RESEARCH ARTICLE

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The study of coagulation process in medium turbidity removal from drinking water

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Background & Aims of the Study: Colloidal impurities are one of the natural contaminants in surface water that cause turbidity and color. Turbidity in spite of create undesirable appearance, can be a haven for disinfection of microorganisms. This study aimed to evaluate the effectiveness of various coagulants in removing average turbidity of water and also their impact on the electrical conductivity and alkalinity.

Materials & Methods: The study was conducted as tentative - interfere research in a laboratory scale. Experiments were carried out based on various parameters including different turbidity (50,100 and 200 NTU) and different concentrations of coagulants (5, 10, 15, 20, 25 and 30 mg/L). Supernatant of samples were taken after Jar test to measuring of turbidity, conductivity and alkalinity. The settling characteristics of the floc were record by observing as descriptive terms such as poor, fair, good and excellent.

Results: Results showed that all coagulants materials in whole used levels be able to completely remove of the initial turbidity (with the exception of Ferrous sulfate coagulant). On the other hand, with increasing concentrations of coagulants, the electrical conductivity increased and alkalinity decreased. Also, the highest and the lowest increase of electrical conductivity and TDS obtained in ferric chloride and poly aluminum chloride coagulants respectively.

Conclusions: The result showed that poly aluminum chloride was best coagulant for turbidity removal and in spite of fine floc, sedimentation rate is good.

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Background

Population growth, improve of living standards, development of urbanization, industry and agriculture are factors that caused the increasing of water consumption and sewage production in the community that caused environmental pollution. Colloidal impurities are natural contaminants in surface waters, especially rivers and lakes (1). Their presence causes turbidity and somedeal color. To colloids removal, the colloidal particles

must be gathered and be large in size. For this aim can be used of chemicals materials. These materials are neutralized the forces which cause stable of colloidal particles. Then, particles be unstable while being gently stirred to create the flocs. This process is to say flocculation. Ultimately, the water pass from the settling basin where the solids flocculated and will be removed by sedimentation (2). The main affecting factors in coagulation process efficiency are pH, ions of solution (ionic strength of water), humic substances concentration, water temperature and the type of coagulant (3). Generally, turbidity or color of the water are due to the presence of suspended matter such as algae, clay, silt, viruses, bacteria, minerals like asbestos, silica, particulate organic matter and dissolved solids. Turbidity in spite of create undesirable appearance, can be a haven for disinfection of microorganisms, while exceeded turbidity can indicate the failure in the treatment system (4-8). The particle settling ability is depends on the density and size of them. So, particles with higher density than water are deposited under influence of gravity force. Smaller particles such as bacteria and colloidal particles that their density are close to the water, May never would been deposited and remain as suspended in the water. Thus the aggregation of particles and increasing their size is a main step in them sedimentation (4). Water that has been contaminated naturally or man-made, must be operated various treatment processes for convert to drinking water. Conventional water treatment processes are coagulation, flocculation, sedimentation, filtration and disinfection. The size of colloidal particles in water is between 0.001 - 1µ, while the rate of spontaneous particle sedimentation with 1 µ of diameter is about 3 meters in a million years. Therefor the water filtration process is impossible without the use of chemical materials that cause boost colloid particle sedimentation rate (9). Normally, metal salts such as aluminum sulfate, ferric sulfate, ferrous sulfate, ferric chloride and poly aluminum chloride as a coagulant, and compounds such as sodium aluminate, bentonite, sodium silicate (active silica) and various cationic, anionic and nonionic polyelectrolyte as coagulant aid used to turbidity removal in the water treatment (8-12). Aluminum and iron salts are common coagulants that have been used for water and waste water treatment. But in recent years a new type of coagulant were prepared using iron and aluminum salts as inorganic polymer coagulant (Inorganic Polymer Flocculants) (13, 14). Which this material is used increasingly in many parts of the worldwide, especially China, Japan, Russia and the countries of Western Europe (13). Among the prominence of inorganic polymer coagulant than conventional coagulants can be noted is good performance in a wide range of pH and better performance at different temperatures, especially at low temperatures (15, 16). Poly aluminum chloride is one of the IPF that has more usage than other species (13, 14).

Based on the study of Omelia et al. (1985) Eric (2002), Malhutra (1994), Tang et al. (1996), Luan (1998), poly aluminum chloride in medium and high turbidity condition was better performance compared with other coagulants such as aluminum sulfate, ferric chloride and etc. For example less dosage utilizable due to more ionic charge, produce larger flocs, reducing the sedimentation time of flock, less sludge production, unneeded to adjust pH due to lower decrease of pH, better performance at lower temperatures, increase the period work of filter and etc (17-20).

Aims of the study: The water of some treatment plants in country (Iran) are provided from surface water sources with a medium turbidity. So, this study aimed to evaluate the performance of poly aluminum chloride, ferrous sulfate, ferric sulfate and aluminum sulfate coagulants in removing of medium turbidity of water and their impacts on electrical conductivity and alkaline.

Materials & Methods

This study was conducted as tentative - interfere research in a laboratory scale using Jar test in water and wastewater chemistry laboratory in faculty of public health of Kermanshah University of medical sciences. To compare the efficiency of poly aluminum chloride, ferrous sulfate, ferric chloride and aluminum sulphate coagulants in removing of turbidity, experiments were carried out on various parameters including different turbidity (50,100 and 200 NTU) and different concentrations of coagulants (5, 10, 15, 20, 25 and 30 mg/L). For turbidity providing, firstly clay and herbaceous soil were mixed and convert to fine particles after sieved it.

Then obtained material was dissolved in urban water and allow to settling for 30 minutes, subsequently supernatant was used for preparing of different turbidity. Given that high consumption of stock solution, one stock prepared for any coagulant. Then different turbidity was prepared using diluting of stock by deionized water. Subsequently, one liter of sample by certain turbidity was added to Jar test's flaks and pH, temperature, electrical conductivity and alkalinity parameters were measured as the response process. Coagulants in 5, 10, 15, 20, 25 and 30 mg /L were added to first until sixth flacks, then the sample was evacuated to Jar plant (HACH) and rapid mixing was carried out with 80 rpm for one minute and slow mixing was performed with 30 rpm for 20 min.

Then the sample was kept in static conditions for 30 minutes in order settling. A 25 mL sample was taken and turbidity of the samples was measured by turbidity meter TURBIDIMETER 2100P model. Flocs features were observed and their features were record by observing as descriptive terms such as poor, fair, good and excellent. Also, size of flocs was described as very fine, fine, medium, coarse and very coarse. pH and electrical conductivity were measured using pHmeter (Microprocessor 537) and EC cymbal (Conductivity Meter BA380).

Data analysis: The data were analyzed by the software of SPSS Version 21 and significance level of these tests in this study was considered lower than 0.05.

Results

Results showed the after using of poly aluminum chloride, ferric chloride, ferrous sulfate, ferric sulfate and aluminum sulfate coagulants in different turbidity (50, 100 and 200 NTU), pH reduced, so that by increasing of 1 mg/L of poly aluminum chloride and ferrous sulfate, pH reduced amount 0.02 value. This subject was 0.03 value for ferric chloride coagulant (table 1). Also, by increasing dose (1 mg/L) of poly aluminum chloride, ferrous sulfate, aluminum sulfate and ferric chloride coagulants, the temperature reduced 0.06, 0.08, 0.05 and 0.035 C^0 respectively.

The results of poly aluminum chloride tests showed, the turbidity achieved from 50 to 0 NTU by adding 5 mg/L of coagulant concentration, so that floc size was fine in 5 – 30 mg/L of coagulant concentration, the sedimentation rate was good and excellent in 5 – 20 mg/L and 25 – 30 mg/L of coagulant concentration respectively. The results were similar for 100 and 200 NTU of turbidity.

The results of ferrous sulfate tests indicated that the turbidity achieved from 50, 100 and 200 NTU to 0 NTU by adding 5 mg/L of coagulant, so that in 5, 10, 15, 20, 25 and 30 mg/L of coagulant concentration and 50 NTU of turbidity, the floc size was very fine, fine,

medium, coarse and very coarse and sedimentation rate was very weak, weak, relatively good, good, good and excellent respectively. For (5 – 30 mg/L) of coagulant concentration and 100 NTU of turbidity, the floc size was very fine, fine, medium, medium, medium, medium and coarse and sedimentation rate was weak, relatively good, good, good and good respectively.

For (5 – 30 mg/L) of coagulant concentration and 200 NTU of turbidity the floc size was fine, medium, coarse, coarse, coarse and coarse and sedimentation rate was weak, relatively good, good, good, good and excellent respectively. The results of aluminum sulfate tests indicated that the turbidity achieved from 50 NTU to 0 NTU by adding 5 mg/L of coagulant, so that For (5 – 30 mg/L) of coagulant concentration and 50 NTU of turbidity, the floc size was very fine, fine, medium, medium, coarse and very coarse and sedimentation rate was very weak, weak, relatively good, relatively good, good and excellent respectively. For (5 – 30 mg/L) of coagulant concentration and 100 and 200 NTU of turbidity, results of floc size and sedimentation rate were similar of 50 NTU of turbidity. The results of ferric chloride tests indicated that the turbidity achieved from 50 NTU to 0 NTU by adding 5 mg/L of coagulant, so that For (5 – 30 mg/L) of coagulant concentration and 50 NTU of turbidity, the floc size was very fine, fine, medium, coarse, coarse and very coarse and sedimentation rate was very weak, weak, relatively good, good, good and excellent respectively. For (5 – 30 mg/L) of coagulant concentration and 100 and 200 NTU of turbidity, results of floc size and sedimentation rate were similar of 50 NTU of turbidity. Table 2 shows the optimum slightly increase of coagulants (1 & 3 mg/L) and their effects on turbidity.

Table 1: results of pH changes after using of coagulants

Coagulant Conc. (mg/L)	Poly aluminum chloride			Aluminum sulfate			Ferrous sulfate			Ferric chloride		
	Turbidity			Turbidity			Turbidity			Turbidity		
	50 NTU	100 NTU	200 NTU	50 NTU	100 NTU	200 NTU	50 NTU	100 NTU	200 NTU	50 NTU	100 NTU	200 NTU
0	7.25	7.45	7.5	7.54	7.98	7.76	7.06	7	7.1	7.67	7.68	7.65
5	7.18	7.07	7.48	7.50	7.85	7.6	6.78	6.7	6.8	7.49	7.41	7.44
10	7.14	6.84	7.32	7.46	7.51	7.44	6.92	6.56	6.9	7.35	7.24	7.31
15	7.27	7.32	7.21	7.41	7.43	7.37	6.68	6.53	6.8	7.23	7.12	7.22
20	7.25	7.29	7.12	7.35	7.43	7.35	6.52	6.62	6.76	7.13	7.03	7.13
25	7.24	7.15	7.39	7.31	7.35	7.29	6.68	6.34	6.72	7.04	6.96	7.03
30	7.15	6.7	7.18	7.23	7.16	7.27	6.78	6.25	6.69	6.98	6.89	6.97

Table 2: Results of water turbidity after using of optimum portion coagulants

Initial turbidity (NTU)	poly aluminum chloride (mg/L)				aluminum sulfate (mg/L)				Ferrous sulfate (mg/L)				Ferric chloride (mg/L)			
	1	Removal %	3	Removal %	1	Removal %	3	Removal %	1	Removal %	3	Removal %	1	Removal %	3	Removal %
50	15.4	62	6.6	79	23.3	53	10.1	80	27.4	45	16.3	67	20.4	59	9.6	81
100	28.9	71	10.3	89	45.8	55	18.2	82	49.1	51	29.1	71	38.5	62	16.6	83
200	41.3	79	15.1	92	81.6	59	31.7	84	88.6	56	42.2	78	65.2	67	25.3	87

Figures 1 – 6 show effect of coagulants concentration on electrical conductivity and alkalinity on different turbidity concentration (50,100 and 200 NTU).

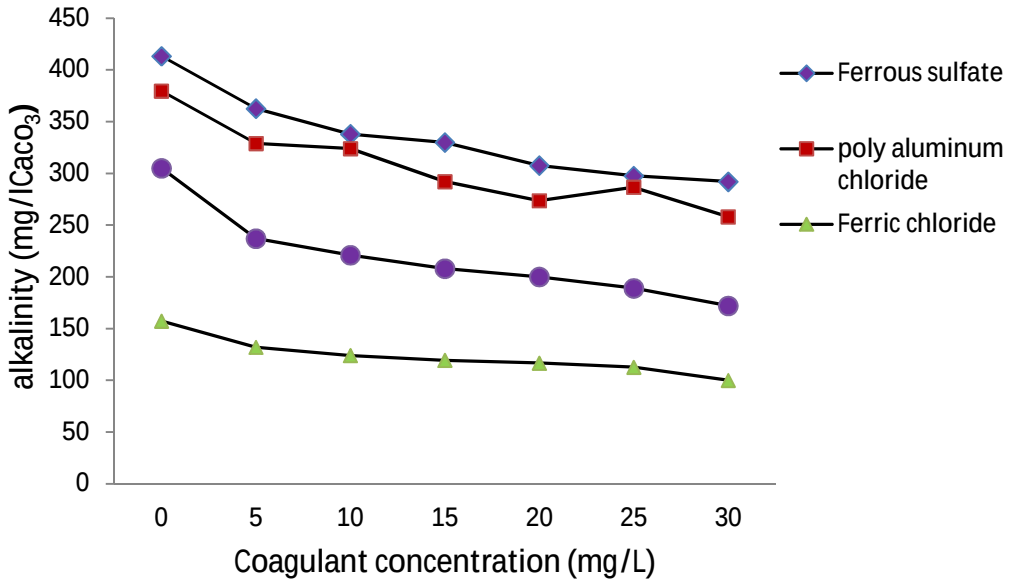

Fig 1: Effect of coagulants concentration on alkalinity in initial turbidity 50 NTU.

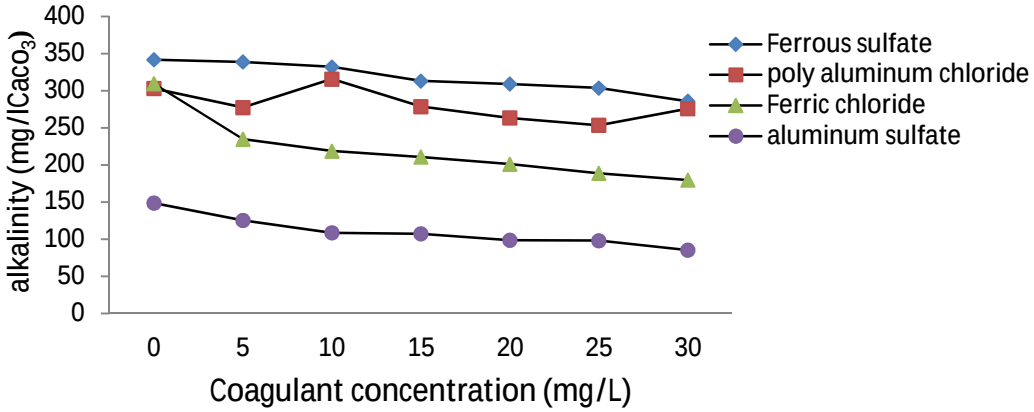

Fig 2: Effect of coagulants concentration on alkalinity in initial turbidity 100 NTU.

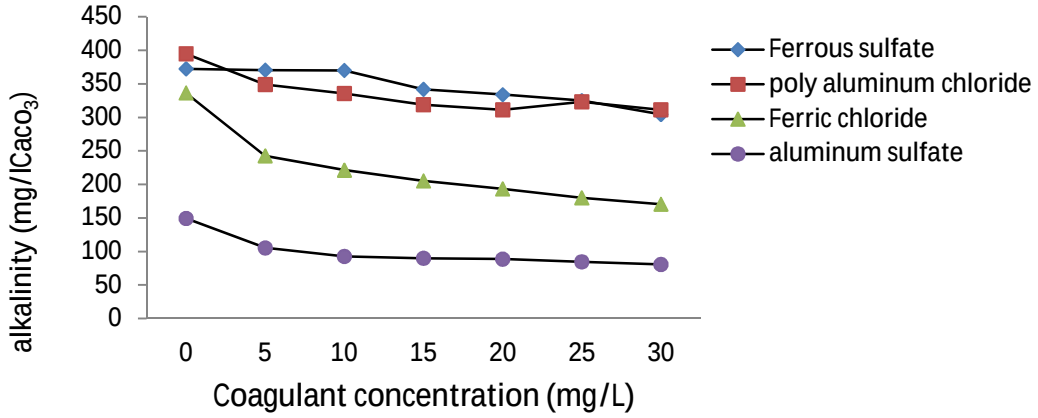

Figure 3: Effect of coagulants concentration on alkalinity in initial turbidity 200 NTU.

According on figure 4 – 6, the electrical conductivity was increased by increasing of coagulants concentration in 50, 100 and 200 NTU of turbidity

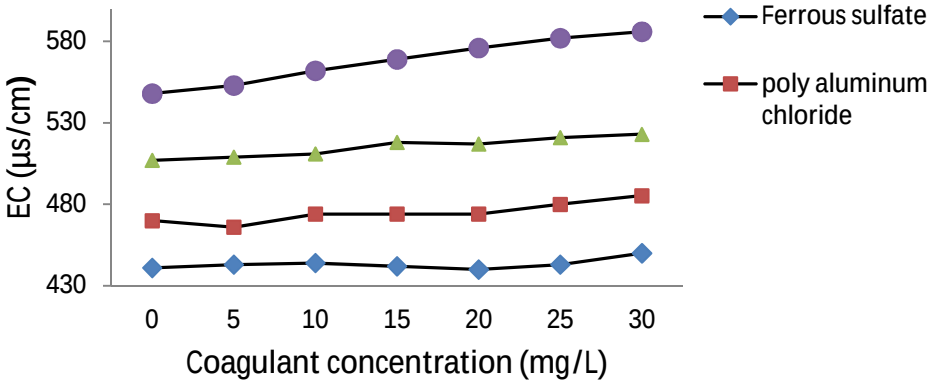

Figure 4: Effect of coagulants concentration on EC in initial turbidity 50 NTU.

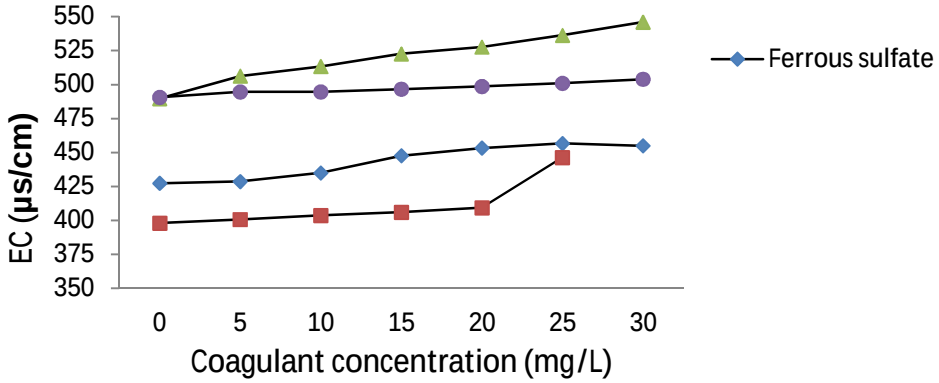

Figure 5: effect of coagulants concentration on EC in initial turbidity 100 NTU.

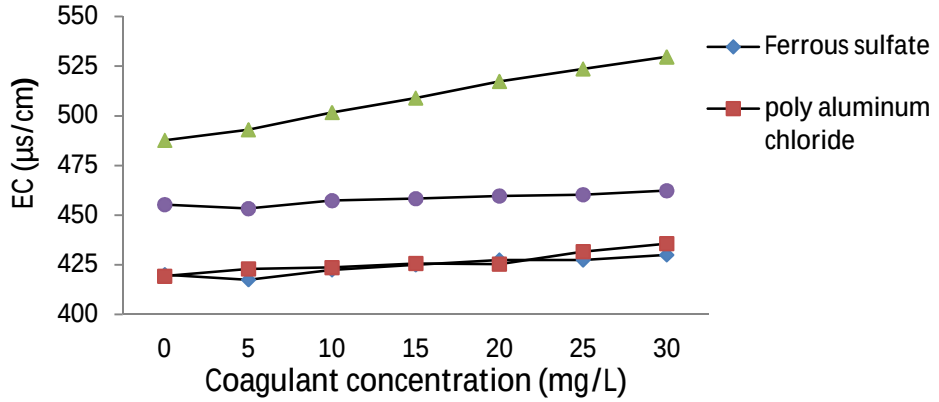

Figure 6: effect of coagulants concentration on EC in initial turbidity 200 NTU.

Discussion

The results of ferrous sulfate tests indicated that the turbidity achieved from 50, 100 and 200 NTU to 0 NTU by adding 5 mg/L of coagulant, so that in 5, 10, 15, 20, 25 and 30 mg/L of coagulant concentration and 50 NTU of turbidity, the floc size was very fine, fine, medium, coarse and very coarse and sedimentation rate was very weak, weak, relatively good, good, good and excellent respectively. For (5 – 30 mg/L) of coagulant concentration and 100 NTU of turbidity, the floc size was very fine, fine, medium, medium, medium, medium and coarse and sedimentation rate was weak, relatively good, good, good and good respectively. For (5 – 30 mg/L) of coagulant concentration and 200 NTU of turbidity the floc size was fine, medium, coarse, coarse, coarse and coarse and sedimentation rate was weak, relatively good, good, good, good and excellent respectively. Also, with increasing of ferrous sulfate, pH, temperature and alkalinity decreased and electrical conductivity increased. The range of pH for 50, 100 and 200 NTU of turbidity have been (6.7 – 7.4), (6.7 – 7.45) and (7.18 – 7.5). The temperature and pH of water samples was low in ferrous sulfate than poly aluminum chloride, while the efficiency removal of turbidity in poly aluminum chloride is better than ferrous sulfate. The results of aluminum sulfate tests showed that in 50, 100 and 200 NTU of turbidity reach to 0 NTU in all levels of coagulants concentrations (5 – 30 mg/L). Moreover, results indicated that by increasing of coagulant level, the pH and temperature decreased. Also in three turbidity range in 5 – 30 mg/L of coagulant, the floc size was very fine, fine, medium, medium, coarse and very coarse and sedimentation rate was very weak,

weak, relatively good, relatively good, good and excellent respectively. The ranges of pH for this coagulant in 50, 100 and 200 NTU of turbidity have been (7.23 -7.54), (7.16 – 7.98) and (7.27 – 7.76).

The results of ferric chloride tests revealed that the 50, 100 and 200 NTU of turbidity reach to 0 NTU in all levels of coagulants concentrations (5 – 30 mg/L). Moreover, results indicated that by increasing of coagulant level, the pH and temperature decreased. Also in three turbidity range in 5 – 30 mg/L of coagulant, the floc size was very fine, fine, medium, coarse, coarse and very coarse and sedimentation rate was very weak, weak, relatively good, good, good and excellent respectively. The ranges of pH for this coagulant in 50, 100 and 200 NTU of turbidity have been (6.98 -7.67), (6.89 – 7.68) and (6.97 – 7.65).

The results of poly aluminum chloride tests indicated that the turbidity achieved from 50, 100 and 200 NTU to 0 NTU by adding all value of coagulant (5 - 30 mg/L). Moreover, results showed by increasing of coagulant level, the pH and temperature decreased. Floc size in all turbidity range was fine and sedimentation rate was good and excellent for (5 – 20 mg/L) and (25 and 30 mg/L) of coagulant concentration. This subject reveal that sedimentation rate has raised which will effective on treatment period. Also, with increasing of poly aluminum chloride, alkalinity decreased and electrical conductivity increased. The range of pH for 50, 100 and 200 NTU of turbidity have been (7.14 – 7.25), (6.7 – 7.45) and (7.18 – 7.5). The compare performance of poly aluminum chloride on initial turbidity showed that this coagulant based on sedimentation rate and floc size has better performance than ferrous sulfate, aluminum sulfate and ferric chloride coagulants in terms of turbidity removal. Mahvi et al. (21) reported that given that low consumption of poly aluminum chloride than other coagulants, the cost of used coagulant will decrease in exchange for 1 m^3 of water.

This study revealed that by increasing of coagulants concentration, the alkalinity decreased and electrical conductivity raised. Due to EC is related to TDS, therefore this parameter is criterion for water ability in electrical current conductivity. Because the electrical current will transform by water's ions, so with TDS increasing, the EC will raise. It's relationship is as TDS= 0.4 – 0.6 EC (22). In this study, the highest EC (546 µs/cm) was as to ferric chloride at 30 mg/L concentration and lowest EC (419 µs/cm) was as to poly aluminum chloride at 5 mg/L concentration. According above formula, the TDS level of water samples that used of ferric chloride and poly aluminum chloride are 273 and 209 mg/L respectively. EPA guideline for TDS is 500 mg/L (23).

Conclusion

Results showed that ploy aluminum chloride is best coagulant in terms of turbidity removal. In spite of obtained fine flocs, but sedimentation rate is very good. On other hand by increasing of coagulants, alkalinity decreased and EC raised, so that poly aluminum chloride and ferrous sulfate had low EC raising and alkalinity reducing, that causes low effect on chemical quality of water and have kept natural chemical of raw water.

Footnotes

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Conflict of Interest:
The authors declared no conflict of interest.

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