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Investigation of Chemical Coagulation and Flocculation Efficiency of Different Coagulants in Phosphorus pentoxide and Fluoride Removal from Kimia Daran Kavir Factory Wastewater

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Abstract

In the water-treatment plants, the process of coagulation and flocculation has a special place and it has always been an effort to achieve high efficiency in this part of the water treatment with low cost. In recent years, extensive research has been carried out on the process of coagulation and flocculation, and various coagulants and flocculants materials have been investigated. The purpose of this study is the investigation of chemical coagulation and flocculation efficiency of different coagulants and flocculants (Aluminium sulfate, Bentonite, Iron(II) sulfate, Polyaluminum chloride, Poly-Ferric chloride, Sodium aluminate, Anionic polyelectrolyte and Cationic polyelectrolyte) in phosphorus pentoxide and fluoride removal in the phosphoric and acid water treatment plant. The present study - a pilot scale experiment- was conducted in the laboratory of water and wastewater chemistry of Kimia Daran Kavir factory in 2018. In order to compare the efficiency of coagulants and flocculants materials in removal of phosphorus pentoxide and fluoride, the experiments were performed based on the variables PH, EC, TH, TDS, particle sedimentation velocity, turbidity after 5, 10 and 30 minutes, size of particles formed and correlation of particles precipitated in the beaker bottom. At the end, the efficiency of each coagulants and flocculants materials was reported qualitatively in the removal of phosphorus pentoxide and fluoride. After preparation of the samples in the Jar test apparatus, rapid mixing for all experiments was 70 rpm for one minute, slow mixing was 10 rpm for 15 minutes and for 30 minutes to sedimentation in static conditions. The results showed that all of the coagulants reviewed in this study are not suitable for use in the phosphoric and acid water treatment plant of Kimia Daran Kavir factory. Cationic polyelectrolyte is a suitable flocculant for use in the phosphoric and acid water treatment plant of Kimia Daran Kavir factory. The use of lime in the phosphoric and acid water treatment plant, in addition to the role of the removal of phosphorus pentoxide and fluoride, plays a coagulant substance role. Therefore, there is no need to use a coagulant. Also, according to the particle sedimentation velocity, the best PH for cationic polyelectrolyte injection is PH = 11. Also, it can be concluded from the results of the above experiments that coagulants and flocculants do not play a role in increasing or decreasing the amount of TDS and TH.

Key words: Coagulation, Flocculation, Phosphorus pentoxide, Fluoride, Cationic polyelectrolyte.

Introduction

Population growth, urbanization development and the development of industry and agriculture increase water use and sewage production in the societies and contaminate the environment. Environmental protection is a common global concern among governments and nations and has grown over the past decades. Today, in the advanced technology world, one of the most important activities in the industry is the effort to protect the environment and reduce the amount of input contamination load the natural ecosystem. For this reason, there are various environmental regulations on industrial wastewater, according to which industrial waste water must have certain standards of purity before being discharged into public waters and entering the environment. Kimia Daran Kavir factory is the largest producer of phosphate fertilizer in Iran. The phosphoric and acid water treatment plant is one of the most important filtration systems in the factory. The influent discharge into this filtration system is 20 m^3h^{-1}. The influent into the phosphoric and acid water treatment plant has phosphorus pentoxide and fluoride that should be purified in this system. Fluoride is a vital element in the human body and is the most often absorbed by water. Fluoride is useful at low concentrations for the body, but it is harmful at high concentrations (Zhu et al, 2007).

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The entry of large amount this element into the body can cause dental fluorosis, skeletal fluorosis, thyroid problems, neurological problems, infertility and alzheimer (Farooqi et al, 2007; Chinoy, 1991). The presence of phosphorus pentoxide in wastewater causes many environmental problems. Research has shown that chemical coagulation and flocculation is one of the best technologies for removing suspended solids and colloidal materials from industrial wastewater. Takdstan et al (2015) investigated the efficiency of coagulants of poly ferric sulfate (PFS) against poly aluminum chloride (PAL) in removing turbidity and coliform bacteria in Ahwaz water treatment plant. This study, was performed in lab scale and using of jar test apparatus in Ahwaz water treatment. Experiments was conducted in 35NTU turbidity in Ahwaz water treatment plant. The studied parameters included concentrations of coagulants, pH, turbidity, total coliform, fecal coliform and heterotrophic bacteria. The most optimal efficiency conditions of poly aluminum chloride were pH=8, rapid mixing of 120rpm and optimal dose of 5ppm which was 93.14% in pH=8 and 93.80% for optimal dose of 5ppm. The most optimal condition for poly ferric sulfate included pH=8, rapid mixing of 120 rpm and optimal dose of 8ppm. In optimal condition of performance for poly aluminum chloride, efficiency of removing total coliform, fecal coliform and heterotrophic bacteria were 90.12, 83.70, 84.08 % respectively. In optimal condition of poly ferric sulfate in dose of 8ppm efficiency removing total coliform, fecal coliform, and heterotrophic bacteria were 90.48, 84.83, and 84.69. Kord Mostafapoor (2008) compared the efficacy of three coagulants of polyaluminum chloride, aluminum sulfate and ferric chloride in turbidity removal from drinking water. The present study -a pilot scale experiment- was conducted in the laboratory of water and wastewater chemistry of Zahedan public health school in 2007. Laboratory experiments were performed using distilled water containing synthetic Caoline. Eight turbidity levels (10-80 NTU), five pH levels (5.5, 6.0, 6.5, 7.0 and 7.5) and five coagulants doses (5, 10, 20, 30 and 40 mg/l) were used for jar test. Rapid mixing for all experiments was 380 rpm for one minute and slow mixing was 30 rpm for 20 minutes. At the end of every experiment, residual turbidity was measured by turbidity meter. Removal efficiency for various conditions was determined by covariance and regression analysis. The results indicated that an increase of aluminum sulfate dose up to 40 mg/l can increase removal efficiency to 99.9%. The highest removal efficiency for ferric chloride occurred at feed dose of 20 mg/l and primary turbidity of 10 NTU, while for PAC the highest removal efficiency (99%) occurred at 40 mg/l. Effect of pH in turbidity removal for all experiments was similar. Yazdanbakhsh et al (2012) determined the efficiency of coagulation process in olive oil wastewater treatment to reduce pollution load and improve the biological degradability. This study was conducted in laboratory scale and Batch reactor on the real wastewater. Coagulation process using alum and polyaluminum chloride (PAC) coagulants was done and the removal value of COD, TSS and total phenolic compounds was investigated. The results demonstrated that the highest removal efficiency of pollutants in the optimum pH and dose of PAC achieved turned out to be 7 and 1 000 mg/L respectively. In these conditions, the removal values of COD, TSS and total phenolic compounds by PAC achieved were 88 .3, 90.2 and 99.2 %, respectively. Also analysis of the ratio of BOD/COD showed that after coagulation process, the value could increase from 0.14 up to 0. 5 8. This process can be regarded an effective and economical method in the reduction of pollution of this type of wastewater. Jamali et al (2014) evaluated the poly aluminum chloride efficiency in removal COD, TSS, color and turbidity of wastes landfill leachate in Qazvin city in 2011. The results showed that the optimum pH and poly aluminum Chloride amount was 7.5 and 2.5 gr / L, respectively. The removal efficiency in the optimum conditions for COD, TSS, turbidity and color was 48.5%, 82.5%, 73.5% and 70.5%, respectively. Qazvin has a high production rate of landfill leachate. Besides, cost effectiveness and high removal efficacy of poly aluminum chloride makes this method a convenient, no high tech technique for treatment of landfill leachate. Zabihollahi et al (2016) investigated the chemical coagulation and flocculation efficiency of different coagulants (Alum, Ferric Chloride, PAC, and Lime) in Navy Blue CE-RN textile dye removal from aqueous solutions. Characteristics of dye such as dominant wavelength, hue, luminance degree, and purity of Navy Blue CE-RN were determined through spectrophotometric-multi-wavelength method. Optimum dose, optimum pH, and sludge volume index (SVI) of coagulants were determined using jar test. The efficiency of coagulants was compared in optimum conditions. Cost and removal efficiency were considered in the selection of the best coagulant. The obtained dominant wavelength, luminance degree, and purity of dye were 473 nm, 19%, and 53%, respectively. PAC (dose of 0.1 g/l and optimum pH =6) had the highest removal efficiency in the removal of Chemical oxygen demand (COD) and dye (84% and 93%, respectively). The SVI of PAC was 1324 l/g. The results of this study showed that PAC can be an appropriate, efficient, and cost-effective coagulant in the removal of Navy Blue CE-RN dye. Alizadeh et al (2016) investigated the optimal condition of coagulation process using poly aluminum chloride in dairy wastewater treatment. In this study the coagulation process with PAC coagulant was used under laboratory conditions. By changing important parameters affecting the system pH (2-12) and coagulant dosage (5-100 mg/L), the decreasing of quality parameters of effluent such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Kjehldahl nitrogen (TKN), Total Phosphorous (TP) and Total Dissolved Solids (TDS) were obtained. Experiments showed the removal efficiency of COD, BOD, TKN, TP, and TDS in pH 8 and coagulant dosage of 50 mg/L at 22±2 °C can be reached to 74.51, 84.81, 68.24, 65.46 and 85.69, respectively, which were the highest amounts among the pHs and coagulant dosages studied. The results showed that PAC coagulant is able to improve quality parameters of dairy wastewaters to standard levels. Because of availability, easy operation and acceptable removal efficiency for this wastewater type, PAC coagulant can be used for treatment of dairy industries wastewater. The purpose of this study is to investigate of chemical coagulation and flocculation efficiency of different coagulants in phosphorus pentoxide and fluoride removal from Kimia Daran Kavir factory wastewater.

Materials and Methods

Kimia Daran Kavir factory was established in 2007 in Behabad county, Yazd province. Kimia Daran Kavir factory is the largest producer of phosphate fertilizer in Iran country. Kimia Daran Kavir factory produces 80 thousand tons of phosphoric acid and 100 thousand tons of chemical fertilizer and produces 200 thousand tons of sulfuric acid annually. This factory uses from soil inside the country to produce phosphoric acid and plays an important role in creating employment and reducing unemployment in the region of Behabad. This factory is the first manufacturer of electricity from renewable energy and is also the first producer of granular triple superphosphate (GTSP) in Iran. Figure 1 shows the location of the Kimiadaran Kavir factory in Yazd province, Iran country.

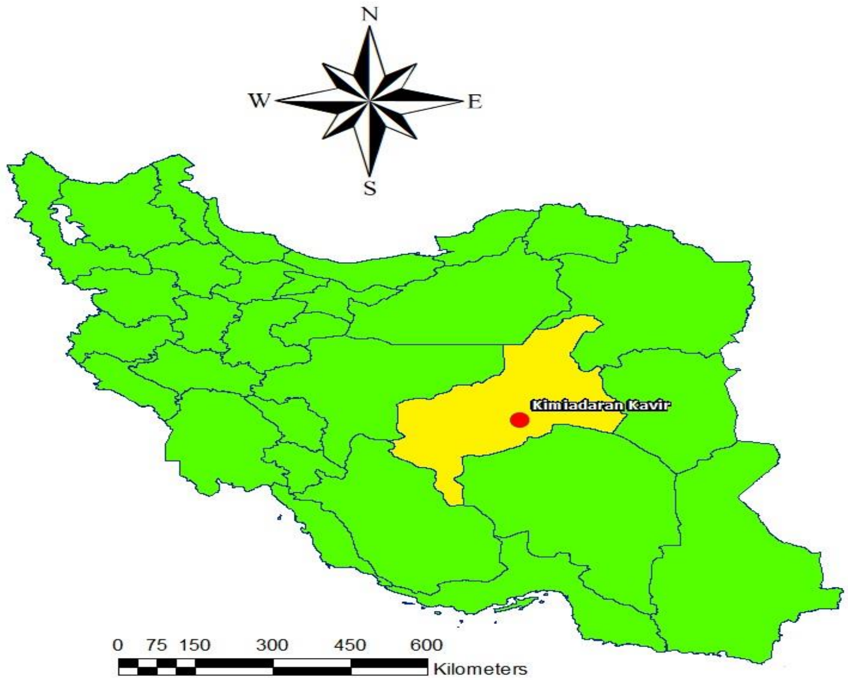

Figure 1- Location of the Kimiadaran Kavir factory in Yazd province, Iran country.

The process of water treatment in the phosphoric and acid water treatment plant includes the following four steps:

1) Acidic water reaction with lime milk
2) Coagulation
3) Flocculation
4) Sedimentation

The reason for the use of coagulants and flocculants is the removal of suspended sediment and colloidal particles in water, which is observed in the form of turbidity in the outlet water from the phosphoric and acid water treatment plant. Table 1 shows the sedimentation time of particles in water.

Table 1-Sedimentation time of particles in water with different diameters

Particle diameter	Particle type	Time to sedimentation within a meter of water
10 mm	gravel	1 second
1 mm	sand	10 second
0.1 mm	very fine sand	2 minutes
10 micron	clay, algae, unicellulars	2 hours
1 micron	bacterias, colloids	8 days
0.1 micron	viruses, colloids	2 years
10 nm	viruses, colloids	20 years
1 nm	viruses, colloids	200 years

In this research, Jar test was used to achieve the objective. Jar test is a simulation test of the wastewater treatment process on a laboratory scale and is used to determine the type of chemical substance, the optimal amount of chemical materials dosing and the determination of the treatment process conditions (sequence, pH, etc.). The jar test was carried out on the coagulants and flocculates mentioned below.

1) Aluminium sulfate
2) Bentonite

3) Iron(II) sulfate
4) Polyaluminum chloride
5) Poly-Ferric chloride
6) Sodium aluminate
7) Anionic polyelectrolyte
8) Cationic polyelectrolyte

The steps for performing the Jar test are as follows:

1) There are four locations in the Jar test machine for sample placement. So, the concentrations of 1ppm, 5ppm,10ppm and 20 ppm were prepared from coagulants and flocculants. These concentrations were then added to beakers with pH = 10 and a minute was stirred with speed of 70 rpm to make the coagulants and flocculants well mixed in solution. It was then stirred for 15 minutes with speed of 10 rpm. The low speed of the stirrer causes the formation of larger clots. The machine was then turned off and the solution was allowed to sediment for 30 minutes. The samples situation was reported at a time interval of 5 minutes, 10 minutes and 30 minutes.
2) Samples number five are blank samples (influent samples) which is sampled from input of water treatment plant.
3) The lime milk is prepared and the pH water is set on 10. The reaction formulas for the removal of phosphorus pentoxide and fluoride are presented in equations 1 and 2.

$$P_2O_5+3Ca(OH)_2=Ca_3(PO4)_2+3H_2O \quad (1)$$

$$H_2SiF_6 + 3Ca(OH)_2=3CaF_2 + SIO_2+4H_2O \quad (2)$$

4) At the end of the solution with the lowest turbidity is chosen as the most optimal.

The turbidity analysis was performed visually and qualitatively because the Nephelometric Turbidity Unit Meter (NTU-Meter) device was not available. The following concepts (particles size, particles sedimentation velocity) are defined to compare samples analysis. In the particles size section:

1) Fine particles: Particle size is about 10 microns.
2) Coarse particles: Particle size is about 0.1nm.
3) Very coarse particles: Particle size is about 1 mm or more.

In the particles sedimentation velocity section:

1) Very slow velocity: The colloids sedimentation velocity is equivalent to moving the colloids at a distance one meter to the bottom of the container for eight days.
2) Slow velocity: The particle is sedimented in the bottom of the container for about 2 hours.
3) High velocity: The particle is sedimented in the bottom of the container for about 15 minutes.
4) Very high velocity: The particle is sedimented in the bottom of the container for about 2 minutes.

Results and Discussion

Table 2 shows the role of aluminum sulfate in removal of phosphorus pentoxide and fluoride. According to Table 2, the particle sedimentation velocity is slow and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of aluminum sulfate as a coagulant does not have an effect in the removal of phosphorus pentoxide and fluoride. Table 3 shows the role of bentonite in removal of phosphorus pentoxide and fluoride. According to Table 3, the particle sedimentation velocity is slow and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of bentonite as a coagulant does not have an effect in the removal of phosphorus pentoxide and fluoride. Table 4 shows the role of iron (II) sulfate in removal of phosphorus pentoxide and fluoride. According to Table 4, the particle sedimentation velocity is slow and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of iron (II) sulfate as a coagulant does not have an effect in the removal of phosphorus pentoxide and fluoride. Table 5 shows the role of Polyaluminium chloride in removal of phosphorus pentoxide and fluoride. According to Table 5, the particle sedimentation velocity is slow and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of Polyaluminium as a coagulant does not have an effect in the removal of phosphorus pentoxide and fluoride. Table 6 shows the role of Poly-Ferric chloride in removal of phosphorus pentoxide and fluoride. According to Table 6, the particle sedimentation velocity is slow and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of Poly-Ferric chloride as a coagulant does not have an effect in the removal of phosphorus pentoxide and fluoride. Table 7 shows the role of Sodium aluminate in removal of phosphorus pentoxide and fluoride. According to Table 7, the particle sedimentation velocity is slow and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of Sodium aluminate as a coagulant does not have an effect in the removal of phosphorus pentoxide and fluoride. All of the coagulants reviewed in this study are not suitable for use in the phosphoric and acid water treatment plant of Kimia Daran Kavir factory. Before using the coagulants, the lime was used to adjust the pH. Due to this, the coagulants did not play a suitable role in the removal of phosphorus pentoxide and fluoride. The use of lime in the phosphoric and acid water treatment plant, in addition to the role of the removal of phosphorus pentoxide and fluoride, plays a coagulant substance role. Therefore, there is no need to use a coagulant. Table 8 shows the role of anionic polyelectrolyte in removal of phosphorus pentoxide and fluoride. According to Table 8, the particle sedimentation velocity is medium and there is no correlation of particles precipitated in the beaker bottom. Therefore, the use of anionic polyelectrolyte as a flocculant does not have an effect on the removal of phosphorus pentoxide and fluoride. Table 9 shows the role of cationic polyelectrolyte in removal of phosphorus pentoxide and fluoride. According to Table 9, the particle sedimentation velocity is very high and there is high correlation of particles precipitated in the beaker bottom. Therefore, cationic polyelectrolyte is a suitable flocculant for use in the phosphoric and acid water treatment plant of Kimia Daran Kavir factory. Also, it can be concluded from the results of the above experiments that coagulants and flocculants do not play a role in increasing or decreasing the amount of TDS and TH. Table 10 shows the effect of cationic polyelectrolyte in different pHs. According to Table 10, the best PH for the particle sedimentation velocity, cationic polyelectrolyte injection is PH = 11 (10.88 ≈11). The efficiency of coagulants is a function of the physical and chemical properties of the water sample. Factors affecting the chemical coagulation process are very diverse. The way these factors influence the chemical coagulation process and the interaction of these effects is still quite unclear. Therefore, this research is valid only for the tested water sample and the use of the results of this study for other water samples is not necessarily correct. The results of this study on the coagulants performance do not match the results of other studies. Birjandi et al (2015) compared the efficiency of Alum and Polyaluminium chloride for removal of paper mill wastewater pollution. In this study, paper mill wastewater was characterized and the reduction of chemical oxygen (COD), turbidity and sludge volume index (SVI) parameters were evaluated. Optimum dosage of coagulants and pH value are obtained with the standard jar test technique. Under optimum condition, the dosage of alum and polyaluminum chloride and initial pH were, respectively, 1000, 500 mg/l and 6. This result reveals that PACl with a 96% removal of turbidity and a 99% reduction of COD could provide the best possible results. Furthermore, SVI reached 250 ml/g when PACl was used as a coagulant. The findings showed that coagulation can be used as a new technology for the treatment of different industrial wastewaters, such as in the paper mill industry. Birjandi et al (2014) investigated the coagulation and clotting process of purge of environmental pollutants of paper mill's wastewater. The present research investigated the effect of coagulant of PACL for reduction of the pollutants in paper mill wastewater. For reduction of the pollutants the quantity and quality of wastewater investigated. This study showed that this wastewater has chemical oxygen demand (COD)=3523 mg/l and turbidity=872. In this test, parameters of turbidity, COD, total solid (TS), optimum pH and dosage of coagulant determined. According to data obtained from studies optimum pH and dosage of PACL were obtained to be 7, 785 mg/l, respectively. The results of the present study revealed that coagulant of PACL could reduce 90% of TS, 88% of COD and 93% of turbidity in paper mill wastewater. Amini et al (2018) optimized the coagulation-flocculation process for dye and COD removal from real dyeing wastewater and evaluated the effluent biodegradability in a carpet factory. The study was conducted in the laboratory scale using Jar test. Dye removal from real wastewater was investigated by the use of three mineral coagulants including poly aluminum chloride, ferric sulfate and ferric chloride. In order to optimize the process, parameters including pH, coagulant dose, time and speed of coagulation were considered. Treated samples were analysed to determine the residual color and COD. According to the results of our experiments, under optimum conditions of process (pH 9, doses of 250 mg/l coagulant and coagulation speed of 175 rpm with a duration of 5 minutes), the highest removal efficiencies (COD 44.4% and color 95%) were obtained by the use of poly aluminum chloride. The results showed that poly aluminum chloride enhanced the biodegradability of wastewater from 0.07 to 0.21 at optimized process conditions. Hassani et al (2011) investigated the best coagulants before and after ozonation to pretreatment of the hospital wastewater. In this study, researchers used a laboratory system including ozone generator with the capacity of 15.5 go3/h, one-liter reaction reactor and Jar-test system by using Alum, PAC, $FeCl_3$ coagulants. Turbidity was tested based on standard methods. PAC was determined as the best coagulant for before ozonation of hospital wastewater. Using 200 mg/Lit of PAC along with l mg/Lit of cationic poly electrolyte resulted in 99.2 percent of turbidity removal. Alum was the best coagulant for after ozonation with a dose of 200 mg/Lit along with 0.3 mg/Lit of cationic poly electrolyte that resulted in 97.98% removal of turbidity. PAC and Alum were determined as the best coagulants for before and after ozonation of the hospital wastewater, respectively. Ozonation reduced the dose of coagulants applied. Bazarafshan and Ahmadi (2017) investigated the efficiency of combined processes of coagulation and modified activated Bentonite with Sodium hydroxide as a bio sorbent in the final treatment of leachate. This experimental-laboratory study included chemical coagulation using polyaluminum chloride (PAC) and modified bentonite. We investigated the effect of critical operating parameters on landfill leachate treatment. These operating parameters included pH (2-10) and PAC concentration (5-25 mg/l) in chemical coagulation process, contact time (15-150 min), solution pH (2-10), bentonite concentration (0.3-1.5 g/l), and temperature (25, 35, and 45ºC) in adsorption process. The overall efficiency rate of this process in removal of total chemical oxygen demand (COD) was 93%, with the optimum PAC concentration of 30 mg/L, pH=6 in the chemical coagulation phase, reaction time of 60 min during the adsorption process, bentonite concentration of 0.5 g/L, pH=6, and temperature of 25ºC. The kinetics of COD adsorption on modified bentonite conformed to the pseudo-second-order model. The application of combined processes of chemical coagulation and activated bentonite is highly efficient in removing major pollutants in leachate. Yari et al (2012) investigated the process of coagulation, flocculation and advanced oxidation in effluent treatment of second refinery oil industries. This study is a descriptive- quasi-experimental that effluent pollution quality measured with COD. Physicochemical processes of coagulation, flocculation, by using conventional coagulants and oxidation with ozone for the removal to access environmental discharge effluent standards were studied. Coagulants such as aluminum sulfate, ferric chloride, sodium silicate, poly aluminum chloride were evaluated. Jar test was used to determine the efficiency of coagulation and flocculation. Samples were collected from Salafchegan industrial district in Qom. Examination methods were extracted from Standard methods for water and wastewater examination. Initial experiments showed that BOD, indicating biological treatment wastewater, in comparison with COD, indicating chemical oxygen demand of wastewater is very low. Thus, the application of biological processes of effluent treatment without using chemical processes, not performance and not economic. The experiment showed that the amount of COD in raw effluent was varied from 38000 to 78000mg/l. Using advanced oxidation with O_3 in pH=11.5 can reach 77.5% and in pH=9 in 57.2 and in pH=3.25 in 21.3 COD removal efficiency respectively. Kiani et al (2015) investigated the leachate treatment of Isfahan composting plant by coagulation-flocculation process. This is an experimental study. Leachate samples were collected from the Isfahan composting leachate´s collection ponds. At first, leachate characteristics including COD, BOD, TSS and pH as well as the following heavy metals Zn, Cu, Ni, Cr, Cd were measured according to the standard methods. Jar-test experiments were carried out to examine the effects of changing coagulants' dosage (0.5, 1, 1.5, 2, 2.5 and 3 g/l) and pH values (4-12) on heavy metal removal. As a result, the effective dosage, optimum pH and the most convenient coagulant were identified. Investigating the average of mentioned heavy metals' concentration, Zn had the highest concentration in leachate (6.2mg/l). The optimum pH for precipitation of the metals using alum, Polyaluminium chloride, ferric chloride, ferrous sulfate and poly ferric sulfate was 6.5,7,10,10 and 11 respectively. Optimum concentration of the mentioned coagulants was obtained 2, 1.5, 1.5, 2 and 2g/l respectively. Poly ferric sulfate with70% to 87% of heavy metals removal and 50% of COD removal had the highest efficiency. Polyaluminium chloride with 65% to 85%, Ferric chloride with 75% to 80%, ferrous sulfate with70% to 80% and finally alum with 70% to 75% were the following priorities at heavy metals removal. Cationic polyelectrolyte is the most effective flocculant to remove phosphorus pentoxide and fluoride from the Kimia Daran Kavir factory wastewater and comparing the results with the Iranian guideline for effluent discharge shows that the concentration of phosphorus pentoxide and fluoride in Kimia Daran Kavir factory wastewater did not exceed the maximum allowed values.

Table 2-Investigating the role of Aluminium sulfate coagulability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.18	9.25	10.01	8.67	3.4
EC(us/cm)	1236	1268	1248	1262	7760
TDS	608	634	624	631	3880
TH(ppm CaCO3)	430	510.6	456.9	526.8	107.5
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	slow	slow	slow	slow	very slow
Size of particles formed	fine	fine	fine	fine	fine
Turbidity after 5 minutes	high	high	medium	high	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	medium	medium	medium	medium	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 3-Investigating the role of Bentonite coagulability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.82	10.56	10.71	9.83	3.53
EC(us/cm)	1137	1168	1151	1042	7060
TDS	569	584	576	521	3530
TH(ppm CaCO3)	392.37	419.25	473	365.5	161.25
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	slow	slow	slow	slow	very slow
Size of particles formed	fine	fine	fine	fine	fine
Turbidity after 5 minutes	medium	medium	medium	medium	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	medium	medium	medium	medium	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 4-Investigating the role of Iron(II) sulfate coagulability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	9.79	9.21	8.81	8.25	2.55
EC(us/cm)	1255	1177	12.40	1326	5540
TDS	627	588	620	663	2770
TH(ppm CaCO3)	400	340	380	420	60
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	slow	slow	slow	slow	very slow
Size of particles formed	fine	fine	fine	fine	fine
Turbidity after 5 minutes	medium	medium	medium	medium	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	medium	medium	medium	medium	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 5-Investigating the role of Polyaluminum chloride coagulability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.28	9.84	9.81	9.06	3.31
EC(us/cm)	1306	1375	1339	1422	7300
TDS	653	688	670	711	3650
TH(ppm CaCO3)	450	300	450	500	200
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	slow	slow	slow	slow	very slow
Size of particles formed	fine	fine	fine	fine	fine
Turbidity after 5 minutes	high	high	high	high	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	medium	medium	medium	medium	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 6-Investigating the role of Poly-Ferric chloride coagulability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.12	9.35	9.15	9.24	3.03
EC(us/cm)	1338	1315	1388	1358	7250
TDS	669	657	694	679	3640
TH(ppm CaCO3)	440	420	420	440	100
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	slow	slow	slow	slow	very slow
Size of particles formed	fine	fine	fine	fine	fine
Turbidity after 5 minutes	high	high	high	high	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	medium	medium	medium	medium	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 7-Investigating the role of Sodium aluminate coagulability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	9.96	9.76	10.42	9.95	3.32
EC(us/cm)	1230	1301	1287	1320	5740

TDS	650	620	648	625	2780
TH(ppm CaCO3)	365.5	387	381	381	241.9
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	slow	slow	slow	slow	very slow
Size of particles formed	fine	fine	fine	fine	fine
Turbidity after 5 minutes	high	high	medium	medium	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	medium	medium	medium	medium	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 8-Investigating the role of Anionic polyelectrolyte flocculability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.43	10.48	10.52	10.45	2.87
EC(us/cm)	668	1161	1168	1203	246
TDS	334	581	584	601	122.8
TH(ppm CaCO3)	322.5	268.7	322.5	295.6	295.6
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	medium	medium	medium	medium	very slow
Size of particles formed	coarse	coarse	coarse	coarse	fine
Turbidity after 5 minutes	medium	medium	medium	medium	medium
Turbidity after 10 minutes	medium	medium	medium	medium	medium
Turbidity after 30 minutes	transparent	transparent	transparent	transparent	medium
Correlation of particles precipitated in the beaker bottom	no correlation	no correlation	no correlation	no correlation	sedimentary does not form

Table 9-Investigating the role of Cationic polyelectrolyte flocculability

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.03	9.95	9.94	10.12	3.33
EC(us/cm)	1306	1296	1237	1279	6250
TDS	653	645	618	640	3130
TH(ppm CaCO3)	370	370	340	380	50
Added amount(ppm)	1	5	10	20	0
Particle sedimentation velocity	very high (10s)	very high (15s)	very high (16s)	very high (18s)	very slow
Size of particles formed	coarse	coarse	coarse	coarse	fine
Turbidity after 5 minutes	transparent	transparent	transparent	transparent	medium
Turbidity after 10 minutes	very transparent	very transparent	very transparent	very transparent	medium
Turbidity after 30 minutes	very transparent	very transparent	very transparent	very transparent	medium
Correlation of particles precipitated in the beaker bottom	high correlation	high correlation	high correlation	high correlation	sedimentary does not form

Table 10-Investigating the effect of Cationic polyelectrolyte in different pHs

Control parameters	sample 1	sample 2	sample 3	sample 4	influent sample
PH	10.88	9.73	9.51	8.69	3.34
EC(us/cm)	1480	1309	1230	1391	6270
TDS	721	670	642	598	3320
TH(ppm CaCO3)	376.25	408.5	408.5	483.75	107.5
Added amount(ppm)	1	5	10	20	0

Particle sedimentation velocity	very high (10s)	very high (14s)	very high (13s)	very high (19s)	very slow
Size of particles formed	coarse	coarse	coarse	coarse	fine
Turbidity after 5 minutes	very transparent	very transparent	very transparent	very transparent	medium
Turbidity after 10 minutes	very transparent	very transparent	very transparent	very transparent	medium
Turbidity after 30 minutes	very transparent	very transparent	very transparent	very transparent	medium
Correlation of particles precipitated in the beaker bottom	high correlation	high correlation	high correlation	high correlation	sedimentary does not form

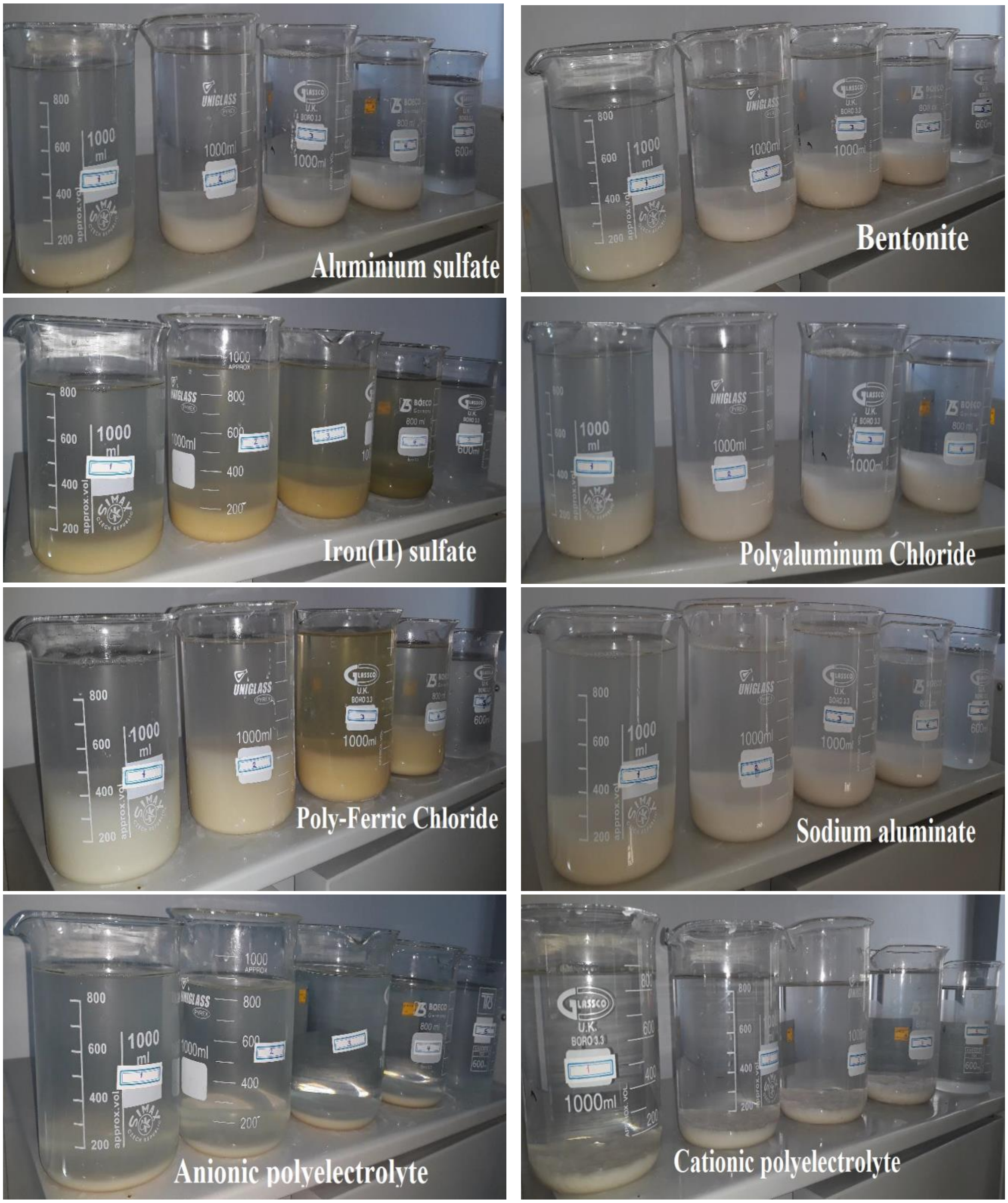

Figure 2-The descriptional results of Jar test for different coagulants and flocculants

Conclusion

Among the available methods for the removal of phosphorus pentoxide and fluoride from the Kimia Daran Kavir factory wastewater, coagulation and flocculation is a process that although similar to other methods has a disadvantage, but due to its economic justification, simplicity of the performance, the lack of production hazardous side-products and low energy consumption are still widely used in developed and developing countries. All of the coagulants reviewed in this study are not suitable for use in the phosphoric and acid water treatment plant of Kimia Daran Kavir factory. Cationic polyelectrolyte is a suitable flocculant for use in the phosphoric and acid water treatment plant of Kimia Daran Kavir factory. The use of lime in the phosphoric and acid water treatment plant, in addition to the role of the removal of phosphorus pentoxide and fluoride, plays a coagulant substance role. Therefore, there is no need to use a coagulant. Also, according to the particle sedimentation velocity, the best PH for cationic polyelectrolyte injection is PH = 11. Also, it can be concluded from the results of the above experiments that coagulants and flocculants do not play a role in increasing or decreasing the amount of TDS and TH. The purpose of using coagulants and flocculants is to form a gel-like layer on the floor of the Thickeners. This gel-like layer creates a perfectly clear border with the transparent portion of the treated water and gives stability to the sediment deposited in the Thickeners. The efficiency of coagulants is a function of the physical and chemical properties of the water sample. Factors affecting the chemical coagulation process are very diverse. The way these factors influence the chemical coagulation process and the interaction of these effects is still quite unclear. Therefore, this research is valid only for the tested water sample and the use of the results of this study for other water samples is not necessarily correct. According to the results of this research, the following suggestions for the continuation of the research are presented:

1) Use of natural polyelectrolytes that can be used as a coagulant and flocculant and is environmentally friendly.
2) A good alternative in terms of performance and economic efficiency for lime is to be determined and used in experiments.
3) This research should be done with other chemical coagulants and flocculants to determine coagulants and flocculants with lower cost and better efficiency.
4) Coagulants and flocculants reviewed in this study that their cost is very low, be modified to improve their performance and can be used to remove phosphorus pentoxide and fluoride.
5) Combine the coagulation process with other methods to achieve the removal of 100% phosphorus pentoxide and fluoride.
6) The effect of temperature as one of the parameters affecting the chemical coagulation process should be investigated.

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