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Improved Method of Data Processing for Flocculating Sedimentation Experiment

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Abstract. The shortages of the present method of data processing of flocculating sedimentation are pointed out and analyzed in this study. A new method of data processing is put forward and the advantages of this new method are discussed. Compared to the conventional method, the isolines of partial removal efficiency need not to be drawn when the new method is employed and the new method is straightforward, practical and accurate and it is worth to be popularized.

Introduction

The removal of suspended and colloidal materials from wastewater by gravity separation is one of the most widely used unit operations in wastewater treatment. The settling characteristics of discrete, nonflocculating particles can be analyzed by means of the classic laws of sedimentation formed by Newton and Stockes [1-12]. Flocculent particles will not act as discrete particles but will aggregate during sedimentation. As aggregation or flocculation occurs, the mass of the particle increases, and it settles faster. The extent to which flocculation occurs is dependent on the opportunity for contact, which varies with overflow rate, depth of the basin, velocity gradients in the system, concentration of particles, and range of particle sizes. Since a mathematical analysis is not possible in the case of flocculent suspensions, a laboratory settling analysis is required to establish the necessary parameters[1-12]. How to calculate the suspended solid (SS) removal efficiency is the most important during data processing of flocculating sedimentation experiments. The data processing of flocculating sedimentation experiments has rarely been reported. The shortages of the present method of data processing of flocculating sedimentation are pointed out in this paper. And the new improved method of data processing is put forward and discussed in this study.

Brief introduction of flocculating sedimentation experiment

The settling characteristics of a suspension of flocculent particles can be obtained by using a settling column test. Such a column can be of any diameter but should be equal in height to the depth of the proposed tank. The solution containing the suspended matter should be introduced into the column in such a way that a uniform distribution of particle sizes occurs from top to bottom. Care should be taken to ensure that a uniform temperature is maintained throughout the test to eliminate convection currents. Settling should take place under quiescent conditions. The duration of the test should be equivalent to the settling time in the proposed tank [1-4].

The advantage of the traditional method is that it is possible to obtain removal data at various depths of settling. The laboratory settling study can be conducted in a column of the type shown in Fig.1 (a). Such a column can be made of plexiglass. A minimum diameter of 150 mm is recommended to minimize wall effects. Sampling tips are located at 300 mm depth intervals. At various time intervals (for example 10 minutes), samples (for example 10 mL) are drawn from the ports and analyzed for suspended solids (Weigh method, China Standard(GB11901-89)). The removal percentage is calculated for each sample and is plotted as a number against time and depth, as elevations are plotted on a survey grid. Curves of equal percent removal are drawn as shown on Fig.1 (b) [1-12].

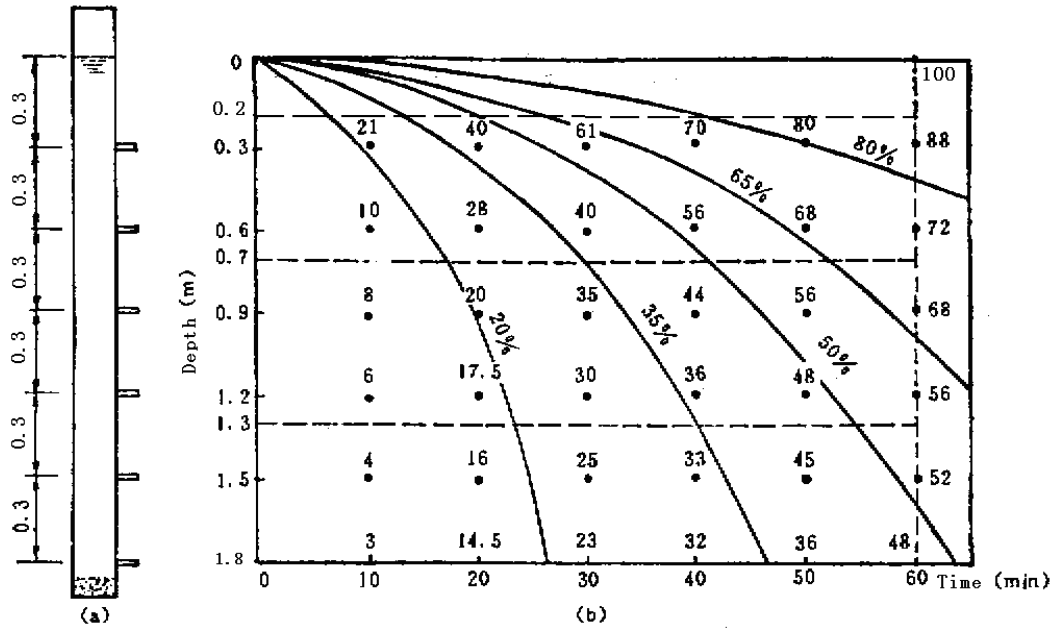

Fig 1 The equal removal efficiency curve of flocculating sedimentation

Present calculating method of removal efficiency of flocculating sedimentation experiment

According to the suspended solids concentrations of sampling ports at different depth and settling time, the partial removal efficiency E_i an be calculated according to Eq. 1:

$$Ei= [(C_0-C_i)/C_0] \times 100\% . \quad (1)$$

Where E_i is the partial suspended solids removal efficiency at time i; C_0 is the suspended solids concentrations of the untreated water, (mg/L);C_i is the suspended solids concentrations of sampling ports at settling time i, (mg/L).

The present calculating method of total removal efficiency of flocculating sedimentation experiment can be explained in the following example [1-12].

For example: if the experiment has been finished according to the requirements, the partial removal efficiency of suspended solids of sample connections at different depth and setting time is shown in the Fig.1 (b). The isoline of partial removal efficiency is drawn according to the interpolation method. The question is how to find out the total removal efficiency of suspended solids within 60 minutes.

The key is that: according to Fig.1(b), the partial removal efficiency of suspended solids at the bottom connection within 60 minutes is 48% which means that 48% of particles have a settling velocity that is equal or bigger than U_0 which can be calculated according Eq. 2:

$$U_0=H/t_0=1800/(60\times60)=0.5\text{mm/s}. \quad (2)$$

in which U_0 is the settling velocity of the particles (mm/s); H is the effective height or depth of the settling column (mm); t_0 is the settling time required for a given degree of removal to be achieved (s).

And all particles having a settling velocity equal to or greater than U_0 (0.5 mm/s) can be removed completely. Only a part of particles with velocity littler than U_0 (0.5 mm/s) can settle to the bottom according to the ratio of U_t/U_0. The particles with partial removal efficiency from 50% to 65% will have an average settling velocity that is equal to average height divided by time t_0. The average height is the midpoint height between isolines of removal efficiency 50% and 65%. According to Fig.1(b), the midpoint height is 1.3m and the average settling velocity is 1300/(60×60)=0.36 mm/s. In the same

way, the particles with partial removal efficiency from 65% to 80% have average settling velocity which is 700/3600=0.2 mm/s; the particles with partial removal efficiency from 80% to 100% have average settling velocity which is 200/(60×60)=0.056mm/s. The total removal efficiency will be increased by $(u_i/u_0)\times P_i$ as the settling particles are increased by P_i. Therefore, the total removal efficiency will be calculated Eq. 3:

$$E=E_0+(u_1/u_0)\times P_1+(u_2/u_0)\times P_2 + \ldots + (u_n/u_0)\times P_n. \quad (3)$$

in which $E_0$is the partial removal efficiency at the settling height of 1.8m and time of 60min; P_1,P_2 …P_n is the data difference between isolines of partial removal efficiency,(%).

As for $u_1/u_0=h_1/H$, $u_2/u_0=h_2/H$ …$u_n/u_0=h_n/H$ (h_1,h_2, …h_n is measured water surface downwards), the total removal efficiency can be calculated as follows:

$$E=E_0+(h_1/H)\times P_1+(h_2/H)\times P_2+ \ldots +(h_n/H)\times P_n$$
$$=48+(1.7/1.8)\times(50-48)+ (1.3/1.8)\times(65-50)+ (0.7/1.8)\times(80-65)+ (0.2/1.8)\times(100-80)$$
$$=68.77\text{（%）}$$

The shortages and improvement of present calculating method

The shortages of present calculating method. The key of conventional calculating method lies in that the isolines of removal efficiency of different section of the settling column are drawn, and then the vertical coordinates of points at expected time can be divided into several phrases based on the isolines. And the total removal efficiency can be calculated by superimposition computation. There are two shortages of this conventional method.

First, the isolines of partial removal efficiency are drawn according to the interpolation method. However the interpolation function is linear, while the settling velocity of flocculating sedimentation is increased with the depth and the removal efficiency is related to the settling depth. This is the reason whey the effective height of settling column for flocculating sedimentation experiment is same as that of actual settling tank. So it is very difficult to draw the isolines correctly according to the linear interpolation function and errors are usually happens.

Second, in the calculation step, h_i is the midpoint height of intersections of two isolines with vertical coordinates of points at expected time. So it is prone to cause error during drawing. If there is error, considering the error analyzed in the first shortage, more errors will occur.

The improvement of present calculating method. There are two shortages in the conventional calculating process as discussed above and it is necessary to improve the method. The solution is: since the total removal efficiency can be found by superimposition computation after the vertical coordinates of points at expected time is divided into several phrases according to the isolines, it can also be worked out by superimposition computation the partial removal efficiency of connections with different height of points at expected time.

As for detail, it can be explained by the example discussed in the above section. In the same way, the experimental data can be listed in table 1.

Table 1 Partial removal efficiency E_i(%)

Height of sampling connections	Setting time (min)					
	10	20	30	40	50	60
0.0	100	100	100	100	100	100
0.3	21	40	61	70	80	88
0.6	10	28	40	56	68	72
0.9	8	20	35	44	56	68
1.2	6	17.5	30	36	48	56
1.5	4	16	25	33	45	52
1.8	3	14.5	23	32	36	48

According to the improved method, the total removal efficiency is:

$$E=E_0+(h_1/H)\times P_1+(h_2/H)\times P_2+ \ldots+(h_n/H)\times P_n$$
$$=48+(1.65/1.8)\times(52-48)+ (1.35/1.8)\times(56-52)+ (1.05/1.8)\times(68-56)+ (0.75/1.8)\times(72-68)$$
$$+ (0.45/1.8)\times(88-72) + (0.15/1.8)\times(100-88)$$
$$=68.33\text{（%）}$$

Conclusions

Based on the discussion above, the total removal efficiency calculated by the improved method is a little less than conventional one. The reason is that the conventional method has two shortages. The isolines of partial removal efficiency need not to be drawn out when the improved method is employed and consequently errors will be avoided. Compared to the conventional method, the new method is straightforward, practical and accurate and it is worth to be popularized.

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