Desalination and Water Treatment
www.deswater.com
doi:10.5004/dwt.2017.20319

68 (2017) 122–128
March

Removal of turbidity and organic matter from car wash wastewater by electrocoagulation process

Mohammad Javad Mohammadi[a,b], Jila Salari[c], Afshin Takdastan[d,*], Majid Farhadi[c], Parviz Javanmardi[e], Ahmad Reza Yari[f], Sina Dobaradaran[g], Halime Almasi[b], Somayeh Rahimi[a]

[a]*Abadan School of Medical Sciences, Abadan, Iran, email: javad.sam200@gmail.com (M.J. Mohammadi), rahimi_s97@yahoo.com (S. Rahimi)*
[b]*Student Research Committee, Department of Environmental Health Engineering, School of Public Health and Environmental Technologies Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran, email: javad.sam200@gmail.com (M.J. Mohammadi), h.almasi14@yahoo.com (H. Almasi)*
[c]*School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran, email: Salari.124@gmail.com (J. Salari), mirmajidfarhadi@yahoo.com (M. Farhadi)*
[d]*Associate Professor, Environmental Technologies Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran, Tel. +989123470776, email: afshin_ir@yahoo.com*
[e]*Department of Environmental Engineering, School of Agricultural, Islamic Azad University, Ahvaz Sciences Branch, Ahvaz, Iran, email: Javanmardi.p12@gmail.com*
[f]*Research Center for Environmental Pollutants, Qom University of Medical Sciences, Qom, Iran, email: yari1ahr@gmail.com*
[g]*Department of Environmental Health Engineering, Faculty of Health & the Persian Gulf Marine Biotechnology Research Center, the Persian Gulf Research Center, Bushehr University of Medical Sciences, Bushehr, Iran, email: sina_dobaradaran@yahoo.com*

Received 9 June 2016; Accepted 31 October 2016

ABSTRACT

Car wash effluent is one of the important threats that can contaminate water resources for drinking, agriculture and industrial uses in Iran. The purpose of this study was assessment and analysis of the efficiency of the electrocoagulation process in the removal of turbidity and organic matter from car wash effluent. Data were taken through laboratory scale and sampling from different car wash sewages of Ahvaz, Iran. In this experimental study, we used a bipolar method to convert alternative electricity to direct current. The important factors of our study were pH, electrical potential, voltage and reaction times. Results show that the percentage of turbidity removal in the electrocoagulation (EC) with an aluminum electrode (E) with an optimum pH = 7 were 75 and 99.59 in 10 and 30 voltages, respectively. According to results, the percentage of chemical oxygen demand (COD) removal in the electrocoagulation with an iron electrode with an optimum pH = 3 were 67 and 94 in 10 and 30 voltages. Consequently, electrocoagulation is a comparatively suitable process for turbidity and organic matter removal from car wash wastewater.

Keywords: Car wash effluent; Electrocoagulation; Turbidity removal; Aluminum electrode; Iron electrode

*Corresponding author.

1. Introduction

In recent years, detergents, turbidity and organic matter from wastewater are one of the main and vital threat (eutrophication phenomenon and production of synthetic foam) for the source of drinking water, agriculture and industrial uses in Ahvaz, Iran that threaten human health [1–5]. Wastewater quality analysis is one of the important issues in water and wastewater studies [6–14]. This pollutants are slow biodegradable and there is no fast break in conventional treatment. Because of the availability conditions, especially in the pond aeration and mixing, foam is produced which disturbs the treatment process because of the high volume and also creates many risks for the refinery workers [10,11,15,16]. Prevention and treatment degradation can very useful for groundwater and surface water resources [11]. Different approaches have been applied for contaminants effluent removal of the environment including physical, biological, chemical and physical-chemical operational processes [2,17–24]. Many methods can be used for treatment BOD, COD, proteins, oils, detergents, paints and solutions containing heavy metals [11,20,25,26]. Electrochemical methods for the wastewater treatment, such as electrocoagulation and electrochemical separation are permanently increasing [27]. Iron and aluminum are the main electrodes which were using for the electrochemical method [19,21,28]. The mechanism happened in electrocoagulation is similar to coagulation reaction and refining with AL salt [29]. The predominant mechanism of electrocoagulation will exchange operating parameters and types of emissions. Electrocoagulation imports electrochemically metal cations in situ, using the following equations:

$$\text{Anode: } M \rightarrow M^{n+} + ne^{+} \quad (1)$$

$$\text{Cathode: } 2H_2O + 2e^{-} \rightarrow 2OH^{-} + H_2 \quad (2)$$

After determining the predominant type by soluble PH, cations hydrolyzed in water form hydroxide. The following equations [18]:

PH ↓

$$E = H_2O \rightarrow EOH^{2+} + H^{+} \quad (3)$$

$$EOH^{2+} + H_2O \rightarrow E(OH)_2^{+} + H^{+} \quad (4)$$

$$E(OH)_2^{+} + H_2O \rightarrow E(OH)_3^{0} + H^{+} \quad (5)$$

$$E(OH)_3^{0} + H_2O \rightarrow E(OH)_4^{-} + H^{+} \quad (6)$$

When you use the iron and aluminum electrodes, the type of reaction that happens is the same. Electrocoagulation processes play significant role in treating various wastewater effluents due to its several advantages including high treatment efficiency, process simplicity, low operating and capital cost, reduction or absence of adding chemicals, and high filterability of treated solution [30,31]. Therefore, this processes could be used as an effective and reliable method for reducing or removing a large variety of pollutants in wastewaters [30–32]. During the recent years, several studies were conducted to evaluate the usage of an electrocoagulation process with iron and aluminum electrodes for removing contamination. Aluminum ions react with water and form insoluble hydroxide and thus take place unstable colloids. Ciorba et al. [28] examined the effect of active substances as synthetic sewage organic matter uses based on aluminum as the electrode material. Mahvi et al. [19] studied the usability of the electrocoagulation process, using aluminum electrodes to remove heavy metal chromium in aquatic environments. Another study has shown the association of electrocoagulation and electro-flotation process for wastewater laundry treatment [22]. Al Momani et al. [1] in their study had shown the relationship between Fenton and Ozone; Also, the impact of them on the oxidation of wastewater containing nitro aromatic compounds. In 2015, in Jordan, Bani-Melhem et al. [2] estimated the efficiency of submerged membrane bioreactor system on the real grey water treatment. In a similar work, Irdimz et al. [24] in Turkey showed the efficiency of removal assessment by aluminum electrodes and electrocoagulation process. In 2011, Tchamango et al. [33] studied the effect of electrocoagulation method to reduce nitrogen, phosphorus, COD and turbidity. Based on the result of their study, electrocoagulation was effective on these pollutants. Onder et al. [25] considered the possibility of removal of the surface-active agents from the solution model and polluted water sample by iron electrodes and electrocoagulation process. An investigation by Al-Qodah et al. [34] showed the association of Thermophilic bacteria and biodegradation of olive mills of wastewater in 2015. Also, in a study, Un et al. [35] used COD removal efficiency assessment by iron and aluminum electrodes. In a similar work, Şengil [36] studied the removal of COD, oil and fats from dairy wastewater by electrocoagulation with direct current. There are no attention to pollution of water resources by wastewater especially car wash wastewater and vital required water for drinking, industrial and agricultural activities in recent years; therefore, the investigation of this trend is important for car wash wastewater management in future. The main objective of this study was to investigate the feasibility of the usage of an electrocoagulation process with iron and aluminum electrodes in removing the turbidity and COD from car wash wastewater.

2. Materials and methods

2.1. Laboratory materials

An experimental study was conducted in the chemical laboratory of Ahvaz Jundishapur University of Medical Sciences of Iran. The effects of pollution were investigated on the continuous flow of electricity washes in the car wash effluent samples; in addition, the effects of variables of electrode type, voltage, retention time and pH on the efficiency of removal were seen. Materials which were needed for testing included: sulfuric acid (H_2SO_4), potassium dichromate ($K_2CR_2O_7$), mercury sulfate ($HgSO_4$), silver sulfate (Ag_2SO_4), potassium hydrogen phthalate ($C_8H_5KO_4$), 3-methyl-2-benzothiazoline hydrazine, developing for solution LR formaldehyde (HCHO), potassium permanganate ($KMnO_4$) and potassium hydroxide (KOH). Equipment which were used in testing included machine photo spectrophotometric meter DR/5000, the AC power supply Tracking Dual JPS-302D, iron and aluminum plate electrodes, glass reactor electrocoagulation, magnetic mixer, oven, hood, pipettes and tube experiment, flask, flasks, graduated cylinders mixing 50 ml pipette 5 mL, 10 mL sample container 1-inch square glass.

2.2. Sampling

Samples of wastewater were collected from different car washes in the city and transferred to the laboratory. The initial concentration of samples have been tested for determination of COD and turbidity. To adjust the primary PH of the solution, the sulfuric acid and one-tenth normal sodium hydroxide were used. Table 1 shows the factors which were affect the electrocoagulation process including retention time, primary pH, voltage and characteristics of the raw carwash wastewater (Table 1).

2.3. Experimental apparatus

A lab-scale reactor with diameters of 15 cm × 15 cm × 15 cm was used for doing this experiment. This reactor was made of glass with a thickness of 10mm with iron and aluminum electrodes with 12 cm × 10 cm × 2 mm dimensions that were upright and a distance of 2 cm from together that the end of each was connected to the DC power supply. Sewage mixing was done, using a magnetic stirrer with a constant speed of 100 rpm. Hydrochloric acid with a weight of 15% was used to clean the electrodes before starting the procedure. The test was assessed in the voltage range of 10, 20, and 30 with the arrangements of AL-AL, AL-Fe, Fe-Fe in the PH domains of 3, 7 and 11 with the intervals of 2 cm. The contact time was 30, 60 and 90 min for each set of pairs of electrodes. In these tests due to the transmission voltage, flow rates were varied between 0.5 to 2 Amp. In each set of experiments, samples were taken from liquid inside of the reactor at specific times. After filtration, according to the DR/5000 UV-Vis HACH spectrophotometer the samples were prepared for testing the parameters; then, their values were determined, using wavelengths which were specified by the device. In addition, the turbidity was measured by a turbidity meter.

Table 1
Parameters measured and characteristics of the raw carwash wastewater used for this study

Parameter	Range	Unit	Raw wastewater Mean ± S.D
PH	3, 7, 11	–	7.08 ± 0.03
Steering time	30, 60, 90	Minutes	–
Voltage	10, 20, 30	Volt	–
Electrode Type	Al-AlFe-Fe,AL-Fe	–	–
Conductivity	–	(mS/cm)	7.6 ± 2.4
Turbidity	–	(NTU)	170 ± 32.5
COD	–	(mg L^{-1})	(480–1560) ± 207.3

3. Results and discussion

Based on the result of our study, the various arrangements under optimal conditions have shown in Figs. 2–7. Results of the voltage, contact time, type of electrode and pH in reducing the turbidity and organic matter were discussed.

3.1. Changes in turbidity due to variations in input voltage during EC

Fig. 2 shows the increase of the turbidity removal in the EC with an optimum pH = 7 with aluminum electrode have been from 75% (in the 10 voltage) to 99.59% turbidity removal (in the 30 voltage), respectively.

According to Fig. 3, turbidity removal in the EC with an aluminum-iron electrode with an optimum pH = 7 have been from 62% (in the 10 voltage) to 87% (in the 30 voltage), respectively.

According to Fig. 4, the removal of turbidity in the EC with iron electrode with an optimum pH = 7 have been from 43 (in the 10 voltage) to 73 (in the 30 voltage), respectively.

3.2. COD concentration changes due to input voltage variations in during EC

According to Fig. 5, the percentage of COD removal in the EC with an aluminum electrode with an optimum pH = 3 have been from 46% (in the 10 voltage) to 88% (in the 30 voltage), respectively.

According to Fig. 6, the percentage of COD removal in the EC with an aluminum-iron electrode with an optimum pH = 3 have been from 36% (in the 10 voltage) to 64% (in the 30 voltage), respectively.

According to Fig. 7, the percentage of COD removal in the EC with iron electrode with an optimum pH = 3 have been from 67% (in the 10 voltage) to 94% (in the 30 voltage), respectively.

3.3. Effect of electrode and array

To determine the effect of the electrode material on removal efficiency, some tests were done in the same conditions such as voltage, retention time and pH between plates with only the change of material. The results of this exper-

Fig. 1. The schematic view of electrocoagulation reactor and how a sampling of reactor.

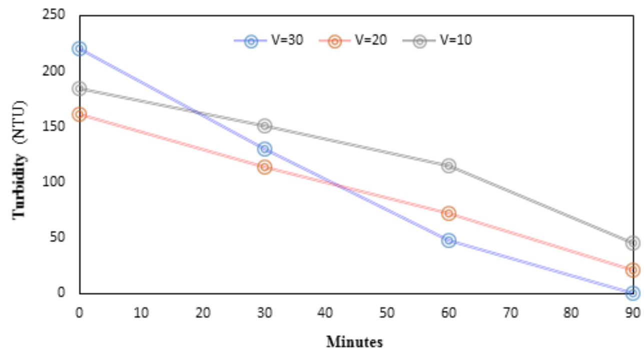

Fig. 2. Effect of applied voltage on turbidity removal efficiency with aluminum electrodes in the optimum pH = 7.

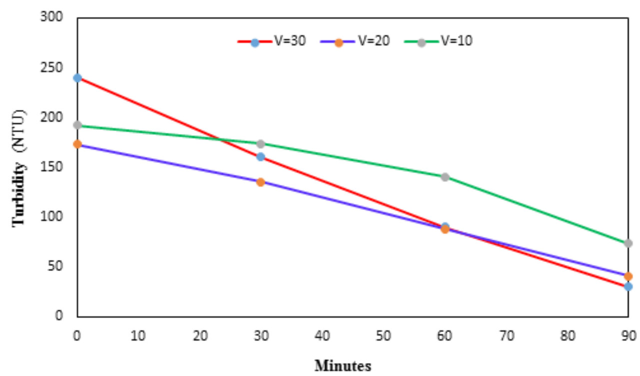

Fig. 3. Effect of applied voltage on turbidity removal efficiency with electrodes made of aluminum– iron at the optimum pH = 7.

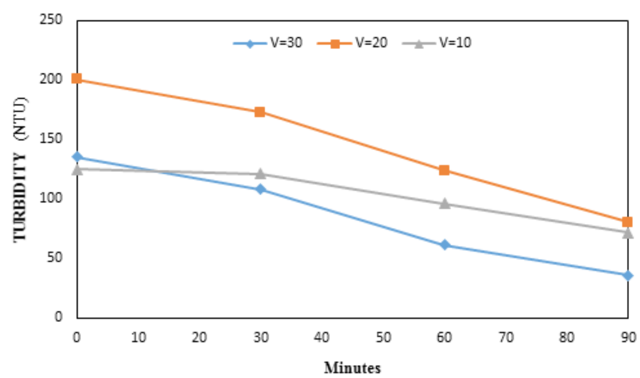

Fig. 4. Effect of applied voltage on turbidity removal efficiency with iron electrodes in the optimum pH = 7.

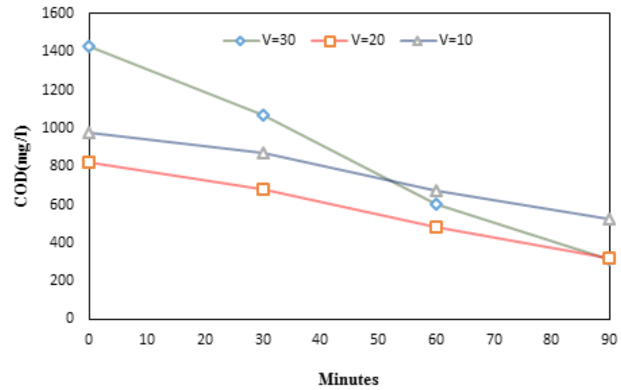

Fig. 5. Effect of applied voltage on COD removal efficiency with aluminum electrodes in the optimum pH = 3.

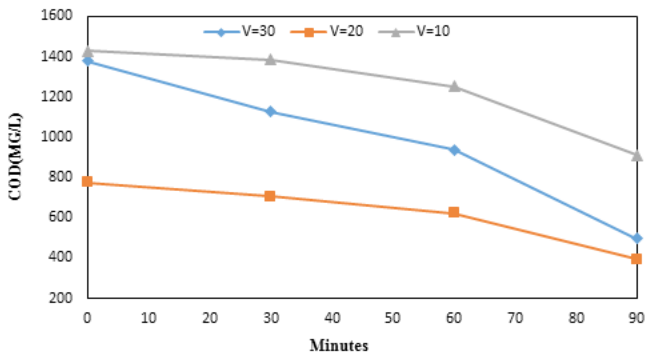

Fig. 6. Effect of applied voltage on COD removal efficiency with aluminum-iron at the optimum pH = 3.

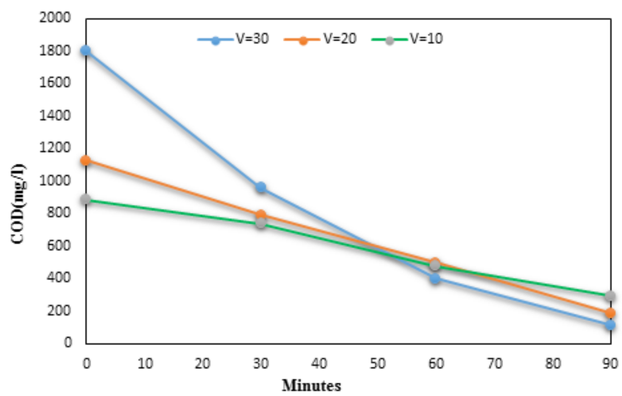

Fig. 7. Effect of applied voltage on COD removal efficiency with iron electrodes in the optimum pH = 3.

iment showed that the type of used electrode was effective for the removal of COD and turbidity. While the use of the iron electrodes was appropriate for achieving the highest COD removal, the highest efficiency of turbidity removal of 100% is achieved when the aluminum electrodes are used. In a study which were conducted by Şengil [36] the removal percentage of COD by iron electrode was 98%. By aluminum electrode, Adhoum et al. [37] attained a COD removal efficiency of 76%. Studies conducted by Un et al. [35] suggested that iron electrode was more effective than aluminum electrode on removal of COD and turbidity as the removal efficiency of COD was 62 to 86% and the efficiency of turbidity removal was 100%. Onder et al. [25] investigated the possibility of removal of surfactants from water contaminated with iron electrodes and they attained a removal efficiency of 100%.

3.4. The effect of voltage

The rates of the removal of the desired parameters which were measured in voltages of 30, 20 and 10 showed that increasing the intensity of the current and voltage were affecting the treatment efficiency of COD. At acidic pH for the iron electrode pair during 90 min at a voltage of 30, the maximum efficiency of COD removal was nearly 94 %. By increasing the potential voltage, the response is increasing. With enough energy, organic compounds can be revived in the cathode, oxidized at the anode and smaller molecules are formed. Some of these small molecules and suspended solids are taken from the molecule 3 (OH) Fe or 3 (OH) AL; then, they formed fluke by settling or flotation mechanisms and are separated by 2H taken in cathode [19–21]. This behavior that filtration efficiency is influenced by voltage is proven by some researchers. For example, in a study, investigating the fluoride removal from water was done, using aluminum electrodes. Drouiche et al. [38] observed that the Al^{+3} amount is increased by increasing the voltage, thereby fluoride ions are eliminated effectively. As well as in studies conducted by Rahmani [39] on the effectiveness of electro-coagulation in removing the COD from wastewater, they concluded that the percentage of COD removal is increased due to increasing the voltage. Chou et al. [40] investigated the possibility of reducing COD and turbidity of wastewater in voltage of 20 and reached the efficiencies of 90 and 98%, respectively.

3.5. The effect of retention time

Increase of an electric coagulation time is important in the process. During the electrolysis, anode reaction occurs in the positive electrode and cathode reaction occurs in the negative electrode. Ions released neutralize the electrical charge of particles and thus coagulation is formed. Removal efficiency depends directly on the concentration of ions produced in the electrodes. With increasing the time of electrolysis, the concentration of produced ions increase, thereby the hydroxide clots increase [17,20]. According to the figure, by increasing the retention time, the removal efficiency is increased.

3.6. Effect of primary PH

The experiments were performed at pH of 11, 7 and 3. According to the results, apart from the COD that had the greatest efficiency removal at acidic pH, turbidity had the greatest efficiency removal at neutral pH. In the course of the electrolysis, when the electrodes of iron or aluminum are used, ions, iron and aluminum are produced at the anode and hydroxyl ion at the cathode, respectively. According to conducted studies, products resulting from hydrolysis such as Al^{3+} and Fe^{3+} involved in the formation and removal of clot [19,24]. There is the possibility of the formation of the various constituents of the hydrolysis products. Also, one or a number of them may be involved in the process [19]. The effect of initial pH on the treatment of the PSW was in a study conducted by Bayramoglu et al. [41] COD removal at pH of 5 was 93% with aluminum electrodes and the removal of TOC was 78% at pH of 5 with electrodes which made by aluminum. In a study by Rahmani [39] on the color removal, it was 96% at pH 3.5 and voltage of 30 with an iron electrode and was 86% with an aluminum electrode. In a study which was conducted by Kobya et al. [42] the removal of the textile wastewater color with an optimum pH of 6.4 was determined, using an aluminum electrode at the time of 12 min. In a study by Adhoum et al. [37] an optimum pH was 6-4, which in this range, treatment olive oil mill without wastewater can be treated during 25 min without the need to adjust the pH with COD removal efficiency of 76%, polyphenols removal efficiency of 91% and the color removal efficiency of 95%.

3.7. The required electrical energy

The electric coagulation operating costs depend on energy consumption in the electric coagulation process. Electrocoagulation electrical energy consumption is calculated in terms of kWh / m^3 of effluent with the following formula:

$$\frac{EE}{V} = \frac{U \times I \times t}{V_r} \tag{7}$$

where U = voltage used in the process (V); I = intensity of the applied current (A); t = reaction time (min); V_r = reactor volume (L).

3.8. Operating cost

The operating cost expressed as \$/m^3 (or \$/kg COD removed) of wastewater treated includes material, mainly electrodes, electrical energy and chemicals used in the process [43]. The comparison is presented in Table 2 and taking into consideration the following parameters:

$$\text{Operating cost} = aC_{\text{energy}} + bC_{\text{electrode}} + cC_{\text{chemicals}} \tag{8}$$

where C_{energy} (consumption kW h energy per m^3 or kg COD or kg TOC), $C_{\text{electrode}}$ (consumption kg electrode per m^3 or kg COD or kg TOC) and $C_{\text{chemicals}}$ (consumption kg chemicals per m^3 or kg COD or kg TOC) of wastewater treated [43]. The comparison shows that the maximum % COD removal is obtained in the present study with low operating cost.

Carwash wastewaters due to numerous pollutants including heavy metals, detergents, surfactants and organic matter can be harmful to human and environment. Electrocoagulation between many treatment processes having to be cost-effective for wastewater treatment with pollutant wide range. Electrocoagulation is a treatment process that is capable of being an effective treatment process as conventional methods. Biological treatment requires specific conditions that limiting the ability to treat many wastewaters whereas electrocoagulation can be used to treat multifaceted wastewaters.

4. Conclusions

In megacities such as Ahvaz, the wastewater especially carwash wastewaters which are enter into the Karun River can be very threaten for this river and espe-

Table 2
The operation costs in the EC process and comparison of various studies

Study	Operating conditions	Influent COD (mg/L)	% COD Removal	Operating cost ($\$/m^3$)
Al-Shannag et al. [30]	60 A/m^2, 30 min, pH = 7.5 (iron electrodes)	2950	97	0.25
Bayramoglu et al. [44]	30 A/m^2, 15 min, pH = 7 (iron electrodes)	2031	65	0.25
Kobya, Delipinar [43]	70 A/m^2, 50 min, pH = 7 (iron electrodes)	2485	69	0.51
Inan et al. [27]	20 A/m^2, 30 min, pH = 6.2 (iron electrodes)	48500	42	–
Present study	30 A/m^2, pH = 3 (iron electrodes)	3511	94	0.28
Un et al. [32]	35 A/m^2, 90 min, pH = 7 (aluminum electrodes)	15000	98.9	0.141
Bayramoglu et al. [45]	30 A/m^2, 15 min, pH = 5 (aluminum electrodes)	27500	93	0.40
Kobya, Delipinar [43]	70 A/m^2, 50 min, pH = 6.5 (aluminum electrodes)	2485	69	1.536
Bayramoglu et al. [44]	30 A/m^2, 15 min, pH = 5 (aluminum electrodes)	2031	63	040
Present study	30 A/m^2, pH = 3 (aluminum electrodes)	3511	88	0.812

cially its creatures, as regards limited dilution capacity of it. In our study, electrocoagulation process with aluminum and iron electrodes in carwash wastewater was investigated. Reaction speed is used to express a reduction in the concentration of reactants and to an increase in the concentration. The reaction rate is a function of temperature, pressure, reactive concentration. The reaction may have zero, one or two that the calculation of the coefficients in this study showed that the degree of reaction is zero. In response of zero degree, speed changes in the concentration are independent to concentration; thus, the speed of changing in the concentration of reactants is always constant.

Acknowledgment

The authors would like to thank student Research Committee, Ahvaz Jundishapur University of Medical Sciences for providing financial supported by grant: (95s45) of this research.

Funding/Support

This work was financially supported by grant: (95s45) from Vice- Chancellor for research Affairs of Ahvaz Jundishapur University of Medical Sciences.

References

[1] F. Al Momani, S. Mo'ayyad, S. Ahmad, A.-S. Mohammad, Impact of Fenton and ozone on oxidation of wastewater containing nitroaromatic compounds, J. Environ. Sci., 20 (2008) 675–682.
[2] K. Bani-Melhem, Z. Al-Qodah, M. Al-Shannag, A. Qasaimeh, M.R. Qtaishat, M. Alkasrawi, On the performance of real grey water treatment using a submerged membrane bioreactor system, J. Membr. Sci., 476 (2015) 40–49.
[3] A. Takdastan, M. Pazoki, Study of biological excess sludge reduction in sequencing batch reactor by heating the reactor, Asian. J. Chem., 23 (2011) 29.
[4] M.H. Nejad, A. Takdastan, N. Jaafarzadeh, M.A. Mogadam, N. Mengelizadeh, Removal of orthophosphate from municipal wastewater using chemical precipitation process in Ahvaz wastewater treatment plant, Iran, Asian. J. Chem., 25 (2013) 25–65.
[5] I. Baraee, S. Mehdi Borghei, A. Takdastan, A.H. Hasani, A.H. Javid, Performance of biofilters in GAC-sand and anthracite-sand dual-media filters in a water treatment plant in Abadan, Iran, Desal. Wat. Treat., 57(42) (2016) 19655–19664.
[6] F. Bateni, S. Fakheran, A. Soffianian, Assessment of land cover changes & water quality changes in the Zayandehroud River Basin between 1997–2008, Environ. Monit. Assess., 185 (2013) 10511–10519.
[7] M.V. Niri, M. Shirmardi, A. Asadi, H. Golestani, A. Naeimabadi, M.J. Mohammadi, M. Heidari, Erratum to: "Reactive red 120 dye removal from aqueous solution by adsorption on nano-alumina", J. Water. Chem. Technol., 36 (2014) 203.
[8] S. Jorfi, G. Barzegar, M. Ahmadi, R.D.C. Soltani, A. Takdastan, R. Saeedi, M. Abtahi, Enhanced coagulation-photocatalytic treatment of Acid red 73 dye and real textile wastewater using UVA/synthesized MgO nanoparticles, J. Environ. Manag., 177 (2016) 111–118.
[9] C.-W. Liu, K.-H. Lin, Y.-M. Kuo, Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan, Sci. Total. Environ., 313 (2003) 77–89.
[10] A. Javid, Methods of waste removal detergent automotive industry workshop, J. Environ. Sci. Technol., (2005) 29–34.
[11] M. Shahmansouri, Check the detergent industry wastewater treatment to help coagulation process on a laboratory scale, martyr University of Medical Sciences and Health Services Yazd, (2003) 62–65.
[12] A. Takdastan, A.A. Azimi, N. Jaafarzadeh, Biological excess sludge reduction in municipal wastewater treatment by chlorine, Asian. J. Chem., 22 (2010) 1665–1674.
[13] M.V. Niri, A.H. Mahvi, M. Alimohammadi, M. Shirmardi, H. Golastanifar, M.J. Mohammadi, A. Naeimabadi, M. Khishdost, Removal of natural organic matter (NOM) from an aqueous solution by NaCl and surfactant-modified clinoptilolite, J. Water Health., 13 (2015) 394–405.
[14] A. Takdastan, A. Eslami, Application of energy spilling mechanism by para-nitrophenol in biological excess sludge reduction in batch-activated sludge reactor, Int. J. Energy. Environ. Eng., 4 (2013) 1–7.
[15] N. Alavi, E. Zaree, M. Hassani, A.A. Babaei, G. Goudarzi, A.R. Yari, M.J. Mohammadi, Water quality assessment and zoning analysis of Dez eastern aquifer by Schuler and Wilcox diagrams and GIS, Desal. Wat. Treat., 57 (2016) 23686–23697.
[16] F. Zohrehvand, A. Takdastan, N. Jaafarzadeh, Z. Ramezani, H. Gharibi, A. Nazarzadeh, Assessment of lead contamination

in vegetables, irrigation water and soil in farmlands irrigated by surface water in Ahvaz, J. Mazandaran. Univ. Med. Sci., 24 (2014) 225–230.
[17] A. Mahvi, Detergent removal using activated sludge plant settlements in the West horizon of knowledge, Faculty of Medical Sciences and Health Services, Gonabad, (2003) 37–41.
[18] P. Holt, G. Barton, C. Mitchell, The future for electrocoagulation as a localised water treatment technology, Chemosphere, (2005) 355–367.
[19] A. Mahvi, Check availability electrocoagulation process using aluminum electrodes for the removal of heavy metal chromium in aquatic environments., J. Water. Wastewater., (2006) 28–36.
[20] A. Rahmani, Eriochrome Black T dye removal efficiency of electrocoagulation in wastewater, J. Water. Wastewater, (2007) 52–58.
[21] A. Rahmani, Electrochemical method COD removal efficiency of wastewater, J. Water. Wastewater., (2006) 9–14.
[22] J. Ge, P. Lei, H. Liu, New bipolar electrocoagulation-electroflotation process for the treatment of laundry wastewater, Sep. Sci. Technol., (2004) 33–39.
[23] C. Feng, N. Sugiura, S. Shimada, T. Maekawa, Development of a high performance electrochemical wastewater treatment system, J. Hazard. Mater., (2003) 65–78.
[24] Ş. İrdemez, Y.Ş. Yildiz, V. Tosunoğlu, Optimization of phosphate removal from wastewater by electrocoagulation with aluminum plate electrodes, Sep. Sci. Technol., 52 (2006) 394–401.
[25] E. Onder, A. Koparal, U. Ogutveren, An alternative method for the removal of surfactants from water. electrochemical coagulation, Sep. Purif. Technol., (2007) 527–532.
[26] W.K. Lafi, M. Al-Anber, Z.A. Al-Anber, M. Al-shannag, A. Khalil, Coagulation and advanced oxidation processes in the treatment of olive mill wastewater (OMW), Desal. Wat. Treat., 24 (2010) 251–256.
[27] H. Inan, A. Dimoglo, H. Şimşek, M. Karpuzcu, Olive oil mill wastewater treatment by means of electro-coagulation, Sep. Purif. Technol., 36 (2004) 23–31.
[28] C. Ciorba, C. Radovan, I. Vlaicu, L. Pitulice, Correlation between organic component and electrode material, consequences on removal of surfactants from wastewater, Electrochim Acta., 46 (2000) 297–303.
[29] A. Takdastan, A. Neisi, M. Jolanejad, K.A. Angaly, M. Abtahi, M.J. Ahmadi, The efficiency of coagulation process using polyaluminum silicate chloride (pasic) in removal of hexavalent chromium and cadmium from aqueous solutions, J. Mazandaran. Univ. Med. Sci., 26 (2016) 99–108.
[30] M. Al-Shannag, W. Lafi, K. Bani-Melhem, F. Gharagheer, O. Dhaimat, Reduction of COD and TSS from paper industries wastewater using electro-coagulation and chemical coagulation, Sep. Sci. Technol., 47 (2012) 700–708.
[31] M. Al-Shannag, K. Bani-Melhem, Z. Al-Anber, Z. Al-Qodah, Enhancement of COD-nutrients removals and filterability of secondary clarifier municipal wastewater influent using electrocoagulation technique, Sep. Sci. Technol., 48 (2013) 673–680.
[32] U.T. Un, A.S. Koparal, U.B. Ogutveren, Electrocoagulation of vegetable oil refinery wastewater using aluminum electrodes, J. Environ. Manag., 90 (2009) 428–433.
[33] S. Tchamango, C.P. Nanseu-Njiki, E. Ngameni, D. Hadjiev, A. Darchen, Treatment of dairy effluents by electrocoagulation using aluminium electrodes, Sci. Total. Environ., 408 (2010) 947–952.
[34] Z. Al-Qodah, M. Al-Shannag, K. Bani-Melhem, E. Assirey, K. Alananbeh, N. Bouqellah, Biodegradation of olive mills wastewater using thermophilic bacteria, Desal. Wat. Treat., 56 (2015) 1908–1917.
[35] U. Un, S. Ugur, A. Koparal, U. Ogutveren, Elecrocoagulation of olive mill wastewaters, Sep. Purif. Technol., (2006) 114–136.
[36] İ.A. Şengil, Treatment of dairy wastewaters by electrocoagulation using mild steel electrodes, J. Hazard. Mater., 137 (2006) 1197–1205.
[37] N. Adhoum, L. Monser, N. Bellakhal, J.-E. Belgaied, Treatment of electroplating wastewater containing Cu^{2+}, Zn^{2+} and Cr (VI) by electrocoagulation, J. Hazard. Mater., 112 (2004) 207–213.
[38] N. Drouiche, S. Aoudj, M. Hecini, N. Ghaffour, H. Lounici, N. Mameri, Study on the treatment of photovoltaic wastewater using electrocoagulation: Fluoride removal with aluminium electrodes—Characteristics of products, J. Hazard. Mater., (2009) 65–69.
[39] A. Rahmani, Efficiency of electrocoagulation for removal of Ario Chrome Black T color from wastewater, J Water. Wastewater., (2009) 52–58.
[40] W.-L. Chou, C.-T. Wang, S.-Y. Chang, Study of COD and turbidity removal from real oxide-CMP wastewater by iron electrocoagulation and the evaluation of specific energy consumption., J. Hazard. Mater., (2009) 1200–1207.
[41] M. Bayramoglu, M. Kobya, M. Eyvaz, E. Senturk, Technical and economical analysis of electrocoagulation for the treatment of poultry slaughterhouse wastewater, Sep. Purif. Technol., (2006) 401–408.
[42] M. Kobya, E. Demirbas, O. Can, M. Bayramoglu, Treatment of levafix orange textile dye solution by electrocoagulation, J. Hazard. Mater., 132 (2006) 183–188.
[43] M. Kobya, S. Delipinar, Treatment of the baker's yeast wastewater by electrocoagulation, J. Hazard. Mater., 154 (2008) 1133–1140.
[44] M. Bayramoglu, M. Eyvaz, M. Kobya, Treatment of the textile wastewater by electrocoagulation: economical evaluation, Chem. Eng. J., 128 (2007) 155–161.
[45] M. Bayramoglu, M. Kobya, M. Eyvaz, E. Senturk, Technical and economic analysis of electrocoagulation for the treatment of poultry slaughterhouse wastewater, Sep. Purif. Technol., 51 (2006) 404–408.