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Evaluation of sodium ferrate as an efficient coagulant for total suspended solids and nematode removal from water

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ABSTRACT

This study aimed to investigate the effect of sodium ferrate (SF) on total suspended solids (TSS) and nematode removal from surface water. Response surface methodology was used to optimize the operational variables such as pH, dosing rate, rapid mixing time, and gentle mixing speed on TSS and nematode removal. The optimum conditions of independent variables including SF dosage, pH, rapid mixing (time and speed), and gentle mix speed were found to be 1.558 (mg/L), 6.5, 30 s at 120 rpm for coagulation followed by 20 min of gentle mix. TSS and nematode removal of 90.76 and 98.04 were observed for SF in optimized conditions, respectively. SF demonstrated 4.3% and 5.76% more TSS nematode removal at a lower dosage compared with poly aluminum chloride, polyelectrolyte, and primary and secondary ozonation. Economic analysis showed that the application of SF instead of using conventional chemicals provides a significant reduction in operational costs to around 65%, which mainly belonged to the reduction of chemicals and energy consumption.

Keywords: Sodium ferrate; TSS; Nematode; Water treatment; Response surface methodology

1. Introduction

Natural waters contain a wide variety of particulate impurities. These consist of inorganic substances such as clays and metal oxides and organic colloids such as viruses, bacteria, protozoa, and algae [1]. In water treatment plants, pollutants such as total suspended solids (TSS) and nematode are usually removed with a combination of coagulation and flocculation, settling tanks, and sand filtration. Chemical reagents injected into the water stream to increase the effectiveness of the settling or filtration process [2]. Many oxidants, disinfectant, and coagulants are widely used in conventional water treatment processes, which all are efficient in pollutant removal from water. The cost of achieving the desired level of water quality depends primarily on the cost and the availability of the coagulation agents [3]. These coagulants are often expensive, and in many developing countries, they have to be imported. In addition, high sensitivity of coagulants to pH and the possibility of production of secondary contamination of drinking water with traces of toxic synthetic polymeric coagulants or residual iron and aluminum ions are the main challenges of flocculation-coagulation water treatment processes [4]. To overcome these drawbacks, novel low-cost multiple role (coagulation, disinfection, and oxidation)

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chemicals are investigated. Ferrate as an iron(VI) derivative is a powerful oxidizing agent over a wide pH range with its standard reduction potential varying between +2.2 and +0.7 V in acidic and basic conditions, respectively, as shown in Eqs. (1) and (2) [5,6]. Under acidic conditions, ferrate(VI) has the strongest reduction potential [7,8].

$$FeO_4^{-2} + 8H^+ + 3e^- \rightarrow Fe^{3+} + 4H_2O \qquad E^0 = +2.2\ \text{V} \tag{1}$$

$$FeO_4^{-2} + 4H_2O + 3e^- \rightarrow Fe(OH)_3 + 5OH^- \qquad E^0 = +0.72\ \text{V} \tag{2}$$

Ferrate(VI) is the hexavalent oxidation state of iron that more stable than ferrate compounds (such as IV and V) known as environmental friendly compounds. In aqueous solution, the ion FeO_4^- (tetraoxoferrate(VI) ion) is a monomer having a tetrahedral structure with a high degree of four covalent character equivalent Fe–O bonds [8,9]. During the aqueous oxidation reactions, Fe(VI) is reduced to nontoxic ferric(III) floc which is then hydrolyzed to form the insoluble iron III (hydroxide), a conventional coagulant depending on pH and dose [10]. That implies ferrate is a multifunction chemical reagent for water treatment, which will act as an oxidant, disinfectant, and coagulant [11]. This combined feature in water treatment process brings about many benefits such as higher water quality and lower operational and capital costs [12,13]. Ferrate(VI) is an efficient coagulant in removing metals, nutrients, radionuclides, and humic acids [8,14–16]. In previous studies, ferrate was found to be a promising multifunctional chemical reagent compared with traditional oxidants and coagulants such as Ferrous sulfate and Ferric nitrate [13,15], Ferric chloride and Alum, Ferro sulfate [14,15], and ozone and chlorine [2,17]. Despite the positive effects of this substance on three parameters removal, because of the complicated, time consuming and therefore costly production process of ferrate in a solid form, the use of ferrate could not be technically and economically justified to the required extent, at least in the drinking water treatment process [9,14]. The mechanism of ferrate function as a coagulant results from the degradation of ferrate in contact with water, which results in the conversion of hexavalent iron (Fe(VI)) into Fe(V), Fe(IV), and Fe(III) [16,18,19]. Hexavalent ferrate turns into pentavalent ferrate by losing one electron and turns into trivalent hydroxide by losing two electrons [20,21]. This hydroxide plays a high coagulating role in the removal of pollutants [22]. In addition, the reaction between ferrate and water produces oxygen, OH^-, and trivalent iron, which are nonharmful products [22,23]. Synthesis and application of sodium ferrate (SF) for TSS and nematode removal were first studied in this work and results are compared with performance of conventional chemicals.

2. Material and methods

2.1. Synthesis of SF

All chemicals applied in the experiments were analytical grade purchased from Merck Co, Germany. SF (Na_2FeO_4) was prepared in the laboratory by wet oxidation method. To synthetize SF, a 500 mL flask was placed inside a 1 L vessel. The space between two vessels was filled with ice-water to keep the temperature below 20°C. The contents of inner vessel were mixed by using an electromagnetic stirrer (Model 1 ka, Iranian Pars Co) and its speed was set up on 350 rpm. First, 31 mL of NaClO (liquid) was poured in inner vessel and cooled by an ice bath covering the container. This vessel was put on a magnetic stirrer with a rotatory speed of 350 rpm in a 5 min period. Then, 56 g of NaOH was removed with a pipette and injected slowly to the NaOH vessel. After mixing at 450 rpm for 12 min, 3.71 g ferric chloride (40%) was slowly injected to the bottom of the reactor mixture. After 15 min, (a red-violet color) SF was produced [6].

2.2. Characterization of SF

Crystalline phase, morphology, and chemical composition of SF were investigated by X-ray diffraction (XRD) (Models X.Pevt-MPD-Philips Netherlands & Asenware and AW-XDM300-Netherlands), scanning electron microscopy (SEM) (SEM-Philips- XL30 Netherlands), and Energy-dispersive X-ray spectroscopy (EDS) (EDS-Seron AIS 2300/ seron-Korea), respectively. Peak adsorption of SF was measured by UV/VIS [24]. Yield, purity, and concentration of SF were derived from Eqs. (3) and (4) and volumetric titration, respectively [17,24,25].

$$\text{Yield} = \frac{\left(1{,}000\text{PS}\varepsilon\text{L}\right)}{\left(\text{MW}_{\text{FeCl}_3}\right)\text{VA}} \times 100 \tag{3}$$

where "ε" equals 1,070 M^{-1} cm^{-1} (molar absorbance coefficient), "*A*" is UV-vis absorbance, "*V*" is the volume of sample (mL), and "MW_{FeCl3}" is the molecular mass of $FeCl_3$ [14,23].

$$P = \frac{\left(A \times V \times M\right)}{\left(\varepsilon \times W\right)} \times 100 \tag{4}$$

where "*P*" is the used Ferric Chloride percent, "*S*" is the mass of Ferrate sample (g), and "*M*" is molecular weight of SF (g/mol).

2.3. Experimental design and optimization

The statistical relationships among four independent factors (SF dosage (mg/L), rapid mix time (s), gentle mix speed (rpm), and pH) for removal of TSS and nematode egg were assessed through response surface methodology (RSM)-d-optimal (Table 1). The Design Expert Software (version 10) was used for the statistical design of experiments and data analysis. The appropriate model is the quadratic model (Eq. (5)) as follows [26,27]:

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \left(\sum_{i=1}^{k} b_{ii} x_i\right)^2 + \sum_{i=1}^{k-1} \sum_{j=1}^{k} b_{ij} x_i x_j \tag{5}$$

Table 1
Levels of independent variables

Variables	Levels				
Level of value	−2	−1	0	1	2
SF dosage (A)	1	2	3	4	5
pH (B)		6.5	7.5	8.5	
Gentle mixing speed (C) (rpm)	40		60, 50, 40 (60)		
Rapid mixing Time (D) (min)	30		60		

where Y is the predicted response, X_i and X_j are the independent variables, b_0 is the constant coefficient, and b_i, b_{ii}, and b_{ij} are the interaction coefficients. To evaluate optimum conditions, four alternatives were defined based upon time and speed of gentle mixing (Table 2). In the second (60 × 30) and fourth (60 × 60) alternative, instead of only one mixing time and speed, these two dependent variables are divided to three subconditions, that is, firstly 7 min of slow mixing with 60 rpm, then 7 min with 50 rpm and finally 6 min with 40 rpm for flocculation.

Results of optimizations were compared with those extracted from using poly aluminum chloride. Coagulation experiments were carried out using a standard jar test apparatus (Model JLT6 made by Velp Co) [2]. TSS and nematode were measured according to standard methods for examination of water and wastewater [28].

3. Result and discussion

3.1. SF characterization

Aqueous solution of ferrate ion has a red-violet color, which corresponds to the visible adsorption spectrum at about 300–800 nm [8]. The peak adsorption spectrum for SF equals to 505 nm, which is similar to adsorption spectrum of potassium ferrate at 505 nm (in previous result obtained by other researchers (500–515 nm)) [19,29]. The concentration, purity, and yield of the produced ferrate were calculated to be 9.15 g/L, 71.14% and 67.19% respectively [27], which were a little more than the results reported in literature [16,19]. The elements distribution prepared by EDS analysis for synthetized SF demonstrated high similarity of elemental weight percentage (Fig. 1) showing the presence of O, Na, and Fe. The XRD patterns (Fig. 1) of synthetized SF were well matched with the standard patterns of SF particles according to standard card JCPDS Card Number: 1-0835 and JCPDS Card Number: 25-0652, which were derived by previous researchers [8]. In this pattern, it can be seen clearly a broad peak at 2θ value of 29.3°, 33.153°, and 33.926° [27].

3.2. Analysis of ANOVA

Table 3 presents the ANOVA analysis of parameters of the predicted response surface quadratic models and other statistical parameters for TSS and nematode egg removal. Data demonstrated that all of the models were significant at the 95% confidence level, given that p values were less than 0.05, which is a good index to show the reliability of the statistical analysis [24,30,31]. According to the results of ANOVA analysis for TSS removal using SF, a high correlation coefficient (R^2) of 0.816 was observed, indicating that 81.6% of the variations for SF are accounted by the independent variables. A high R^2 value close to 1 illustrates good agreement between the calculated and observed results within the range of experiment and shows that a desirable and reasonable agreement with adjusted R^2 is necessary [18]. The "Pred R^2" of 0.7635 is in reasonable agreement with the adjusted-R^2 of 0.7619, which implies good agreement between the observed and predicted values of TSS removal. Also, nematode removal had a similar condition, so that the amount of three coefficients (including R^2, adjusted-R^2, and pred R^2) were near each other and also standard value (equal to 1), as shown in Table 3. The "Adequate Precision" ratio of the models varied between 15.424 and 21.663 for TSS and nematode which is an adequate signal for the model. Adequate Precision values higher than four are desirable and confirm that the predicted models can be used to navigate the space defined by the d-optimal [22,32]. The coefficient of variation for TSS and nematode equal to 2.42% and 1.92%, respectively, which all are less than 10%, confirmed the suitability of d-optimal modeling for SF. In addition, the F-value of TSS and nematode was 15.08 and 39.81, respectively, confirming that the model is significant. There is only a 0.01% chance that an "F-value" model is larger than noise value. Furthermore, based on data reported in Table 3, the p-value of 0.0001 is lower than 0.05. Values of "$p > F$" less than 0.05 indicate that the model terms are significant [33,34]. In this case, for TSS, the significant terms were A, B, C, D, and B^2 and in addition to earlier mentioned terms, another significant terms were AB for nematode. The final regression models, in terms of their coded and actual factors, are presented in Eqs. (6) and (7) as follows:

$$Y_{\text{TSS}} = 92.079 + 3.25\text{A} + 0.873\text{B} + 2.569\text{C} - 1.327\text{D} - 1.98\text{B}^2 \tag{6}$$

$$Y_{\text{Nematode}} = 93.24 + 2.53\text{A} - 4.81\text{B} + 1.99\text{C} - 0.84\text{D} + 2.39(\text{A} \times \text{B}) - 2.75\text{B}^2 \tag{7}$$

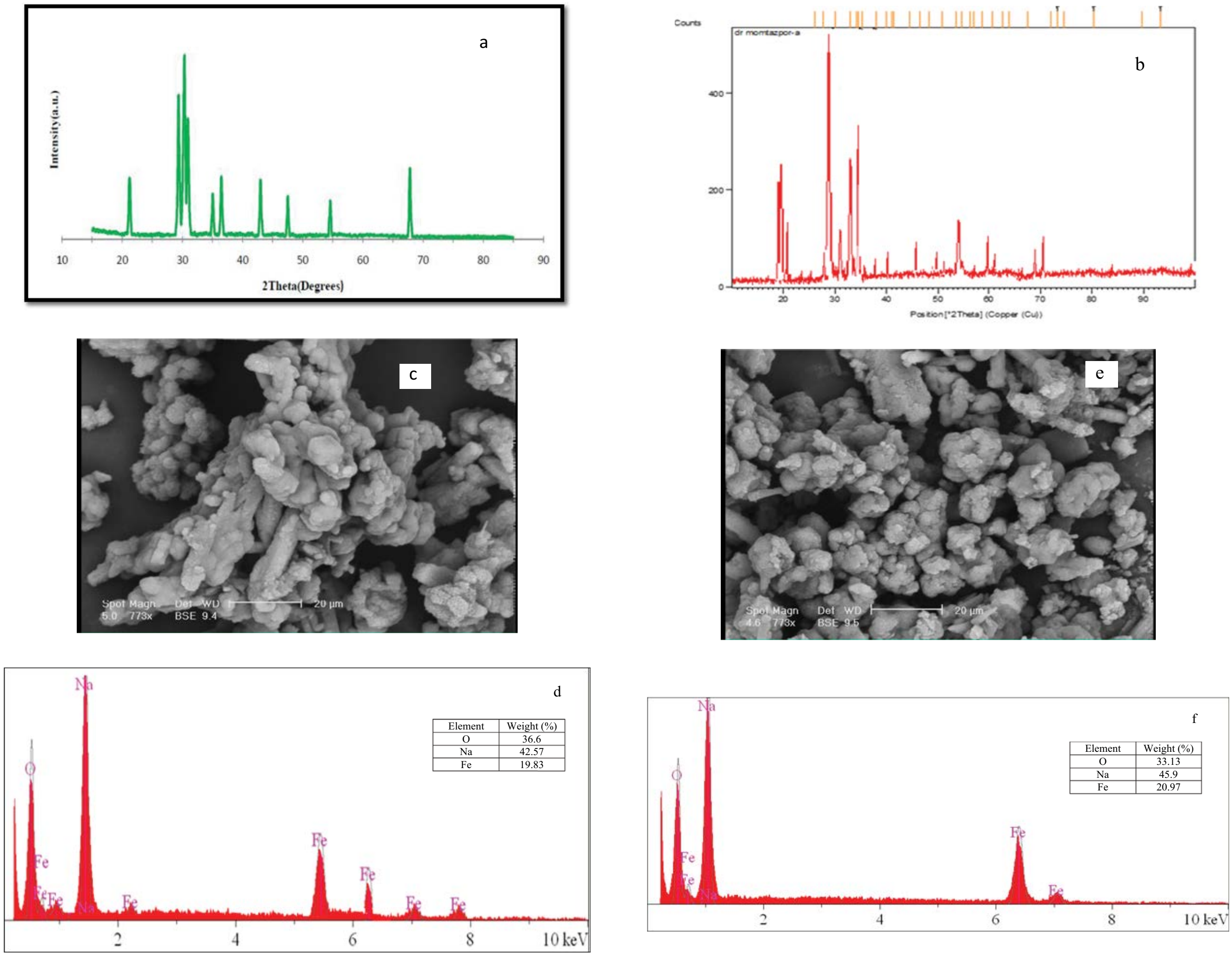
The comparison of removals of experimental results and the model's prediction (Table 4) indicate a close relationship for all variables.

3.3. Response surface analysis for variables

To confirm if the selected model provides an adequate approximation, the normal probability plots of the studentized residuals and diagnostics were provided.

Table 2
Operational conditions of rapid mixing and gentle mixing

Alternative	Symbol	Rapid mixing		Gentle mixing		Sedimentation time (min)
		Time (s)	Speed (rpm)	Time (s)	Speed (rpm)	
1	60 × 40	60	120	20	40	30
2	30 × 60	30		6–7–7	40–50–60	
3	30 × 40	30		20	40	
4	60 × 60	60		6–7–7	40–50–60	



Element	Weight (%)
O	36.6
Na	42.57
Fe	19.83

Element	Weight (%)
O	33.13
Na	45.9
Fe	20.97

Fig. 1. XRD patterns of SF synthetized from original chemicals in this study (a) compared with that synthetized from other studies (b), FE-SEM images of SF synthetized from original chemicals (c) along with EDS analysis (d) compared with that synthetized from other studies (e) along with EDS analysis (f).

Figs. 2(a) and (e) demonstrate the normal probability plots of the standardized residuals for TSS and nematode removal. A normal probability plot (Figs. 2(b) and (f)) indicates that if the residuals follow a normal distribution, as the points will follow a straight line for each case. Accordingly, the data can be possibly considered as normally distributed in the responses of certain models. Residual is defined as a difference between experimental and predicted values of TSS and nematode removal calculated in order to evaluate the adequacy of the model. According to Figs. 2(c) and (g), the points are near diagonal line indicating the low discrepancies between them and variables removal. The "residuals" (externally studentized residuals) were plotted versus run numbers (Figs. 2(d) and (h)), in which all results indicated high reliability of the obtained data.

3.4. Interaction between operational variables

To assess the interactive relationships between independent variables and the responses of certain models, the 3D surface response plot was utilized. TSS removal (SF) was affected by pH and dosage rate increase up to around of 4 mg/L and thereafter remained constant (Fig. 3(a)). The pH increase had a positive effect on the removal efficiency of TSS and negative effect on the removal efficiency of nematode egg (Figs. 3(b) and (c)).

3.5. Determination of optimum conditions and experimental confirmation

The desired goal for each operational condition (SF dosage, pH, rapid mixing time, and gentle mixing speed) was chosen "within" the range. The responses (TSS and nematode removal) were defined as maximum to achieve the highest performance. Accordingly, the optimum working conditions and respective percent removal efficiencies were established, and the results are presented in Table 4. A TSS and nematode removal of 90.76% and 98.04% were predicted for using SF, respectively. Based on the model results, operational condition of (30 × 60) (alternative 2) was

Table 3
Analysis of ANOVA for the effect of variables on TSS and nematode removal

TSS						Nematode					
Source	Sum of squares	*df*	Mean square	*F*	*p*-value ($p > F$)	Source	Sum of squares	*df*	Mean square	*F*-value	*p*-value ($p > F$)
Model	357.91	5	71.58	15.08	<0.0001	Model	716.09	6	119.35	39.81	<0.0001
A-DOSE	136.55	1	136.55	28.77	<0.0001	A-DOSE	82.51	1	82.51	27.52	<0.0001
B-PH	10.12	1	10.12	2.13	0.1624	B-PH	303.72	1	303.72	101.30	<0.0001
C-SPEED SLOW	150.50	1	150.50	31.71	<0.0001	C-SPEED SLOW	89.78	1	89.78	29.94	<0.0001
D-TIME FLASH	38.34	1	38.34	8.08	0.0113	D-TIME FLASH	15.44	1	15.44	5.15	0.0374
B2	21.21	1	21.21	4.47	0.0496	AB	43.50	1	43.50	14.51	0.0015
Residual	80.70	17	4.75			B2	39.88	1	39.88	13.30	0.0022
Lack of fit	59.71	12	4.98	1.19	0.4556	Residual	47.97	16	3.00		
Pure error	20.98	5	4.20			Lack of fit	36.27	11	3.30	1.41	0.3715
Cor total	438.60	22				Pure error	11.70	5	2.34		
Variable	R^2	R^2 adjusted	Pred R^2	Adequate precision	Coefficient of variation	Cor total	764.06	22			
TSS	0.816	0.7619	0.7635	15.424	2.42%	Variable	R^2	R^2 adjusted	Pred R^2	Adequate precision	Coefficient of variation
						Nematode	0.9372	0.9137	0.8826	21.663	1.92%

Table 4
Experimental and predicted removal efficiency of TSS and nematode removal

Run no.	Independent variable				TSS removal (%)			Nematode removal (%)		
	A	B	C	D	Experimental (%)	Predicted (%)	Residuals	Experimental (%)	Predicted (%)	Residuals
1	4	7.5	60	60	86.46	88.09	−1.63	83.35	82.07	1.28
2	7	8.5	60	30	87.32	87.58	−0.26	91.11	89.56	1.55
3	2	8.5	40	60	89.22	88.18	1.04	91.16	90.41	0.75
4	7	7.5	60	60	91.05	91.23	−0.18	93.45	94.29	−0.84
5	2	7.5	60	30	84.32	86.94	−2.62	94.25	92.54	1.71
6	4	6.5	60	30	97.98	99.22	−1.24	99.99	98.62	1.37
7	5	8.5	40	60	93.22	91.48	1.74	97.81	98.08	−0.27
8	4	7.5	60	60	88.98	91.34	−2.36	85.23	86.99	−1.76
9	2	8.5	60	60	93.39	91.48	1.91	97.20	98.08	−0.88
10	7	6.5	60	30	93.67	93.71	−0.039	96.11	96.60	−0.49
11	7	8.5	40	60	89.12	92.20	−3.08	88.91	86.84	2.07
12	2	6.5	60	60	84.39	83.81	0.58	80.02	77.92	2.10
13	7	7.5	60	60	88.34	90.06	−1.72	93.07	91.87	1.20
14	2	8.5	40	30	94.21	90.32	3.89	87.87	87.77	0.10
15	2	7.5	40	60	92.90	90.83	2.07	92.24	92.09	0.15
16	6	7.5	60	30	97.67	99.22	−1.55	98.84	98.62	0.22
17	7	6.5	40	60	82.98	84.92	−1.94	84.81	87.88	−3.07
18	2	6.5	40	30	90.39	88.18	2.21	87.67	90.41	−2.74
19	5	8.5	40	30	94.67	92.20	2.47	85.89	86.84	−0.95
20	6	7.5	60	30	87.57	88.95	−1.38	79.90	81.92	−2.02
21	7	7.5	40	30	91.45	90.06	1.39	92.43	91.87	0.56
22	7	6.5	40	60	93.11	91.60	1.51	82.78	83.60	−0.82
23	7	7.5	40	30	81.25	82.06	−0.81	93.10	92.33	0.77

better than normal conditions of water treatment plants. On the other hand, the widest removal range occurred when the rapid mixing time changed from 60 to 30 s and the speed of flocculation changed from 40 rpm and 20 min (which is the normal condition in the water treatment plant) to 60, 50, and 40 rpm in 20 min (30 × 60) (alternative 2). One of the reasons for this issue may be due to breaking the flocks at mixing state with a constant speed rate and more duration compared to state with stepwise mixing rate. Results obtained for synthetized SF at the optimum condition (30 × 60) (alternative 2) showed up to 4.3% and 5.76% increase in TSS and nematode removal over conventional conditions of water treatment (40 × 60) (alternative 1). This can be explained by this fact that, SF due to its multifunctional impact, in addition to being a strong oxidizer and disinfectant, and while is degraded in reaction with water, produces a useful byproduct; namely, trivalent iron which plays a coagulating role, and is capable of reducing the TSS. In fact, the mechanism of reaction using SF is based on the rapid degradation of hexavalent ferrate into trivalent iron hydroxide when reacted with water. Therefore, under appropriate conditions in rapid mixing and gentle mixing, the produced iron hydroxide produces coarse-grained flocs through reacting with water constituents, in a way that would be removed in a sedimentation tank within a short time (under 10 min). Effects of four independent variables are shown in Table 5.

3.6. Residual Fe

In ferrate production as a Fe-based substance, cautions should be taken, since the value of Fe in drinking water should be limited to standard range and therefore, it is very important to check the Fe concentration in final treated water. Result showed that the residual Fe was in the range of 0.23–0.89 mg/L with dosing rate of 4–mg/L of ferrate, respectively. In fact, after sedimentation, water contained the residual Fe more than standard dosing rate of 3 mg/L (about twice as much as that of standard value). To solve this problem, the effect of simulated filtration such as Isfahan treatment plant process was implemented. The pilot filter was comprised of a cylindrical container with height of 120 cm, diameter of 15 cm and graded filter layers of 80 cm silica sand (2.65 g/cm^3), and 40 cm anthracite (1.5 g/cm^3). Result showed the residual Fe after filtration ranged between 0.14 (for dosing SF less than 3 mg/L) to 0.32 mg/L (for dosing SF more than 3 mg/L). In fact, the filtration can reduce the Fe residue about 50% for the SF dosing rate of less than 3 mg/L, and for more values, it stays around standard rate.

3.7. Technical and economical evaluation

In the economical assessment, all the constructional costs such as civil works, equipment, and also all operational costs such as personnel, chemicals, electricity, and other costs

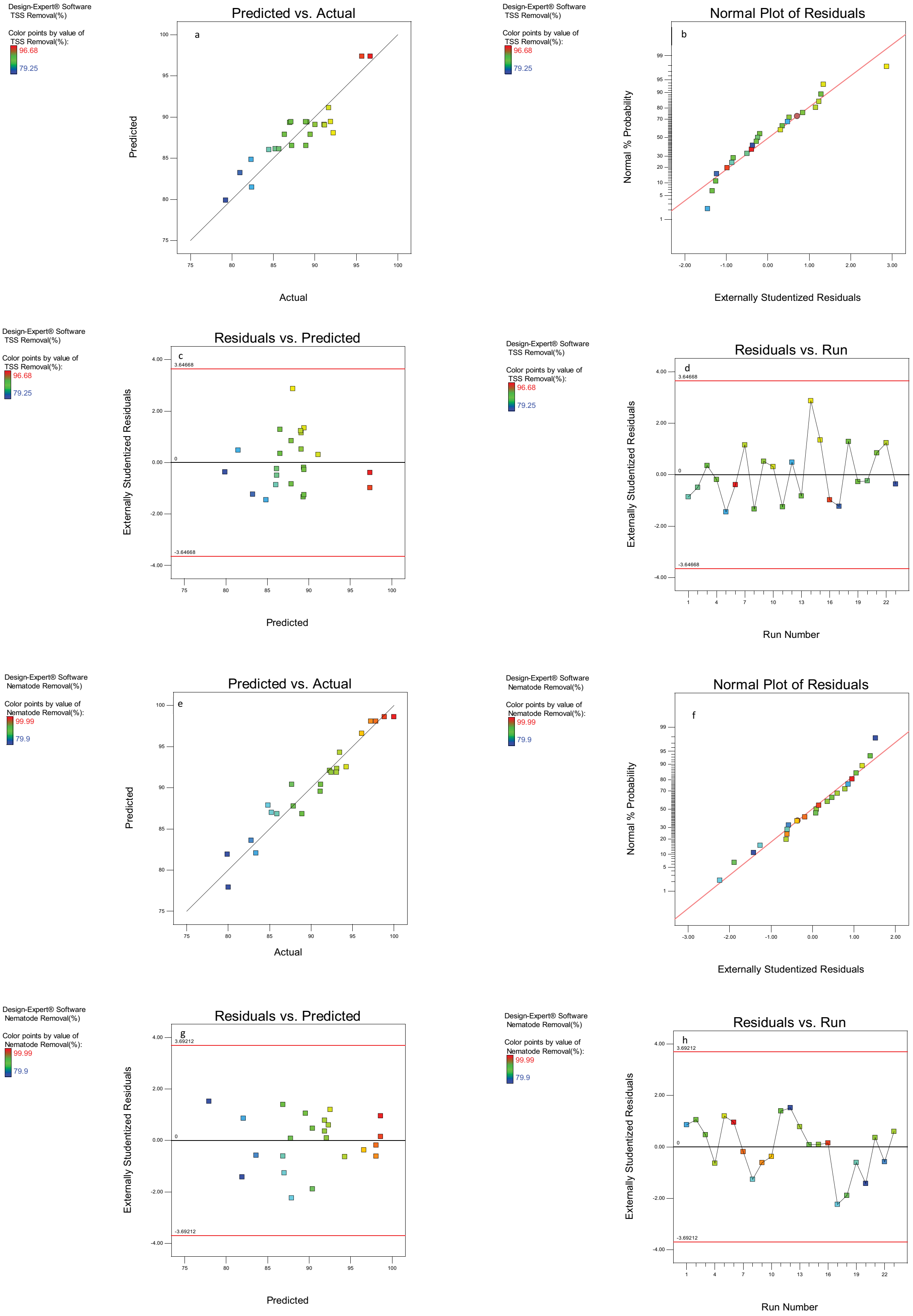


Fig. 2. Plots of predicted versus observed TSS removal (a), nematode egg removal (e), normal plot of residual (b and f), externally studentized residual than predicted (c and g), externally studentized residuals than run number (d and h).

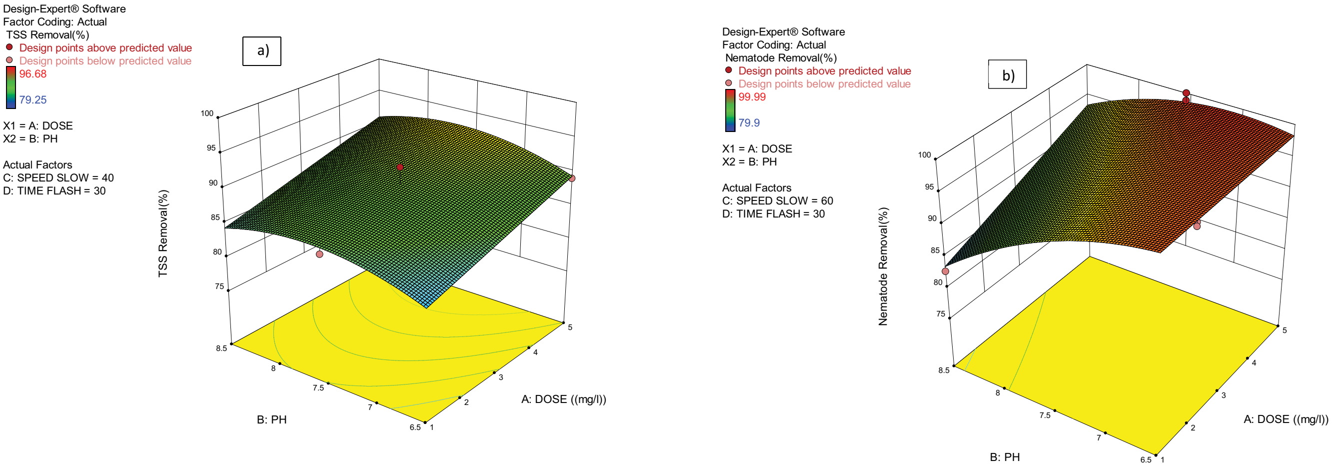


Fig. 3. The 3D surface plots of combined effect of studied variables on turbidity removal, TSS (a), nematode egg (b).

Table 5
Solutions for four combinations of categorical factor levels

Alternative	Variables				Removal efficiency (%)	
	Dosage (mg/L)	pH	Rapid mixing speed (rpm)	Gentle mixing time (S)	TSS	Nematode
1	1.558	6.50	60	30	90.76	98.04
2	2.025	6.52	60	60	88.97	96.38
3	2.522	6.75	40	30	88.29	93.97
4	2.811	6.85	40	60	86.46	92.28

Table 6
Comparison the efficiency of SF with conventional chemicals in samples obtained from Esfahan water treatment plant, Iran

Parameter removal (%)	Local					
	Primary ozonation	Coagulation	Secondary ozonation	Filter	Primarychlornation	Outlet
Conventional treatment with (3 mg/L PAC + 1 mg/L CL2 + 1 mg/L Ozone + 0.5 mg/L polyelectrolyte)-before filtration						
TSS	+11.84[a]	68.32	81.17	91.76	+16	93.53
Nematode	10	30	70	80	+30	80
SF						
Alternative	Dosage (mg/L)	pH	Gentle mixing speed (rpm)	Rapid mixing Time (s)	TSS removal (%)	Nematode removal (%)
SF	1.558	6.50	60	30	90.76	98.04

[a] The number with positive sign shows variable increase during material dosing.

were considered. The lifetime of the project was assumed to be 35 years and for the equipment 20 years. The interest rate was 8%. The finished price per cubic meter of water derived from economical assessment was 0.0034$ and 0.01$/m^3 for SF and conventional chemicals (poly aluminum chloride, primary and secondary ozonation, and primary chlorination), respectively. Consequently, the use of SF instead of conventional chemicals led to lower costs of operation, up to 65%. To investigate the possibility of replacing SF with conventional chemicals used in water treatment process including chlorine, ozone, and poly aluminum chloride, the samples were derived from seven points of treatment process. The sampling points included inlet, after bar screen (where primary ozonation is carried out), after secondary ozonation, at the point of primary chlorination, after filtration and at the outlet. Results showed there is a significant increase for TSS and nematode removal efficiency, when using SF instead of conventional chemicals, with lower SF consumption (Table 6). This proves the positive result for using SF instead of conventional chemicals in water treatment plants.

4. Conclusions

Results demonstrated that SF is an efficient agent in water treatment practices yielding a TSS and nematode removal of 90.76% and 98.04%, respectively. Results indicated that 4.3% and

5.76% increase would be obtained in TSS and nematode removal compared with conventional chemicals (poly aluminum chloride and polyelectrolyte) at a lower dosage. The optimum amounts of independent variables including SF, pH, rapid mixing (time and speed), and gentle mix speed were found to be 1.558 (mg/L), 6.5, 30 s of rapid mixing (120 rpm) for coagulation followed by 20 min of gentle mix speed (60 rpm for 7 min, 50 rpm for 7 min, and 40 rpm for 6 min) for flocculation. The using of only one chemical material instead of several chemicals (poly aluminum chloride and polyelectrolyte in Esfahan treatment plant), not only reduces the costs but also prevents the production and entrance of harmful chemical sludge into the environment, or at least reduces the costs of recycling these materials. Application of SF instead of using conventional chemicals provides a significant reduction operational costs, around 65%. The result showed residual Fe after filtration ranging between 0.14 (for dosing Na_2FeO_4 less than 3 mg/L) to 0.32 mg/L (for dosing Na_2FeO_4 upper 3 mg/L). Therefore, it stays around standard rate.

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