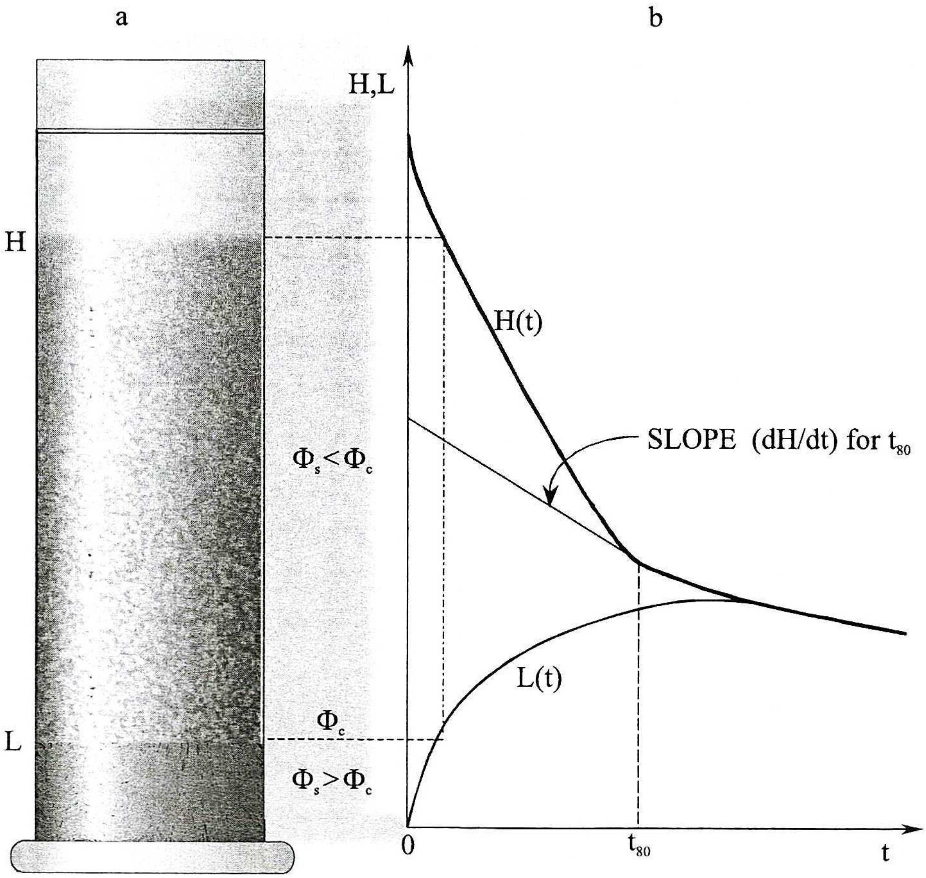

Figure 1. Interface in suspension batch sedimentation

Consider a sedimentation process of flocculated suspension in the settling column as shown in Figure 1a. The exemplary suspension-supernatant interface height H and the compression zone height L are plotted vs. settling time t in Figure 1b. It can be assumed that individual flocs retain their identity and perform hindered settling in the zone-settling regime, where volumetric concentration of solids is smaller than critical $\Phi s < \Phi c$ [3]. From that assumption one can say that the size, and hence density and permeability, of flocs determines the overall settling rate. So it also concerns the fall of suspension-supernatant interface and the growth of compression zone, where $\Phi s > \Phi c$. In order to specify the influence of floc size on clarification efficiency the batch sedimentation theory would be used [4, 5]. From that theory the following formula for the zone-settling rate can be deducted:

$$\frac{dH}{dt} = \frac{\Phi}{\Phi_s} \cdot \frac{1-(n+1)j\Phi_s}{1-j\Phi_s} \tag{1}$$

where Φ is the settling flux, Φs is the solid volume fraction, j is the parameter known as the Aggregate Volume Index and n is a function of test column diameter and floc Reynolds number.

The quotient $\Phi/\Phi s$ is being given by:

$$\frac{\Phi}{\Phi_s} = v_0 \cdot j^{2/3}(1-j\Phi_s)^n \tag{2}$$

where v_0 is the free settling velocity of a hypothetical solid particle, which has the same amount of solids as a floc, $1-j\Phi_s$ is a so called interfloc porosity [5].

Taking into consideration linear d_l and mass d_e floc size and their relation:

$$\frac{d_l}{d_e} = j^{1/3} = \left(\frac{\rho_s-\rho_c}{\rho_f-\rho_c}\right)^{-k} \tag{3}$$

Equation 2 can be rewritten as:

$$\frac{\Phi}{\Phi_s} = \frac{g}{18\mu}(\rho_s-\rho_c)d_e^2 \cdot \left(\frac{d_l}{d_e}\right)^2 \left[1-\left(\frac{d_l}{d_e}\right)^3 \Phi_s\right]^n \tag{4}$$

where ρ_s, ρ_c and ρ_f are solid, liquid and floc density respectively, μ is liquid viscosity, g is gravitational acceleration and k is function of floc Reynolds number.
From Equations 1 and 4, and assuming constant value of $j\Phi_s$, the following expression for the suspension-supernatant interface settling time can be obtained:

$$t = a \cdot d_e^{-b} \tag{5}$$

where a and b are constants denoting the aggregation state and the settling conditions of the system.

The above relation makes the suspension-supernatant interface settling time and hence clarification efficiency depend on mass floc size. The same relation concerns the settling time of 80 % of suspension, which is easier to determine, more precise and is technologically more important parameter.

EXPERIMENTAL

In order to empirically verify the relation between suspension-supernatant interface settling time and mass floc size, selected clay mineral suspensions were used [1]. The size of particles ranged within 0–60 μm and their average density was 2.411 g/cm^3. The initial concentration of particles in distilled water was 1.625 g/dm^3. To get flocs of various sizes, different doses of ionic and nonionic flocculants were used [2].

The sedimentation tests were carried out in the settling column of Sartorius sedimentation balance.

The experimental procedure consisted of [1]:

- formation of flocs of various sizes,
- determination of mass floc sizes,
- measurement of settling time of 80% of suspension.

RESULTS AND DISCUSSION

The relationship between the settling time of 80% of suspension and the mass median floc size is shown in Figure 2.

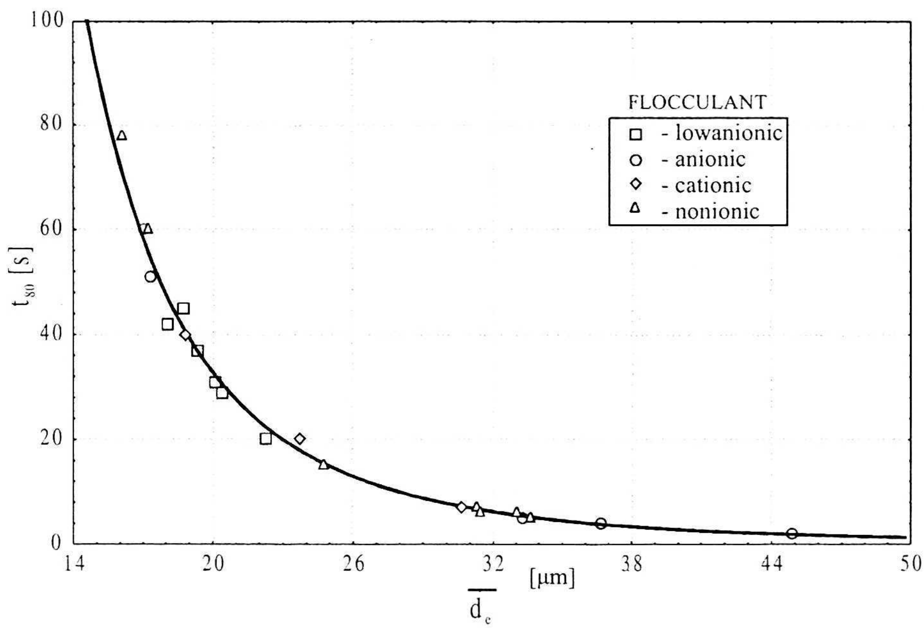

Figure 2. The relation between the settling time of 80% of suspension and the mass median floc size for clay mineral suspensions aggregated by different flocculants

The visible strong relation indicates that shorter suspension settling time is associated with large flocs. This dependence is not linear and is not influenced by the kind of used flocculants. The regression line can be described by the following Formula:

$$t_{80} = a \cdot \overline{d}_e^{\,-b} \tag{6}$$

where the estimated constants are $a \cong e^{14.09}$, $b \cong 3.54$.

The correlation coefficient equals 0.993, the standard error of estimation amounts to 2.65. The obtained Formula is in good agreement with theoretical Equation 5. Since, as noted previously, the settling time of 80% of suspension is correlated with the zone-settling rate, floc size measurements could be helpful in clarification efficiency estimation.

CONCLUSIONS

The presented empirical relation between settling time of 80 % of suspension and mass median floc size, which confirmed the theoretical zone-settling rate and mass floc size dependence could be the base to develop the new method for clarification efficiency estimation.

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