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Research Article

Treatment of Domestic Wastewater by Using Electrochemical Process Using Different Metal Electrodes

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Keywords

- Electrocoagulation process
- Chemical oxygen demand
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- Nutrient removal
- Domestic wastewater

Abstract

In recent years, operational and capital cost for the treatment facilities have become more important when sustainability is considered in relation to domestic wastewater treatment in developing countries. The electrochemical processes are one of the sustainable process. In this study, the removal of chemical oxygen demand (COD: 5760 mg/L), suspended solids (SS: 260 mg/L), total phosphorus (5.3 mg/L), nitrate nitrogen (1.1 mg/L) and nitrite nitrogen (0.24 mg/L) from domestic wastewater were experimentally investigated at 7.5 and 15V voltage and different processing times (15-30-60-120 min.) by using electrochemical processes. Electrical conductivity, temperature, and pH as experimental parameters were measured after the treatment. Aluminum, iron, titanium and graphite electrodes were used in the reactor. Samples were taken in certain time intervals and removal efficiencies were determined. The results showed that 80-99% COD removals were obtained by using iron electrode. Experimental results showed that the electrochemical process was also effective on SS and nutrients (total phosphorus, nitrate nitrogen and nitrite nitrogen) removal.

ABBREVIATIONS

COD: Chemical Oxygen Demand; **SS:** Suspended Solids; **TP:** Total Phosphorus **EC:** Electrocoagulation Process

INTRODUCTION

Among of all wastewaters, Domestic wastewater is the most produced type of waste in the world. Although biological treatment is the conventional method for domestic wastewaters, treatability by using novel technologies have been studied cause of determinate effective variety of pollutants operating cost, operating difficulties and undesirably low efficiency.

In general mechanism of electrochemical treatment processes involve coagulation, adsorption, precipitation and flotation. The most significant difference is the form and structure of the process of electrochemical processes. Especially the electrode type is one of the factors that determines what the system trigger is electrocoagulation whether to electrooxidation [1].

Electrochemical treatment methods have been successfully used for the treatment of and leachate water [2], textile [3], slaughter [4], olive oil [5], yeast industry [6], tannery wastewater [7], bilge wastewater [8], pharmaceutical [9], dairy wastewater [10].

Electrocoagulation (EC) contains the production of coagulants in situ by electrically dissolving metal electrodes. The metal ion production occurs at the anode, while hydrogen gas from the electrolysis of water is produced at the cathode. The metal hydroxide ions absorb and trap contaminants while the hydrogen gas floats these particles [11]. Reactions that take place for the iron and aluminum in an electrocoagulation process are as follows:

$$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^- \quad (1)$$

$$Al^{3+} + 3\,OH^- \rightarrow Al(OH)_3 \quad (2)$$

$$Fe_{(s)} \rightarrow Fe^{3+}_{(aq)} + 3e^- \quad (3)$$

$$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3 \quad (4)$$

Oils, suspended solids and organic compounds can be treated by electroflotation [11].

Electroflotation process does not occur alone, mostly observed with electrocagulation process. Process is based on elimination of pollutant by the gas bubbles which were produced by electrodes. Reactions that take place on the electrode surface are shown below.

$$\text{Anode: } 2H_2O \rightarrow O_2\uparrow + 4H^+ + 4e^- \quad (5)$$

$$\text{Cathode: } 4H^+ + 4e^- \rightarrow 2H_2\uparrow \quad (6)$$

The electrooxidation is mainly used for degradation of: aromatic compounds [12], pharmaceuticals [13], paints [14,15], industrial pollutants [16], pesticides [17], waste [18] and other organics [19-21] by using inert electrodes. The advantage of this method is that finally products are mainly CO_2 and H_2O [22].

Electrochemical treatment methods are more favorable since the low volume of sludge is produced compared with the conventional chemical treatment methods. Electrochemical processes are usually applied at room temperature and the produced sludge is easily recoverable [23]. The electrocoagulation process is more applicable than the electrooxidation process because it affects various contaminants. Nevertheless electrooxidation is likely to be more preferable because the amount of sludge formed is almost negligible compared to the electrocoagulation as a result of convension of the final product to CO_2 and H_2O.

In this study, the efficiency of electrochemical treatment process in removing of COD, SS and nutrient from domestic wastewater was examined. The effects of potential difference, types of used electrode and retention time on removal efficiency were investigated to determine the optimal operational conditions. At the same time, the effect of non-metallic graphite electrode on removal efficiency was investigated for comparison with metal electrodes.

MATERIALS AND METHODS

Study area

The wastewater sample which was taken from a domestic wastewater treatment plant in Cigli (Izmir,Turkey) was used in the experiments. Water sample only passed through a mechanical sieve that removed coarse material from water but concentrations of colloidal and dissolved material were not affected. The characteristics of the wastewater sample are given in Table 1.

Electrochemical reactor

Electrochemical treatments were studied in regular beherglass. Water was stirred with a standard magnetic stirrer during the process. Treatment by electrocoagulation/ electroflotation occurs while aluminum and iron materials used as electrodes in reactor and treatment by electrooxidation takes place while graphite and titanium electrodes used in reactor. Aluminum-iron electrodes were in the form of plate and scaled as 6 cm * 9 cm. Graphite-titanium electrodes were in the form of stick and scaled as 10 cm * 1 cm^2. All wastewater samples settled 20°C before electrochemical process. The inherent pH of the wastewater sample was measured as 7.7. The voltages in the experiments were set as 7.5V and 15V. Samples withdrawn during the study in different time intervals (15, 30, 60, 120 min) were subjected to analyses for determining COD, SS and nutrients. A laboratory scale reactor was used for the EC process as shown in Figure 1.

Distances between the electrodes are 6.5 cm and electrodes were placed as 80-90% of surface area stay in water. After electrochemical treatment, the electrodes were washed with 6% HCl solution and distilled water for the removal of the residual on the surface and weighed.

Table 1: Domestic wastewater characteristics.

Parameters	Concentration
Chemical oxygen demand (COD) (mg O_2/L)	5760
Suspended solids (SS) (mg/L)	260
Nitrate (NO_3-N) (mg/L)	1.1
Nitrite (NO_2-N) (mg/L)	0.24
Total phosphorus (TP) (mg/L)	5.3
pH	7.7
Electrical conductivity (mS / cm)	5
Salinity (ppt)	1

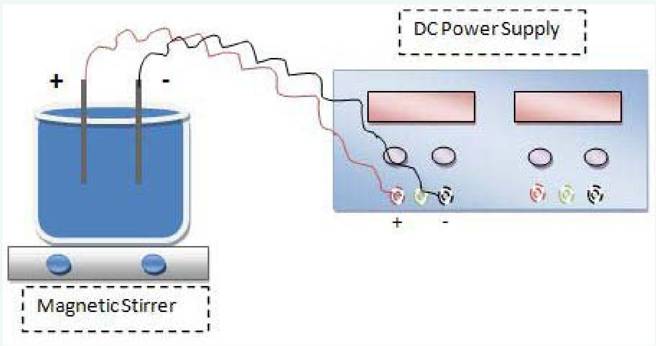

Figure 1 Laboratory scale electrochemical reactor.

Methods of analysis

Water samples were stored after pH, conductivity and temperature were measured by using standard laboratory devices. The organic matter removal efficiency was determined by analyzing COD. 5220 D Method, (APHA, 2005) was used to determine chemical oxygen demand and it was repeated twice. Nutrient content of samples were analyzed using a Merck Nova60 spectrofotometer. Suspended solids were analyzed based on standard methods for both raw wastewater and treated water with EC processes.

RESULTS AND DISCUSSION

This study is mainly aimed to determine basic operation parameters of treatment of domestic wastewaters. Therefore, COD, SS and nutrient were investigated in terms of selection of electrode material, applied voltage and retention time in order to determine optimum operating conditions for maximum removal efficiency of COD, SS and nutrient.

Removal efficiency (RE) equation is shown below:

$$\frac{A-B}{A}x100 = \text{RE \%} \quad (8)$$

Where A is initial COD and B is current result.

Changes on pH, electrical conductivity, temperature

The changes during process operation are also important as much as start up parameters. The changes in pH, temperature and electrical conductivity were measured in 15, 30, 60, 120 minutes.

The initial pH was not changed; all electrodes were studied at pH 7.7. But as a result of reactions taking place in the reactor, pH values were measured for purpose of control. pH values were change between 6.68 to 9.16 as shown in Figure 2. For both voltage values, pH get higher than initial pH when iron electrode was used. pH value was almost the same as initial pH when titanium electrode was used. pH values were get lower than initial pH where aluminum and graphite electrodes were used.

Although there is no negative effect of temperature, some studies about effect of temperature on electrochemical treatment methods show that amount of removal efficiency increase as the temperature increases [24].

Figure 3 show that temperature increases for four electrodes as time passes. Above all temperature was 57°C in reactor when voltage was 15V and aluminum electrode was used.

For the iron, aluminum, titanium and graphite electrodes, Figure (4(a) and (b)) shows the effect of electrochemical treatment processes on the changing of the wastewater conductivity.

As seen, operation of process caused an increase dissolved ions as from 15 minutes. And results indicate that changes in electrical conductivity is not reletaed with pH.

Chemical oxygen demand removal

To optimize the electrocoagulation operating conditions, the COD was measured as a function of treatment time and different electrodes. The reduction of the COD as a function of treatment time under conditions of electrical conductivity 5 mS/cm pH 7.7 and reactor voltage 7.5V is shown in Figure 5 for four electrodes.

There is a rapid increase in the COD for the first 15 min of treatment then a limiting value is reached with no further improvement.

To determine effect of voltage, reactor was operated at 15V while other parameters were the same. The results of this operation were given in Figure 6.

When we examine the literature and check other studies [25,26], COD removal efficiencies are almost the same for domestic wastewater if we compare about the same conditions

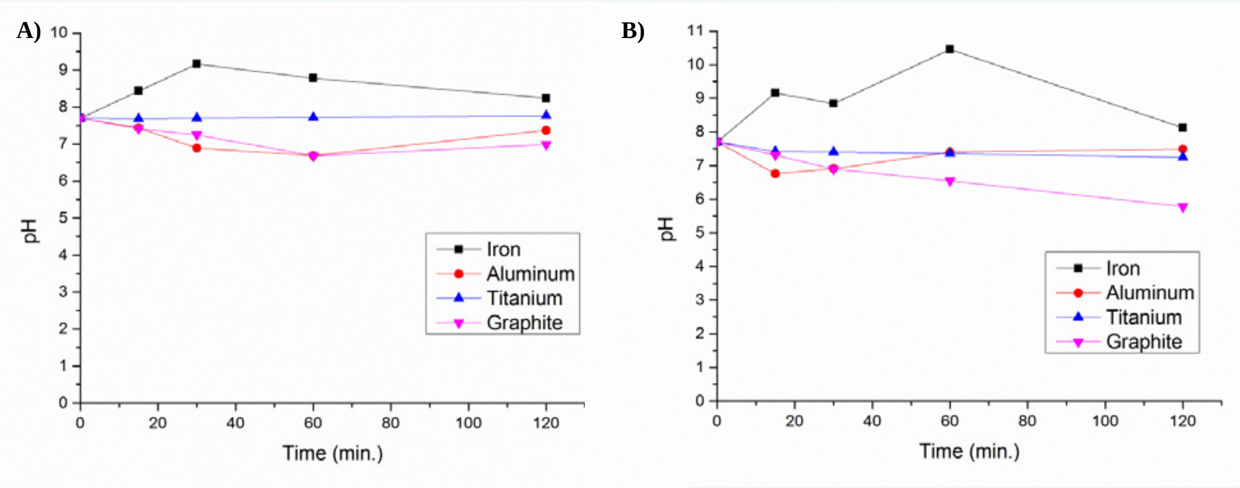

Figure 2 Changes in pH on four electrodes for 7.5V (a) and 15V (b).

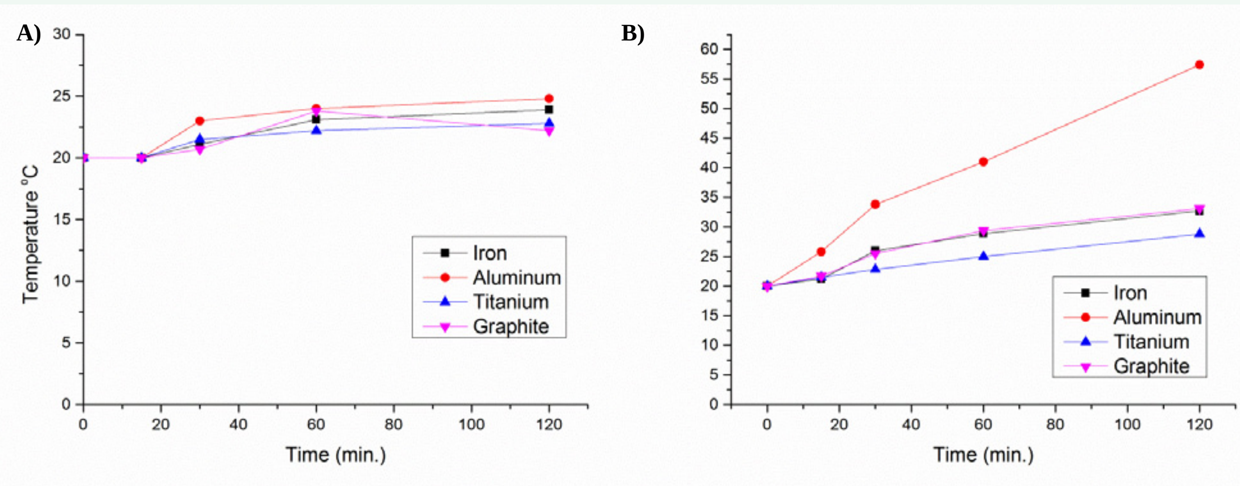

Figure 3 Changes in Temperature on four electrodes for 7.5V (a) and 15V (b).

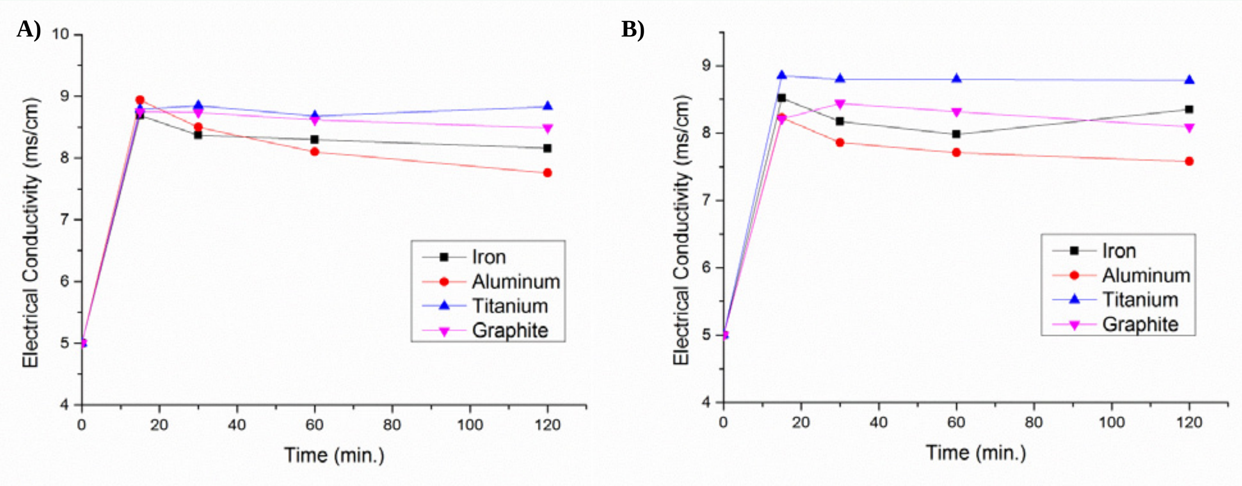

Figure 4 Changes in electrical conductivity on four electrodes for 7.5V (a) and 15V (b).

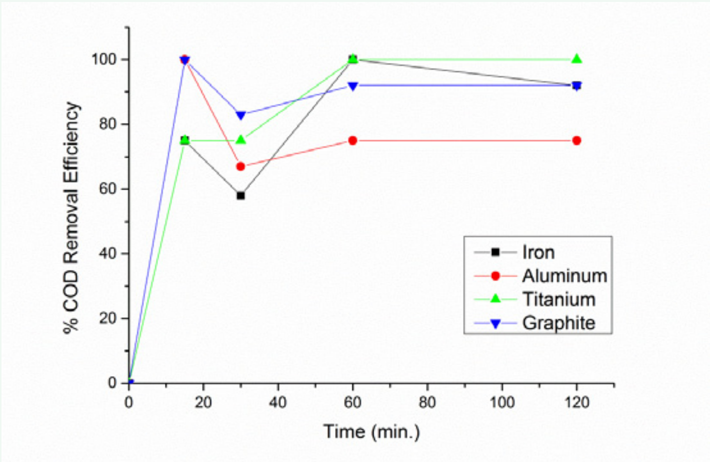

Figure 5 COD removal efficiency at 7.5V as a function of time for iron, aluminum, titanium and graphite electrodes.

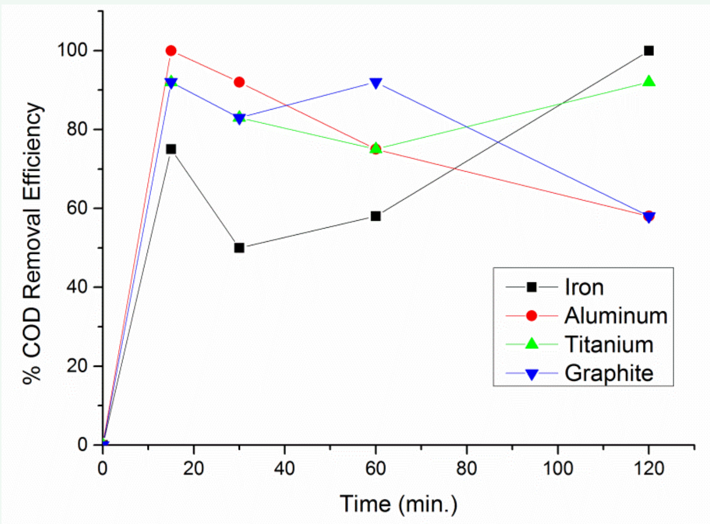

Figure 6 COD removal efficiency at 15V as a function of time for iron, aluminium, titanium and graphite electrodes.

like time intervals and iron electrode. But in this study removal efficiencies are remarkable with aluminium, titanium, graphite electrodes and also results show us that removal efficiency gets higher enough with iron electrode when the reaction time is increased 60 to 120 minutes.

The effluent treatment of titanium electrodes was found to be more clear and stable than the others. The removal efficiency with iron, aluminium and graphite electrodes was highly desired values in 15 minutes whereas removal efficiency results changes due to inorganic pollution in 30, 60 and 120 minutes retention time.

The effect of applied voltage is an important parameter for organic matter removal in EC process and also causes undesirable decomposition of the electrode. As in Figure 5 and Figure 6 7.5 voltage is provide sufficient energy to ionize metal ions which has better removal capacity than 15 V.

Suspended solids removal

The relationship between the SS removal efficiency and retention time for four electrodes used is depicted in Figure 7 and Figure 8 under 7.5V – 15 V operation voltage. The figure shows that as the contact time increased from 15 to 120 min, concentration of suspended solids varies from 40 mg/L to 2600 mg/L for both voltages of 7.5V and 15V as a function of time.

In 15 voltage operation conditions, aluminum ions were over dissolved in reactors and cause increase in dissolved solids amount after 60 min for iron and 30 min for aluminum. These results show that the applied voltage is high enough to cause over dissolved metal ions which effect suspended solid results. However, Titanium electrode was extremely efficient at removing suspended solids after 60 minutes reaction time as seen at Figure 7 and Figure 8. These suspended solid results were under limit of Turkish Domestic Wastewater Discharge Standards [27].

Nutrient removal

Table 2: Total phosphorus, nitrate and nitrite removal in domestic wastewater after 120 minutes, 7.5V electrochemical process.

Sample	Total P (mg/L)	NO_3 (mg/L)	NO_2(mg/L)
Raw Wastewater	5.3	1.1	0.24
Iron	1.65	0.3	0.87
Aluminium	0.8	1.5	1.84
Titanium	4.7	1.1	1.73
Graphite	1	5.8	2.15

Table 3: Total phosphorus, nitrate and nitrite removal in domestic wastewater after 120 minutes 15V electrochemical process.

Sample	Total P (mg/L)	NO_3 (mg/L)	NO_2(mg/L)
Raw Wastewater	5.3	1.1	0.24
Aluminium	0.254	5.5	1.15
Titanium	2.8	4	1.68
Graphite	2.3	13.4	3.38

Abbreviations: COD: Chemical Oxygen Demand; SS: Suspended Solids; TP: Total Phosphorus

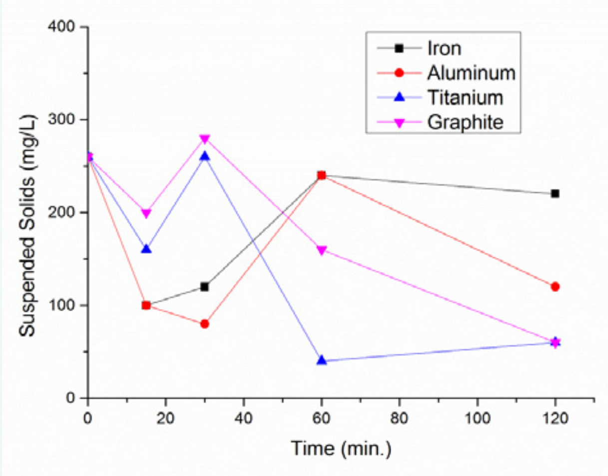

Figure 7 Removal of suspended solids from domestic wastewaters after 7.5V voltage.

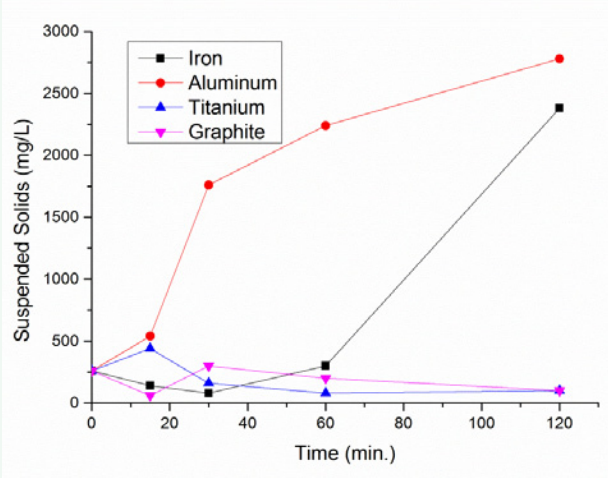

Figure 8 Removal of suspended solids from domestic wastewaters after 15V voltage.

Nitrogen in domestic wastewater exists as ammonium or organic form, both may be solid or dissolved. Only 30% of total nitrogen is removable with conventional biological treatment methods [28].

%90 of total phosphorus is dissolved in wastewaters. Removal of dissolved phosphorus is quite difficult with the conventional biological treatment methods [29].

Due to this facts, nutrient removal efficiency was investigated during this research. Total nitrate, nitrite and phosphorus concentrations were analyzed after 120 minutes reaction time under 7.5V and 15V voltage in reactor as shown in Table 2 and Table 3.

In 15V process operation, iron electrodes over dissolved after 120 minutes reaction time and react with chemicals during analysis. These results show that 120 minutes reaction time is more than it should be. For the other electrodes, aluminium electrode was quite effective at removing nutrients from domestic wastewaters.

CONCLUSION

This study aimed determines optimum electrode type, applied voltage and reaction time for removal of COD, SS and nutrients in domestic wastewater. Domestic wastewater was succesfully treated by electrochemical process in a very short time (15 min.). These results show that aluminium was affective at removing COD and nutrients with 15 minutes reaction time however need more sedimentation time to provide desired values at suspended solids removal. Although graphite is more limited conductive quality, results show that graphite electrodes highly effective for COD, SS and nutrients removal and with enough reaction time (60 min.) can provide dischargeable wastewater.

When the results are compared with the domestic wastewater discharge standards in Turkey, It seems that COD, SS and pH are parameters which to be controlled. It is seen that the data obtained as a result of the study provide the desired conditions.

Based on these results, electrochemical treatment methods are effective method of treatability of domestic wastewater and also the results obtained from the graphite electrode seem to be promising in terms of realizing other studies.

REFERENCES

1. Ihara I, Kanamura K, Shimada E. High gradient magnetic separation combined with electrocoagulation and electrochemical oxidation for the treatment of landfill leachate. Transactions on Applied Superconductivity. 2004; 14-2: 1558-1560.

2. Ilhan F, Kurt U, Apaydın Ö, Arslankaya E. Elektrokimyasal aritim ve uygulamalari: kati atik sizinti suyu çalişmasi. Turkay. 2007.

3. Vlyssides AG, Israilides CJ. Electrochemical oxidation of a textile dye and finishing wastewater using a Pt/Ti electrode. J Environ Sci and Health. 1998; 33: 847-862.

4. Asselin M, Drogui P, Benmoussa H, Blais JF. Effectiveness of electrocoagulation process in removing organic compounds from slaughterhouse wastewater using monopolar and bipolar electrolytic cells. Chemosphere. 2008. 72; 1727-1733.

5. Inan H, Anatoly Dimoglo H¸ Simsek Karpuzcu M. Olive oil mill wastewater treatment by means of electro-coagulation. Separation and Purification Technology. 2004; 36: 23-31.

6. Kobya M, Delipinar S. Treatment of the baker's yeast wastewater by electrocoagulation. J Hazard Mater. 2008; 154: 1133-1140.

7. Feng J, Sun Y, Zheng Z, Zhang J, Li S, Tian Y. Treatment of tannery wastewater by electrocoagulation, J Environ Sci. 2007; 19: 1409-1415.

8. Rincóna GJ, La Mottab EJ. Simultaneous removal of oil and grease, and heavy metals from artificial bilge water using electro-coagulation/ flotation, J Environ Manage. 2014; 144: 42-50.

9. Farhadi S, Aminzadeh B, Torabian A, Khatibikamal V, Fard MA. Comparison of COD removal from pharmaceutical wastewater by electrocoagulation, photoelectrocoagulation, peroxi-electrocoagulation and peroxi-photoelectrocoagulation processes. J Hazard Mater. 2012; 219: 35- 42.

10. Tchamango S, Nanseu-Njiki CP, Ngameni E, Hadjiev D, Darchen A. Treatment of dairy effluents by electrocoagulation using aluminium electrodes. Science of the Total Environment. 2010; 408: 947-952.

11. Chen G. Electrochemical technologies in wastewater treatment. Sep. Purif. Technol. 2004; 38: 11-41.

12. Belaid C, Khadraoui M, Mseddi S, Kallel M, Elleuch B, Fauvarque JF. Electrochemical treatment of olive mill wastewater: Treatment extent and effluent phenolic compounds monitoring using some uncommon analytical tools. J Environ Sci. 2013; 25: 220-230.

13. Tran N, Drogui P, Nguyen L, Brar SK. Optimization of sono-electrochemical oxidation of ibuprofen in wastewater. J Environl Chem Engin. 2015; 3: 2637-2646.

14. Raju GB, Karuppiah MT, Latha SS, Parvathy S, Prabhakar S. Treatment of wastewater from synthetic textile industry by electrocoagulation–electrooxidation. J Chem Engin. 2008; 144: 51-58.

15. Aquino JM, Rocha-Filho RC, Ruotolo LAM, Bocchi N, Biaggio SR. Electrochemical degradation of a real textile wastewater using β-PbO_2 and DSA® anodes. J Chem Engin. 2014; 251: 138-145.

16. García AG, Miranda VM, Cienfuegos IGM, Almazán-Sánchez PT, Castañeda-Juárez M, Linares-Hernández I. Industrial wastewater treatment by electrocoagulation–electrooxidation processes powered by solar cells. Fuel. 2015; 149: 46-54.

17. Sarigül T, İnam R, Aboul-Enein HY. Electro-oxidation of herbicide halosulfuron methyl on glassy carbon electrode and applications. Talanta. 2010; 82: 1814-1819.

18. Barriosa JA, Becerril E, De León C, Barrera-Díaz C, Jiménez B. Electrooxidation treatment for removal of emerging pollutants in wastewater sludge. Fuel. 2015; 149: 26-33.

19. Wang L, Wu B, Li P, Zhang B, Balasubramanian N, Zhao Y. Kinetics for electro-oxidation of organic pollutants by using a packed-bed electrode reactor (PBER). Chem Engine J. 2016; 284: 240-246.

20. Xue A, Yuan Z, Sun Y, Cao A, Zhao H. Electro-oxidation of perfluorooctanoic acid by carbon nanotube sponge anode and the mechanism. Chemosphere. 2015; 141: 120-126.

21. Murphy OJ, Hitchens GD, Kaba L, Verostko CE. Direct electrochemical oxidation of organics for wastewater treatment. Water Research. 1992; 26: 443-451.

22. Silvana B, Stevan PD, Milovan DV. Modern water treatment by electrochemical oxidation - a review. 17th International Research/ Expert Conference. 2013; 281-284.

23. Yousuf M, Mollah A, Schennach R, Parga JR, Cocke DL. Electrocoagulation (EC) science and applications, J Hazard Mater. 2001; 84: 29-41.

24. El-Shazly AH, Daous MA. Kinetics and performance of phosphate removal from hot industrial effluents using a continuous flow electrocoagulation reactor. Int J Electrochem Sci. 2013; 8: 184-194.

25. Kurt U, Gonullu MT, Ilhan F, and Varinca K. Environmental Engineering Science. 2008; 25: 153-162.

26. Sarala C. Domestic wastewater treatment by electro coagulation with fe-fe electrodes, International Journal of Engineering Trends and Technology. 2012; 3.

27. Su Kirliliği Kontrolü Yönetmeliği, 10.03.2016, 16:06.

28. Metcalf & Eddy. Wastewater Engineering, Treatment, Disposal and Reuse, McGraw-Hill international Editions. 1991.

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