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Defining the most Convenient Coagulant for Microbiological Pollution and Turbidity Removal in Ardabil's Water Treatment Plant

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Any kind of life requires water, to provide a suitable for drinking and urban public usages, series of operations are applied in the water treatment plant, to deliver the received water from sources as water with acceptable quality standards of "drinking water". There are various methods for water and wastewater treatments and they are used depending on the water consumption and the kind of contaminant it has. One of the most important methods for turbidity and organic matter removal from raw water sources, is to coagulate the waste material of the water with coagulants. This study was done to evaluate the performance of coagulants poly aluminum chloride (PACL) and ferric chloride ferric chloride (FeCL3) in reducing turbidity and organic matter from the raw water source of Ardebil's treatment plant. This experimental-analysis study was done using a Jar test machine. Studied samples were taken from a raw water transmission pipeline, from Yamchi dam to Ardebil's treatment plant, in four seasons of year 2014. In order to conduct a qualitative and quantitative research process, more than 48 samples were tested in spring, summer, autumn and winter, respectively with turbidities of 17-21-13-7 NTU, by coagulants poly aluminum chloride (PACL) and ferric chloride ($FeCL_3$) results showed that coagulant poly aluminum chloride had a better performance than ferric chloride in using less coagulant materials, making bigger flocks, reducing the sludge settling time and creating sludge with high adhesion. Assigned to the removal of dissolved organic matter of the water (DOC), coagulant poly aluminum chloride was able to remove the highest amount of DOC from samples, at a rate of 7 percent. The results showed that, in Ardebil's water treatment plant, PACL can be a suitable alternative for low consumption of coagulants and removing organic matter of raw water, more than coagulant ferric chloride.

Key words: Drinking water treatment; Coagulation; Poly aluminum chloride; ferric chloride; Dissolved organic carbon (DOC); Iran.

Nowadays, the topic of optimum water treatment is one of the largest and most serious environmental and health issues worldwide. Removal of suspended and colloidal particles is one of the most important steps in the process of coagulation, flocculation and settling (Torkyan, 2000). During the coagulation process, coagulants and coagulant aids are different. Coagulants are substances used to make particles unstable and attach them to each other. While the purpose of adding a coagulant aid is to increase the density of attached particles and help them to settle faster (Alipour and Bazrafshan, 2002).

The most important factors affecting the efficiency of coagulation process are PH, ions in aqueous solutions (strength of water's ion), humic substances concentration, water temperature and

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the type of coagulant (UNESCO, WHO and UNEP , 2000). Restrictions on the use of alum salt are remaining aluminum and suspicious relation between Alzheimer disease and it. Also using ferric chloride in removing turbidity is associated with creating colors in water and this causes a yellow reddish brown color on materials and if the its amount is more than 1 mg/l in water, it will cause turbidity and a medical taste in water (Sadeddin *et al*, 2011). Normally, metal salts such as aluminum sulfate (alum), ferric sulfate, ferrous sulfate, ferric chloride, and poly aluminum chloride as coagulants and compounds such as sodium aluminate, bentonite, sodium silicate (active silica) and various cationic, anionic and non-ionic polyelectrolyte as coagulant aids are used in water treatment to remove turbidity (Alipour, 2002). Some studies in Iran and the world in the field of coagulants are as follow:

Pirsaheb *et al*. (2012) had studied the evaluation of coagulation process performance for removing small amount of water turbidity and its color, using different coagulants. The results showed that using poly aluminum chloride, ferrous sulfate, ferric chloride and Aluminum Sulphate coagulants in 50, 20 and 10 NTU turbidities reduces PH, so that for adding each mg of poly aluminum chloride, ferrous sulfate and ferric chloride coagulants, PH reduces about 0.01 unit. Yet for every milligram per liter of ferric chloride, reducing PH units was about 0.02. The research results of Shahmansoori *et al*. (2011) showed that ferric chloride and PAC have better results in turbidity, total coliform and TOC removals than alum and ferric chloride is more effective than PAC in TOC removal. Considering problems related to the use of ferric chloride, using PAC as a coagulant to remove turbidity, total coliform and TOC, is a better option in comparison with ferric chloride in the process of coagulation (Shahmansouri and Neshat, 2011).

Mostafapour *et al*. (2008) had studied the use of aluminum sulfate, ferric chloride and poly aluminum chloride in turbidity removal from drinking water. The results showed that by increasing the dose of Coagulant consumption, the removal will increase too. Removal is affected by initial turbidity so if the initial turbidity gets more, removal will increase too.

Abdullahzadeh *et al*. (2009) examined the performance of coagulants in advanced coagulation conditions of turbidity and organic matter removal of a river in Karaj.The results showed that in comparison with ferric chloride in annual average turbidity about 6NTU, PAC had better results in turbidity, TTHM, UV254, TOC, DOC removal and less drop in PH and alkalinity, than ferric chloride. Quality wise, using PAC is more efficient than ferric chloride in forming larger particles, more flock sedimentation rate, and percentage of settled sludge volume and turbidity removal than ferric chloride.

Researches of Amin *et al*. (2012) in studying the remaining amount of aluminumby using coagulant PACL showed that the average of remaining aluminum in advanced coagulation is more than common coagulation, but the amount of aluminum in these two stages is less than The maximum recommended daily allowance by EPA.

The results of a study by Banihashem *et al*. (2007) showed that flocks' sedimentation rate with the use of PACL is more than the two other coagulants, alum and ferric chloride. It is also found that PACL is able to reach the sample's turbidity to the desired amount 1 NTU, after 10 minutes, and this shows a high speed settling of flocks with coagulant PACL. Unlike the two coagulants alum and ferric chloride, poly aluminum chloride is not sensitive to water temperature changes and remaining turbidity fluctuations are not seen. This shows PACl's suitable performance in comparison with two other coagulants in variable water temperatures in summer and winter. Sinha *et al* (2004) concluded that compared with other coagulants such as aluminum sulfate, in medium or high turbidity conditions ferric chloride performs better. Examples of these cases are, the lower amount needed due to the more ionic charge, formation of larger clots, reducing flocks' settling time, producing less sludge, no need for regulators, better performance at lower temperatures and PH increasing.

One of the problems of drinking water treatment plant, which the raw water comes from rivers, is high turbidity and organic matter. Ardebil's drinking water which is placed in North West of this city is supplied from Balkhou River and as this river is exposed to various contaminants, high organic matter is one of the main problems of this treatment plant. Therefore, the point of this research is to evaluate the use of two coagulants, poly aluminum chloride and ferric chloride, in turbidity removing and reducing organic matter from the raw water entering Ardebil's treatment system plant.

MATERIALS AND METHODS

This study is an experimental and analytical one. In a jar test, coagulants poly aluminum chloride and ferric chlorideare used in order to compare their performance in the removal of organic matter and turbidity of raw water of Ardebil's treatment plant. Jar tests were done by using raw water of Ardebil's treatment plant in jar containers with capacity of one liter of water and with samples from a depth of 2 cm from the surface of the water. The jar test device is planned with 60 seconds of rapid mixing with 140 rpm, 20 minutes of slow mixing with 40 rpm and 30 minutes of settling time (Abdollahzade *et al.* 2010). After completion of settling time, jar samples are immediately analyzed. The tests were done in the Chemistry and Environment laboratory of Islamic Azad University of Ardebil during four seasons of a year and it was tried to be the same as the actual turbidity of entering water to the treatment plant. Sampling was started in spring of 2014 and it continued for one year from raw water transmission pipeline to the treatment plant in accordance with the contents of Table 1 and according to the standard methods of water analysis edition 21 year 2005 (AWWA, WPCF, 2005, APHA.). Comparing the efficiency of dissolved organic carbon (DOC) removal at different PH only or in different turbidities were analyzed. In order to perform the qualitative and quantitative steps of research, 48 samples in four seasons with turbidity close to natural raw water, 7, 13, 21 and 17 NTU, respectively in spring, summer, autumn and winter, for two

Table 1. The average of(4 seasons) entering raw water quality parameters to Ardebil's water treatment plant

The amount (in terms of annual average)	Parameter
4.21	DOC (mg/L)
14.5	Turbidity
11	Temperature (°C)
8.3	PH

Table 2. The results of defining the optimal dose of coagulant in Ardebil's raw water treatment plant in different seasons of the year 2014

	Ferric Chloride (FeCl3)				Poly Aluminum Chloride (PACL)					Seasons
Turbidity Removal Percentage (NTU)	Remaining Turbidity After Jar Test	DOC Removal Percentage	Optimal Dose of Matter mg/L	Turbidity Removal Percentage	Remaining Turbidity After Jar Test	DOC Removal Percentage	Optimal Dose Matter mg/L	Raw Water Turbidity (NTU)	Drinking water Turbidity Standards 1053 WHo EPA	
55	3.15	35	14	97.14	0.2	40	8	7	6.5-8	Spring
75.53	3.18	22.5	13	98.46	0.2	35	6	13	6.5-8	Summer
85	3.15	72.41	13	97.61	0.5	82.75%	9	17	6.5-8	Autumn
81.23	3.19	32.43	13	97.64	0.4	45.94	8	21	6.5-8	Winter

coagulants, ferric chloride and poly aluminum chloride ,were tested.

Sampling (dishes, sample size, maintenance and retention time) was conducted according to Table 1:1060 of standard methods of American Environmental Protection Agency's (EPA) (USPEA, 2005).

Techniques used for measuring understudied parameters during the study, were as below:

a) Turbidity was measured by Nephelometric Method using P 2100 machine, production of American HATCH Company.

b) DOC was measured according to the standard and using a spectrophotometer machine DR/5000 after filtering the sample with membrane filter paper type 47.0 mm and

Table 3. Results of the remaining aluminum

Aluminum in raw water	Remaining Aluminum	Coagulant
0.5	0.025	$FeCl_3$
	0.022	PAC

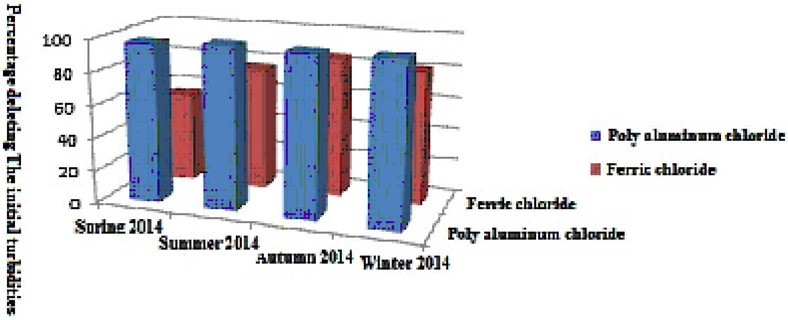

Fig. 1. The initial turbidity removal percent (NTU) of raw water by coagulants

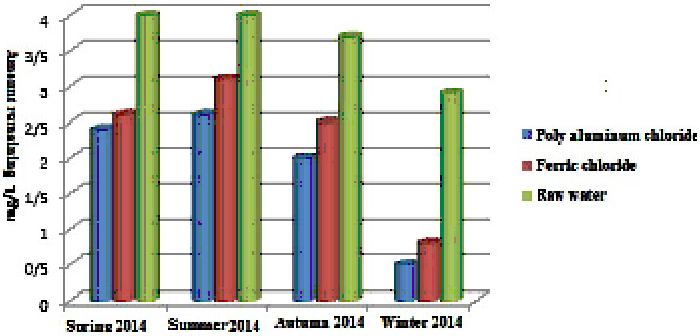

Fig. 2. Remaining amount of dissolved organic carbon (DOC) in samples

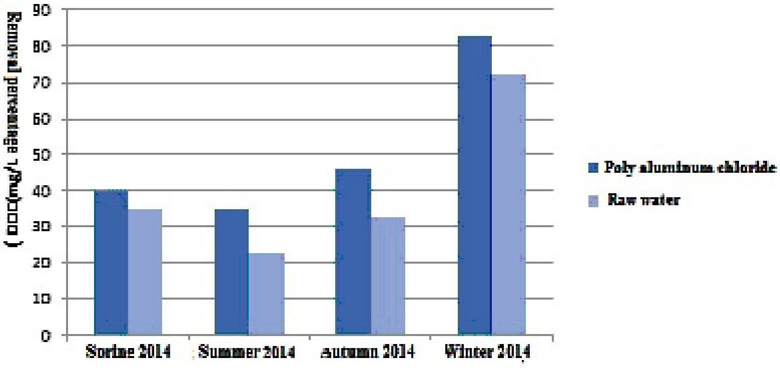

Fig. 3. Removal percent of dissolved organic carbon (DOC) in samples

45.0 microns in diameter, without sterile cellulose acetate.

c) PH of the samples was measured by a model 830 PH meter, produced by Metromcompany in Switzerland. This device was calibrated daily, using the standard buffer solutions. Alkalinity was measured using a standard titration method (2005).

Quantitative parameters including remaining turbidity, PH, DOC and alkalinity and quality parameters including particles size, particles sedimentation velocity and sludge volume index, were compared before and after the jar test. In this study 37% ferric chloride and liquid poly aluminum chloride at concentration of 13%, active ions Al, O*f* as coagulant and one hundred percent pure potassium hydrogen phthalate from Merk company in Germany as a standard of organic matter, were used. All of jar tests were done at room temperature, ie 20°C

Chromic acid sulfosuccinates was used as an organic matter removal of the surface of contaminated containers and shaft and level jar's mixer's levers. All concentrations of coagulants on the active ions were used according to the US Environmental Protection Agency(APHA, AWWA, WPCF, 2005).To determine the optimal dose of coagulants, different turbidities of raw water as 17-21-13-7 NTU were used in jar test for a year, respectively in four seasons of spring, summer, autumn and winter. The optimal dose for all of these turbidities is defined in Table 2 and the optimal dose has been determined based on the transparency of the supernatant, velocity of clot formation and also being economically efficient. Figures and graphs 1 to 6 are presented according to the results.

According to the results shown in graphs 2 and 3, the difference between the percentage of DOC removal using poly aluminum chloride coagulant were 5% in spring, 12.5% in summer, 13.25% in autumn and 10.34% in winter and it indicates good performance of coagulant poly aluminum chloride compared with coagulant ferric chloride with higher removal percentage of 10.34%.

The results in Table 3 show that the amount of remaining aluminum from using poly aluminum chloride in water in the settling step of jar test, on average of four seasons is less than the remaining amount of it using coagulant ferric chlorideand also in raw water.

DISCUSSION

Results presented in Table 2 show that with the average annual turbidity of Yamchi dam, 14.5 NTU, the average of DOC in raw water entering to the treatment plant during seasons of a year is 4.21 (mg/l), with using ferric chloride coagulant and conducting tests to get COD, the average remaining COD in raw water is 2.63 (mg/l) so that the average removal of organic matter is 47.45%. Byusing coagulant poly aluminum chloride and conducting tests for DOC, the average remaining of DOC in raw water in a year is 1.87 so that the COD average removal percentage is going to be 50.92%. This interpretation from Figures 1,2 and 3 showed that the amount of turbidity removal and DOC parameters using coagulant poly aluminum chloride are higher than coagulant ferric chloride.Changes in optimal dose of coagulants with raw water turbidity and remaining turbidity values after using coagulants poly aluminum chloride and ferric chloride is presented in Figure 1.Changes in DOC parameter values using coagulants ferric chloride and poly aluminum chloride less than ferric chloride, in four season samples are presented in Figure 5.

Interpretation concluded from comparison of coagulants operations in DOC removal of samples is presented in Figures 2 and 3, it indicates that DOC removal using coagulant poly aluminum chloride is more than coagulant ferric chloride.

CONCLUSION

The results of this research, which was done to investigate possibility of higher organic pollution removal of raw water treatment plant in Ardebil, using two coagulants poly aluminum chloride and ferric chloride in a jar test and in four seasons of a year, showed that: aluminum chloride as a coagulant in organic matter (dissolved organic carbon) and turbidity removal is better than ferric chloride in raw water supply of Yamchi's dam.

As it was seen, time needed for creating the first flock of PACL is less than ferric chloride and in some tests it had reached to one minute, but for ferric chloride it took a couple of minutes. Sinha *et al* (2004) reported that compared with other coagulants such as aluminum sulfate and ferric chloride, poly aluminum chloride has a better performance in medium and high turbidity conditions. On the other hand, since ferric chloride is made of cheap and inferior raw materials(scrap) , so there is a possibility of entering heavy metals such as lead, mercury, chromium, cobalt, cadmium, arsenic, etc. into the treated water, whereas PACl is made of high quality raw materials. Also poly aluminum chloride is not corrosive and the system using this coagulant is not going to be under the risk of corrosion.

On the other hand, coagulant poly aluminum chloride conducted the removal of organic matter about 3.5% more than ferric chloride; also poly aluminum chloride needs a lower dose and has less concentration compared with ferric chloride and it is affordable. Shahemmannsoori *et al*. (2011) stated that cferric chloride and poly aluminum chloride do better in turbidity, total coliforms and TOC removal in comparison with alum and ferric chloride is better than PACL in TOC removal. Considering the problems associated with ferric chloride, using PACL as coagulant in turbidity, total coliforms and TOC removal in coagulation process is a better option than using alum and ferric chloride. So it can be concluded from this research that using poly aluminum chloride instead of ferric chloride in coagulation process of Ardebil's drinking water treatment plant, is a priority.

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