Australian Journal of Basic and Applied Sciences

2019 August; 13(8): pages 141-146
DOI: 10.22587/ajbas.2019.13.8.18

Original paper
Journal home page: www.ajbasweb.com

AENSI Publications

Application of iron and aluminum electrodes for wastewater treatment via electrocoagulation

Rehab M. El-Hefny[1], **Mohamed N. Ali**[2*], **Mostafa E. Y. Ahmed**[3]

[1]Environmental and Sanitary Engineering Department, Faculty of Engineering– Shoubra, Benha University, Egypt.
[2]Environmental and Sanitary Engineering Department, Faculty of Engineering– Beni- suef University, Egypt.
[3]Demonstrator at Civil Engineering Department, Pyramids Higher Institute for Engineering and Technology, Egypt.

Correspondence Author: Mohamed N. Ali. Environmental and Sanitary Engineering Department, Faculty of Engineering– Beni- suef University, Egypt.
E-mail: engmohamedbayoumi@yahoo.com

Received date: 18 May 2019, Accepted date: 28 July 2019, Online date: 29 July 2019

Abstract

The present study deals with the possibility of using iron and aluminum monopolar electrodes for raw domestic wastewater treatment under different treatment conditions. Wastewater samples were collected from Abu Rawash wastewater treatment plant, Egypt. A mini model was constructed for the treatment process. Experiments were carried out using iron and aluminum electrodes separately and for each type at different distances between electrodes (10 and 15 cm). Different factors were studied to enhance the electrocoagulation treatment process which include sedimentation period (3 and 5 h), different electrocoagulation periods (30 and 60 min), and different electrical voltages (12 and 24 V). Alum was used as a coagulant and the final effluent was disinfected with chlorine. The results showed that iron electrodes were more effective than aluminum electrodes for treatment and the distances between electrodes have played a role in the treatment process since 10 cm was more effective than 15 cm. Iron electrodes with 10 cm distance between electrodes showed the maximum removal percent of physicochemical parameters such as TSS (94.2%), COD (90.1%), TKN (89.3%), BOD (95.1%) and total phosphorus (83.3%). Alum enhanced the treatment efficiency and the final chlorinated effluent was in comparable with the local laws for reuse purposes.

Keywords: Electrocoagulation, wastewater treatment, iron and aluminum electrodes

INTRODUCTION

Egypt is suffering from water shortage since Egypt receives only 55 billion cubic meters annually while the population increases and subsequently water demand increases. As a result, Egypt is searching for new resources of water. Wastewater treatment and reuse i.e. recovery, is one of the suggested solutions as a new source for water. On the other hand, wastewater usually contains high concentrations and levels of chemical, physical and biological pollutants which require proper treatment before discharge into environment or for reuse purposes (Hussien et al., 2015). Most of the wastewater treatment plants apply the biological treatment technologies for wastewater treatment. However, biological treatment technologies have some disadvantages such as the need for higher oxygen volume for aeration as a result of increased biological oxygen demand (BOD) concentration, which in turn leads to increasing the capital, running, and energy costs. Additionally, biological treatment technologies require huge treatment areas, long retention time and qualified technicians (Grau, 1996). Electrocoagulation treatment is considered as one of the promising cheap, efficient and simple methods for wastewater treatment (Chen et al., 2000). This electrochemical treatment method has some advantages including lower maintenance cost, high effectiveness, rapid achievement of results and less need for labor (Feng et al., 2003). Many researchers reported the promising and effective treatment capability of electrocoagulation method for treating different types of wastewater including tannery wastewater (Pouet and Grasmick, 1995), food wastewater (Zheng and Chen, 2010), textile wastewater (Kobya et al., 2006; Phalakornkule et al., 2010; Hussein et al., 2014), restaurant wastewater (Chen et al., 2000), urban wastewater (Pouet and Grasmick, 1995), potato chips wastewater (Kobya et al., 2006), and heavy metals removal (Meunier et al., 2009; Akbal and Camci, 2011; Shafaei et al., 2011). Electrocoagulation method is an alternative for coagulation chemicals such as polymers or metal salts because during the treatment process, the electrode generates metal hydroxides and coagulated species which destabilize and aggregate suspended particles and precipitate. Also, the released hydrogen gas from cathode helps to float the flocculated particles away from the water (Kobya et al., 2006). In Egypt, Abu Rawash wastewater treatment (ARWWTP) plant is one of the largest wastewater treatment plants which operated in 1992 and is located at the north-west side of 6th of October city. ARWWTP contains only pretreatment and primary treatment for wastewater then discharge wastewater directly to a series of drains which finally discharge into Rasheed Nile river branch. This incomplete treated wastewater pollutes the Nile river. Thus, ARWWTP was chosen to study the application of electrocoagulation treatment method for wastewater treatment. The aim of the present study was to install a mini model for wastewater treatment from ARWWTP using electrocoagulation method. Two different types of electrodes (iron and aluminum) were used under different conditions such as sedimentation period (3 and 5 h), different electrodes distances (10 and 15 cm), different electrocoagulation periods (30 and 60 min), and different electrical voltages (12 and 24 V). Alum was used as a coagulant. The final effluent was disinfected with chlorine.

MATERIAL AND METHODS

1. Abu Rawash wastewater treatment plant (ARWWTP).

ARWWTP is located at north-west side of 6th of October city, Egypt with area of 520 acre including the expansion area. ARWWTP design capacity is 1.2 million cubic meters per day. The current stage (first stage) uses pretreatment and primary treatment only for wastewater. ARWWTP receives wastewater from different areas via lift stations in Egypt which include Imbaba, Boulaq, Janoob Almoheet, Alwaslah, Abu Rawash, Khufu and Alharam.

2. Samples and sampling.

Four samples were collected from ARWWTP, each sample was consisted of 10 containers with a capacity of 20 liters for each container. Samples were collected after the aerated girt removal chamber because it was hard to collect them after the circular settling tank. Samples were acidified to fix BOD and COD values. Samples were transferred directly to the experimental site where the mini model was installed.

3. Measured parameters.

Collected raw wastewater samples were analyzed for characterization. Also, samples collected after each treatment stage from the mini model were analyzed. The measured parameters were biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, total phosphorus (TP), total Kjeldahl nitrogen (TKN) and ammonia-nitrogen (NH_3-N). All parameters were measured according to standard methods (APHA, 2010).

4. Mini model components.

Figure (1) showed components of the mini model. The mini model consists of four tanks. The first tank (primary sedimentation), the second tank (electrical coagulation) which contains iron and aluminum electrodes, the third tank (alum coagulation), and the fourth tank (chlorination and final sedimentation).

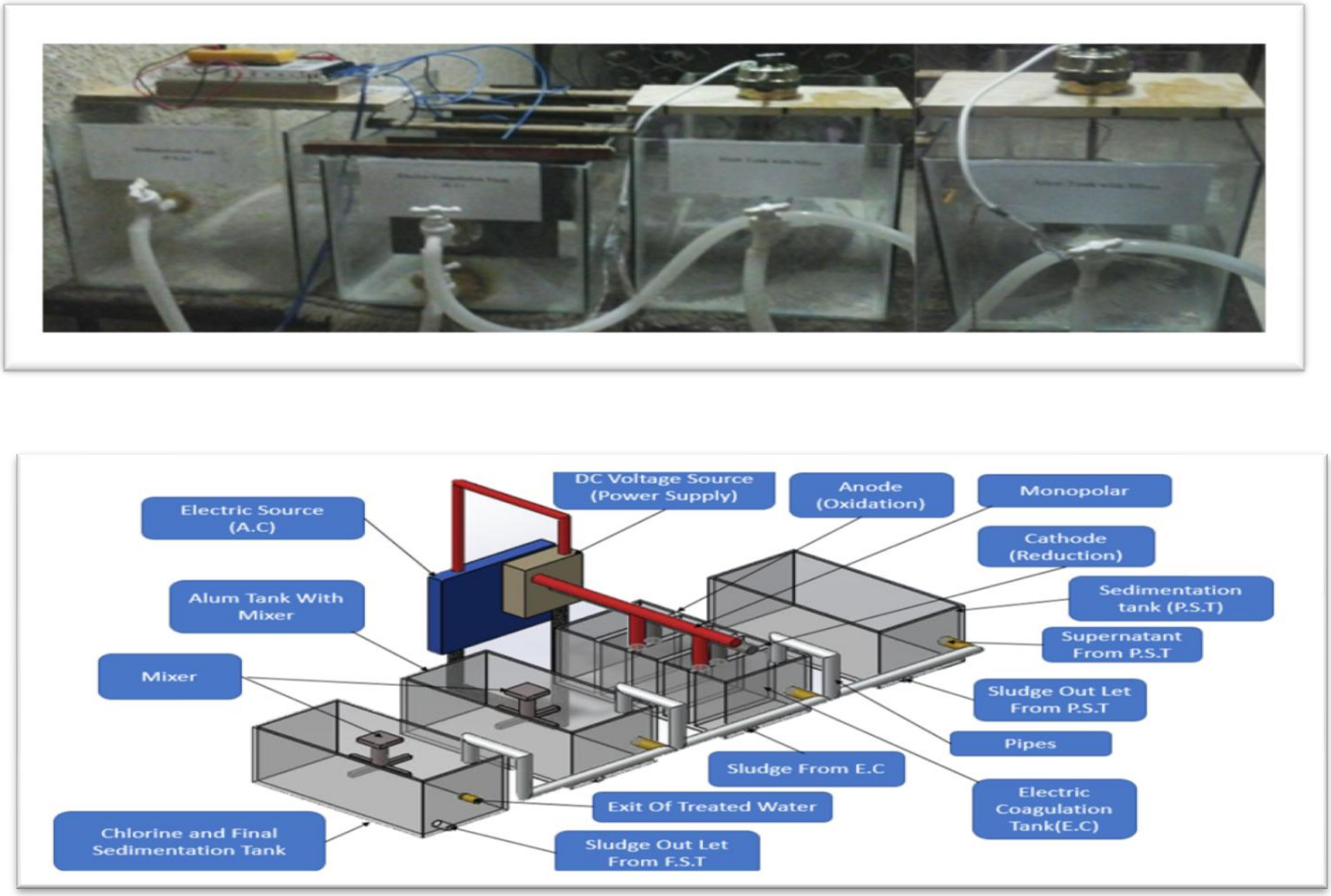

Figure 1. components of the mini model.

EXPERIMENTAL METHOD.

The first tank was filled with 54 liters of wastewater. The wastewater was left (1 hour) for sedimentation. Wastewater then physically transferred into the second tank. Inside the second tank, iron and aluminum monopolar electrodes were set separately in pairs. Monopolar electrodes were connected in parallel with a DC power supply (LRS-350W series ultra-thin single switching). The electrochemical treated wastewater transferred into the third tank where alum was added (30 mg/l) and mixed through a mixer for 15 min and left for 2 h for sedimentation. The alum dose was determined using Jar test method. After that, treated wastewater was transferred into the fourth tank where disinfection was carried out using powdered chlorine (5 ppm) with a contact time of 40 min. Sediments were withdrawn from the mini model through pipes. The experiment was carried out twice, first using iron electrodes and second using aluminum electrodes. For each experiment, some variables were examined to study their effects on the electrocoagulation process. These variables include; sedimentation period in first tank (3 and 5 h), the distance between electrodes (10 and 15 cm), electrocoagulation period (30 and 60 min) and the electrical voltage (12 and 24 V).

RESULTS AND DISCUSSION

1. Raw wastewater characterization.

Table 1. Raw wastewater characterization from ARWTP.

Parameters	Unit	Samples				Min.	Max.	Average
		1st	2nd	3rd	4th			
COD	mg/l	383	365	375	370	365	383	372.5
BOD	mg/l	330	305	300	310	300	330	307.5
pH	-	7.7	7.7	7.7	7.7	7.7	7.7	7.7
TSS	mg/l	126	120	122	125	120	126	123.5
NH_3-N	mg/l	46	52	49	45	45	52	47.5
TKN	mg/l	65	75	70	67	65	75	68.5
TP	mg/l	7.2	7.5	7.0	7.2	7.0	7.5	7.2

Table 1 summarizes the characteristics of the four different samples used during the experiments. The samples were symmetric and no significant differences were observed.

2. Iron electrodes efficiency for electrocoagulation.

Table 2 summarizes the efficiency of primary sedimentation tank for removal of pollutants from wastewater samples collected from ARWWTP. It was clear that by increasing the sedimentation period from 3 h to 5 h, the removal percent increased for all measured parameters. TSS showed the maximum removal percent of 44.5% after 5 h. Also, BOD and COD showed the same behavior during sedimentation periods with a maximum removal percent of 36.0% for both after 5 h. In addition, it was clear the proportional relationship between increasing the current voltage from 12 V to 24 V and the contact time from 30 min to 60 min. By increasing the current voltage and increasing the contact time, there was an observed enhancement in the removal efficiency of measured pollutants. The maximum removal percentages using electrical current of 24 V for 60 min contact time, were 83.3%, 91.1% and 90.0% for COD, BOD and TSS, respectively. After the addition of alum as a coagulant, the overall removal percent enhanced significantly. The overall removal percentages reached to 90.1% for COD, 95.1% for BOD and 94.2% for TSS. However, by increasing the distances between iron electrodes from 10 cm to 15 cm under the same treatment conditions, the same treatment behavior was observed for all measured parameters while the treatment efficiency slightly decreased (Table 3). The overall removal percentages decreased to 83.0% and 93.5% to 93.3% for COD, BOD and TSS, respectively. The obtained results were in comparable with the results reported by Hussien et al. (2015). They used iron electrodes for sewage water treatment through electrocoagulation and stated that electrocoagulation using iron electrodes could be an ideal pretreatment step for wastewater treatment.

3. Aluminum electrode efficiency for electrocoagulation.

Iron electrodes were replaced with aluminum electrodes and the same experiments were repeated to study the effect of aluminum electrodes for wastewater treatment by electrocoagulation and compare the removal efficiencies of iron and aluminum electrodes. The results in Table 4 shows the removal efficiency of aluminum electrodes with a 10 cm distance between electrodes. The same treatment behavior of iron electrodes was observed during the experiment procedures. The sedimentation period showed a proportional relationship with the removal efficiency. The maximum removal percent of COD, BOD, TSS were 33.3%, 32.7% and 44.3%, respectively after 5 h sedimentation period. Also, increasing the current voltage from 12 V to 24 V, increased the removal percent. Moreover, the increase in current voltage in parallel with increasing the contact time from 30 min to 60 min, led to a significant increase in the removal percent of all measured pollutants. The maximum removal percent were 56.0% for COD, 82.7% for BOD and 79.4% for TSS. The addition of alum increased the overall removal efficiencies from 70.7% to 83.0% for COD, 88.3% to 93.5% for BOD, and from 88.5% to 93.2% for TSS. However, results in Table 5 summarizes the removal efficiencies of aluminum electrodes for wastewater treatment after increasing the distance between electrodes from 10 cm to 15 cm under the same experiment conditions and procedures. The obtained results showed that the treatment behavior was the same for all measured pollutants with a slight decrease in removal percent. The overall removal percent after coagulation with alum were 80.0%, 92.9% and 91.7% for COD, BOD and TSS, respectively. The obtained results were almost the same with the results reported by Tchamango et al. (2012) since they used aluminum electrodes for the treatment of artificial wastewater and reported removal efficiencies of 61.0% for COD and 100.0% for TSS. In another study (Bazrafshan et al., 2013), aluminum electrodes were used for electrocoagulation with potassium chloride as electrolyte for wastewater treatment and showed removal efficiencies of 97.95% for BOD, 98.84% for COD and 97.75% for TSS. In the electrocoagulation process an electrical current flow between two electrodes and the coagulant is generated in situ via electrolytic oxidation of the anode material. With an iron anode, ferrous or ferric hydroxide is formed at the anode. Murthy and Raina (2008) and Hossain et al. (2013) reported the reaction mechanism of the iron electrode at the anode and cathode. The increasing in current density produces heavier and larger flocs (Yengejeh et al., 2017). The effect of current density on pollutants removal was due to the higher amounts of ions produced on the electrodes promoting destabilization of the pollutant molecules (Hossain et al., 2013). The effect of contact (operating) time on the electrocoagulation process maybe attributed to the two stages involved in electrocoagulation process. These two stages are destabilization and aggregation. Destabilization stage is short while aggregation stage is relatively long. Metal ions (iron and aluminum) as destabilization agents are produced at anode thorough electrochemical reactions which result in a low charge loading when the contact time is shortened. The metal ions dosage was not sufficient to stabilize all colloidal and suspended particles (Shammas et al., 2010; Hossain et al., 2013). Merzouk et al. (2009), El-Ashtoukhy et al. (2010) and Parsa and Vahidian (2011) reported that the contact time should not be more than 60 min because of economic reasons and formation of many clots. They suggested that the appropriate contact time for electrocoagulation is between 15 to 60 minutes.

Table 2. Efficiency of iron electrode (10 cm distance between electrodes) for wastewater treatment.

parameter	Raw	PST				electrical coagulation								C & S	AC	OR %	Law 48 (1992)
		3h	R%	5hr	R%	12 volt				24 volt							
						30 min	R%	60 min	R%	30 min	R%	60 min	R%				
COD	383	310	19.1	245	36.0	220	10.2	150	38.8	115	53.1	50	79.6	33	28	92.7	30-40
BOD	330	264	20.0	211.2	36.0	102	51.7	70	66.9	52	75.4	24	88.6	15.5	11	96.6	20-30
PH	7.7	7.7	-----	7.7	-----	7.7	-----	7.6	-----	7.6	-----	7.6	-----	7.6	7.6	------	
TSS	126	82	34.9	70	44.4	30	57.1	21	70.0	19	72.9	9	87.1	5	4.8	96.1	30
NH_3-N	46	32	30.4	26	43.5	24	7.7	21	19.2	18	30.8	14	46.2	8	7	84.7	30
TKN	65	43	33.8	38	41.5	30	21.1	20	47.4	17	55.3	12	68.4	6.8	5.4	91.6	25
TP	7.2	6	16.7	4.5	37.5	3.6	20.0	3.1	31.1	2.9	35.6	2.4	46.7	1.5	0.9	87.5	

Table 3. Efficiency of iron electrode (15 cm distance between electrodes) for wastewater treatment.

parameter	Raw	PST				electrical coagulation								C & S	AC	OR %	Law 48 (1992)
		3h	R%	5hr	R%	12 volt				24 volt							
						30 min	R%	60 min	R%	30 min	R%	60 min	R%				
COD	365	300	17.8	260	28.8	228	12.3	178	31.5	136	47.7	61	76.5	42	36	90.1	30-40
BOD	305	255	16.4	207	32.1	122	41.1	85	58.9	65	68.6	27	87.0	18	15	95.1	20-30
PH	7.7	7.7	-	7.7	-	7.7	-	7.6	-	7.6	-	7.6	-	7.6	7.6	-	
TSS	120	78	35.0	65	45.	36	44.6	25	61.	22	66.	12	81.	7.5	6.9	94.	30

					8				5		2		5			2	
NH_3-N	52	36	30.8	29	44.2	24	17.2	20	31.0	17.5	39.7	15	48.3	9.2	8.8	83.0	30
TKN	75	55	26.7	43	42.7	36	16.3	29	32.6	19	55.8	14	67.4	8.4	8	89.3	25
TP	7.5	6.5	13.3	5	33.3	4.3	14.0	3.8	24.0	3.4	32.0	2.9	42.0	1.88	1.25	83.3	

PST: primary sedimentation tank, R%: removal percent, OR%: overall removal percent, C & S: coagulation and sedimentation, AC: after chlorine

Table 4. Efficiency of aluminum electrode (10 cm distance between electrodes) for wastewater treatment.

parameter	Raw	PST				electrical coagulation								C & S	AC	OR %	Law 48 (1992)
		3h	R%	5hr	R%	12 volt				24 volt							
						30 min	R%	60 min	R%	30 min	R%	60 min	R%				
COD	375	295	21.3	250	33.3	226	9.6	152	39.2	127	49.2	110	56.0	72.5	64	83.0	30-40
BOD	300	250	16.7	202	32.7	100	50.5	82	59.4	63	68.8	35	82.7	24	19	93.5	20-30
PH	7.7	7.7	-	7.7	-	7.7	-	7.7	-	7.6	-	7.6	-	7.6	7.6	-	
TSS	122	81	33.6	68	44.3	32	52.9	26	61.8	22	67.6	14	79.4	8.7	8.2	93.2	30
NH_3-N	49	38	22.4	30	38.8	25	16.7	23	23.3	20	33.3	17	43.3	10.6	10	79.5	30
TKN	70	52	25.7	40	42.9	30	25.0	21.5	46.3	18	55.0	16	60.0	10.2	9.8	86.0	25
TP	7	6	14.3	4.8	31.4	4.3	10.4	4.1	14.6	4	16.7	2.6	45.8	1.7	1.4	80.0	

PST: primary sedimentation tank, R%: removal percent, OR%: overall removal percent, C & S: coagulation and sedimentation, AC: after chlorine

Table 5. Efficiency of aluminum electrode (15 cm distance between electrodes) for wastewater treatment.

parameter	Raw	PST				electrical coagulation								C & S	AC	OR %	Law 48 (1992)
		3h	R%	5hr	R%	12 volt			24 volt								
						30 min	R%	60 min	R%	30 min	R%	60 min	R%				
COD	370	290	21.6	255	31.1	232	9.0	168	34.1	141	44.7	127	50.2	87.5	74	80.0	30-40
BOD	310	260	16.1	206	33.5	111	46.1	92	55.3	70	66.0	40	80.6	27.5	22	92.9	20-30
PH	7.7	7.7	-	7.7	-	7.7	-	7.7	-	7.6	-	7.6	-	7.6	7.6	-	
TSS	125	80	36.0	71	43.2	37	47.9	29	59.2	24	66.2	19	73.2	11.2	11	91.2	30
NH_3-N	45	36	20.0	28	37.8	24	14.3	21.5	23.2	20.5	26.8	18	35.7	12.5	12	73.0	30
TKN	67	49	26.9	42	37.3	34	19.0	27	35.7	20	52.4	17	59.5	11.5	11	83.5	25
TP	7.2	6.3	12.5	5	30.6	4.4	12.0	4.2	16.0	4	20.0	3.6	28.0	2.5	2	72.2	

Citation: Mohamed N. Ali *et al*., **Application of iron and aluminum electrodes for wastewater treatment via electrocoagulation**. Australian Journal of Basic and Applied Sciences, 13(8): 141-146. DOI: 10.22587/ajbas.2019.13.8.18

CONCLUSION

The present study showed that:

- the ability of iron and aluminum electrodes via electrocoagulation method for raw domestic wastewater treatment collected from Abu Rawash wastewater treatment plant, Egypt.
- The iron electrodes were more effective than aluminum electrodes for removal of pollutants.
- The distance between electrodes played a vital role in the treatment process. The maximum removal efficiency was observed by using iron electrodes with a distance of 10 cm.
- Electrocoagulation process for wastewater treatment can be a suitable technology for domestic wastewater treatment.
- The treated effluent after coagulation with alum and disinfection with chlorine was in comparable with the Egyptian law for reuse purposes.

REFERENCES

Akbal F. and Camcı S. 2011. Copper, chromium and nickel removal from metal plating wastewater by elctrocoagulation. Desalination, 269: 214-22.

APHA (American Public Health Association). 2010. Standard methods for the Examination of Water and Wastewater, 21st ed. Washington D.C., U.S.A.

Bazrafshan E., Moein H., Mostafapour F.K. and Nakhaie S. 2013. Application of electrocoagulation process for dairy wastewater treatment. Journal of Chemistry, 2013: 1-8, http://dx.doi.org/10.1155/2013/640139.

Chen X., Chen G. and Yue. P. L. 2000. Separation of pollutants from restaurant wastewater by electrocoagulation. Separation and Purification Technology, 19: 65-76.

El-Ashtoukhy E.S., Zewail T.M., Amin N.K. 2010. Removal of heavy metal ions from aqueous solution by electrocoagulation using a horizontal expanded Al anode. Desalination and Water Treatment, 20(1-3): 72-9. doi: 10.5004/ dwt.2010.1127.

Feng C., Sugiura N., Shimada S. and Maekawa T. 2003. Development of a high performance electrochemical wastewater treatment system. Journal of Hazardous Materials, 103: 65-78.

Grau P. 1996. Integrated water and waste management. Water Science and Technology. 33: 39-46.

Hossain M., Mahmud I., Parvez S., Cho H.M. 2013. Impact of Current Density, Operating Time and pH of Textile Wastewater Treatment by Electrocoagulation Process. Environ. Eng. Res., 18(3): 157-161.

Hussien N.H., Shaarawy H. H. and Shalaby M. S. 2015. Sewage water treatment via electrocoagulation using iron anode. ARPN Journal of Engineering and Applied Sciences, 10(18): 8290- 8299.

Kobya M., Demirbas E., Can O. T. and Bayramoglu M. 2006. Treatment of levafix orange textile dye solution by elctrocoagulation. Journal of Hazardous Materials, 132: 183-188.

Merzouk B., Gourich B., Sekki A., Madani K., Chibane M. 2009. Removal turbidity and separation of heavy metals using electrocoagulation–electroflotation technique A case study. J Hazard Mater., 164(1): 215-22. doi: 10.1016/j. jhazmat.2008.07.144.

Meunier N., Drogui P., Mercier G. and Blais J.F. 2009. Treatment of metal-loaded soil leachates by elctrocoagulation. Separation and Purification Technology, 67: 110-116.

Murthy Z.V., Raina A. 2008. Treatment of wastewater of navy blue- 3G by electrocoagulation. Int. J. Chem. React. Eng., 6 Note S2. http://dx.doi.org/10.2202/1542-6580.1631.

Parsa B.J., Vahidian R.H. 2011. Removal of acid brown 14 in aqueous media by electrocoagulation: optimization parameters and minimizing of energy consumption. Desalination, 278(1–3): 295-302. doi: 10.1016/j. desal.2011.05.040.

Phalakornkule C., Mangmeemak J. and Intrachod K. 2010. Pretreatment of palm oil mill effluent by elctrocoagulation and coagulation. Scienceasia, 36:142-149.

Pouet M. F. and Grasmick A. 1995. Urban wastewater treatment by electrocoagulation and flotation. Water Science and Technology, 31: 275-283.

Shafaei A., Pajootan E., Nikazar M. and Arami M. 2011. 2011. Removal of Co (II) from aqueous solution by elctrocoagulation process using aluminum electrodes. Desalination, 279(1–3): 121-126.

Shammas N.K., Pouet M., Grasmick A. 2010. Wastewater treatment by electrocoagulation-flotation. Flotat. Technol., 12:199-220.

Tchamango S., Nanseu-Njiki C.P., Ngameni E., Hadjiev D. and Darchen A. 2010. Treatment of dairy effluents by electrocoagulation using aluminum electrodes. Science of The Total Environment, 408(4): 947-952.

Yengejeh S.G., Mansoorian H.J., Majidi G., Yari A.R., Khanjani N. 2017. Efficiency of electrical coagulation process using aluminum electrodes for municipal wastewater treatment: a case study at Karaj wastewater treatment plant. Environmental Health Engineering and Management Journal, 4(3): 157–162.

Zheng Y. M. and Chen J. P. 2010. Handbook of advanced industrial and hazardous wastes treatment. Water.