

Study of efficiency of mechanical and contact flocculation tanks

Zh M Govorova

Moscow State University of Civil Engineering, 26, Yaroslavskoe highway, Moscow, 129337, Russia

E-mail: GovorovaZhM@mgsu.ru

Abstract. The paper presents the data on the efficiency of using mechanical and contact flocculation tanks as a part of clarification and chromaticity removal technological scheme. The dynamics of variation in contaminants concentration depending on the dose of coagulant was studied. The curves of sedimentation of suspended matter in the settlement tank after the preliminary reagent treatment in the agitator and two different types of flocculation tanks. For low turbidity and low colored water reducing the chemical dosage requires more rapid and long-lasting water mixing in flocculation tanks. The studies have shown that the contact flocculation tank works effectively with a filtration rate up from 5 to 10 m/h, and a mechanical flocculation tank with a velocity gradient from 70.6 to 73.1 s⁻¹. The duration time of water in tanks should be at least 20-25 minutes. In addition, the parameters of contact flocculation tank flushing when the washing of the media is achieved.

1. Introduction

Coagulation combined with further sedimentation and filtration through granular media is one of the most common clarification and discoloration methods [1-4]. Agitators and flocculation tanks are one of the most important parts of water treatment plant. Agitators are used for quick and even distribution of reagents in the treated water, flocculation tanks are needed to create optimal conditions for the formation of suspended flakes as a result of hydrolysis of the coagulant. Flakes should be large, easy to settle and have a developed surface. The process of flocculation is determined by the probability of collision of colloidal particles which depends on its concentration, mobility and ordering of movement. The size of the flakes that form during slow mixing is affected by the intensity and duration of mixing, physical and chemical composition of water, adhesion forces and other factors [5-9, 13].

Recently, using mechanical or contact flocculation tank as a part of water treatment process has become one of the most promising directions of low turbidity chromatic water treatment. In the mechanical flocculation tank smooth mixing to complete the ortokinetic coagulation of contaminants is carried by paddle or propeller mixers [5, 10-11]. The operation of contact flocculation tank is based on the contact coagulation process that depends on the ability of small particles and microflakes of the coagulant after mutual neutralization of electrokinetic charges to adhere to the surface of larger particles of filter media [14].

This paper presents a study of the efficiency of mechanical and contact flocculation tanks.



2. Materials and methods

An experimental stand that simulates the operation of water treatment station was mounted in the building of water treatment plant. It contained of sodium hypochlorite dosing unit → coagulant and flocculant dosing unit → rapid mixing chamber → mechanical and contact flocculation tanks → settlement tanks with thin-layer modules → high-rate filter → disinfection unit → clean-water reservoir (Figure 1).



Figure 1. Experimental stand: a – rapid mixing chamber; b – mechanical and contact flocculation tanks and settlement tanks.

In the research process, aluminium oxychloride was used as a coagulant with a solution concentration of 2% and a dose was 3.5-6.4 mg/L depending on the quality of source water. Doses of the flocculant Praestol 650TR with a concentration of 0.05-0.1 % varied from 0.15 to 1.2 mg/L.

Coagulant was released into the source water pipeline before the agitator, and the flocculant – right after the agitator.

Table 1 presents flocculation tanks operation parameters and Figure 2 shows the overview of tank models.

Table 1. Flocculation tanks operation parameters

Parameter	Mechanical flocculation tank	Contact flocculation tank
Duration time, minutes	7.1-26.2	6.9-27.5
Rate, m/h	-	2.5-24
Velocity gradient, s ⁻¹	70.6-73.1	-
Rotation speed, rpm	50	-

In the mechanical flocculation tank mixing was carried out by the overhead stirrer with an electronic controller EUROSTAR digital Package. Velocity gradient ranged from 70.6 to 73.1 s⁻¹ Camp criteria was achieved and varied from 39.9x10³ to 112.7x10³ with this design of mixer blades, tank volume and constant rotation speed.

Contact flocculation tank was filled with foam granular polystyrene [14, 15]. Grain size was 2-4 mm. The thickness of the loading layer did not exceed 0,8 m. The direction of the warer movement was assumed to be downward with a wide range of filtration rates.

The water quality was estimated by indicators of the turbidity, chromaticity, permanganate oxidation and the others with using standard methods (state standards: GOST R 57164-2016, GOST 31868-2012, GOST R 55684-2013, GOST 18190-72) and the certified equipment.

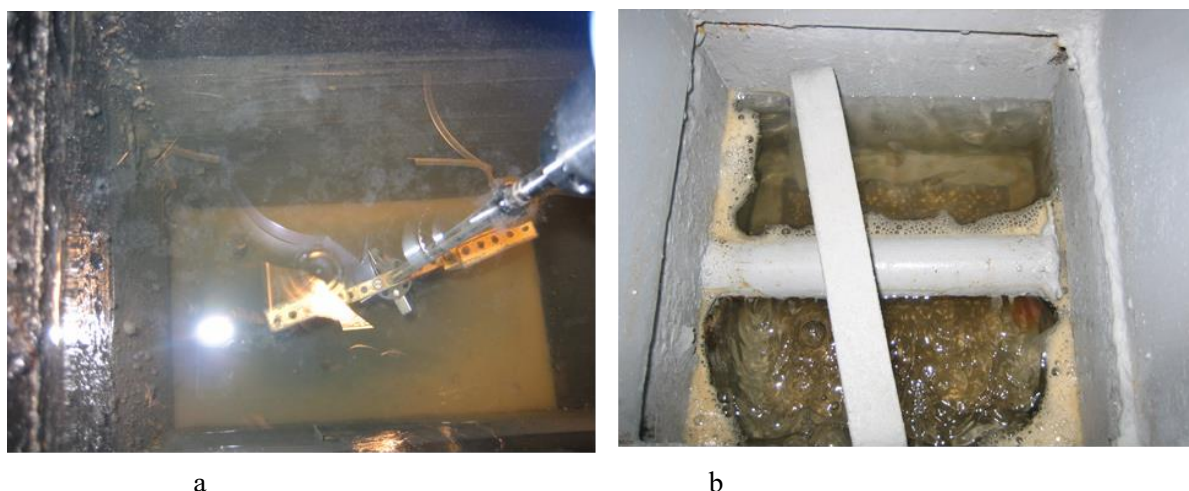


Figure 2. Flocculation tank model: a – mechanical; b – contact.

3. Results

Research was conducted in the fall season. Water temperature did not exceed 3-5.5 °C. Water chromaticity was 27-47 degrees, slight turbidity– from 3.5 to 50 mg/L, smell intensity did not exceed 2 points. permanganate oxidizability was 5.6-7.9 mgO₂/L, pH varied from 7.1 to 8.9, alkalinity – 0,56-1,68 mmol/dm³, total dissolved solids - 56-140 mg/L. River water contained bacterial contaminants. The total microbial number did not exceed 140 CFU/mL. The amount of coliform organisms and thermotolerant coliform organisms was up to 2600 CFU/100 mL, coliphages - 15 PFU/100 mL.

The operation of flocculation tanks was analyzed under various modes of reagent treatment and doses of coagulant of 4; 8; 12 mg/L.

Table 2 shows that with a duration time in mechanical and contact flocculation tanks of 18.8 and 27.5 minutes respectively. The conditions for the formation of flakes and its further sedimentation in a settlement tank were much better in the contact flocculation tank.

Table 2. Dynamics of contaminants concentration change after the flocculation tank depending on the dose of coagulant

Dose of coagulant, mg/L	Mechanical flocculation tank			Contact flocculation tank		
	Turbidity, mg/L	Chromaticity, degrees	Oxidizability, mgO ₂ /L	Turbidity, mg/L	Chromaticity, degrees	Oxidizability, mgO ₂ /L
0	48.1	27.4	7.62	48.1	27.4	7.62
4	44.7	16.4	6.93	31.2	14.8	7.05
8	38.6	14.3	7.29	27.6	10.5	6.53
12	37.2	6.0	7.15	25.6	19.2	6.32

The efficiency of the flocculation process was determined by the curves of sedimentation of suspended matter and the effect of sedimentation of suspended coagulated conglomerates along the length of the settlement tank model. The effect of suspended matter sedimentation in the treatment of water with a turbidity of 3.3 mg/L and a sedimentation time of 3 hours was 40% after the contact flocculation tank and 10% after the mechanical flocculation tank. Duration time was 20-25 minutes. It was revealed that an increase in turbidity from 3.3 to 10.1 mg/L at the same treatment modes has made it possible to achieve a better clarification effect (Figure 3).

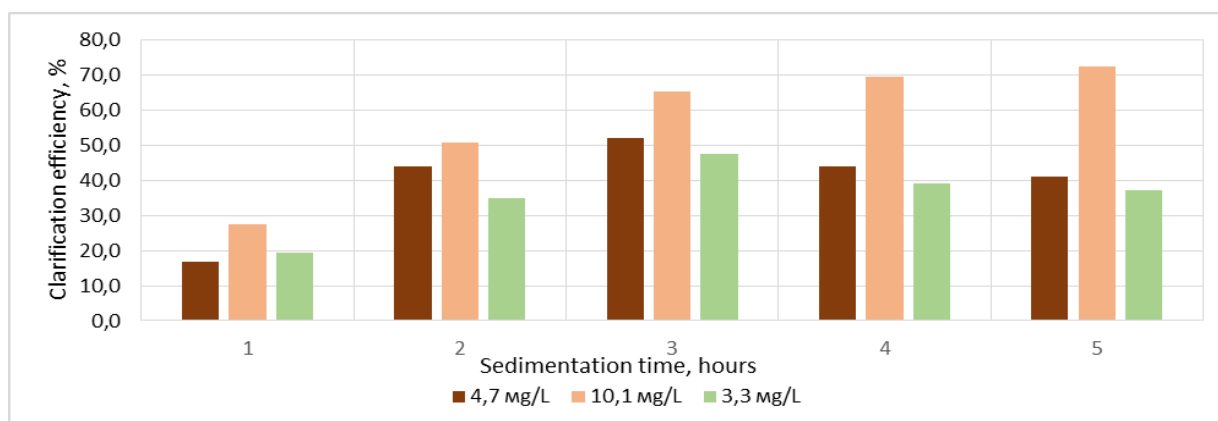


Figure 3. Clarification efficiency after the contact flocculation tank depending on the sedimentation time

In the contact flocculation tank the change in the filtration rate up to 24 m/h and expansion of the loading layer under the action of a downward flow up to 30% in the first 1.5 hours has led to a slowdown in the sedimentation of suspended flakes. However, in the next 2 hours the efficiency of sedimentation in two types of tanks became almost the same and reached 80%.

Occasional flushing is needed to avoid the contamination of the contact flocculation tank media. Flushing is carried out by the downward stream of source water. The studies have shown that sufficient washing of granular media is achieved with a flushing intensity of 25-30 L/s.m² and a duration time of 2-4 minutes (Table 3).

Table 3. Concentration of suspended solids (SS) and aluminum in flush water

Flushing time, s	SS, mg/L	Aluminum, mg/L
0	0	0
10	695	2.15
40	2266	0.96
60	3900	1.58
90	1519	1.3
120	191	0.8
180	60	0.4
240	30	0.15

4. Conclusion

The studies have shown that the use of both mechanical and contact flocculation tanks as a part of water treatment process contributes to the formation of larger flakes and faster sedimentation. It was established that with the higher turbidity of source water the higher clarification efficiency after the reagent treatment in the contact flocculation tank is achieved. The following parameters of the operation of the flocculation tank lead to a high efficiency of clarification: duration time - 20-25 minutes, velocity gradient - 70.6 to 73.1 s⁻¹, filtration rate- 3.5-5 m/h, flushing time of contact flocculation tank– 2-4 minutes, flushing intensity - 25-30 L/s.m²).

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