Modern coagulants and flocculants in the cleaning of washing waters of water treatment plants

G S Kachalova
Department of General and Special Chemistry, Industrial University of Tyumen, 2, Lunacharsky Str., Tyumen 652001, Russia

E-mail: galinakachalova@mail.ru

Abstract. This paper contains a comparative analysis and the principle of the action of modern coagulants and flocculants, used in the purification of natural and waste water, laboratory studies based on the processes of cleaning the washing water of the fast filters of water treatment plants in the cities of Tyumen and Kurgan with the selection of the most effective coagulants and flocculants. The following reagents were studied: coagulants - aluminum sulphate (AS), aluminum oxychloride (AO). Flocculants - polyacrylimide (PA), Praestol 650, Flopam FO4140SH and a mixture of the given chemicals. The results reveal that using coagulants with the subsequent introduction of flocculants for the summer period is the most effective (the optimal doses are Praestol 0,4 mg/l and Flopam 0,4 mg/l), using a mixture of coagulants AS (12 mg/l)+AO (6 mg/l) is most preferable in winter, while in spring it is recommended to use a mixture of coagulants AS (12 mg/l)+AO (6 mg/l) with the flocculant PA (1,5 mg/l) added. The introduction of filters into the technological scheme for the wash water clarification will make it possible to exclude the discharge of contaminated water into the water bodies; to reduce the amount of water for its own needs.

1. Introduction
Practical significance of the work: a selection of modern reagents was made, their doses were determined to reduce the turbidity of the wash water of the fast filters for their reversible use. Water treatment plants in Kurgan and Tyumen are the largest in the region of Middle and Southern Trans-Urals, therefore their impact on ecosystems of the Tura, Tobol, Irtysh rivers is quite significant due to dumping irrelevant chemical substances into the water bodies [1-5]. It is a common practice to use coagulants in natural and waste water treatment. Usually they are salts formed by a weak base and a strong acid. There are three characteristic stages of coagulation: getting to water of salt are exposed to hydrolysis on a cation; at the second stage of the coagulation the main role is given to adsorption on colloidal particles of aluminum hydroxides; coagulation in the third stage is caused by collision of molecules of aluminum hydroxides with each other, colloidal particles of water impurities and the resultant consolidation of floccules formed due to their connection with each other, followed by precipitation. Exactly such coagulants have been used in this research: $Al_2(SO_4)_3 \cdot 18H_2O$ and $Al_2(OH)_3CI$ [6-8].

Aluminum sulphate: when it is put into water hydrolysis by a cation takes place. Since $Al(OH)_3$ is amphoteric hydroxide it is possible to obtain stable sediment when $pH = 6,5-7,5$ proceeding from the hydrolysis constant. In order to obtain a more stable sediment, soda or lime alkalization is used. The
process of neutralizing hydrogen ions due to the consumption of bicarbonate alkalinity of water can be represented by the following equation:

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca(HCO}_3\text{)}_2 + 6\text{H}_2\text{O} = 2\text{Al(OH)}_3^- + 3\text{Ca(SO}_4\text{)}_3$$

As pH > 4, 0 – 4, 5 precipitates a flocculent deposit of alumina hydrate. It is quite noticeable in the solution and indicates the need for acidification of the electrolyte; it is affordable and economical [9].

Aluminum oxychloride $\text{Al(OH)}_2\times\text{Cl}_2\times\text{H}_2\text{O}$: another name aluminum hydroxychlorid. The advantages of using aluminum oxychloride are stability of the coagulation process, low temperatures of water included; there is no need to alkalize in order to reduce the concentration of H+; maintenance of residual aluminum content less than 0,2 mg / l; when put into water it does not reduce alkalinity and pH of the treated water [10-13].

Flocculants based on PA: flocculants are reagents promoting coagulation. Flocculants with their charge and very high molecular weight adsorb the destabilized particles and combine them along the polymer chain [14-16]. Consequently, larger flocculates are formed at the stage of flocculation. This causes sludge thickening. The following flocculants were used in the study: Flopam – the product of SNFFloergerr company; Praestol – the product of the joint Russian-German company ZAO Company Moscow-Stockhausen-Perm (MSP). Both flocculants are organic, high molecular compounds based on polyacrylimide. Flocculants can be classified into three different categories: nonionic, anionic, cationic [16-18]. Nonionic flocculant grades are technically pure polyacrylimide. It is produced by copolymerization of monoacrylamide and acrylic acid salts. Being an amphoteric polyelectrolyte, PA can dissociate depending on the pH medium, by acid and by basic type:

- in an acidic medium: $\text{OHNH}_3^+ - \text{R} - \text{COOMe} = \left[ \text{NH}_3^+ - \text{R} - \text{COOMe} \right]^- + \text{OH}^-$

- in an alkaline medium: $\text{HONH}_3^- - \text{R} - \text{COOMe} = \left[ \text{HONH}_3^- - \text{R} - \text{COO} \right]^- + \text{Me}^+$

where R - a hydrocarbon chain of a PA molecule.

At pH values corresponding to the isoelectric state PA molecules, generally remaining electrically neutral, contain positively charged and negatively charged ionogenic groups. As a result of the interaction of the charged groups, the PAA molecules in the neutral medium collapse into a ball, trapping colloidal impurities, and in the acids and alkaline medium are extended in a chain, also capturing colloidal impurities.

Anionic flocculant grades are copolymers of acrylamide with increasing proportions of acrylate imparting negative charges to polymers in an aqueous solution and thus anionic character. This causes dissociation according to the basic type. The dissociation of acrylate forms a particle with a negative charge.

Cationic flocculant grades are copolymers of acrylamide with increasing proportions of cationic comonomers. The cationic groups introduced in the aqueous solution have positive charges. A task of the research was to select the most effective chemicals for wash water treatment and to determine optimal doses to use in different periods of a year. The studied reagents: coagulants - aluminum sulphate (AS), aluminium oxychloride (AO); flocculants - polyacrylimide (PA), Praestol 650, Flopam (FO4140SH, produced by the firm SNFFrance).

2. Methods and materials

Instruments used in the laboratory research: a flocculator – model 8800, a spectrophotometer Lovibond PS spektro, a spectrophotometer PE-5400V.

In order to determine reagents optimal doses the examined wash water was poured into 5 measuring cylinders with a capacity of 500 ml. Then doses of reagents were defined for each cylinder. Based on the results of settling, turbidity was determined on the instruments [19,20].

3. Results

The graphs show changes of a physical indicator of water quality – turbidity over time.
It is obvious that the usage of coagulants in winter is not effective, suspended particles are rather few, all the processes are slow (figure 1).

Figure 1. The impact of AS dose on the efficiency of wash water purification in winter (January, the river Tura) 1 – without reagents, 2 – a 50 mg/l dose, 3 – a 100 mg/l dose, 4 – a 150 mg/l dose, 5 – a 200 mg/l dose.

The jumps occur due to the increased turbidity caused by the addition of the reagent, the formation of flakes of the hydrolysis product (figure 2).

Figure 2. Effect of the type and dose of reagents on the efficiency of wash water purification in winter (January, the river Tobol) 1- without reagents, 2 – PA, 3 – AO, 4 - FO4140SH.

In winter the largest deposition effect is achieved due to Flopam (0.5 mg/l), and the least effect is achieved without reagents (figure 3).

Figure 3. The impact of doses of mixed coagulant and FO4140SH on the efficiency of wash water purification in winter (March, the river Tura) AS (12 mg/l)+AO (6 mg/l)+ FO4140SH: 1 – without reagents, 2 – without a floculant, 3 – a 0.25 mg/l dose of FO4140SH, 4 - a 0.5 mg/l dose of FO4140SH, 5 - a 0.75 mg/l dose of FO4140SH.
In spring it is efficient to use a mixture of reagents – AS (12) + AO (6) + PA (1.5) (figure 4).

![Figure 4](image)

Figure 4. Effect of the type and dose of reagents on the efficiency of wash water purification in spring (May, the river Tura) 1 – without reagents, 2 – AS (12 mg/l)+AO (6 mg/l), 3 – AS (12 mg/l)+AO (6 mg/l)+PA (0.5 mg/l), 4 - AS (12 mg/l)+AO (6 mg/l)+PA (1 mg/l), 5 - AS (12 mg/l)+AO (6 mg/l)+PA (1.5 mg/l).

In summer a dose 0.4 mg/l of Praestol is preferable (figure 5).

![Figure 5](image)

Figure 5. Effect of the type and dose of reagents on the efficiency of wash water purification in summer (July, the river Tobol) 1 – without reagents, 2 – Praestol 650 (0.2 mg/l), 3 - Praestol 650 (0.4 mg/l), 4 - Praestol 650 (0.6 mg/l), 5 - Praestol 650 (0.8 mg/l).

4. Conclusion
The research analysis shows that:
- in summer the best results are achieved through the use of coagulants followed by flocculants: the most effective are the following doses – Praestol (0.4 mg/l) and Flopam (0.4 mg/l);
- in winter the greatest decrease in turbidity was noticed when the water was treated with the mixture of coagulants AS (12 mg/l) and AO (6 mg/l) only;
- in spring the most efficient is the mixture of coagulants AS (12 mg/l) + AO (6 mg/l) and a flocculant PA (1.5 mg/l) added;
- purification of the filters washing waters will allow to exclude the discharge of water containing pollution into reservoirs, to reduce the water volumes used for the stations own needs.

References
[1] Ivakin D N 2008 Peculiarities of using aluminum oxychloride manufactured by JSO “Sibresurs” Water treatment, Water supply 9 26
[2] Pazenko T Y 2010 Treatment of washing water from water treatment filters News of Higher Educational Institutions 9 65
[3] Pazenko T Y 2017 Treatment of filter washings Dynamics of mutual relations of various fields of science in modern conditions Collection of articles of the international scientific-practical conference in 3 parts pp 51–55
[4] Butko D A 2009 Waste water of fast filters and their reuse: monograph (Rostov State University of Civil Engineering Rostov-on-Don) p 393
[5] Voitov E L 2018 Purification and reuse of wash water from wastewater treatment plants Proceedings of Sibstroyin 20 84
[6] Draginski V L 2008 The peculiarities of using coagulants in natural coloured water purification Water supply and sanitary engineering 19
[7] Orlova T N 2013 Chemistry of natural and industrial waters: textbook (Yaroslavl: YarSU) p 120
[8] Gubonina Z I 2010 Industrial ecology. Problems of drinking water: textbook (Moscow: MGOU) p 127
[9] Zapolsky A K 2010 Physicochemical theory of coagulation purification water (Kiev: NUPT) p 46
[10] Ryabchikov B E 2013 Modern water treatment (Moscow: DeLi plus) p 680
[11] Frog B N 2014 Water treatment: University textbook (Moscow: Building Universities Association) p 512
[12] Hetmantsev S V, Nechaev I A, Gandurina L V 2008 Cleaning of industrial wastewater with coagulants and flocculants (Moscow: Association of Construction Universities) p 272
[13] Aksenov V I, Ladygichev M G, Nichkova I I 2008 Water management of industrial enterprises. Flocculants: Reference edition (Teplotehnik) Vol 1 chapter 6 p 256
[14] Ulrich E 2012 Modified Flocculants (Lambert Academic Publishing) p 132
[15] Kachalova G S 2018 International Journal of Applied and Fundamental Research (Moscow: Scientific and Publishing Center of the Academy of Natural History) 2 23
[16] Kachalova G S, Antipina A A 2017 The use of modern flocculants to intensity the process of coagulation of waste water at the Akkumulyatorn Plant Materials of the International Scientific and practical Conference of Young Researchers name Mendeleev Collection of articles (Tyumen: TIU) 1 377
[17] Halturin T A 2014 Wastewater treatment of industrial enterprises: textbook (Krasnoyarsk: Sib.fed.Univ) p 164
[18] Kopylov A S 2009 Processes and apparatuses of advanced water treatment technologies and their programmed calculation: textbook for universities (Moscow: Publishing house MPEI) p 222
[19] Panov V P 2008 Theoretical basis for environmental protection: textbook for university students (Moscow: Academy) p 320
[20] Kachalova G S 2018 Ecological aspects of waste water treatment “Tyumenske Akkumulyatorn Plant” Collection of report of the XX International Conference (Tyumen: TIU) 1 pp 288–294