O 11. TREATMENT OF TEXTILE WASTEWATERS WITH ELECTROCOAGULATION ADVANCED TREATMENT DROGEN PEROXIDE SENSOR APPLICATION OF TI AND TINI CATALYSTS

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ABSTRACT: Textile industry wastewater is one of the most important hazardous wastewater species threatening the environment and public health. Textile wastewater with a high proportion of dyestuffs accumulates in the receiving environment, disrupts the aesthetic appearance of the waters and reduces the light penetration. Reduction of light penetration and dissolved oxygen leads to a decrease in the living organism population and restricts the use of water resources. It is also known that certain types of dyestuffs have toxic properties. Textile wastewaters containing even very small amounts of dyestuffs have high dispersion rates and can spread to largely water bodies and threaten the environment and human health, when discharged without treatment. While adsorption, filtration and chemical processes are preferred for color removal, biological activated sludge systems are used for COD removal from colored wastewaters, generally. Today, nanotextile membrane processes are used for more efficient treatment. However, compared to other treatment methods, it can be concluded that electrocoagulation (EC) processes are more suitable for color and COD removal from textile industry wastewater. Electrocoagulation, which has a wide application area in wastewater treatment, makes a major contribution to the economy of concentrated waste discharging industries. Moreover, these processes can greatly reduce the pollutant load. In the studies carried out by the electrocoagulation process of textile industry wastewater, up to 100% color removal was determined. In addition, high levels of chromium, COD and turbidity removal efficiencies were observed from tannery industry wastewater with high Cr content by EC process.

Keywords: Electrocoagulation, Dyestuff, Wastewater Treatment, Textile Industry.

1. INTRODUCTION

In recent years, studies on electrooxidation and electrocoagulation (EC), which have environmental impact, high pollutant removal rates, operational convenience and economic efficiency, have begun to attract much attention (Cameselle et al., 2005; Chen, 2004; Mollah et al., 2001). With the electrocoagulation process, the pollutant removal from wastewater can be provided by coagulation, adsorption, precipitation and flotation methods and combinations. In this process, metal anodes such as aluminum and iron are used and hydrolysis of metal hydroxides is formed by anodic dissolution and thus, the basic mechanism of the treatment process is realized. Due to its advantages, the electrocoagulation process is now used as an effective method in treatment of various industrial wastewaters.

In general, the wastewaters from the textile industry are among the high polluted wastewaters due to their high pH, high color content and also low biodegradability (Lin and Chen, 1997). The increase in product diversity and the use of dyestuffs with highly variable chemical properties make the treatment of textile industry wastewater much more difficult (O'neill et al., 1999).

These wastewaters contain high concentrations of dyestuff, BOD, COD and suspended solids. Substances with high COD and color content cause wastewater to be aesthetically distorted, reducing the amount of dissolved oxygen required for normal aquatic life and making the treatment of wastewater more difficult (Dörtkol, 2014). In terms of dye process, the properties of the wastewater vary depending on the chemistry of the process, the batch or continuous dyeing process (Şahin, 2014). Wastewater discharged into the receiving aquatic environments with color content prevents the spread of light into the water and thus, photosynthetic activities are adversely affected. In addition, dyestuffs accumulate in some aquatic organisms and this poses a risk of toxic and carcinogenic products (Kocaer and Alkan, 2002). These toxic effects cause the change of flora and fauna of the current receiving aquatic environment. As a result of direct discharge of wastewater containing dyestuff without treatment, may

cause significant environmental impacts such as the formation of aromatic amines having toxic and carcinogenic properties under anaerobic conditions (Mıdık, 2011). The wide range of pollutant parameters present in textile industry wastewaters necessitates the use of different treatment methods in treatment of wastewater belonging to this sector (Dörtkol, 2014). Therefore, before the discharge of the textile wastewater into the receiving environment, the sources of the pollutant parameters should be determined and the necessary treatment processes should be applied in accordance with the characteristics of the wastewater.
For this purpose, conventional methods such as adsorption, biological treatment, oxidation, coagulation and flocculation are used (Jia et al., 1999). However, due to the difficulty of adsorbent regeneration in the adsorption process (Daneshvar et al., 2004), extra contamination and excess sludge formation due to unwanted reactions as a result of chemical addition in chemical coagulation (Lin and Chen, 1997), toxic effects of certain dyestuffs on microorganisms, there is need to develop other methods from biological treatment. However, these methods are often expensive and ineffective due to the wide variety of components of textile wastewater (Vlyssides et al., 1999). Many studies show that COD, turbidity and dissolved solids are effectively eliminated by EC process in treatment of textile wastewater (Bayramoglu et al., 2004; Daneshvar et al., 2004; Kobya et al., 2003; Can et al., 2003; Lin and Chen, 1997). For the development and optimization of the EC unit; process configurations such as the characteristics of wastewater such as pH, current density and application time, and the type of connection with the type of electrode material should be considered in detail. In this study, the effects of the treatment of textile wastewater with EC on the COD and turbidity parameters were determined by taking into consideration the effect of electrode material and connection form. For this purpose, process analysis were carried out both technically and economically by founding the conditions when the highest pollutant removal occurs for the EC process widely used in treatment of textile wastewater and at the same time economic data are minimum. In addition, the advantages and disadvantages of this process and the issues to be considered in process selection were investigated.

2. ELECTROCOAGULATION PROCESS

Electrocoagulation (EC) is a process that consists of dissolving the anode as a result of electrolysis and forming metal hydroxide flocks in the wastewater to be treated. The principle of the EC process in removing contaminants is based on one or more of the coagulation, adsorption precipitation and flotation removal mechanisms, the anodic dissolution, hydrolysis of the metal anodes such as aluminum and iron and the formation of metal hydroxides such as $Al(OH)_3$, $Fe(OH)_2$ ve $Fe(OH)_3$ (Holt et al., 2002; Mollah et al., 2001). Metal ions dissolved from these electrodes form metal-polymer complexes according to ambient conditions and are coagulated adsorbing the contaminants. It is generally accepted that there are three consecutive stages in EC process; 1. formation of coagulant species and electrode dissolving in electrolytic oxidation, 2. destabilization of pollutants, particle suspension and breakage of emulsions, 3. collecting of flocks in destabilized phases (Mollah et al., 2001; Canizares et al., 2005). The rate of formation of different types of metal-polymer complexes plays an important role in color removal. Several interaction mechanisms are possible between dye molecules and hydroxyl products. They depend on the ambient pH and the type of ions present. In general, there are two main mechanisms. Adsorption at pH>6.5 and precipitation at lower pH values (Kobya et al., 2003; Alinsafi et al., 2005; Gurse et al., 2002; Rebhun and Lurie, 1993).

<u>Precipitation</u>

DYE + monomeric Al → [DYE - monomeric Al] pH 4-5 (1)

DYE + polimeric Al → [DYE - polimeric Al] pH 5-6 (2)

<u>Adsorption</u>

DYE + $Al(OH)_3$ → → → particul (3)

[DYE - polimeric Al] + $Al(OH)_3$ → → → particul (4)

The formed amorphous $Al(OH)_3$ "sweeper flocks" have a large surface area. Thus, they rapidly remove the organic compounds in wastewater and remove the collodial particles by catching them from the wastewater. These flocks are polymerized as n $Al(OH)_3$; $Al_n(OH)_{3n}$. They can be easily removed either by precipitation or H_2 flotation.

3. ELECTROCOAGULATION OF TEXTILE WASTEWATERS

Due to its advantages, the electrocoagulation process is now used as an effective method in treatment of industrial wastewater, especially in treatment of textile industry wastewater. The increase in product diversity and the use of dyestuffs with highly variable chemical properties make the treatment of textile wastewater difficult (O değişkenneill et al., 1999). In addition, a wide range of pollutant species in textile industry wastewater requires the use of different methods for treatment of such wastewater (Dörtkol, 2014).

Many studies have shown that COD, turbidity and dissolved solids are effectively eliminated by electrocoagulation process in treatment of textile wastewater (Bayramoglu et al., 2004; Daneshvar et al., 2004; Kobya et al., 2003; Can et al., 2003; Lin and Chen, 1997). In this study, the effects of the treatment of textile and tannery wastewater with EC on the removal efficiencies were demonstrated considering the effect of the electrode material and the shape of the connection (Table 1.). Process analyzes were carried out both technically and economically by founding the conditions when the highest pollutant removal occurs for the EC and at the same time economic data are minimum. Also, the advantages and disadvantages of the process and the issues to be considered in process selection were investigated.

Table 1. The effects of the treatment of textile wastewater with EC on the removal efficiencies

Wastewater type	Reaction conditions	Removal efficiencies (%)	References
Textile wastewater	continuous operation mode, iron anode and aluminum cathode	35% BOD, 42% TDS, 42% COD and 46% Cr	Babu et al. (2007)
Textile wastewater	Fe hexagonal wire anode-cathode, 200 A/m^2 current density, pH 7 and 90 min reaction time	%93 and 93 for COD and dyestuff	Tezcan and Aytac (2011)
Textile wastewater	batch mode and monopolar parallel iron anode&cathode	70% SS, 97% Cr, 46% COD and 90% sulfide	Apaydin et al. (2009)
Textile wastewater	batch mode, iron anode&cathode	84% COD and 100% color	Zaroual et al. (2006)
Textile wastewater	pH 7,5-10, 30 min reaction time and 30 V voltage with Fe-Fe anode&cathode	60-92% orange II dye	Nazrul et al. (2011)
Textile wastewater	batch mode with monopolar parallel aluminum anode&cathode and iron anode&cathode	82.2% COD (Al-Al), 85.5% TSS (Al-Al), 67.4% COD (Fe-Fe) and 86.2% TSS (Fe-Fe)	Varank et al. (2014)
Tannery wastewater	batch mode with monopolar parallel iron anode&cathode	96% turbidity, 98% Cr, 80% TVS, more than 80% Ca, 80% Zn, 50% COD and 65% TSS&TFS	Espinoza-Quinones et al. (2009)
Textile wastewater	batch reactor operation and aluminum anode&cathode	98% dyestuff (direct red 81)	Aoudj et al. (2010)
Textile wastewater	monopolar parallel, aluminum anode&cathode with batch mode	49%, 57% TOC and 59% 63% dye for DY and 81%, 89% TOC and 96% 99.9% dye	Eyvaz et al. (2009)
Textile wastewater	pH 9, 140-170 A/m^2 current density with Fe-Fe anode&cathode, 60 min reaction time	%76 and %95 for BR dye 5001B and COD	Tyagi et al. (2014)
Textile wastewater	pH 3-11, 10-50 V, with Al-Al anode&cathode for 10-60 min reaction	%99,88 for RG-19 dye	Alizad et al. (2014)
Textile wastewater	batch operation mode with monopolar aluminum and iron anode&cathode	76% COD (Fe-Fe) and 65% COD (Al-Al)	Can et al. (2006)
Textile wastewater	at pH 12 and 80 A/m^2 with Fe-Fe anode&cathode for 10-20 min	%80 for MB dye	Mahmoud et al. (2013)

Textile wastewater	2 stage electrocoagulation process at batch mode with iron and aluminum anode&cathode	68% COD, 43.1% ammonia, 55.1% TOC 96.7% sulfide and 84.3% color	Feng et al. (2007)
Textile wastewater	batch reactor mode with bipolar iron and aluminum anode&cathode	82% COD, 90% sulfide and 96% oil-grease	Şengil et al. (2009)
Textile wastewater	Al-Al anode&cathode, pH 6,5-9,7 251,6 A/m^2 current density and 60 min reaction time	87-97% for 4 synthetic dyes	Zerrouki et al. (2014)
Textile wastewater	at the conditions of 10-40 V, pH 2, 10-25 min reaction time	99.27% for azo dye	Yari et al. (2013)
Textile wastewater	100-300 A/m^2 current density with Fe-Fe anode&cathode	96.5% for RS dye	Kumar and Sahu (2013)
Textile wastewater	pH 5-7, 50-125 A/m^2 current density with Fe-Fe anode&cathode, 0-60 min reaction	%79.86 for COD and %96.88 for turbidity	Hossain et al. (2013)
Textile wastewater	at pH 3-11, 10-60 V, 0-5 A for 10-60 min with Al-Al anode&cathode	97.7% for BR-18 dye	Abbas and Ali (2018)
Textile wastewater	at pH 3-9 and 10-50 A/m^2 current density with Fe-Fe and Al-Al anode&cathode for 2-24 min of reaction	100 (Fe-Fe) and 95.78 (Al-Al) for MB dye	Mostafa et al. (2015)

Babu et al. (2007) studied treatment of textile wastewater with electrocoagulation (EC) process, at the conditions of continuous operation mode, iron anode and aluminum cathode and they obtained 35% BOD, 42% TDS, 42% COD and 46% Cr removal efficiencies. Tezcan and Aytac (2011) obtained max removal efficiency (%) as %93 and 93 for COD and dyestuff parameters, respectively for the EC of textile wastewater, with Fe hexagonal wire anode-cathode, 200 A/m^2 current density, pH 7 and 90 min reaction time. Apaydin et al. (2009) investigated EC of textile wastewater with batch mode and monopolar parallel iron anode&cathode, and 70% SS, 97% Cr, 46% COD and 90% sulfide removals were observed. Zaroual et al. (2006) studied EC with batch mode, iron anode&cathode and they found 84% COD and 100% color removal efficiencies. Nazrul et al. (2011) obtained 60-92% removal rates as the best for the orange II dye parameter, with pH 7.5-10, 30 min reaction time and 30 V voltage with Fe-Fe anode&cathode. Varank et al. (2014) obtained 82.2% COD (Al-Al), 85.5% TSS (Al-Al), 67.4% COD (Fe-Fe) and 86.2% TSS (Fe-Fe) removal, at the conditions of batch mode with monopolar parallel aluminum anode&cathode and iron anode&cathode. Espinoza-Quinones et al. (2009) investigated EC of tannery industry wastewater and they observed 96% turbidity, 98% Cr, 80% TVS, more than 80% Ca, 80% Zn, 50% COD and 65% TSS&TFS at batch mode with monopolar parallel iron anode&cathode. Aoudj et al. (2010) studied with batch reactor operation and aluminum anode&cathode and they observed more than 98% dyestuff (direct red 81) degradation. Eyvaz et al. (2009) investigated electrocoagulation of textile wastewater containing disperse dye (DY) and reactive dye (RY) and they obtained 57% TOC and 63% dye removals for DY and 89% TOC and 99.9% dye removals for RY, at the conditions of monopolar parallel, aluminum anode&cathode with batch mode. Tyagi et al. (2014) studied at the conditions of pH 9, 140-170 A/m^2 current density with Fe-Fe anode&cathode, and they obtained %76 and 95 removal efficiencies for the BR dye 5001B and COD parameters respectively, in 0-60 min reaction time. Alizad et al. (2014) found 99.88 removal efficiency for RG-19 dye at pH 3-11, 10-50 V, with Al-Al anode&cathode for 10-60 min reaction. Can et al. (2006), found 76% COD (Fe-Fe) and 65% COD (Al-Al) mineralizations at batch operation mode with monopolar aluminum and iron anode&cathode. Mahmoud et al. (2013) studied electrocoagulation of textile wastewater and they found %80 removal efficiency for MB dye for 10-20 min, at pH 12 and 80 A/m^2 with Fe-Fe anode&cathode. 68% COD, 43.1% ammonia, 55.1% TOC, 96.7% sulfide and 84.3% color removal efficiencies were obtained in a study with textile wastewater for 2 stage electrocoagulation process at batch mode with iron and aluminum anode&cathode (Feng et al., 2007). Şengil et al. (2009) found 82% COD, 90% sulfide and 96% oil-grease removals in their studies made at batch reactor mode with bipolar iron and aluminum anode&cathode. Zerrouki et al. (2014) studied removal of 4 synthetic dyes with EC, at the conditions of Al-Al anode&cathode, pH 6.5-9,7, 251.6 A/m^2 current density and 60 min reaction time and 87-97% max removal efficiencies were observed. Yari et al. (2013) investigated azo dye removal from the wastewater with EC, at the conditions of 10-40 V, pH 2, 10-25 min reaction time and they found 99.27% degradation. Kumar and Sahu (2013) obtained 96.5% removal efficiency for RS dye at 100-300 A/m^2 current density with Fe-Fe anode&cathode. Hossain et al. (2013) investigated the electrocoagulation of textile watewater and they observed the removal efficiencies %79.86 for COD and %96.88 for turbidity parameter as the best, at the conditions of pH 5-7, 0-60 min reaction time, 50-125 A/m^2 current density with Fe-Fe anode&cathode. In a study made with textile wastewater for EC process, 97.7% removal rate was observed for BR-18 dye, at pH 3-11, 10-60 V, 0-5 A for 10-60 min with Al-Al anode&cathode (Bazrafshan et al., 2014). MB dye treatment was investigated with electrocoagulation in textile wastewater by Mostafa et al. (2015), and 100, 95.78 removal efficiencies were observed as the best at pH 3-9 and 10-50 A/m^2 current density with Fe-Fe and Al-Al anode&cathode for 2-24 min of reaction.

4. CONCLUSIONS

Studies on electrocoagulation (EC), have begun to attract attention in recent years, for the textile wastewater treatment. The process is now used as an effective method in treatment of textile industry wastewaters, due to its advantages. These wastewaters, threaten the environment and human health, when discharged without treatment due to, have high dispersion rates, containing even very small amounts of dyestuffs. Nowadays, adsorption, filtration, chemical processes and biological activated sludge processes are preferred for color and COD removal from colored textile wastewaters. However, the electrocoagulation processes are more suitable for COD and color removal compared to other methods. EC processes, having a wide range of application area in wastewater treatment, could make a major contribution to the economy of concentrated waste discharging industries. Moreover, these processes can greatly reduce the pollutant load. Up to 100% color removal and high levels of chromium, COD and turbidity removal efficiencies were observed from textile and tannery industry wastewaters by EC process, in the studies made by different researchers.

REFERENCES

Alinsafi, A., Khemis, M., Pons, M.N., Leclerc, J.P., Yaacoubi, A., Benhammous, A., Nejmeddine, A., 2005, Electro-coagulation of reactive textile dyes and textile wastewater, *Chemical Engineering and Processing*, 44, 461-470.

Alizad, M., Ghahremani, E., Sadeghi, S., 2014, Removal of reactive green 19 dye from synthetic wastewater using electrocoagulation and aluminum electrodes, *Journal of Advances in Environmental Health Research*, 3(1), 42-48.

Aoudj, S., Khelifa, A., Drouiche, N., Hecini, M., Hamitouche, H., 2010, Electrocoagulation process applied to wastewater containing dyes from textile industry, *Chem. Eng. Process*, 49(11), 1176-1182.

Apaydin, O., Kurt, U., Gonullu, M., 2009, An investigation on the treatment of tannery wastewater by electrocoagulation, *Glob. NEST J.*, 11 (4), 546-555.

Babu, R.R., Bhadrinarayana, N.S., Meera, K.M., Begum, S., Anantharaman, N., 2007, Treatment of tannery wastewater by electrocoagulation, *J. Univ. Chem. Technol. Metallurgy*, 42(2), 201-206.

Bayramoglu, M., Kobya, M., Can, O.T. ve Sozbir, M., 2004, Operating cost analysis of electrocoagulationof textile dye wastewater, *Separation and Purification Technology*, 37, 117–125.

Bazrafshan, E., Mahvi, A.H., Zazouli M.A., 2014, Textile wastewater treatment by electrocoagulation process using aluminum electrodes, *Iranian Journal of Health Sciences*, 2(1), 16-29.

Cameselle, C., Pazos, M., Sanromán, M.A., 2005, Selection of an electrolyte to enhance the electrochemical decolourisation of indigo, Optimisation and scale-up, *Chemosphere*, 60, 1080-1086.

Can, O.T., Bayramoglu, M., Kobya, M., 2003, Decolorization of reactive dye solutions by electrocoagulation using aluminum electrodes, *Engineering Chemistry Research*, 42, 3391–3396.

Can, O.T., Kobya, M., Demirbas, E., Bayramoglu, M., 2006, Treatment of the textile wastewater by combined electrocoagulation, *Chemosphere*, 62(2), 181-187.

Canizares, P., Carmona, M., Lobato, J., Martinez, F., Rodrigo, M.A., 2005, Electrodissolution of aluminum electrodes in electrocoagulation processes, *Indian journal of Engineering Chemical Research*, 44, 4178-4185.

Chen, G., 2004, Electrochemical technologies in wastewater treatment, *Separation and Purification Technology*, 38, 11–41.

Daneshvar, N., Sorkhabi, H.A., Kasiri, M.B., 2004, Decolorization of dye solution containing acid red 14 by electrocoagulation with a comparative investigation of different electrode connections, *Journal of Hazardous Materials*, 112, 55–62.

Dörtkol, M., , 2014, Doğal ve modifiye kil ile sulu çözeltilerden boyar madde giderimi, Yüksek lisans tezi, *Nevşehir Hacı Bektaş Veli Üniversitesi Fen Bilimleri Enstitüsü*, Nevşehir, 86s.

Espinoza-Qui~nones, F.R., Fornari, M.M.T., Modenes, A.N., Palacio, S.M., da Silva Jr., F.G., Szymanski, N., Kroumov, A.D., Trigueros, D.E.G., 2009, Pollutant removal from tannery effluent by electrocoagulation, *Chem. Eng. J.*, 151(1-3), 59-65.

Eyvaz, M., Kirlaroglu, M., Aktas, T.S., Yuksel, E., 2009, The effects of alternating current electrocoagulation on dye removal from aqueous solutions, *Chem. Eng. J.*, 153(1-3), 16-22.

Feng, J., Sun, Y., Zheng, Z., Zhang, J., Li, S., Tian, Y., 2007, Treatment of tannery wastewater by electrocoagulation, *J. Environ. Sci.*, 19(12), 1409-1415.

Gurses, A., Yalcın, M., Dogan, C., 2002, Electrocoagulation of some reactive dyes; A statistical investigation of some electrochemical variable, *Waste Management*, 22, 491-499.

Holt, P.K., Barton, G.W., Wark, M., Mitchell, C.A., 2002, A quantitative comparison between chemical dosing and electrocoagulation, *Colloids Surf.*, 211-233.

Hossain, M.M., Mahmud, M.I., Parvez, M.S., Cho, H.M., 2013, Impact of current density, operating time and pH of textile wastewater treatment by electrocoagulation process, *Environmental engineering research*, 18(3), 157-161.

Jia, J., Yang, J., Liao, J., Wang, W., Wang, Z., 1999, Treatment of dyeing wastewater with ACF electrodes, *Water Research*., 33, 881–884.

Kocaer, F.O., Alkan, U., 2002, Boyar madde içeren tekstil atıksularının arıtım alternatifleri, *Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi*, 1(7), 47-55,.

Kobya, M., Can, O.T., Bayramoglu, M., 2003, Treatment of textile wastewaters by electrocoagulation using ıron and aluminum electrodes, *Journal of Hazardous Materials*, 100, 163-178.

Kumar, K., Sahu, O., 2013, Removal of dye by electrocoagulation method, *Hydrology*, 1(1), 8-11.

Lin, S.H., Chen, M.L., 1997, Treatment of textile wastewater by electrochemical methods for reuse, *Water Research*, 31, 868–876.

Mahmoud, M.S., Farah, J.Y., Farrag, T.E., 2013, Enhanced removal of Methylene Blue by electrocoagulation using iron electrodes, *Egyptian journal of petroleum*, 22, 211-216.

Mıdık, F., 2011, Reaktif sarı 145 azo boyar maddesinin ve 2,4-diklorofenoksiasetik asit pestisitinin yüksüz nano demir, fenton ve foto-fenton prosesleri ile karşılaştırmalı giderilmesi, Yüksek lisans tezi, *Çukurova Üniversitesi, Fen Bilimleri Enstitüsü*, Adana, 89s.

Mollah, M.Y.A., Schennach, R., Parga, J.R., Cocke, D.L., 2001, Electrocoagulation (EC)–science and applications, *Journal of Hazardous Materials*, 84, 29-41.

Mostafa, A., Esmail, G., Mansur, Z., Sara, H., 2015, Efficient de-colorization of Methylene Blue by electrocoagulation method: Comparison of iron and aluminum electrode, *Iranian journal of chemistry and chemical engineering*, 34(1), 39-47

Nazrul Islam, S.M., Rahman, S.H., Adyel, T.M., Ahmed, M.S., Yesmin, R.A., Rahman, M.M., Kaiser, N., 2011, Electrocoagulation (EC) technique for color removal from orange II dye, *Bangeladesh Journal Of Environmental Research*, 9, 45-52.

O'neill, C., Hawkes, F.R., Hawkes, D.L., Lourenço, N.D., Pinheiro, H.M., Delée, W., 1999, Colour in textile effluents-sources, measurement, discharge consents and simulation: a review, *Journal of Chemical Technology&Biotechnology*, 74, 1009–1018.

Rebhun, M., Lurie, M., 1993, Control of organic matter by coagulation and separation, *Water Science and Technology*, 27(11), 1-20.

Şahin, Y., Asit boya banyosu atıksularının kimyasal prosesler ile ön arıtılabilirliğinin incelenmesi, 2006, Yüksek lisans tezi, *İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü*, İstanbul, 137s.

Şengil, I.A., Kulaç, S., Özacar, M., 2009, Treatment of tannery liming drum wastewater by electrocoagulation, *J. Hazard. Mater.*, 167(1-3), 940-946.

Tezcan, U., Aytac, E., 2011, Treatment of textile wastewaters by electrocoagulation method, *2 nd international conference on chemical engineering and applications, IPCBEE*, Singapore, 138-140.

Tyagi, N., Mathur, S., Kumar, D., 2014, Electrocoagulation process for textile wastewater treatment in continuous upflow reactor, *Journal of Scientific & Industrial Research*, 73, 195-198.

Varank, G., Erkan, H., Yazıcı, S., Demir, A., Engin, G., 2014, Electrocoagulation of tannery wastewater using monopolar electrodes: process optimization by response surface methodology, *Int. J. Environ. Res.*, 8(1), 165-180.

Vyssides, A.G., Loizidou, M., Karlis, P.K., Zorpas, A.A., Papaioannou, D., 1999, Electrochemical oxidation of a textile dye wastewater using a Pt/Ti electrode, *Journal of Hazardous Materials*, 70, 41-52.

Yari, A.R., Alizadeh, M., Hashemi, S., Biglari, H., 2013, Efficiency of electrocoagulation for removal of reactive yellow 14 from aqueous environments, *Archives of Hygiene Sciences*, 2(1), 7-15.

Zaroual, Z., Azzi, M., Saib, N., Chainet, E., 2006, Contribution to the study of electrocoagulation mechanism in basic textile effluent, *J. Hazard. Mater.*, 131(1-3), 73-78.

Zerrouki, D., Benhadji, A., Ahmed, M.T., 2014, Treatment of textile wastewater by electrocoagulation, *2 nd international conferencefor renewable energy CIER*, Sci Technol, 1993, 27, 1-20.