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Electro-chemical treatment of wastewater

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ABSTRACT: Conventional treatment of industrial wastewater is often ineffective in removing color, especially from highly colored textile wastewater. This research was undertaken to investigate the removal of color and COD from textile effluent using electro-chemical treatment system. The effects of applied electric charge (0-200 Amp-min) and pH on the removal of color and COD have been analyzed. Efficiency of electro-chemical treatment in removing Arsenic (As) and Chromium (Cr) from synthetic wastewater has also been assessed. In the laboratory electrochemical treatment system, mild steel plates have been used as electrodes in both parallel and series connections. For color and COD removal, four electrodes each with a surface area of 177.3 cm^2 and with inter-electrode distance of 2.3 cm in parallel connection have been used in the electro-chemical cell. Under the experimental conditions, color removal (initial concentration 1070 Pt.Co. unit) approaching 100% and COD removal (initial concentration 110 mg/l) of over 50% have been achieved. Removal of both color and COD increased with increasing electric charge and initial pH of wastewater sample. The results suggest that electro-chemical treatment could be very effective for removal of color from textile wastewater. Electro-chemical treatment has also been found to be very effective in removing As and Cr from synthetic wastewater samples. Thus, electro-chemical treatment in combination with biological treatment could provide an efficient treatment solution for highly colored textile wastewater and wastewater containing heavy metals.

1 INTRODUCTION

The surface and ground waters of Bangladesh have been undergoing severe pollution from untreated domestic sewage and industrial effluents, especially from textile and tannery industries. In textile industries, dyeing and finishing are the two most important process operations, which consume large amount of water and generates considerable amount of wastewater containing strong color, suspended particles, high pH, and high COD and BOD. The textile effluent is hard to be treated by chemical methods as these techniques generate considerable amount of sludge, which itself requires further treatment. While the biological methods are relatively cheap, they are often difficult to apply for treatment of textile wastewater since most commercial dyes are non-biodegradable and toxic to the organisms resulting in sludge bulking. Biological treatment systems are not efficient in removing color from highly colored textile effluents. On the other hand, the advanced techniques such as reverse osmosis/ultra-filtration have the disadvantages of high cost and low throughput. Electro-chemical treatment in combination with biological treatment could provide a cost effective and efficient treatment solution for colored industrial effluent.

Electro-chemical treatment of wastewater is a process in which wastewater is treated by passing electricity through electrodes where wastewater acts as electrolyte in an electro-chemical reactor. Electro-chemical treatment produces in situ coagulants by dissolution of metal ions from the anode with simultaneous formation of hydroxyl ions and hydrogen gas at the cathode. This process produces corresponding metal hydroxides and/or poly-hydroxides which work like coagulants and flocculants to remove the pollutants (Daneshwar *et al.*, 2004). Gas bubbles are also generated which provide the flocculated particles additional buoyancy to float at the water surface and also adsorbs pollutants (e.g., oil). Application of electricity introduces strong oxidizing agents (e.g., H_2O_2, Cl_2, H_2O_2) which oxidize the soluble organic matters in wastewater (Naumczyk *et al.*, 1996; Vlyssides *et al*., 1997; Brillas *et al*., 1995, 1996; Matsue *et al*., 1981).

Successful electro-chemical treatment of various industrial effluents has been reported by several researchers and it is considered to be a potentially effective technique for treatment of wastewaters with high removal efficiency. Electro-chemical technology has been adopted successfully to treat various types of water/ wastewater, such as textile wastewater (Can et *al.*, 2003); heavy metal laden wastewater (Lai and Lin, 2003); landfill leachate (Tsai et *al.*, 1997); salina wastewater (Lin et *al.*, 1998). It has also been used for defluoridation (Zhu et *al.*, 2007), arsenic removal (Balasubramanian and Madhavan, 2001), removal of nitrate (Koparal *et al.*, 2002), removal of dissolved organic carbon (Jiang *et al.*, 2002), and removal of oil and grease (Chen *et al.*, 2000). In Bangladesh, research on and utilization of electro-chemical treatment system are rather limited. A textile industry (JK textile industry, South Dariapur, Savar, Dhaka) has been found to use electro-chemical treatment for the treatment of its wastewater. In this study, efficiency of electro-chemical treatment system for the removal of color and COD from textile wastewater has been analyzed; removal efficiency of As and Cr from synthetic wastewater has also been assessed.

2 MATERIALS AND METHODS

2.1 *Experimental setup*

The laboratory electro-chemical treatment system used in the present study consists of two components: (a)Electro-chemical cell/reactor, and (b)DC power system.

a) *Electro-chemical cell*

The electro-chemical cell consists of body of the cell and electrodes. Body of the electro-chemical cell was made with a glass biker of 2 liter capacity having 12 cm inside diameter and 85 cm height (see Fig. 1). Four mild steel plates with a thickness of 0.3 cm have been used as electrodes, arranged parallel to each other. The dimension of each electrode that remains in contact with wastewater when the biker is filled with 1 liter of sample is 9 cm (height) by 9.4 cm (width). An inter-electrode distance of 2.3 cm has been kept between each pair of electrodes. Provisions were made in the cell for both parallel and series connection of the electrodes.

Figure 1. Laboratory scale electro-chemical treatment system

(b) *DC power system*

A DC (Direct Current) power system was made using stepped down transformer and rectifier to supply DC at desired voltage to the reactor. The system converted the input Alternating Current (AC) into DC of desired voltage. Provision was made to regulate the voltage in the range of 20- 25 volts. There was also provision to change the current density. A digital multi-meter (DT-830 B) of 0-10 Ampere range was used with the power system to measure the applied current density at different time intervals. Figure 1 shows the electro-chemical treatment system used in the laboratory.

2.2 *Wastewater sample*

2.2.1 *Textile wastewater*

Textile effluent collected after dyeing process from the JK textile industry, South Dariapur, Savar, Dhaka, was used as wastewater sample for color and COD removal study. The sample was collected on March 10, 2010.

The characteristics of the wastewater sample are presented in Table 1.

Table 1. Characteristics of wastewater sample from JK textile industry

Parameter	Value
pH	9.74
Conductivity, EC (μs/cm)	1813
COD (mg/L)	110
Color (Pt-Co units)	1070
TSS (mg/L)	120
TDS (mg/L) 100°C	3000

The laboratory experiments were conducted using parallel connection of the electrodes. An average current density of 2.5 Amp and a constant DC voltage of 23 volts were applied. The electrodes were washed with tap water to remove the impurities before the tests were started. Three sets of tests were performed with different initial pH values in the range of 5 to 11.1 for three samples keeping the other parameters unchanged. NaOH was used to increase the pH and HNO_3 was used to lower the pH of the sample. In each experiment, sample volume was 1 liter. The current density was found to change with time during the test and was measured at regular time interval with the help of the multi-meter. Samples were collected from the reactor at different treatment times with the help of a pipette. After collection, each sample was allowed to settle for 30 minutes and was filtered with normal filter paper to remove the solids. Electrical conductivity pH, Color and COD of the collected samples were measured.

2.2.2 *Wastewater containing heavy metals*

A synthetic wastewater sample containing 30.46 ppm Cr and 511 ppb As was prepared by addition required quantities of standard 1000 ppm Cr and standard 1000 ppm As solution to groundwater (collected from a deep tubewell pump station at BUET). The conductivity of the groundwater was increased by adding NaCl (2 gm per liter of solution); the conductivity was raised to 4.36 ms/cm. Initial sample pH was 7.03 and initial temperature was 26.7^{o}C.

The laboratory experiments were conducted with series connection of the electrodes. A constant DC voltage of 26 volt at an average current density of 1.5 Amp was used. Samples were collected from the reactor at different treatment times with the help of a pipette. All treated samples were filtered with normal filter paper before determination of the concentration of As and Cr.

2.3 *Analytical techniques*

pH and Electrical conductivity were measured using pH/Conductivity meter (WTW, Model: 82362,Germany). COD was determined using potassium permanganate as oxidizing agent, following the Standard Methods. Color was measured using a Portable Spectrophotometer (HACH DR/2010). Concentration of Chromium was determined using Atomic Adsorption Spectrophotometer (Flame-AAS). Concentration of Arsenic was determined using an Atomic Adsorption Spectrophotometer (GF-AAS, Shimadzu, AA-6800).

3 RESULTS AND DISCUSSIONS

3.1 *Removal of COD and color from textile wastewater*

3.1.1 *Effect of applied electric charge*

Figure 2 and Fig. 3 show color and COD removal efficiencies, respectively as a function of applied electric charge for samples with different initial pH values. The figures show increasing removal of both color and COD with increasing electric charge, similar to the results reported by Chithra *et al.*, (2008). This is because increased electric charge enhances the anodic dissolution, resulting in a greater amount of precipitates for the removal of pollutants. In addition, the rate of bubble generation also increases with an increase in current density, which enhances the pollutant removal efficiency. Figures 2 and 3 also show that higher pH favors removal of both color and COD. Figure 2 shows that nearly 100% removal of color was achieved at an applied electric charge of about 50 Amp-min for a sample with initial pH of 11.1. With lower pH of wastewater, higher electric charge is required to achieve similar removal efficiency. Figure 3 shows that highest COD removal of about 55% was achieved at applied electric charge of about 130 Amp-min for a sample with initial pH of 11.1; removal decreases with decreasing initial pH of wastewater. Figure 3 shows that beyond an electric charge of about 130 Amp-min, the COD removal efficiency reaches a plateau with minor increase in COD removal with increasing electric charge. The results demonstrate that electro-chemical treatment could be very effective in removing color, and could also be used to reduce COD to some extent. Thus, a combination of biological and electro-chemical treatment could be utilized to reduce both color and COD from textile wastewater.

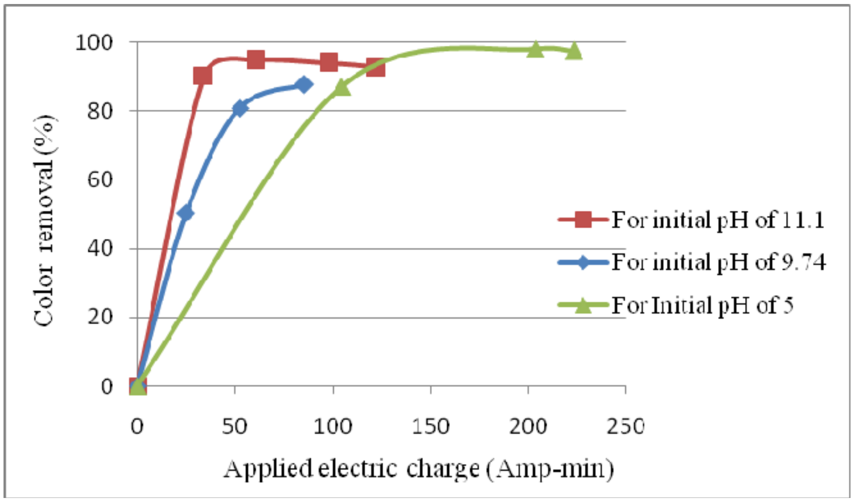

Figure 2. Removal of color with applied electric charge for samples with different initial pH values

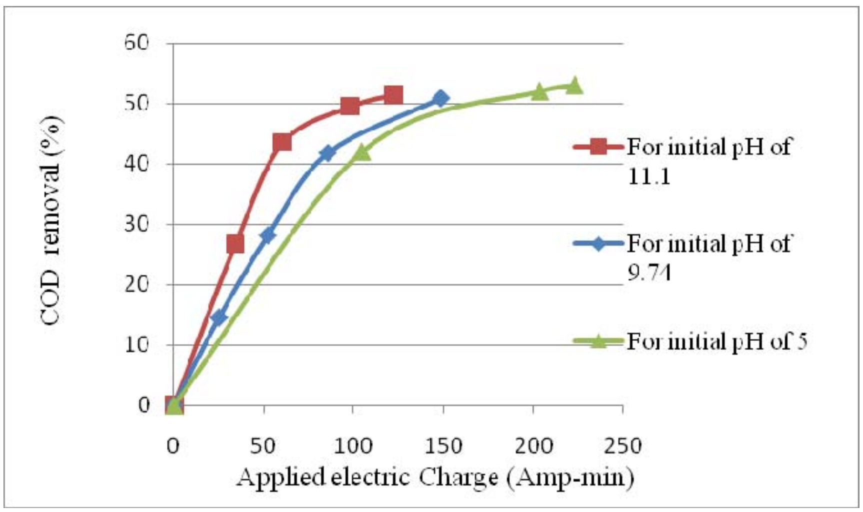

Figure 3. Removal of COD with applied electric charge for samples with different initial pH values

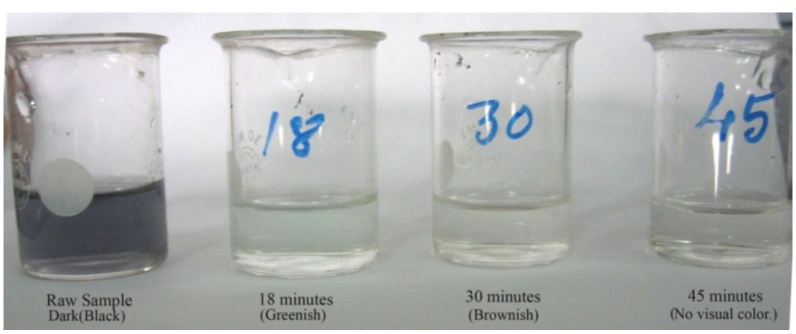

Figure 4. Color of raw sample and samples at different treatment times with initial sample pH of 11.1

Figure 4 shows the color of raw wastewater sample (initial pH 11.1) and samples at different treatment times. As shown in Fig. 4, the dark color of the raw wastewater sample turns greenish, brownish and colorless at 18 minutes, 30 minutes and 45 minutes of treatment time, respectively.

3.1.2 *Effect of initial sample pH*

Figures 2 and 3 show that the removal of both color and COD increases with increasing initial pH of the raw wastewater sample. Similar results have also been reported by Chithra *et al.* (2008), who used electro-coagulation to treat synthetic bismarck brown dye effluent. The possible reason for this phenomenon is that hydroxyl ions (OH^-) act as an aid to form $Fe(OH)_2$ and $Fe(OH)_3$ which are major coagulants.

3.1.3 *Variation of sample pH and EC with treatment time*

Figure 5 shows that the pH of the wastewater sample increases with increase in applied electric charge. This could be due to the reduction of water at cathode and production of Hydrogen gas (H_2) and hydroxyl ions (OH^-).

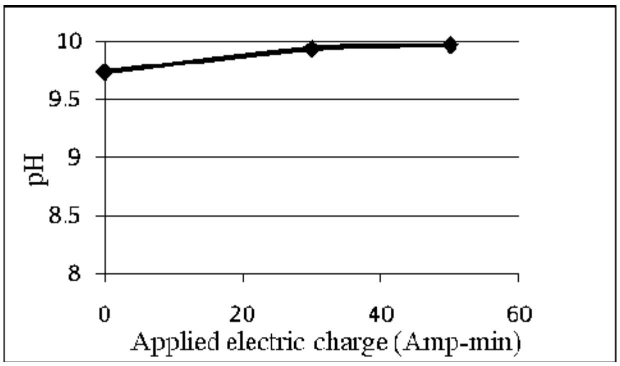

Figure 5. Change of sample pH with applied electric charge for the sample with initial pH of 9.74

Figure 6 shows that the Electrical conductivity (EC) of the wastewater sample increases with increasing applied electric charge. This is most likely due to the dissolution of metal ions at the anode generating ferrous ions and simultaneous formation of hydroxyl ions at the cathode.

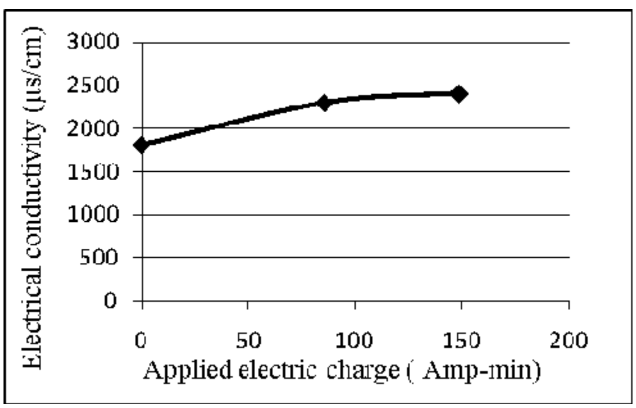

Figure 6. Change of Electrical conductivity with applied electrical charge for sample with initial pH of 9.74

3.2 *Simultaneous removal of As and Cr*

Figure 7(a) and Fig. 7(b) show the removal of As as a function of applied electric charge and treatment time, respectively. An excellent As removal efficiency of 94% was achieved for a synthetic wastewater sample with an initial As concentration of 511 ppb at an applied electric charge of 12 Amp-min and at treatment time of 7 minutes.

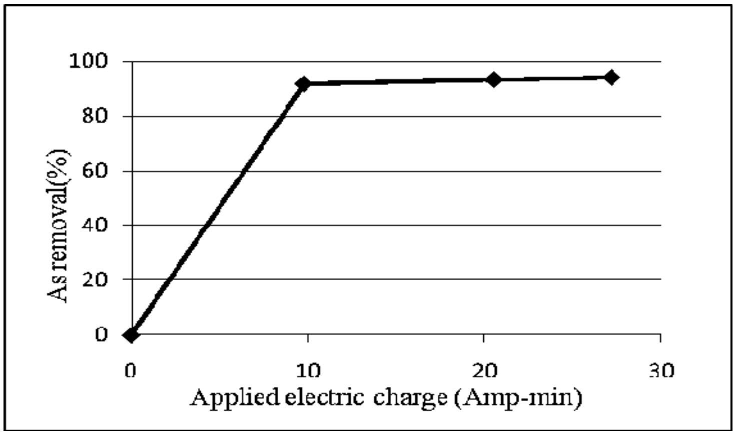

Figure 7(a). Arsenic removal as function of applied electric charge

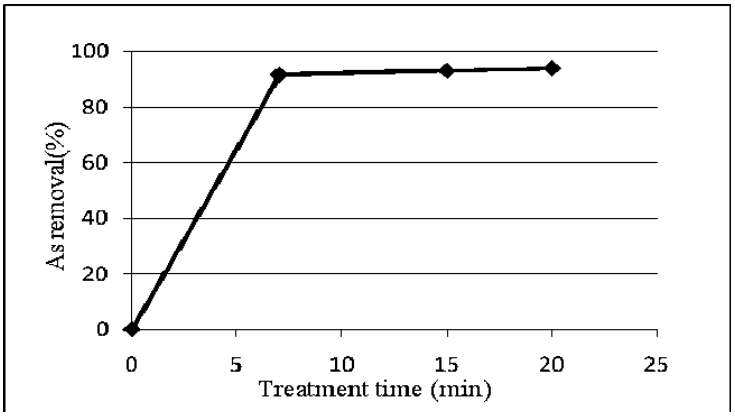

Figure 7(b). Arsenic removal as a function of treatment time

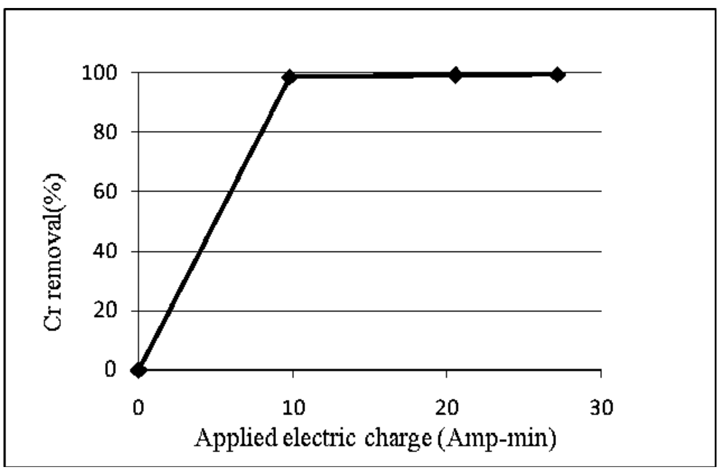

Figure 8(a). Chromium removal as a function of applied electric charge

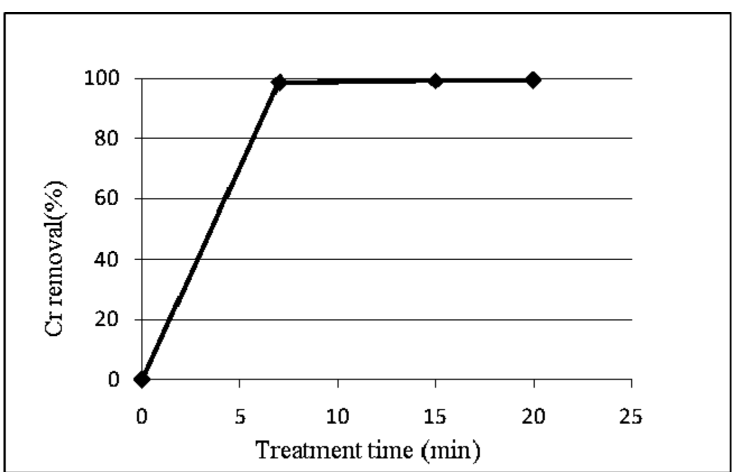

Figure 8(b). Chromium removal as a function of treatment time

Figure 8(a) and Fig. 8(b) show the removal of Cr as a function of applied electric charge and treatment time, respectively. It shows excellent Cr removal of around 99% for a synthetic wastewater sample with an initial

Cr concentration of 30.5 ppm at an applied electric charge of 10 Amp-min and at treatment time of 6.5 minutes. Kongjao *et al.* (2008) applied electro-chemical technique for removal of chromium and various pollutants from tannery wastewater and reported about 95% removal of chromium from wastewater with an initial Cr concentration of 14.3 ppm.

4 CONCLUSIONS

It appears that electro-chemical treatment could be very effective in removing color from wastewater; it could also be used to remove COD to some extent. Under the experimental conditions employed in this study, color removal approaching 100% and COD removal of over 50% have been achieved. Removal of both color and COD has been found to increase with increasing initial pH of raw wastewater sample. The pH and Electrical Conductivity of the wastewater sample have been found to increase with increasing applied electric charge during treatment. Electro-chemical treatment has also been found to be very effective in removing both As and Cr from synthetic wastewater samples. The results of this study suggest that electro-chemical treatment, in combination with other treatment methods (e.g., biological treatment), could be effectively used for the treatment of highly colored textile wastewater and wastewater containing heavy metals. The findings from this study could be used to improve the design of electro-chemical treatment systems and modify existing systems to improve efficiency.

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REFERENCES

Balasubramanian, N. and Madhavan, K. 2001. Arsenic removal from industrial effluent through electrocoagulation. *Chemical Engineering Technology* 24: 519-521.

Brillas, E., Bastida, R.M., Llosa, E. and Casado, J. 1995. Electrochemical destruction of aniline and 4-chloroaniline for wastewater treatment using a carbon-PTFE O2-fed cathode. *Journal of the Electrochemical Society* 142 (6): 1733–1741.

Brillas, E., Mur, E. and Casado, J. 1996. Iron(II) catalysis of the mineralization of aniline using a carbon-PTFE O2-fed cathode. *Journal of the Electrochemical Society* 143 (3): L49–L53.

Can, O.T., Bayramoglu, M. and Kobya, M. 2003. Decolorization of reactive dye solutions by electrocoagulation using aluminum electrodes. *Ind. Eng. Chem. Res*. 42**:** 3391–3396.

Chen, X., Chen G. and Yue P. L. 2000. Separation of pollutants from restaurant wastewater by electro – coagulation. *Separation and purification technology* 19**:** 65 – 76.

Chithra, K., Thilakavathi.R., Murugan.A.A.,Marimuthu.C. and Balasubramanian.N. 2008. Treatment of Textile Effluent Using Sacrificial Electrode. *Modern Applied Science* 2 (4): 38-43.

Daneshwar, N., Oladegaragoze, A. and Djafarzadeh, N. 2004. Decolorization of basic dye solutions by electro coagulation: An investigation of the effect of operational parameters. *Journal of Hazardous Materials* B129: 116-122.

Jiang, J.Q., Graham N., André C., Kelsall G. H. and Brandon N. 2002. Laboratory study of Electro-coagulation–flotation for water treatment. *Water research* 36**:** 4064-4078.

Kongjao, S., Damronglerd,S., and Hunsom,M. 2008. Simultaneous removal of organic and inorganic pollutants in tannery wastewater using electro-coagulation technique. *Korean Journal of Chemical Eng*ineering 25 (4): 703-709.

Koparal S. A. and Ogutveren U. B. 2002. Removal of nitrate from water by electro reduction and electro-coagulation. *Journal of hazardous waste material* B89: 83-94.

Lai, C.L. and Lin, S.H. 2003. Electrocoagulation of chemical mechanical polishing (CMP) wastewater from semiconductor fabrication. *Chem. Eng. J*. 95**:** 205–211.

Lin, S.H., Shyu, C.T. and Sun, M.C. 1998. Saline wastewater treatment by electrochemical method. *Water res.* 32**:** 1059-1066.

Matsue, T., Fujihira, M. and Osa, T. 1981. Oxidation of alkylbenzenes by electrogenerated hydroxyl radical. *Journal of the Electrochemical Society* 128 (12): 2565–2569.

Naumczyk, J., Szpyrkowicz, L. and Zilio-Grandi, F. 1996. Electrochemical treatment of textile wastewater. *Water Science and Technology* 34 (17): 17–24.

Tsai, C.T., Lin, S.T., Shue, Y.C. and Su, P.L. 1997. Electrolysis of soluble organic matter in leachate from landfills. *Water Res*. 31**:** 3073–3081.

Vlyssides, A.G., Israilides, C.J., Loizidou, M., Karvouni, G. and Mourafeti, V. 1997. Electrochemical treatment of vinasse from beet molasses. *Water Science and Technology* 36 (2–3): 271–278.

Zhu, J., Zhao, H. and Ni, J. 2007. Fluoride distribution in electro-coagulation defluoridation process. *Separation and Purification Technology* 56 (2): 184-191.