ELECTROCOAGULATION USING NOVEL CONFIGURATIONS ELECTRODES FOR TREATMENT OF TEXTILE WASTEWATER

AHMED SAMIR NAJE

A thesis submitted in fulfilment of the
requirements for the award of degree of
Doctor of Philosophy

UTM Razak School of Engineering and Advanced Technology
Universiti Teknologi Malaysia

OCTOBER 2016

DEDICATION

To Allah (SWT), my beloved mother and father

ACKNOWLEDGEMENT

My deepest gratitude is to my family for their understanding, encouragement, and patience that supported me through the whole course of this study. Without there, I would not have been able to complete much of what I have done.

Professor Datin. Dr. Zuriati Zakaria, my supervisor, provided a motivating, enthusiastic, and critical atmosphere during many discussions we had. It was a great pleasure to me to conduct this thesis under her supervision.

I would like to express my genuine appreciation to Assoc. Prof. Dr. Shreeshivadasan Chelliapan, my co-supervisor for his incessant support, guidance, advice and encouragement.

Special thanks to my friend Dr. Mohammed A. Ajeel for his help and also thanks to lab mates in the environmental laboratories, Razak School and MJIIT, UTM.

Last but definitely not least, my deepest and most heartfelt gratitude to my beloved parents and my in-laws for their endless love and support.

Ahmed S. Naje
October 2016

ABSTRACT

Textile wastewater is considered as one of the most polluted wastewater. Conventional chemical coagulation is the most famous technique used to treat the textile effluent. However, this method produces low removal rate, long retention time and a large quantity of sludge and chemicals. The electrocoagulation (EC) technology is an active wastewater treatment used before sedimentation and filtration. It is still in the "black box" stage where process design, control, and optimization have been primarily empirical. In this research, the EC process was performed in two models for the treatment of textile wastewater. The first model is the conventional reactor with a new configuration that has static electrodes, classified in two phases. The two phases are the EC process alone, using Mp Al-Bp Al or Mp Al-Bp Fe and EC combined with electrooxidation process (EO) in the same reactor using MpTi-Bp Al or MpTi-Bp Fe. The second model is a novel reactor design with a rotating anode using aluminum electrodes. The rotating anode consists of 10 impellers supported by a shaft with 10 rings used as a cathode. The operational parameters were investigated, and the process was performed under optimal conditions. For model one, the results showed that the Mp Al-Bp Al was more effective than the Mp Al-Bp Fe and it was more efficient than chemical coagulation. The optimal combination (EC-EO) treatment was established with Mp Ti-Bp Al, and it is found to be more active than EC alone. The optimal parameters of the EC process with a novel rotating anode were 4 mA/cm^2 current density, 150 rpm rotational speed, and 10 minutes reaction time. EC process with a rotating anode was more active than model one and chemical coagulation, where the removal efficiency was higher, and the operational cost were reduced significantly. The increase of impellers anode diameter led toenhance the mass transfer coefficient of ionic aluminum. This result was confirmed by computational fluid dynamic (CFD) simulation results. By solar cell supply, the EC process with rotating anode reactor using batch and continuous flow regime had almost similar removal rate. Zeta potential tests showed that reaction was chemo-adsorption, and this was validated by the X-ray diffraction (XRD) analysis. Moreover, the reaction product was environmental friendly. Hydrogen production was improved at a rotation speed of anode. The electrode passivation was reduced by increasing rotational speed of anode which led to an improved in the EC process performance and validated the reactor design. Finally, the contribution of this study is a novel EC reactor with a rotating anode which is more efficient and economic as compared to the conventional coagulation process in the textile wastewater treatment.

ABSTRAK

Air sisa tekstil dianggap sebagai salah satu air sisa yang paling tercemar. Penggumpalan bahan kimia konvensional adalah teknik yang paling terkenal untuk merawat efluen tekstil. Namun begitu, kaedah ini mempunyai kadar penyingkiran yang rendah, masa penahanan yang lama, dan kuantiti enapcemar dan bahan kimia yang banyak. Teknologi elektroenap cemar (*electrocoagulation*, EC) merupakan rawatan air sisa aktif yang digunakan sebelum proses pemendapan dan penapisan. Teknologi ini masih dalam peringkat percubaan memandangkan reka bentuk proses, kawalan dan pengoptimuman masih di tahap empirikal. Dalam kajian ini, proses EC telah dilaksanakan dengan menggunakan dua model untuk rawatan air sisa tekstil. Model pertama ialah reaktor konvensional dengan konfigurasi baru yang menggunakan elektrod-elektrod statik, yang diklasifikasikan dalam dua fasa. Dua fasa tersebut ialah proses EC sahaja yang menggunakan Mp Al-Bp Al atau Mp Al-Bp Fe dan proses EC digabungkan dengan elektropengoksidaan (*electro-oxidation*, EO) dalam reaktor yang sama menggunakan Mp Ti-Bp Al atau Mp Ti-Bp Fe. Model kedua ialah reka bentuk reaktor baharu dengan anod berputar menggunakan elektrod aluminium. Anod berputar terdiri daripada 10 pendesak yang disokong oleh aci dengan 10 cecincin sebagai katod. Parameter operasi disiasat dan proses ini dilaksanakan dalam keadaan yang optimum. Keputusan bagi model pertama menunjukkan Mp Al-Bp Al lebih berkesan berbanding Mp Al-Bp Fe dan lebih cekap berbanding penggumpalan kimia. Rawatan gabungan optimum (EC-EO) dibina dengan Mp Ti-Bp Al dan rawatan ini didapati lebih aktif berbanding EC sahaja. Parameter optimum untuk proses EC dengan anod berputar baharu adalah 4 mA/cm^2 untuk ketumpatan semasa, kelajuan putaran pada 150 rpm, dan 10 minit untuk masa tindak balas. Proses EC dengan anod berputar adalah lebih aktif berbanding model pertama, kecekapan penyingkiran proses penggumpalan kimia adalah lebih tinggi dan kos operasi berjaya dikurangkan dengan ketara. Penambahan diameter anod pendesak menjurus kepada peningkatan pekali pemindahan jisim bagi aluminium ionik. Keputusan ini disahkan dengan keputusan simulasi pengiraan dinamik bendalir (CFD). Berbekalkan sel solar, proses EC dengan reaktor anod berputar menggunakan rejim kelompok dan rejim aliran berterusan menunjukkan kadar penyingkiran yang hampir sama. Ujian potensi Zeta menunjukkan bahawa tindak balas yang berlaku ialah kemo-jerapan, sebagaimana yang disahkan oleh analisis belauan sinar-X (XRD). Selain itu, produk tindak balas ialah mesra alam. Pengeluaran hidrogen adalah bertambah baik dengan kelajuan putaran anod. Pempasifan elektrod dikurangkan dengan meningkatkan kelajuan putaran anod yang mana meningkatkan prestasi proses EC dan mengesahkan reka bentuk reaktor. Akhir sekali, sumbangan kajian ini adalah reaktor EC baharu dengan anod berputar yang lebih effisien dan lebih ekonomi berbanding dengan unit kimia konvensional untuk rawatan air sisa tekstil.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

I	-	Current intensity (A)
Mw	-	Molecular weight of the substance (g/mol)
F	-	Faraday's constant (96485 C/mol)
z	-	Number of electrons (2 for Fe^{2+} and 3 for Fe^{3+} and Al^{3+})
m	-	Quantity of metal dissolved (g)
XRD	-	X-ray diffraction
Mp Al- Bp Al	-	Monopolar aluminum –Bipolar aluminum
AC	-	Alternating current
DC	-	Direct current
η_{AP}	-	Applied overpotential (V)
η_{k}	-	Kinetic overpotential (V)
η_{Mt}	-	Concentration overpotential (V)
η_{IR}	-	Overpotential caused by solution resistance or IR-drop (V)
IR-drop	-	Drop of internal resistance between electrodes (V)
d_e	-	Distance between the electrodes (cm)
A	-	Surface area of the cathode (cm^2)
w	-	Specific conductivity of the solution (µS/cm)
Km	-	Mass transfer coefficient (cm/sec)
i_L	-	Limiting current (A)
n	-	Electron moles (3 for Al and 2 for Fe)
C_b	-	Bulk concentration (mol/cm^3)
D	-	Diffusion coefficient or particle diffusivity (cm^2/s)
K_B	-	Boltzmann constant (1.388×10^{-16} $g \cdot cm^2/s \cdot k$)
T	-	Temperature (298 K)
µ	-	Viscosity of solution (g/cm·s)
d_o	-	Particle (ionic aluminum or iron) size (cm)
Re	-	Reynolds number

Sh	-	Sherwood number
Sc	-	Schmidt number
d	-	Effective diameter (cm)
N	-	Rotational speed (rps)
ρ	-	Fluid density (g/cm^3)
a and b	-	Constants of model mass transfer
$\emptyset$	-	Variable velocity along x, y, and z direction (cm/sec)
C_0	-	Concentrations of pollutants before treatment (mg/L)
C	-	Concentrations of pollutants after treatment (mg/L)
$m_{theoretical}$	-	Theoretical amount of aluminum or iron generated (mg/L)
M	-	Molecular mass of Al (26.98 g/Mol) and Fe (55.84 g/Mol)
RT	-	Reaction time of treatment (min)
V	-	Volume of wastewater (L)
DO_0	-	Dissolved oxygen concentration immediately (mg/L)
DO_5	-	Dissolved oxygen concentration after 5 days(mg/L)
SRF	-	Specific resistance to filtration (m/kg)
Kb	-	Slope of the volume vs time/volume plot
P	-	Pressure during sludge filtration (Pas)
a_w	-	Weight of the solid per unit volume of filtrate (g)
m_2 and m_1	-	Mass of the cup (with the membrane) before and after filtration
m_3	-	Mass of cup after drying process
SVI	-	Sludge volume index (mL/g)
VD_{30}	-	Volume of settled sludge after 30 min (mL/L)
C_{energy}	-	Energy consumption (kWh/m^3)
$C_{electrode}$	-	Electrodes consumption (kg/m^3)
C_{sludge}	-	Amount of sludge (kg/m^3)
$C_{chemicals}$	-	Quantity of chemicals (kg/m^3)
a	-	Total electricity costs (US$/kWh)
b	-	Cost of aluminum or iron (US$/kg)
d	-	Cost of sludge disposal(US$/kg)
e	-	Cost of chemicals added (US$/kg)
U		Voltage (volt)
$(C_{energy})_S$	-	Energy consumption of DC power supply (kWh/m^3)

$(C_{energy})_M$	-	Energy consumption of DC motor anode rotation (kWh/m^3)
C.E	-	Current efficiency (%)
M_{rpm}	-	Mixer rotational speed (rpm)
CD	-	Current density (mA/cm^2)
K_B	-	Boltzmann constant (1.388×10^{-16} $g \cdot cm^2/s \cdot k$)
d_o	-	Aluminum size (cm).
n_{H2}	-	Amount of hydrogen generated (mole)
H	-	Number of hydrogen molecules per electron in the redox reactions (1/2)
V_{H2}	-	Volume of the cumulative hydrogen (L)
m_{H2}	-	Mass of the produced cumulative hydrogen (g)
M_{H2}	-	Hydrogen's molar mass (2 g /mol)
R	-	Gas constant (0.082 L atm. mol^{-1} K^{-1})
E_{H2}	-	Energy contents of the hydrogen gas ($kW.h/m^3$)
Q	-	Discharge flow rate (L/min)
R_{ct}	-	Passivation resistance (Ω)
R_{ads}	-	Adsorption resistance (Ω)
C_{ads}	-	Adsorption capacitance (μF)
C_{dl}	-	Double layer capacitance (μF)
R_s	-	Solution resistance (Ω)
U_0	-	Flow velocity (cm/sec)
T	-	Turbulence intensity (%)
SD	-	Standard deviation
R1	-	Simulation results
R2	-	Experimental results
I_1	-	Applied current of power supply (A)
I_2	-	Applied current of motor rotational anode (A)
U_1	-	Voltage of power supply (V)
U_2	-	Voltage of motor rotational anode (V)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The advancement in the search for new wastewater treatment technologies seems lacking as, fresh water sources are being polluted with increasing population (Ntwampe *et al.*, 2016, Cosgrove, 2010). The developing countries are soft targets of water-borne diseases due to a lack of the knowledge in water decontamination and less authoritative support. A limited resource of water is consumed by the industry acquiescing lower quality raw water, whereas a larger fraction of fresh water is required for human consumption. Wastewater pollutants produced from industry have become a central issue, as these contaminants cause environmental problems which are harmful to public health. It is estimated that nearly half a million organic compounds are synthesized and 10,000 new compounds are added each year (Sarala, 2012).

Some of the wastewater sources, for example, textile wastewater, oily and greasy wastewater from restaurant or canteen, cannot be collated and discharged to municipal drainages directly due to the faultiness of the existing wastewater treatment system. Discharging these wastes into municipal drainages directly, may spoil the drainage system as it will make the treatment process difficult and unviable due to the presence of different types of pollutants (Xu and Zhu, 2004, Vepsäläinen, 2012). With the passage of time, wastewater treatment technology have developed by improving the reliability and competence of treatment systems to meet the certain criteria and lessen the land engaged by treatment works by speeding up the natural treatment rates under defined conditions. Despite the improvements in wastewater treatment systems, they are still mainly focused on the removal of suspended and floatable materials, the treatment of biodegradable organic and in some cases the removal of pathogenic organisms. Filtration, sedimentation or flotation is the focused areas of particle separation in wastewater treatment processes. Yan *et al.*(2008) reported that to know destabilization of particles by coagulants and flocculants, it is necessary to know the mechanism, which stabilizes particles in aqueous solutions. Chemical coagulation and flocculation are used in both industrial and municipal raw water and wastewater treatment systems due to their efficacy in removal of several types of pollutants from the water streams (Verma *et al.*, 2012, Dorea, 2009).

In past two decades, electrochemical technologies, like electrodeposition, electrocoagulation (EC), electroflotation (EF), electrooxidation and electrokinetic remediation emerged as effective processes due their distribution and smaller amount and number of chemicals required. Furthermore, resilient and compact instrumentation is also available with minimal effort (Mollah *et al.*, 2004a, Barrera-Díaz *et al.*, 2012). These technologies benefit in terms of environmental compatibility, adaptability, energy effectiveness, safety, selectivity, and amenability to automation, and cost reduction (Rajeshwar and Ibanez, 1997). This indicates the potential of electrochemical technologies to serve as localized treatment facilities to substitute sophisticated processes (chemical coagulation and flocculation), which need large volumes and/or number of chemicals, massive containers in a typical wastewater treatment plant (Barrera-Díaz *et al.,* 2012, Chen, 2004, Comninellis and Chen, 2010).

Chemical coagulation has been studied extensively compared to electrocoagulation (EC). For water and wastewater treatment, electrocoagulation is a good technique that avoids many complicated processes involving many chemicals and physical phenomena, e.g. formation of coagulants, destabilization of contaminants, particulate suspension and breaking of emulsions, and flocculation (Mollah *et al*., 2004a, Chaturvedi, 2013). This process has received substantial consideration so far. It has been widely studied depending on the process behaviours and the operational parameters to remove the pollutants from various type of water or wastewater such as drinking water (Holt *et al*., 2005), domestic wastewater (Sarala, 2012), laundry wastewater (Janpoor *et al.,* 2011), electroplating wastewater (Verma *et al*., 2013, Adhoum *et al.,* 2004), oil refinery wastewater (Un *et al.,* 2009), restaurant wastewater (Chen *et al*., 2000), metal plating wastewater (Al Aji *et al.,* 2012, Kabdaşli *et al*., 2009a) and poultry slaughter house wastewater (Bayar *et al*., 2011, Kobya *et al*., 2006). However, no attempts have been made to present two different models with a new style for the process optimization.

1.2 Problem Statement

Nowadays, high quantities of wastewater are being produced, especially from the industrial and residential sectors that may affect the environmental life. Industrial activities always cause a problem to the environment and the society. Textile mill effluent needs proper treatment before it is discharged into the environment due to high pollutants characteristics such as chemical oxygen demand (COD), total suspended solid (TSS), biological oxygen demand (BOD), turbidity, and color (Verma *et al.,* 2012). There are many *batiktextile* mills in Malaysia. The effluents of these textile mills mostly have high COD due to intensive dyes use. Moreover, the electrical conductivity of the effluent is high as a result of the presence of sodium silicate which was used during the textile process (Rashidi *et al.,* 2016). Conventional treatment of these textile mills contains primary sedimentation unit, chemical coagulation unit, sedimentation unit, filtration unit, and a collection unit for disposal to the river. In the present study, the conventional chemical coagulation units were focused. The drawbacks of this treatment unit are; low removal efficiency, creates week and low dense addition of coagulant, long detention time, and high costs coming from large quantity of sludge after treatment, and large quantity of chemicals needed for coagulation and flocculation, and requirements of pH and conductivity (Un *et al.,* 2009, Moreno C *et al.,* 2009, Yildiz *et al*., 2008, Barrera-Díaz *et al*., 2012).

For environmental protection, it is important to find the best method to overcome the above problem. Some technologies like biological oxidation, chemical oxidation, advanced oxidation, nanofiltration and adsorption, and electrochemical technologies such as electrooxidation (EO), electrodeposition and electrocoagulation (EC) can be used to reduce this problem. However, most of the discussed methods have some major drawbacks. For example, biological oxidation is undoubtedly the inexpensive process, but the existence of toxic or biorefractory molecules may hinder this approach due to effluents polluted with organic compounds (Barrera-Díaz *et al.,* 2012, Panizza and Cerisola, 2009). Chemical oxidations have low capacity rates and need transportation and storage of dangerous reactants (Panizza and Cerisola, 2009); advanced oxidation processes require high investment costs (Martinez-Huitle and Ferro, 2006, Panizza and Cerisola, 2009); nanofiltration and adsorption processes are not always sufficient to achieve the discharge limits (Bousher *et al*., 1997, Wachinski, 2012); and electrooxidation and electrodeposition processes need long reaction times to achieve the treatment (Chen, 2004, Martinez-Huitle and Ferro, 2006).

According to previous research of the EC process, no set configuration is applicable to all needs, and the problem of EC reactor is due to the generating of hydrogen (H_2) and oxygen (O_2) bubbles that accumulate onto the electrode surface and forms an insulating layer (oxide film) (Gunukula, 2011, Mollah *et al.,* 2004a, Khandegar and Saroha, 2013c, Nasrullah *et al*., 2012). Due to this layer, the electrodes will be passive and it will affect the active time of the electrodes, large electrical energy is required to achieve optimum removal efficiency of pollutants, IR drops between electrodes will increase, and long reaction time gives way to high operational cost.

This study explored the method of EC for the treatment of textile wastewater in two models. The first model is the conventional reactor with new configurations of parallel electrodes. The second model is a rotated bed of EC reactor in a unique design, which was not subjugated in previous studies. Thereby, developing this new reactor will overcome the passivation problem and improve the electrolyte homogeneity, and making efficient improvements such as improve efficiency and quality of waste water treated, low power consumption, low sludge production, and reduction of the reaction time of EC process.

1.3 Research Question

Following are the research questions for this study:

1. What are the operational parameters of the EC technique used for the treatment of textile wastewater?
2. How to improve the wastewater effluent quality of textile manufacturing using the EC technique?
3. Why the EC technique is used instead of the conventional treatment to remove wastewater pollutant in textile manufacturing?
4. What are the methods, materials and equipment that are used to improve the performance of the EC treatment in economic terms?

1.4 Research Objective

The aim of this research is to evaluate the effectiveness of electrocoagulation process, compared with the chemical coagulants, as a treatment unit before the sedimentation unit in textile wastewater treatment plant. This research had two models. Each case produced data that was necessary to observe trends and support conclusions suitable for publication in peer-reviewed research journals. The specific objectives of this study are:

1. To investigate the best conditions of the operational parameters affecting removal efficiency of textile wastewater using new EC configurations with static electrodes under combined electrical connections and compare with conventional coagulation process.
2. To combine EC - EO processes static electrodes under combined electrical connections for the treatment of textile wastewater with optimum operational parameters and compare with EC alone.
3. To develop EC technology using a novel reactor design with rotating anode by investigating the operational parameters affecting removal efficiency of

pollutants. The enhancement of the mass transfer coefficients, the mechanism of treatment, and hydrogen production were also investigated.

4. To conduct the comparative study of the unique EC reactor with CFD simulation for ionic mass transfer and investigate the passivation phenomenon.

1.5 Scope of Study

In the pursuit of meeting all the objectives, the scope of this project is crucial. The scope of this research focuses on EC method using two models for the treatment of textile wastewater. The first model was the EC process with a new configuration of static electrodes in two phases, first, using the EC process alone, and then combining EC process with another process technology (electrooxidation, EO) to reduce the amount of produced sludge. The second model is a unique design of EC with a rotating anode. Two types of effluent textile wastewater were examined and tested before and after using the suggested treatment process. The first sample was taken from a textile industry located at Hilla-Iraq. Here, the experimental investigations were achieved for the first and second model to find the differences of effluent quality and to optimize the operational parameters affecting removal rate of treatment. The effluent samples before and after treatment were analysed and organized according to the chemical oxygen demand (COD), total suspended solid (TSS) and colors of textile wastewater. For model two (EC with rotating anode), advanced investigations were achieved to ionic mass transfer study. For more experimental investigations and verifications about the unique design (model two), the second type of effluent (textile wastewater) was used which was taken from the textile industry located in Kajang, Selangor-Malaysia.

1.6 Engineering Significance

The EC technology investigated in this research is different (in composition, but smaller scale) to those currently used as the option for chemical coagulation (historically, alum) prior to the sedimentation unit in the textile industry. Historically, the lacks of practical experience and predicted high energy requirements have eliminated EC as a membrane pretreatment option. Recent technological improvements and the desire to reduce liquid chemical storage and usage have made electrocoagulation a more desired pretreatment option for the textile wastewater.

However, the EC system requires a better understanding of the mechanisms of coagulation involved, the species of coagulant generated, and the impact of EC coagulated wastewater on removal efficiency. This research provides further data on the treatment of textile wastewater using electrocoagulation as a pretreatment before sedimentation and filtration units.

The option of EC systems (with doctrinal approval from previous research) would increase the quality of wastewater produced with less energy consumption, and low operational and maintenance costs. The most immediate application of this research is the employment of EC treatment process with the new configuration and the incorporation of EC process with electrooxidation in a single reactor (model one). The model two is a novel EC reactor with a rotating anode will improve wastewater quality, reduction of retention time and reduction of the passivation phenomenon in the EC treatment.

1.7 Organization of Thesis

This thesis consists of nine chapters. Chapter 1 introduces the subject of this study by demonstrating the relevance of electrocoagulation to the textile industry. Published reports are summarized in a literature review as fundamental principles and operational parameters effecting on EC process in Chapter 2. The comparison with conventional coagulation process, combination EC with another technologies, and operational cost analysis of the previous study are discussed in this chapter. Chapter 3 presents the methodology of this study where research layout, collection and sampling of textile wastewater, models design, measurement tools and methods for chemical and cost analysis are discussed.

In Chapter 4, the EC static electrodes with the new configuration (model one, phase one) were examined and the results were observed under optimal conditions. The comparison with conventional coagulation was also discussed in this chapter. Chapter 5 presents the combination model with static electrodes (EC-EO, model one, phase two) with the results obtained under optimal conditions. The comparison with EC static electrodes was also presented in this chapter. Chapter 6 presents a novel EC reactor with the rotating anode (model two) and the results under optimal conditions were discussed and validated. The comparison of EC rotating anode performance with a model of the conventional static electrode (model one, EC and EC-EO) was also discussed. Chapter 7 presents the investigations for the enhancement of ionic mass transfer using EC rotating anode reactor by the experimental work and CFD simulation. The verification of experimental results was studied using statistical method. Chapter 8 presents EC rotating anode reactor using solar energy feed. The investigations included batch and continuous flow mode, mechanism of treatment, enhancing of hydrogen production, and passivation phenomenon study by impedance. Finally, conclusions, and recommendations for further study were made in Chapter 9.

REFERENCES

Abdel-Aziz, M., El-Shazly, A., Farag, H. & Sedahmed, G. 2011. Mass transfer behavior of rotating square cylinder electrochemical reactor in relation to wastewater treatment. *Energy Conversion and Management,* 52**,** 2870-2875.

Abdel-Gawad, S. A., Baraka, A. M., Omran, K. A. & Mokhtar, M. M. 2012. Removal of some pesticides from the simulated waste water by electrocoagulation method using iron electrodes. *Int J Electrochem Sci,* 7**,** 6654-6665.

Abuzaid, N. S., Bukhari, A. A. & Al-Hamouz, Z. M. 2002. Ground water coagulation using soluble stainless steel electrodes. *Advances in Environmental Research,* 6**,** 325-333.

Adhoum, N., Monser, L., Bellakhal, N. & Belgaied, J.-E. 2004. Treatment of electroplating wastewater containing Cu 2+, Zn 2+ and Cr (VI) by electrocoagulation. *Journal of Hazardous Materials,* 112**,** 207-213.

Ahmed, M. T., Chaabane, T., Maachi, R. & Darchen, A. 2012. Efficiency of a pretreatment by electrocoagulation with aluminum electrodes in a nanofiltration treatment of polluted water. *Procedia Engineering,* 33**,** 465-474.

Ajeel, M. A., Aroua, M. K. & Daud, W. M. A. W. 2015. P-Benzoquinone anodic degradation by carbon black diamond composite electrodes. *Electrochimica Acta,* 169**,** 46-51.

Akbal, F. & Camci, S. 2010. Comparison of electrocoagulation and chemical coagulation for heavy metal removal. *Chemical Engineering & Technology,* 33**,** 1655-1664.

Akbal, F. & Camci, S. 2011. Copper, chromium and nickel removal from metal plating wastewater by electrocoagulation. *Desalination,* 269**,** 214-222.

Akbal, F. & Camci, S. 2012. Treatment of metal plating wastewater by electrocoagulation. *Environmental Progress & Sustainable Energy,* 31**,** 340-350.

Akbal, F. & Kuleyin, A. 2011. Decolorization of levafix brilliant blue E-B by electrocoagulation method. *Environmental Progress & Sustainable Energy,* 30**,** 29-36.

Akyol, A. 2012. Treatment of paint manufacturing wastewater by electrocoagulation. *Desalination,* 285**,** 91-99.

Al Aji, B., Yavuz, Y. & Koparal, A. S. 2012. Electrocoagulation of heavy metals containing model wastewater using monopolar iron electrodes. *Separation and Purification Technology,* 86**,** 248-254.

Aleboyeh, A., Daneshvar, N. & Kasiri, M. 2008. Optimization of CI Acid Red 14 azo dye removal by electrocoagulation batch process with response surface methodology. *Chemical Engineering and Processing: Process Intensification,* 47**,** 827-832.

Ali, E. & Yaakob, Z. 2012. *Electrocoagulation for treatment of industrial effluents and hydrogen production*, INTECH Open Access Publisher.

Alizadeh, M., Mahvi, A. H. & Mansoorian, H. J. 2014. The survey of electrocoagulation Process for removal dye Reactive Orange 16 from aqueous solutions using sacrificial iron electrodes. *Iranian Journal of Health, Safety and Environment,* 1**,** 1-8.

Almazán-Ruiz, F. J., Caballero, F. V., Cruz-Díaz, M. R., Rivero, E. P. & González, I. 2012. Scale-up of rotating cylinder electrode electrochemical reactor for Cu (II) recovery: Experimental and simulation study in turbulence regimen. *Electrochimica Acta,* 77**,** 262-271.

Andersson, B., Andersson, R., Håkansson, L., Mortensen, M., Sudiyo, R. & Van Wachem, B. 2011. *Computational fluid dynamics for engineers*, Cambridge University Press.

Aoudj, S., Khelifa, A., Drouiche, N., Hecini, M. & Hamitouche, H. 2010. Electrocoagulation process applied to wastewater containing dyes from textile industry. *Chemical Engineering and Processing: Process Intensification,* 49**,** 1176-1182.

Aouni, A., Fersi, C., Ali, M. B. S. & Dhahbi, M. 2009. Treatment of textile wastewater by a hybrid electrocoagulation/nanofiltration process. *Journal of Hazardous Materials,* 168**,** 868-874.

APHA, A. 1998. WEF (American Public Health Association, American Water Works Association, and Water Environment Federation). 1998. *Standard Methods for the Examination of Water and Wastewater,* 20.

Asaithambi, P., Susree, M., Saravanathamizhan, R. & Matheswaran, M. 2012. Ozone assisted electrocoagulation for the treatment of distillery effluent. *Desalination,* 297**,** 1-7.

Asselin, M., Drogui, P., Brar, S. K., Benmoussa, H. & Blais, J. F. 2008. Organics removal in oily bilgewater by electrocoagulation process. *Journal of Hazardous Materials,* 151**,** 446-455.

Baek, K., Kasem, N., Ciblak, A., Vesper, D., Padilla, I. & Alshawabkeh, A. N., 2012. Electrochemical reduction of selenate using reactive anode. *GeoCongress 2012 © ASCE*. 4024-4032.

Bagga, A., Chellam, S. & Clifford, D. A. 2008. Evaluation of iron chemical coagulation and electrocoagulation pretreatment for surface water microfiltration. *Journal of Membrane Science,* 309**,** 82-93.

Barrera-Díaz, C., Bilyeu, B., Roa-Morales, G. & Balderas-Hernández, P. 2008. A comparison of iron and aluminium electrodes in hydrogen peroxide-assisted electrocoagulation of organic pollutants. *Environmental Engineering Science,* 25**,** 529-538.

Barrera-Díaz, C., Roa-Morales, G., Avila-Córdoba, L., Pavón-Silva, T. & Bilyeu, B. 2006. Electrochemical treatment applied to food-processing industrial wastewater. *Industrial & Engineering Chemistry Research,* 45**,** 34-38.

Barrera-Díaz, C. E., Lugo-Lugo, V. & Bilyeu, B. 2012. A review of chemical, electrochemical and biological methods for aqueous Cr (VI) reduction. *Journal of Hazardous Materials,* 223**,** 1-12.

Baudequin, C., Couallier, E., Rakib, M., Deguerry, I., Severac, R. & Pabon, M. 2011. Purification of firefighting water containing a fluorinated surfactant by reverse osmosis coupled to electrocoagulation–filtration. *Separation and Purification Technology,* 76**,** 275-282.

Bayar, S., Yildiz, Y. Ş., Yilmaz, A. E. & Irdemez, Ş. 2011. The effect of stirring speed and current density on removal efficiency of poultry slaughterhouse wastewater by electrocoagulation method. *Desalination,* 280**,** 103-107.

Bayramoglu, M., Eyvaz, M. & Kobya, M. 2007. Treatment of the textile wastewater by electrocoagulation: Economical evaluation. *Chemical Engineering Journal,* 128**,** 155-161.

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

Bazrafshan, E., Ownagh, K. A. & Mahvi, A. H. 2012. Application of electrocoagulation process using iron and aluminum electrodes for fluoride removal from aqueous environment. *Journal of Chemistry,* 9**,** 2297-2308.

Behbahani, M., Alavi Moghaddam, M. & ARAMI, M. 2011a. A comparison between aluminum and iron electrodes on removal of phosphate from aqueous solutions by electrocoagulation process. *International Journal of Environmental Research,* 5**,** 403-412.

Behbahani, M., Moghaddam, M. A. & Arami, M. 2011b. Techno-economical evaluation of fluoride removal by electrocoagulation process: Optimization through response surface methodology. *Desalination,* 271**,** 209-218.

Bektaş, N., Öncel, S., Akbulut, H. Y. & Dimoglo, A. 2004. Removal of boron by electrocoagulation. *Environmental Chemistry Letters,* 2**,** 51-54.

Bellebia, S., Kacha, S. & Bouyakoub, A. Z. 2012. Experimental investigation of chemical oxygen demand and turbidity removal from cardboard paper mill effluents using combined electrocoagulation and adsorption processes. *Environmental Progress & Sustainable Energy,* 31**,** 361-370.

Bensadok, K., Benammar, S., Lapicque, F. & Nezzal, G. 2008. Electrocoagulation of cutting oil emulsions using aluminium plate electrodes. *Journal of Hazardous Materials,* 152**,** 423-430.

Bo, Z., Wen, Z., Kim, H., Lu, G., Yu, K. & Chen, J. 2012. One-step fabrication and capacitive behavior of electrochemical double layer capacitor electrodes using vertically-oriented graphene directly grown on metal. *Carbon,* 50**,** 4379-4387.

Boroski, M., Rodrigues, A. C., Garcia, J. C., Sampaio, L. C., Nozaki, J. & Hioka, N. 2009. Combined electrocoagulation and TiO_2 photoassisted treatment applied to wastewater effluents from pharmaceutical and cosmetic industries. *Journal of Hazardous Materials,* 162**,** 448-454.

Bouhezila, F., Hariti, M., Lounici, H. & Mameri, N. 2011. Treatment of the OUED SMAR town landfill leachate by an electrochemical reactor. *Desalination,* 280**,** 347-353.

Bousher, A., Shen, X. & Edyvean, R. G. 1997. Removal of coloured organic matter by adsorption onto low-cost waste materials. *Water Research,* 31**,** 2084-2092.

Brett, C. M. A. & Brett, A. M. O. 1993. *Electrochemistry:Principles, Methods and applications*. Oxford University Press, Oxford.

Brkanac, S. R., Vujčić, V., Cvjetko, P., Baković, V. & Oreščanin, V. 2014. Removal of landfill leachate toxicity and genotoxicity by two treatment methods. *Archives of Industrial Hygiene and Toxicology,* 65**,** 89-99.

Burns, J. & Jachuck, R. 2005. Determination of liquid–solid mass transfer coefficients for a spinning disc reactor using a limiting current technique. *International Journal of Heat and Mass Transfer,* 48**,** 2540-2547.

Can, O. & Bayramoglu, M. 2010. The effect of process conditions on the treatment of benzoquinone solution by electrocoagulation. *Journal of Hazardous Materials,* 173**,** 731-736.

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

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

Cañizares, P., García-Gómez, J., Fernández De Marcos, I., Rodrigo, M. & Lobato, J. 2006. Measurement of mass-transfer coefficients by an electrochemical technique. *Journal of Chemical Education,* 83**,** 1204-1212.

Cañizares, P., Jimenez, C., Martínez, F., Rodrigo, M. A. & Sáez, C. 2009a. The pH as a key parameter in the choice between coagulation and electrocoagulation for the treatment of wastewaters. *Journal of Hazardous Materials,* 163**,** 158-164.

Cañizares, P., Martínez, F., Jimenez, C., Sáez, C. & Rodrigo, M. A. 2009b. Technical and economic comparison of conventional and electrochemical coagulation processes. *Journal of Chemical Technology and Biotechnology,* 84**,** 702-710.

Chafi, M., Gourich, B., Essadki, A., Vial, C. & Fabregat, A. 2011. Comparison of electrocoagulation using iron and aluminium electrodes with chemical coagulation for the removal of a highly soluble acid dye. *Desalination,* 281**,** 285-292.

Chang, S. H., Wang, K.S., Liang, H. H., Chen, H. Y., Li, H. C., Peng, T.H., Su, Y.C. & Chang, C. Y. 2010. Treatment of Reactive Black 5 by combined electrocoagulation–granular activated carbon adsorption–microwave regeneration process. *Journal of Hazardous Materials,* 175**,** 850-857.

Chaturvedi, S. I. 2013. Electrocoagulation: a novel waste water treatment method.*Int. J. Mod. Eng. Res.,* 3**,** 93-100.

Chavalparit, O. & Ongwandee, M. 2009. Optimizing electrocoagulation process for the treatment of biodiesel wastewater using response surface methodology. *Journal of Environmental Sciences,* 21**,** 1491-1496.

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

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

Chen, Z. D. & Chen, J. 1999. Comparison of mass transfer performance for various single and twin impellers. *Chemical Engineering Research and Design,* 77**,** 104-109.

Chou, W. L., Wang, C.T. & Chang, S.Y. 2009. Study of COD and turbidity removal from real oxide-CMP wastewater by iron electrocoagulation and the evaluation of specific energy consumption. *Journal of Hazardous Materials,* 168**,** 1200-1207.

Chou, W. L., Wang, C.T., Chang, W.C. & Chang, S.Y. 2010. Adsorption treatment of oxide chemical mechanical polishing wastewater from a semiconductor manufacturing plant by electrocoagulation. *Journal of Hazardous Materials,* 180**,** 217-224.

Ciorba, G., Radovan, C., Vlaicu, I. & Masu, S. 2002. Removal of nonylphenol ethoxylates by electrochemically-generated coagulants. *Journal of Applied Electrochemistry,* 32**,** 561-567.

Comninellis, C. & Chen, G. 2010. *Electrochemistry for the environment*, Springer, New York. USA.

Cosgrove, T. 2010. *Colloid science: principles, methods and applications*, John Wiley & Sons.

Coskun, T., Ilhan, F., Demir, N. M., Debik, E. & Kurt, U. 2012. Optimization of energy costs in the pretreatment of olive mill wastewaters by electrocoagulation. *Environmental Technology,* 33**,** 801-807.

Da Silva, J. R. P., Mercon, F., Da Silva, L. F., Cerqueira, A. A., Ximango, P. B. & Da Costa Marques, M. R. 2015. Evaluation of electrocoagulation as pre-treatment of oil emulsions, followed by reverse osmosis. *Journal of Water Process Engineering,* 8**,** 126-135.

Daghrir, R., Drogui, P., Francois Blais, J. & Mercier, G. 2012. Hybrid process combining electrocoagulation and electro-oxidation processes for the treatment of restaurant wastewaters. *Journal of Environmental Engineering,* 138**,** 1146-1156.

Dalvand, A., Gholami, M., Joneidi, A. & Mahmoodi, N. M. 2011. Dye removal, energy consumption and operating cost of electrocoagulation of textile wastewater as a clean process. *CLEAN–Soil, Air, Water,* 39**,** 665-672.

Daneshvar, N., Ashassi-Sorkhabi, H. & Tizpar, A. 2003. Decolorization of orange II by electrocoagulation method. *Separation and Purification Technology,* 31**,** 153-162.

Daneshvar, N., Khataee, A., Ghadim, A. A. & Rasoulifard, M. 2007. Decolorization of CI Acid Yellow 23 solution by electrocoagulation process: Investigation of operational parameters and evaluation of specific electrical energy consumption (SEEC). *Journal of Hazardous Materials,* 148**,** 566-572.

Daneshvar, N., Oladegaragoze, A. & Djafarzadeh, N. 2006. Decolorization of basic dye solutions by electrocoagulation: an investigation of the effect of operational parameters. *Journal of Hazardous Materials,* 129**,** 116-122.

Daneshvar, N., Sorkhabi, H. A. & Kasiri, M. 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.

Daous, M. & El-Shazly, A. 2012. Enhancing the performance of a batch electrocoagulation reactor for chromium reduction using gas sparging. *Int. J. Electrochem. Sci,* 7**,** 3513-3526.

Dehghani, M., Seresht, S. S. & Hashemi, H. 2014. Treatment of hospital wastewater by electrocoagulation using aluminum and iron electrodes. *International Journal of Environmental Health Engineering,* 3**,** 15-20.

Delgadillo, J. A. & Rajamani, R. K. 2005. A comparative study of three turbulence-closure models for the hydrocyclone problem. *International Journal of Mineral Processing,* 77**,** 217-230.

Demirci, Y., Pekel, L. C. & Alpbaz, M. 2015. Investigation of different electrode connections in electrocoagulation of textile wastewater treatment. *Int. J. Electrochem. Sci,* 10**,** 2685-2693.

Den, W. & Huang, C. 2005. Electrocoagulation for removal of silica nano-particles from chemical–mechanical-planarization wastewater. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 254**,** 81-89.

Den, W. & Huang, C. 2006. Electrocoagulation of silica nanoparticles in wafer polishing wastewater by a multichannel flow reactor: A kinetic study. *Journal of Environmental Engineering,* 132**,** 1651-1658.

Deng, Y. & Englehardt, J. D. 2007. Electrochemical oxidation for landfill leachate treatment. *Waste Management,* 27**,** 380-388.

Dermentzis, K., Christoforidis, A., Valsamidou, E., Lazaridou, A. & Kokkinos, N. 2011a. Removal of hexavalent chromium from electroplating wastewater by electrocoagulation with iron electrodes. *Global Nest J,* 13**,** 412-418.

Dermentzis, K., Christoforidis, A., Valsamidou, E. & Loucas, A. 2011b. Removal of nickel, copper, zinc and chromium from synthetic and industrial wastewater by electrocoagulation. *International Journal of Environmental Sciences,* 1**,** 697-710.

Deshpande, A. M., Ramakant& Satyanarayan, S. 2011. Treatment of pharmaceutical wastewater by electrochemical method: Optimization of operating parameters by response surface methodology. *Journal of Hazardous, Toxic, and Radioactive Waste,* 16**,** 316-326.

Djedidi, Z., Khaled, J. B., Cheikh, R. B., Blais, J.F., Mercier, G. & Tyagi, R. D. 2009. Comparative study of dewatering characteristics of metal precipitates generated during treatment of monometallic solutions. *Hydrometallurgy,* 95**,** 61-69.

Dorea, C. 2009. Coagulant-based emergency water treatment. *Desalination,* 248**,** 83-90.

Drogui, P., Asselin, M., Brar, S. K., Benmoussa, H. & Blais, J.F. 2008. Electrochemical removal of pollutants from agro-industry wastewaters. *Separation and Purification Technology,* 61**,** 301-310.

Drogui, P., Asselin, M., Brar, S. K., Benmoussa, H. & Blais, J. F. 2009. Electrochemical removal of organics and oil from sawmill and ship effluents. *Canadian Journal of Civil Engineering,* 36**,** 529-539.

Drogui, P., Blais, J. F. & Mercier, G. 2007. Review of electrochemical technologies for environmental applications. *Recent Patents on Engineering,* 1**,** 257-272.

Drouiche, N., Aoudj, S., Lounici, H., Drouiche, M., Ouslimane, T. & Ghaffour, N. 2012. Fluoride removal from pretreated photovoltaic wastewater by electrocoagulation: an investigation of the effect of operational parameters. *Procedia Engineering,* 33**,** 385-391.

Drouiche, N., Ghaffour, N., Lounici, H. & Mameri, M. 2007. Electrocoagulation of chemical mechanical polishing wastewater. *Desalination,* 214**,** 31-37.

Durango-Usuga, P., Guzmán-Duque, F., Mosteo, R., Vazquez, M. V., Peñuela, G. & Torres-Palma, R. A. 2010. Experimental design approach applied to the elimination of crystal violet in water by electrocoagulation with Fe or Al electrodes. *Journal of Hazardous Materials,* 179**,** 120-126.

Easterby-Smith, M., R. Thorpe, & A. Lowe. 2002. *Management Research,* LondonSage.

Eickhoff, J. & Roeser, H.-P. 2009. *Simulating Spacecraft Systems*, Springer.

Eisenberg, M., Tobias, C. & Wilke, C. 1954. Ionic mass transfer and concentration polarization at rotating electrodes. *Journal of the Electrochemical Society,* 101**,** 306-320.

El-Ashtoukhy, E., El-Taweel, Y., Abdelwahab, O. & Nassef, E. 2013. Treatment of petrochemical wastewater containing phenolic compounds by electrocoagulation using a fixed bed electrochemical reactor. *Int. J. Electrochem. Sci,* 8**,** 1534-1550.

El-Naas, M. H., Al-Zuhair, S., Al-Lobaney, A. & Makhlouf, S. 2009. Assessment of electrocoagulation for the treatment of petroleum refinery wastewater. *Journal of Environmental Management,* 91**,** 180-185.

El-Shazly, A., Al-Zahrani, A. & Alhamed, Y. 2013. Kinetics and performance analysis of batch electrocoagulation unit used for the removal of a mixture of phosphate and nitrate ions from industrial effluents.*Int. J. Electrochem. Sci,* 8**,** 3176-3185.

Emamjomeh, M. M. 2006. *Electrocoagulation technology as a process for defluoridation in water treatment*. PhD Thesis, University of Wollongong.

Emamjomeh, M. M. & Sivakumar, M. 2006. An empirical model for defluoridation by batch monopolar electrocoagulation/flotation (ECF) process. *Journal of Hazardous Materials,* 131**,** 118-125.

Emamjomeh, M. M. & Sivakumar, M. 2009. Fluoride removal by a continuous flow electrocoagulation reactor. *Journal of Environmental Management,* 90**,** 1204-1212.

Emamjomeh, M. M., Sivakumar, M. & Varyani, A. S. 2011. Analysis and the understanding of fluoride removal mechanisms by an electrocoagulation/flotation (ECF) process. *Desalination,* 275**,** 102-106.

Enciso, R., Padilla, L., Ojeda, C., Delgadillo, J. & Rodríguez, I. 2012. Computational fluid dynamics characterization of a rotating cylinder electrochemical reactor using an RANS-RNG turbulence model. *Int. J. Electrochem. Sci,* 7**,** 12181-12192.

EPA 1996. *Best management practices for pollution prevention in the textile industry*. National Service Center for Environmental Publications (NSCEP). Ohio, USA.

Espinoza-Quiñones, F. R., Fornari, M. M., Módenes, A. N., Palácio, S. M., DA Silva, F. G., Szymanski, N., Kroumov, A. D. & Trigueros, D. E. 2009. Pollutant removal from tannery effluent by electrocoagulation. *Chemical Engineering Journal,* 151**,** 59-65.

Essadki, A., Bennajah, M., Gourich, B., Vial, C., Azzi, M. & Delmas, H. 2008. Electrocoagulation/electroflotation in an external-loop airlift reactor—application to the decolorization of textile dye wastewater: a case study. *Chemical Engineering and Processing: Process Intensification,* 47**,** 1211-1223.

Estheru, G., Shrikanth, G., Babu, N. C., Rao, D. S. &Venkateswarlu, P. 2012. Effect of radial flow 2-blade flat turbine on ionic mass transfer in an electrolytic cell. *Acta Chim. Pharm. Indica,* 2**,** 176-187.

Eyvaz, M., Kirlaroglu, M., Aktas, T. S. & Yuksel, E. 2009. The effects of alternating current electrocoagulation on dye removal from aqueous solutions. *Chemical Engineering Journal,* 153**,** 16-22.

Feng, J. W., Sun, Y. B., Zheng, Z., Zhang, J.B., Shu, L. & Tian, Y. C. 2007. Treatment of tannery wastewater by electrocoagulation. *Journal of Environmental Sciences,* 19**,** 1409-1415.

Fouad, Y., Malash, G., Zatout, A. & Sedahmed, G. 2013. Mass and heat transfer at an array of vertical tubes in a square stirred tank reactor. *Chemical Engineering Research and Design,* 91**,** 234-243.

Frías-Ferrer, Á., Tudela, I., Louisnard, O., SáEZ, V., Esclapez, M. D., Díez-García, M. I., Bonete, P. & González-García, J. 2011. Optimized design of an electrochemical filter-press reactor using CFD methods. *Chemical Engineering Journal,* 169**,** 270-281.

Gamvroudis, C., Nikolaidis, N., Tzoraki, O., Papadoulakis, V. & Karalemas, N. 2015. Water and sediment transport modeling of a large temporary river basin in Greece. *Science of the Total Environment,* 508**,** 354-365.

García-Morales, M., Roa-Morales, G., Barrera-Díaz, C., Martínez Miranda, V., Balderas Hernández, P. & Pavón Silva, T. 2013. Integrated advanced oxidation process (ozonation) and electrocoagulation treatments for dye removal in denim effluents. *Int. J. Electrochem. Sci,* 8**,** 8752-8763.

Geankoplis, C. 2003. *Transport processes and separation process principles (includes unit operations)*, Prentice Hall Press.

Gengec, E., Kobya, M., Demirbas, E., Akyol, A. & Oktor, K. 2012. Optimization of baker's yeast wastewater using response surface methodology by electrocoagulation. *Desalination,* 286**,** 200-209.

Ghanim, A. & Ajjam, S. 2013. Kinetic modelling of nitrate removal from aqueous solution during electrocoagulation. *Civil and Environmental Research,* 3**,** 64-73.

Ghernaout, D., Ghernaout, B. & Boucherit, A. 2008. Effect of pH on electrocoagulation of bentonite suspensions in batch using iron electrodes. *Journal of Dispersion Science and Technology,* 29**,** 1272-1275.

Ghosh, D., Medhi, C. & Purkait, M. 2008a. Treatment of fluoride containing drinking water by electrocoagulation using monopolar and bipolar electrode connections. *Chemosphere,* 73**,** 1393-1400.

Ghosh, D., Medhi, C. & Purkait, M. 2011. Techno-economic analysis for the electrocoagulation of fluoride-contaminated drinking water. *Toxicological & Environ Chemistry,* 93**,** 424-437.

Ghosh, D., Solanki, H. & Purkait, M. 2008b. Removal of Fe (II) from tap water by electrocoagulation technique. *Journal of Hazardous Materials,* 155**,** 135-143.

Golder, A., Hridaya, N., Samanta, A. & Ray, S. 2005. Electrocoagulation of methylene blue and eosin yellowish using mild steel electrodes. *Journal of Hazardous Materials,* 127**,** 134-140.

Golder, A., Samanta, A. & Ray, S. 2006. Anionic reactive dye removal from aqueous solution using a new adsorbent—Sludge generated in removal of heavy metal by electrocoagulation. *Chemical Engineering Journal,* 122**,** 107-115.

Golder, A. K., Chanda, A. K., Samanta, A. N. & Ray, S. 2007a. Removal of Cr (VI) from aqueous solution: Electrocoagulation vs chemical coagulation. *Separation Science and Technology,* 42**,** 2177-2193.

Golder, A. K., Samanta, A. N. & Ray, S. 2007b. Trivalent chromium removal by electrocoagulation and characterization of the process sludge. *Journal of Chemical Technology and Biotechnology,* 82**,** 496-503.

Gomes, J. A., Daida, P., Kesmez, M., Weir, M., Moreno, H., Parga, J. R., Irwin, G., Mcwhinney, H., Grady, T. & Peterson, E. 2007. Arsenic removal by electrocoagulation using combined Al–Fe electrode system and characterization of products. *Journal of Hazardous Materials,* 139**,** 220-231.

González-Landaeta, R., Casas, O. & Pallas-Areny, R. 2008. Heart rate detection from plantar bioimpedance measurements. *Biomedical Engineering, IEEE Transactions,* 55**,** 1163-1167.

Grau, J. & Bisang, J. 2005. Mass transfer studies at rotating cylinder electrodes of expanded metal. *Journal of Applied Electrochemistry,* 35**,** 285-291.

Grau, J. & Bisang, J. 2011. Mass-transfer studies at rotating cylinder electrodes with turbulence promoters. *Chemical Engineering and Processing: Process Intensification,* 50**,** 940-943.

Gunukula, S. R. 2011. *Electrocoagulation/flotation Treatment of Synthetic Surface Water.* Cleveland State University.

Gupta, V. K. & ALI, I. 2012. *Environmental water: Advances in treatment, remediation and recycling*, Newnes.

Gurses, A., Yalcin, M. & Doğar, C. 2002. Electrocoagulation of some reactive dyes: a statistical investigation of some electrochemical variables. *Waste Management,* 22**,** 491-499.

Hanafi, F., Assobhei, O. & Mountadar, M. 2010. Detoxification and discoloration of Moroccan olive mill wastewater by electrocoagulation. *Journal of Hazardous Materials,* 174**,** 807-812.

Hanay, Ö. & Hasar, H. 2011. Effect of anions on removing Cu^{2+}, Mn^{2+} and Zn^{2+} in electrocoagulation process using aluminum electrodes. *Journal of Hazardous Materials,* 189**,** 572-576.

Harif, T., Khai, M. & Adin, A. 2012. Electrocoagulation versus chemical coagulation: Coagulation/flocculation mechanisms and resulting floc characteristics. *Water Research,* 46**,** 3177-3188.

Hasson, D., Lumelsky, V., Greenberg, G., Pinhas, Y. & Semiat, R. 2008. Development of the electrochemical scale removal technique for desalination applications. *Desalination,* 230**,** 329-342.

He, Z., Song, S., Qiu, J., Yao, J., Cao, X., Hu, Y. & Chen, J. 2007. Decolorization of CI Reactive Yellow 84 in aqueous solution by electrocoagulation enhanced with ozone: Influence of operating conditions. *Environmental Technology,* 28**,** 1257-1263.

Heidmann, I. & Calmano, W. 2008. Removal of Zn (II), Cu (II), Ni (II), Ag (I) and Cr (VI) present in aqueous solutions by aluminium electrocoagulation. *Journal of Hazardous Materials,* 152**,** 934-941.

Heidmann, I. & Calmano, W. 2010. Removal of Ni, Cu and Cr from a galvanic wastewater in an electrocoagulation system with Fe-and Al-electrodes. *Separation and Purification Technology,* 71**,** 308-314.

Henriques, D. M., Kummerer, K., Mayer, F. M., Vasconcelos, T. G. & Martins, A. F. 2012. Nonylphenol polyethoxylate in hospital wastewater: A study of the subproducts of electrocoagulation. *Journal of Environmental Science and Health, Part A,* 47**,** 497-505.

Hernández-Ortega, M., Ponziak, T., Barrera-Díaz, C., RODRIGO, M., Roa-Morales, G. & Bilyeu, B. 2010. Use of a combined electrocoagulation–ozone process as a pre-treatment for industrial wastewater. *Desalination,* 250**,** 144-149.

Hernando, J., Lud, S. Q., Bruno, P., Gruen, D. M., Stutzmann, M. & Garrido, J. A. 2009. Electrochemical impedance spectroscopy of oxidized and hydrogenterminated nitrogen-induced conductive ultrananocrystalline diamond. *Electrochimica Acta,* 54**,** 1909-1915.

Holt, P., Barton, G. & Mitchell, C. 1999. Electrocoagulation as a wastewater treatment. *The Third Annual Australian Environmental Engineering Research Event,* 41-46.

Holt, P. K., Barton, G. W. & Mitchell, C. A. 2005. The future for electrocoagulation as a localised water treatment technology. *Chemosphere,* 59**,** 355-367.

Holt, P. K., Barton, G. W., Wark, M. & Mitchell, C. A. 2002. A quantitative comparison between chemical dosing and electrocoagulation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 211**,** 233-248.

Hong, X., Huang, W., Yan, X., Haibo, L., Honghai, J., Jiang, M., Xiaobo, L. & Shucai, G. 2008. Effect of configuration on mass transfer in a filter-press type electrochemical cell. *Chinese Journal of Chemical Engineering,* 16**,** 198-202.

Hu, C., Lo, S. & Kuan, W. 2003. Effects of co-existing anions on fluoride removal in electrocoagulation (EC) process using aluminum electrodes. *Water Research,* 37**,** 4513-4523.

Hu, Z. J. & Li, Y. M. 2011. A combined electrocoagulation-electrooxidation treatment on CTMP wastewater. *Advanced Materials Research*, 619-622.

Ibrahim, D. S., Veerabahu, C., Palani, R., Devi, S. & Balasubramanian, N. 2013. Flow dynamics and mass transfer studies in a tubular electrochemical reactor with a mesh electrode. *Computers & Fluids,* 73**,** 97-103.

Irdemez, Ş., Demircioğlu, N. & Yildiz, Y. Ş. 2006a. The effects of pH on phosphate removal from wastewater by electrocoagulation with iron plate electrodes. *Journal of Hazardous Materials,* 137**,** 1231-1235.

Irdemez, Ş., Demircioğlu, N., Yildiz, Y. Ş. & Bingul, Z. 2006b. The effects of current density and phosphate concentration on phosphate removal from wastewater by electrocoagulation using aluminum and iron plate electrodes. *Separation and Purification Technology,* 52**,** 218-223.

Islam, S., Rahman, S., Rahman, M., Adyel, T., Yesman, R., Ahmed, M. & Kaiser, N. 2011. Excessive turbidity removal from textile effluents using electrocoagulation technique. *Journal of Scientific Research,* 3**,** 557-568.

Jame, S. A. 2012. *Electrochemical treatment of synthetic wastewater containing textile dyes*, Lamar University-Beaumont.

Janpoor, F., Torabian, A. & Khatibikamal, V. 2011. Treatment of laundry waste-water by electrocoagulation. *Journal of Chemical Technology and Biotechnology,* 86**,** 1113-1120.

Jaworski, Z., Dyster, K. & Nienow, A. 2001. The effect of size, location and pumping direction of pitched blade turbine impellers on flow patterns: LDA measurements and CFD predictions. *Chemical Engineering Research and Design,* 79**,** 887-894.

Jiang, J.-Q., Graham, N., Andre, C., Kelsall, G. H. & Brandon, N. 2002. Laboratory study of electro-coagulation–flotation for water treatment. *Water Research,* 36**,** 4064-4078.

Jović, M., Stanković, D., Manojlović, D., Anđelković, I., Milić, A., Dojčinović, B. & Roglić, G. 2013. Study of the electrochemical oxidation of reactive textile dyes using platinum electrode. *Int. J. Electrochem. Sci,* 8**,** 168-183.

Kabdaşli, I., Arslan, T., Ölmez-Hanci, T., Arslan-Alaton, I. & Tunay, O. 2009a. Complexing agent and heavy metal removals from metal plating effluent by electrocoagulation with stainless steel electrodes. *Journal of Hazardous Materials,* 165**,** 838-845.

Kabdaşli, I., Keleş, A., Ölmez-Hanci, T., Tunay, O. & Arslan-Alaton, I. 2009b. Treatment of phthalic acid esters by electrocoagulation with stainless steel electrodes using dimethyl phthalate as a model compound. *Journal of Hazardous Materials,* 171**,** 932-940.

Kabdaşli, I., Vardar, B., Arslan-Alaton, I. & Tunay, O. 2009c. Effect of dye auxiliaries on color and COD removal from simulated reactive dyebath effluent by electrocoagulation. *Chemical Engineering Journal,* 148**,** 89-96.

Kang, K. U. & Chung, B. J. 2010. The effects of the anode size and position on the limiting currents of natural convection mass transfer experiments in a vertical pipe. *Transactions of the Korean Society of Mechanical Engineers B,* 34**,** 1-8.

Kara, S. 2013. Treatment of transport container washing wastewater by electrocoagulation. *Environmental Progress & Sustainable Energy,* 32**,** 249-256.

Kargi, F., Catalkaya, E. C. & Uzuncar, S. 2011. Hydrogen gas production from waste anaerobic sludge by electrohydrolysis: Effects of applied DC voltage. *International Journal of Hydrogen Energy,* 36**,** 2049-2056.

Kashefialasl, M., Khosravi, M., Marandi, R. & Seyyedi, K. 2006. Treatment of dye solution containing colored index Acid Yellow 36 by electrocoagulation using iron electrodes. *Int. J. Environ. Sci. Tech,* 2**,** 365-371.

Katal, R. & Pahlavanzadeh, H. 2011. Influence of different combinations of aluminum and iron electrode on electrocoagulation efficiency: Application to the treatment of paper mill wastewater. *Desalination,* 265**,** 199-205.

Keshmirizadeh, E., Yousefi, S. & Rofouei, M. K. 2011. An investigation on the new operational parameter effective in Cr (VI) removal efficiency: A study on electrocoagulation by alternating pulse current. *Journal of Hazardous Materials,* 190**,** 119-124.

Khaled, B., Wided, B., Bechir, H., Elimame, E., Mouna, L. & Zied, T. 2015. Investigation of electrocoagulation reactor design parameters effect on the removal of cadmium from synthetic and phosphate industrial wastewater. *Arabian Journal of Chemistry*.

Khandegar, V. & Saroha, A. K. 2012. Electrochemical treatment of distillery spent wash using aluminum and iron electrodes. *Chinese Journal of Chemical Engineering,* 20**,** 439-443.

Khandegar, V. & Saroha, A. K. 2013a. Electrochemical treatment of effluent from small-scale dyeing unit.*Indian Chemical Engineer,* 55**,** 112-120.

Khandegar, V. & Saroha, A. K. 2013b. Electrochemical treatment of textile effluent containing Acid Red 131 dye. *Journal of Hazardous, Toxic, and Radioactive Waste,* 18**,** 38-44.

Khandegar, V. & Saroha, A. K. 2013c. Electrocoagulation for the treatment of textile industry effluent–A review. *Journal of Environmental Management,* 128**,** 949-963.

Khaoula, M., Wided, B., Chiraz, H. & Bechir, H. 2013. Boron removal by electrocoagulation using full factorial design. *Journal of Water Resource and Protection,* 5, 867-875.

Khatibikamal, V., Torabian, A., Janpoor, F. & Hoshyaripour, G. 2010. Fluoride removal from industrial wastewater using electrocoagulation and its adsorption kinetics. *Journal of Hazardous Materials,* 179**,** 276-280.

Khemis, M., Tanguy, G., Leclerc, J., Valentin, G. & Lapicque, F. 2005. Electrocoagulation for the treatment of oil suspensions: Relation between the rates of electrode reactions and the efficiency of waste removal. *Process Safety and Environmental Protection,* 83**,** 50-57.

Khoomsab, K. & Khummongkol, P. 2013. Journal of Atmospheric Pollution. *Journal of Atmospheric Pollution,* 1**,** 1-4.

Kilic, M. G. & Hoşten, Ç. 2010. A comparative study of electrocoagulation and coagulation of aqueous suspensions of kaolinite powders. *Journal of Hazardous Materials,* 176**,** 735-740.

Kirzhner, F., Zimmels, Y. & Shraiber, Y. 2008. Combined treatment of highly contaminated winery wastewater. *Separation and Purification Technology,* 63**,** 38-44.

Kobya, M., Bayramoglu, M. & Eyvaz, M. 2007. Techno-economical evaluation of electrocoagulation for the textile wastewater using different electrode connections. *Journal of Hazardous Materials,* 148**,** 311-318.

Kobya, M. & Delipinar, S. 2008. Treatment of the baker's yeast wastewater by electrocoagulation. *Journal of Hazardous Materials,* 154**,** 1133-1140.

Kobya, M., Demirbas, E. & Sözbir, M. 2010. Decolorisation of aqueous reactive dye Remazol Red 3B by electrocoagulation. *Coloration Technology,* 126**,** 282-288.

Kobya, M., Senturk, E. & Bayramoglu, M. 2006. Treatment of poultry slaughterhouse wastewaters by electrocoagulation. *Journal of Hazardous Materials,* 133**,** 172-176.

Kobya, M., Ulu, F., Gebologlu, U., Demirbas, E. & Oncel, M. S. 2011. Treatment of potable water containing low concentration of arsenic with electrocoagulation: Different connection modes and Fe–Al electrodes. *Separation and Purification Technology,* 77**,** 283-293.

Koile, R. C. & Johnson, D. C. 1979. Electrochemical removal of phenolic films from a platinum anode. *Analytical Chemistry,* 51**,** 741-744.

Koparal, A. S., Yildiz, Y. Ş., Keskinler, B. & Demircioğlu, N. 2008. Effect of initial pH on the removal of humic substances from wastewater by electrocoagulation. *Separation and Purification Technology,* 59**,** 175-182.

Körbahti, B. K., Artut, K., Gecgel, C. & Özer, A. 2011. Electrochemical decolorization of textile dyes and removal of metal ions from textile dye and metal ion binary mixtures. *Chemical Engineering Journal,* 173**,** 677-688.

Körbahti, B. K. & Tanyolac, A. 2008. Electrochemical treatment of simulated textile wastewater with industrial components and Levafix Blue CA reactive dye: Optimization through response surface methodology. *Journal of Hazardous Materials,* 151**,** 422-431.

Kraljić Roković, M., Čubrić, M. & Wittine, O. 2014. Phenolic compounds removal from mimosa tannin model water and olive mill wastewater by energy-efficient electrocoagulation process. *Journal of Electrochemical Science and Engineering,* 4**,** 215-225.

Kresta, S. M. & Wood, P. E. 1993. The flow field produced by a pitched blade turbine: characterization of the turbulence and estimation of the dissipation rate. *Chemical Engineering Science,* 48**,** 1761-1774.

Krishna, B., Murthy, U. N., Kumar, B. M. & Lokesh, K. 2010. Electrochemical pretreatment of distillery wastewater using aluminum electrode. *Journal of Applied Electrochemistry,* 40**,** 663-673.

Kumar, M., Ponselvan, F. I. A., Malviya, J. R., Srivastava, V. C. & Mall, I. D. 2009. Treatment of bio-digester effluent by electrocoagulation using iron electrodes. *Journal of Hazardous Materials,* 165**,** 345-352.

Kuroda, Y., Kawada, Y., Takahashi, T., Ehara, Y., Ito, T., Zukeran, A., Kono, Y. & Yasumoto, K. 2003. Effect of electrode shape on discharge current and performance with barrier discharge type electrostatic precipitator. *Journal of Electrostatics,* 57**,** 407-415.

Kurt, U., Gonullu, M. T., Ilhan, F. & Varinca, K. 2008. Treatment of domestic wastewater by electrocoagulation in a cell with Fe-Fe electrodes. *Environmental Engineering Science,* 25**,** 153-162.

Lacasa, E., Canizares, P., Saez, C., Fernandez, F. J. & Rodrigo, M. A. 2011a. Electrochemical phosphates removal using iron and aluminium electrodes. *Chemical Engineering Journal,* 172**,** 137-143.

Lacasa, E., Canizares, P., Sáez, C., Fernández, F. J. & Rodrigo, M. A. 2011b. Removal of arsenic by iron and aluminium electrochemically assisted coagulation. *Separation and Purification Technology,* 79**,** 15-19.

Laidler, K. J., and & Meister, J. H. 1999. *Physical Chemistry,* Amazon Prime, Boston. USA.

Lambert, J., Vega, M. M., Isarain-Chavez, E. & Peralta-Hernandez, J. M. 2011. Ozone and Electrocoagulation Processes for Treatment of Dye in Leather

Industry Wastewater: A Comparative Study. *International Journal of Emerging Technology and Advanced Engineerin*, 3, 1-9.

Lanza, M. & Bertazzoli, R. 2000. Removal of Zn (II) from chloride medium using a porous electrode: current penetration within the cathode. *Journal of Applied Electrochemistry,* 30**,** 61-70.

Lee, W. J. & Pyun, S.I. 1999. Effects of hydroxide ion addition on anodic dissolution of pure aluminium in chloride ion-containing solution. *Electrochimica Acta,* 44**,** 4041-4049.

Lekhlif, B., Oudrhiri, L., Zidane, F., Drogui, P. & Blais, J. 2014. Study of the electrocoagulation of electroplating industry wastewaters charged by nickel (II) and chromium (VI). *J. Mater. Environ. Sci.,* 5**,** 111-120.

Li, X., Song, J., Guo, J., Wang, Z. &Feng, Q. 2011. Landfill leachate treatment using electrocoagulation. *Procedia Environmental Sciences,* 10**,** 1159-1164.

Linares-Hernández, I., Barrera-Díaz, C., Bilyeu, B., Juárez-Garcíarojas, P. & Campos-Medina, E. 2010. A combined electrocoagulation–electrooxidation treatment for industrial wastewater. *Journal of Hazardous Materials,* 175**,** 688-694.

Linares-Hernández, I., Barrera-Díaz, C., Roa-Morales, G., Bilyeu, B. & Ureña-Núñez, F. 2007. A combined electrocoagulation–sorption process applied to mixed industrial wastewater. *Journal of Hazardous Materials,* 144**,** 240-248.

Linares-Hernández, I., Barrera-Díaz, C., Roa-Morales, G., Bilyeu, B. & Ureña-Núñez, F. 2009. Influence of the anodic material on electrocoagulation performance. *Chemical Engineering Journal,* 148**,** 97-105.

Liu, Y., Liu, H., Ma, J. & Wang, X. 2009. Comparison of degradation mechanism of electrochemical oxidation of di-and tri-nitrophenols on Bi-doped lead dioxide electrode: effect of the molecular structure. *Applied Catalysis B: Environmental,* 91**,** 284-299.

Lopez-Vizcaino, R., Saez, C., Canizares, P. & Rodrigo, M. 2012. Electrocoagulation of the effluents from surfactant-aided soil-remediation processes. *Separation and Purification Technology,* 98**,** 88-93.

Mahajan, R., Khandegar, V. & Saroha, A. K. 2013. Treatment of hospital operation theatre effluent by electrocoagulation. *International Journal of Chemical & Environmental Engineering,*4, 104-107.

Mahmoodi, N. M. & Dalvand, A. 2013. Treatment of colored textile wastewater containing acid dye using electrocoagulation process. *Desalination and Water Treatment,* 51**,** 5959-5964.

Mahvi, A. H., Ebrahimi, S. J. A.-D., Mesdaghinia, A., Gharibi, H. & Sowlat, M. H. 2011. Performance evaluation of a continuous bipolar electrocoagulation/electrooxidation–electroflotation (EC/EO–EF) reactor designed for simultaneous removal of ammonia and phosphate from wastewater effluent. *Journal of Hazardous Materials,* 192**,** 1267-1274.

Malakootian, M. & Yousefi, N. 2009. The efficiency of electrocoagulation process using aluminum electrodes in removal of hardness from water. *Iranian Journal of Environmental Health Science and Engineering*, 6, 131-136.

Malakootian, M., Yousefi, N. & Fatehizadeh, A. 2011. Survey efficiency of electrocoagulation on nitrate removal from aqueous solution. *International Journal of Environmental Science & Technology,* 8**,** 107-114.

Malpass, G., Miwa, D., Mortari, D., Machado, S. & Motheo, A. 2007. Decolorisation of real textile waste using electrochemical techniques: Effect of the chloride concentration. *Water Research,* 41**,** 2969-2977.

Mansour, S. E. & Hasieb, I. H. 2012. Removal of Ni (II) and Co (II) mixtures from synthetic drinking water by electrocoagulation technique using alternating current. *International Journal of Chemical Technology,* 4**,** 31-44.

Mansouri, K., Elsaid, K., Bedoui, A., Bensalah, N. & Abdel-Wahab, A. 2011. Application of electrochemically dissolved iron in the removal of tannic acid from water. *Chemical Engineering Journal,* 172**,** 970-976.

Martínez-Delgadillo, S., Gutierrez, M., Barceló, I. & Mendez, J. 2010a. Performance of a tubular electrochemical reactor, operated with different inlets, to remove Cr (VI) from wastewater. *Computers &Chemical Engineering,* 34**,** 491-499.

Martínez-Delgadillo, S., Mollinedo-Ponce, H., Mendoza-Escamilla, V. & Barrera-Díaz, C. 2010b. Residence time distribution and back-mixing in a tubular electrochemical reactor operated with different inlet flow velocities, to remove Cr (VI) from wastewater. *Chemical Engineering Journal,* 165**,** 776-783.

Martinez-Delgadillo, S., Mollinedo-Ponce, H., Mendoza-Escamilla, V., Gutierrez-Torres, C., Jimenez-Bernal, J. & Barrera-Diaz, C. 2012. Performance evaluation of an electrochemical reactor used to reduce Cr (VI) from aqueous media applying CFD simulations. *Journal of Cleaner Production,* 34**,** 120-124.

Martínez-Delgadillo, S., Ramírez-Muñoz, J., Mollinedo, H., Huerta, O., Barrera-Diaz, C. & Mendoza-Escamilla, V. 2013a. Analysis by CFD tool to evaluate the performance of a tubular electrochemical flow reactor with rotating anode. *Int. J. Electrochem. Sci,* 8**,** 3939-3952.

Martínez-Delgadillo, S. A., Gutierrez-Torres, C. & Jimenez-Bernal, J. 2013b. Determination of the spatial distribution of the turbulent intensity and velocity field in an electrochemical reactor by CFD. *Int. J. Electrochem. Sci,* 8**,** 274-289.

Martinez-Huitle, C. A. & Ferro, S. 2006. Electrochemical oxidation of organic pollutants for the wastewater treatment: direct and indirect processes. *Chemical Society Reviews,* 35**,** 1324-1340.

Martinez, G. V. F., Torres, J. R. P., García, J. L. V., Munive, G. C. T. & Zamarripa, G. G. 2012. Kinetic aspects of gold and silver recovery in cementation with zinc power and electrocoagulation iron process. *Advances in Chemical Engineering and Science,* 2, 826-834.

Martinez, S., Rodriguez, M. & Barrera, C. 2000. A kinetic model that describes removal of chromium VI from rinsing waters of the metal finishing industry by electrochemical processes. *Water Science And Technology,* 42**,** 55-61.

Matilainen, A., Vepsäläinen, M. & Sillanpää, M. 2010. Natural organic matter removal by coagulation during drinking water treatment: A review. *Advances in Colloid and Interface Science,* 159**,** 189-197.

Matis, K. & Peleka, E. 2010. Alternative flotation techniques for wastewater treatment: Focus on electroflotation. *Separation Science and Technology,* 45**,** 2465-2474.

Merzouk, B., Gourich, B., Madani, K., Vial, C. & Sekki, A. 2011a. Removal of a disperse red dye from synthetic wastewater by chemical coagulation and continuous electrocoagulation. A comparative study. *Desalination,* 272**,** 246-253.

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. *Journal of Hazardous Materials,* 164**,** 215-222.

Merzouk, B., Madani, K. & Sekki, A. 2010. Using electrocoagulation–electroflotation technology to treat synthetic solution and textile wastewater, two case studies. *Desalination,* 250**,** 573-577.

Merzouk, B., Yakoubi, M., Zongo, I., Leclerc, J. P., Paternotte, G., Pontvianne, S. & Lapicque, F. 2011b. Effect of modification of textile wastewater composition on electrocoagulation efficiency. *Desalination,* 275**,** 181-186.

Mishra, V. P., Dyster, K. N., Nienow, A. W., Mckemmie, J. & Jaworski, Z. 1998. A study of an up-and a down-pumping wide blade hydrofoil impeller: Part I. LDA measurements. *The Canadian Journal of Chemical Engineering,* 76**,** 577-588.

Módenes, A., Espinoza-Quiñones, F., Borba, F. & Manenti, D. 2012. Performance evaluation of an integrated photo-Fenton–Electrocoagulation process applied to pollutant removal from tannery effluent in batch system. *Chemical Engineering Journal,* 197**,** 1-9.

Modirshahla, N., Abdoli, M., Behnajady, M. A. & Vahid, B. 2013. Decolourization of tartrazine from aqueous solutions by coupling electrocoagulation with ZnO photocatalyst. *Environment Protection Engineering,* 39, 59-73.

Modirshahla, N., Behnajady, M. & Kooshaiian, S. 2007. Investigation of the effect of different electrode connections on the removal efficiency of tartrazine from aqueous solutions by electrocoagulation. *Dyes and Pigments,* 74**,** 249-257.

Modirshahla, N., Behnajady, M. & Mohammadi-Aghdam, S. 2008. Investigation of the effect of different electrodes and their connections on the removal efficiency of 4-nitrophenol from aqueous solution by electrocoagulation. *Journal of Hazardous Materials,* 154**,** 778-786.

Mollah, M. Y., Morkovsky, P., Gomes, J. A., Kesmez, M., Parga, J. & COCKE, D. L. 2004a. Fundamentals, present and future perspectives of electrocoagulation. *Journal of Hazardous Materials,* 114**,** 199-210.

Mollah, M. Y., Pathak, S. R., Patil, P. K., Vayuvegula, M., Agrawal, T. S., Gomes, J. A., Kesmez, M. & Cocke, D. L. 2004b. Treatment of orange II azo-dye by electrocoagulation (EC) technique in a continuous flow cell using sacrificial iron electrodes. *Journal of Hazardous Materials,* 109**,** 165-171.

Mollah, M. Y. A., Gomes, J. A., Das, K. K. & Cocke, D. L. 2010. Electrochemical treatment of Orange II dye solution—Use of aluminum sacrificial electrodes and floc characterization. *Journal of Hazardous Materials,* 174**,** 851-858.

Morao, A., Lopes, A., De Amorim, M. P. & Goncalves, I. 2004. Degradation of mixtures of phenols using boron doped diamond electrodes for wastewater treatment. *Electrochimica Acta,* 49**,** 1587-1595.

Moreno C, H. A., Cocke, D. L., Gomes, J. A., Morkovsky, P., Parga, J., PETERSON, E. & Garcia, C. 2009. Electrochemical reactions for electrocoagulation using iron electrodes. *Industrial & Engineering Chemistry Research,* 48**,** 2275-2282.

Mouedhen, G., Feki, M., Wery, M. D. P. & Ayedi, H. 2008. Behavior of aluminum electrodes in electrocoagulation process. *Journal of Hazardous Materials,* 150**,** 124-135.

Moussavi, G., Majidi, F. & Farzadkia, M. 2011. The influence of operational parameters on elimination of cyanide from wastewater using the electrocoagulation process. *Desalination,* 280**,** 127-133.

Murthy, Z., Nancy, C. & Kant, A. 2007. Separation of pollutants from restaurant wastewater by electrocoagulation. *Separation Science and Technology,* 42**,** 819-833.

Murugananthan, M., Latha, S., Raju, G. B. & Yoshihara, S. 2010. Anodic oxidation of ketoprofen—an anti-inflammatory drug using boron doped diamond and platinum electrodes. *Journal of Hazardous Materials,* 180**,** 753-758.

Nandi, B. K. & Patel, S. 2013. Effects of operational parameters on the removal of brilliant green dye from aqueous solutions by electrocoagulation. *Arabian Journal of Chemistry*. 4, 1-8.

Nanseu-Njiki, C. P., Tchamango, S. R., Ngom, P. C., Darchen, A. & Ngameni, E. 2009. Mercury (II) removal from water by electrocoagulation using aluminium and iron electrodes. *Journal of Hazardous Materials,* 168**,** 1430-1436.

Narayanan, N. V. & Ganesan, M. 2009. Use of adsorption using granular activated carbon (GAC) for the enhancement of removal of chromium from synthetic wastewater by electrocoagulation. *Journal of Hazardous Materials,* 161**,** 575-580.

Nasrullah, M., Singh, L. & Wahida, Z. A. 2012. Treatment of sewage by electrocoagulation and the effect of high current density. *Energy Environ Eng J,* 1, 27-31.

Nielsen, N. F. & Andersson, C. 2009. Electrode shape and collector plate spacing effects on ESP performance. *Electrostatic Precipitation.* Springer.

Nienow, A. 1997. On impeller circulation and mixing effectiveness in the turbulent flow regime. *Chemical Engineering Science,* 52**,** 2557-2565.

Nilsson, A., Ronlán, A. & Parker, V. D. 1973. Anodic oxidation of phenolic compounds. Part III. Anodic hydroxylation of phenols. A simple general synthesis of 4-alkyl-4-hydroxycyclo-hexa-2, 5-dienones from 4-alkylphenols. *Journal of the Chemical Society, Perkin Transactions*, 1**,** 2337-2345.

Nouri, J., Mahvi, A. & Bazrafshan, E. 2010. Application of electrocoagulation process in removal of zinc and copper from aqueous solutions by aluminum electrodes. *International Journal of Environmental Research,* 4**,** 201-208.

Ntwampe, I., Waanders, F. & Bunt, J. 2016. Reactivity of Fe salts in the destabilization of acid mine drainage employing mixing and shaking techniques without pH adjustment. *International Journal of Mineral Processing,* 146**,** 65-73.

O'hayre, R. P., Cha, S.W., Colella, W. & Prinz, F. B. 2006. *Fuel Cell Fundamentals*, John Wiley & Sons New York.

Oldshue, J. M. 1983. *Fluid mixing technology,* McGraw-Hill Publications Co., New York. USA.

Oliveira, S. C. B. & Oliveira-Brett, A. M. 2010. Voltammetric and electrochemical impedance spectroscopy characterization of a cathodic and anodic pre-treated boron doped diamond electrode. *Electrochimica Acta,* 55**,** 4599-4605.

Olmez-Hanci, T., Kartal, Z. & Arslan-Alaton, İ. 2012. Electrocoagulation of commercial naphthalene sulfonates: process optimization and assessment of implementation potential. *Journal of Environmental Management,* 99**,** 44-51.

Ölmez, T. 2009. The optimization of Cr (VI) reduction and removal by electrocoagulation using response surface methodology. *Journal of Hazardous Materials,* 162**,** 1371-1378.

Orescanin, V., Kollar, R., Ruk, D. & Nad, K. 2012. Characterization and electrochemical treatment of landfill leachate. *Journal of Environmental Science and Health, Part A,* 47**,** 462-469.

Ozyonar, F. 2015. Optimization of operational parameters of electrocoagulation process for real textile wastewater treatment using Taguchi experimental design method. *Desalination and Water Treatment***,** 2, 1-11.

Ozyonar, F. & Karagozoglu, B. 2012. Systematic assessment of electrocoagulation for the treatment of marble processing wastewater. *International Journal of Environmental Science and Technology,* 9**,** 637-646.

Pajootan, E., Arami, M. & Mahmoodi, N. M. 2012. Binary system dye removal by electrocoagulation from synthetic and real colored wastewaters. *Journal of the Taiwan Institute of Chemical Engineers,* 43**,** 282-290.

Panizza, M., Bocca, C. & Cerisola, G. 2000. Electrochemical treatment of wastewater containing polyaromatic organic pollutants. *Water Research,* 34**,** 2601-2605.

Panizza, M. & Cerisola, G. 2004. Electrochemical oxidation as a final treatment of synthetic tannery wastewater. *Environmental Science & Technology,* 38**,** 5470-5475.

Panizza, M. & Cerisola, G. 2009. Direct and mediated anodic oxidation of organic pollutants. *Chemical reviews,* 109**,** 6541-6569.

Papouchado, L., Sandford, R., Petrie, G. & Adams, R. 1975. Anodic oxidation pathways of phenolic compounds Part 2. Stepwise electron transfers and coupled hydroxylations. *Journal of Electroanalytical Chemistry and Interfacial Electrochemistry,* 65**,** 275-284.

Parga, J., González, G., Moreno, H. & Valenzuela, J. 2012. Thermodynamic studies of the strontium adsorption on iron species generated by electrocoagulation. *Desalination and Water Treatment,* 37**,** 244-252.

Parga, J. R., Cocke, D. L., Valverde, V., Gomes, J. A., Kesmez, M., Moreno, H., Weir, M. & Mencer, D. 2005. Characterization of electrocoagulation for removal of chromium and arsenic. *Chemical Engineering & Technology,* 28**,** 605-612.

Parga, J. R., Vazquez, V., Gonzalez, G. & Cisneros, M. M. 2010. Thermodynamic studies of chromium adsorption on iron species generated by electrocoagulation. *Chemical Engineering & Technology,* 33**,** 1582-1590.

Parsa, J. B., Vahidian, H. R., Soleymani, A. & Abbasi, M. 2011. Removal of Acid Brown 14 in aqueous media by electrocoagulation: Optimization parameters and minimizing of energy consumption. *Desalination,* 278**,** 295-302.

Patel, U. D., Ruparelia, J. & Patel, M. U. 2011. Electrocoagulation treatment of simulated floor-wash containing Reactive Black 5 using iron sacrificial anode. *Journal of hazardous materials,* 197**,** 128-136.

Paul, E. L., Atiemo-Obeng, V. A. & Kresta, S. M. 2004. *Handbook of industrial mixing: science and practice*, John Wiley & Sons.

Peterson, R. A. 2005. In Search of Authenticity. *Journal of Management Studies,* 42**,** 1083-1098.

Pfaff, J. D. 1993. Method 300.0 Determination of inorganic anions by ion chromatography. *USEPA Environ. Monit. Syst. Lab., Cincinnati, OH*.

Phalakornkule, C., Polgumhang, S. & Tongdaung, W. 2009. Performance of an electrocoagulation process in treating direct dye: Batch and continuous upflow processes. *World Academy Sci. Technol,* 57**,** 277-282.

Phalakornkule, C., Polgumhang, S., Tongdaung, W., Karakat, B. & Nuyut, T. 2010a. Electrocoagulation of blue reactive, red disperse and mixed dyes, and application in treating textile effluent. *Journal of Environmental Management,* 91**,** 918-926.

Phalakornkule, C., Sukkasem, P. & Mutchimsattha, C. 2010b. Hydrogen recovery from the electrocoagulation treatment of dye-containing wastewater. *International Journal of Hydrogen Energy,* 35**,** 10934-10943.

Pirkarami, A. & Olya, M. E. 2014. Removal of dye from industrial wastewater with an emphasis on improving economic efficiency and degradation mechanism. *Journal of Saudi Chemical Society*. In Press.

Platts, K. W. 1993. A process approach to researching manufacturing strategy. *International Journal of Operations & Production Management,* 13**,** 4-17.

Pociecha, M. & Lestan, D. 2010. Using electrocoagulation for metal and chelant separation from washing solution after EDTA leaching of Pb, Zn and Cd contaminated soil. *Journal of Hazardous Materials,* 174**,** 670-678.

Ponce-De-Leon, C., Low, C., Kear, G. & Walsh, F. 2007. Strategies for the determination of the convective-diffusion limiting current from steady state linear sweep voltammetry. *Journal of Applied Electrochemistry,* 37**,** 1261-1270.

Puthran, S. L. 2011. 3-dimensional computational fluid dynamics modeling of solid oxide fuel cell using different fuels. DTIC Document. *Masters Theses*, Missouri University of Science and Technology.

Ragnini, C. A., Di Iglia, R. A., Bizzo, W. & Bertazzoli, R. 2000. Recycled niobium felt as an efficient three-dimensional electrode for electrolytic metal ion removal. *Water Research,* 34**,** 3269-3276.

Rahimi, M., Amraei, S. & Alsairafi, A. A. 2011. Experimental and computational fluid dynamics modeling of mixing by Visco-jet impellers. *Korean Journal of Chemical Engineering,* 28**,** 1372-1379.

Rajeshwar, K. & Ibanez, J. G. 1997. *Environmental electrochemistry: Fundamentals and applications in pollution sensors and abatement*, Academic Press.

Raju, G. B., Karuppiah, M. T., Latha, S., Parvathy, S. & Prabhakar, S. 2008. Treatment of wastewater from synthetic textile industry by electrocoagulation–electrooxidation. *Chemical Engineering Journal,* 144**,** 51-58.

Rashidi, H. R., Nik Sulaiman, N. M., AwanisHashim, N., Che Hassan, C. R. & Davazdah Emami, S. 2016. Simulated textile (batik) wastewater pre-treatment through application of a baffle separation tank. *Desalination and Water Treatment,* 57**,** 151-160.

Rivero, E., Granados, P., Rivera, F., Cruz, M. & González, I. 2010. Mass transfer modeling and simulation at a rotating cylinder electrode (RCE) reactor under turbulent flow for copper recovery. *Chemical Engineering Science,* 65**,** 3042-3049.

Rodríguez, C. T. C., Amaya-Chávez, A., Roa-Morales, G., Barrera-Díaz, C. E. & Urena-Nunez, F. 2010. An integrated electrocoagulation-phytoremediation process for the treatment of mixed industrial wastewater. *International Journal of Phytoremediation,* 12**,** 772-784.

Rodriguez, J., Stopić, S. & Friedrich, B. 2007. Continuous electrocoagulation treatment of wastewater from copper production. *World Mettall.: ERZMETALL,* 60**,** 8.

Rodriguez, M. G., Aguilar, R., Soto, G. & Martínez, S. A. 2003. Modeling an electrochemical process to remove Cr (VI) from rinse-water in a stirred reactor. *Journal of Chemical Technology and Biotechnology,* 78**,** 371-376.

Rong, X., Haiyan, F., Peng, Z. & Heping, G. 2007. Measurement of enhanced mass transfer coefficient in tube by limiting diffusion current technique. *Petrochemical Technology,* 36**,** 712.

Roopashree, G. & Lokesh, K. 2014. Comparative study of electrode material (iron, aluminium and stainless steel) for treatment of textile industry wastewater. *International Journal of Environmental Sciences,* 4**,** 519.

Roy, S., Acharya, S. & Cloeter, M. D. 2010. Flow structure and the effect of macro-instabilities in a pitched-blade stirred tank. *Chemical Engineering Science,* 65**,** 3009-3024.

Sakharova, A., Nyikost, L. & Pleskov, Y. 1992. Adsorption and partial charge transfer at diamond electrodes—I. Phenomenology: An impedance study. *Electrochimica Acta,* 37**,** 973-978.

Saleem, M., Bukhari, A. A. & Akram, M. N. 2011. Electrocoagulation for the treatment of wastewater for reuse in irrigation and plantation. *Journal of Basic and Applied Sciences,* 7**,** 11-20.

Samet, Y., Agengui, L. & Abdelhedi, R. 2010. Electrochemical degradation of chlorpyrifos pesticide in aqueous solutions by anodic oxidation at boron-doped diamond electrodes. *Chemical Engineering Journal,* 161**,** 167-172.

Santos, J., Geraldes, V., Velizarov, S. & Crespo, J. 2010. Characterization of fluid dynamics and mass-transfer in an electrochemical oxidation cell by experimental and CFD studies. *Chemical Engineering Journal,* 157**,** 379-392.

Sarala, C. 2012. Domestic wastewater treatment by electrocoagulation with Fe-Fe electrodes. *International Journal of Engineering Trends and Technology,* 3**,** 530-533.

Sarkar, M. S. K. A., Evans, G. & Donne, S. 2010. Bubble size measurement in electroflotation. *Minerals Engineering,* 23**,** 1058-1065.

Sasson, M. B., Calmano, W. & Adin, A. 2009. Iron-oxidation processes in an electroflocculation (electrocoagulation) cell. *Journal of Hazardous Materials,* 171**,** 704-709.

Sayiner, G., Kandemirli, F. & Dimoglo, A. 2008. Evaluation of boron removal by electrocoagulation using iron and aluminum electrodes. *Desalination,* 230**,** 205-212.

Sbizzaro Filho, D., Bota, G. B., Borri, R. B. & Teran, F. J. C. 2012. Electrocoagulation/flotation followed by fluidized bed anaerobic reactor applied to tannery effluent treatment. *Desalination and Water Treatment,* 37**,** 359-363.

Schulz, M., Baygents, J. & Farrell, J. 2009. Laboratory and pilot testing of electrocoagulation for removing scale-forming species from industrial process waters. *International Journal of Environmental Science & Technology,* 6**,** 521-526.

Secula, M. S., Cagnon, B., DeOliveira, T. F., Chedeville, O. & Fauduet, H. 2012. Removal of acid dye from aqueous solutions by electrocoagulation/GAC adsorption coupling: Kinetics and electrical operating costs. *Journal of the Taiwan Institute of Chemical Engineers,* 43**,** 767-775.

Secula, M. S., Creţescu, I. & Petrescu, S. 2011. An experimental study of indigo carmine removal from aqueous solution by electrocoagulation. *Desalination,* 277**,** 227-235.

Sedahmed, G., Farag, H., Kayar, A. & El-Nashar, I. 1998. Mass transfer at the impellers of agitated vessels in relation to their flow-induced corrosion. *Chemical Engineering Journal,* 71**,** 57-65.

Selman, J. R. & Tobias, C. W. 1978. Mass-transfer measurements by the limiting-current technique. *Adv. Chem. Eng,* 10**,** 1-318.

Şengil, İ. A. 2006. Treatment of dairy wastewaters by electrocoagulation using mild steel electrodes. *Journal of Hazardous Materials,* 137**,** 1197-1205.

Şengil, İ. A. & Özacar, M. 2009. The decolorization of CI Reactive Black 5 in aqueous solution by electrocoagulation using sacrificial iron electrodes. *Journal of Hazardous Materials,* 161**,** 1369-1376.

Shalaby, A., Nassef, E., Mubark, A. & Hussein, M. 2014. Phosphate removal from wastewater by electrocoagulation using aluminium electrodes. *American Journal of Environmental Engineering and Science,* 1**,** 90-98.

Shen, F., Chen, X., Gao, P. & Chen, G. 2003. Electrochemical removal of fluoride ions from industrial wastewater. *Chemical Engineering Science,* 58**,** 987-993.

Shin, H.-S. & Lee, J. K. 2006. Performance evaluation of electrocoagulation and electrodewatering system for reduction of water content in sewage sludge. *Korean Journal of Chemical Engineering,* 23**,** 188-193.

Shivayogimath, C. & Jahagirdar, R. 2013. Treatment of sugar industry wastewater using electrocoagulation technique. *International Journal of Research in Engineering and Technology***,** 262-265.

Shivayogimath, C. & Naik, V. R. 2014. Treatment of dairy industry wastewater using electrocoagulation technique. *International Journal of Engineering Research and Technology*,3, 1897-1902 .

Shreesadh, E., Thakur, S. & Chauhan, M. 2014. Electro-coagulation in wastewater treatment.*International Journal of Engineering & Science Research*, 4, 584-589.

Silverman, D. 2004. The rotating cylinder electrode for examining velocity-sensitive corrosion-a review. *Corrosion,* 60**,** 1003-1023.

Singh, H., Fletcher, D. F. & Nijdam, J. J. 2011. An assessment of different turbulence models for predicting flow in a baffled tank stirred with a Rushton turbine. *Chemical Engineering Science,* 66**,** 5976-5988.

Singh, T. S. A. & Ramesh, S. T. 2014. An experimental study of CI Reactive Blue 25 removal from aqueous solution by electrocoagulation using Aluminum sacrificial electrode: kinetics and influence of parameters on electrocoagulation performance. *Desalination and Water Treatment,* 52**,** 2634-2642.

Singhal, S. C. & Kendall, K. 2003. *High-temperature solid oxide fuel cells: Fundamentals, design and applications*, Elsevier, London. UK.

Song, S., He, Z., Qiu, J., Xu, L. & Chen, J. 2007. Ozone assisted electrocoagulation for decolorization of CI Reactive Black 5 in aqueous solution: An investigation of the effect of operational parameters. *Separation and Purification Technology,* 55**,** 238-245.

Sridhar, R., Sivakumar, V., Immanuel, V. P. & Maran, J. P. 2011. Treatment of pulp and paper industry bleaching effluent by electrocoagulant process. *Journal of Hazardous Materials,* 186**,** 1495-1502.

Srinivasan, S. 2006. *Fuel cells: From fundamentals to applications*, Springer Science & Business Media.

Stapelfeldt, B., Mornieux, G., Oberheim, R., Belli, A. & Gollhofer, A. 2007. Development and evaluation of a new bicycle instrument for measurements of pedal forces and power output in cycling. *International Journal of Sports Medicine,* 28**,** 326-332.

Stergiopoulos, D., Dermentzis, K., Giannakoudakis, P. & Sotiropoulos, S. 2014. Electrochemical decolorization and removal of indigo carmine textile dye from wastewater.*Global NEST Journal,* 16**,** 499-506.

Su, J., Lu, H. Y., Xu, H., Sun, J. R., Han, J.L. & Lin, H.B. 2011. Mass transfer enhancement for mesh electrode in a tubular electrochemical reactor using experimental and numerical simulation method. *Russian Journal of Electrochemistry,* 47**,** 1293-1298.

Su, Y., Zhang, Y., Jin, Y., Yao, Y., Zhang, R., Jiang, Y. & Xu, L. 2014. The feasibility for dicrotic augmentation index to replace tidal augmentation index. *Information and Automation (ICIA), 2014 IEEE International Conference on,* IEEE, 943-948.

Sulaymon, A. H. & Abbar, A. H. 2012. Mass transfer to amalgamated copper rotating disk electrode. *Journal of Electrochemical Science and Technology,* 3**,** 165-171.

Tamas, A., Martagiu, R. & Minea, R. 2007. Experimental determination of mass transfer coefficients in dissolution processes.*Chem. Bull."Politeh." Univ. Timisoara,* 52**,** 133-138.

Thakur, C., Srivastava, V. C. & Mall, I. D. 2009. Electrochemical treatment of a distillery wastewater: parametric and residue disposal study.*Chemical Engineering Journal,* 148**,** 496-505.

Thilakavathi, R., Rajasekhar, D., Balasubramanian, N., Srinivasakannan, C. & Al Shoaibi, A. 2012. CFD modeling of continuous stirred tank electrochemical reactor. *Int. J. Electrochem. Sci,* 7**,** 1386-1401.

Top, S., Sekman, E., Hoşver, S. & Bilgili, M. S. 2011. Characterization and electrocaogulative treatment of nanofiltration concentrate of a full-scale landfill leachate treatment plant. *Desalination,* 268**,** 158-162.

Torres-Sánchez, A. L., López-Cervera, S. J., De La Rosa, C., Maldonado-Vega, M., Maldonado-Santoyo, M. & Peralta-Hernández, J. M. 2014. Electrocoagulation process coupled with advance oxidation techniques to treatment of dairy industry wastewater.*Int. J. Electrochem. Sci,* 9**,** 6103-6112.

Trompette, J.L. & Vergnes, H. 2009. On the crucial influence of some supporting electrolytes during electrocoagulation in the presence of aluminum electrodes. *Journal of Hazardous Materials,* 163**,** 1282-1288.

Tufekci, N., Sivri, N. & Toroz, İ. 2007. Pollutants of textile industry wastewater and assessment of its discharge limits by water quality standards. *Turkish Journal of Fisheries and Aquatic Sciences,* 7, 97-103.

Uğurlu, M., Gurses, A., Doğar, Ç. & Yalcin, M. 2008. The removal of lignin and phenol from paper mill effluents by electrocoagulation. *Journal of Environmental Management,* 87**,** 420-428.

Ukiwe, L., Ibeneme, S., Duru, C., Okolue, B., Onyedika, G. & Nweze, C. 2014. Chemical and electrocoagulation techniques in coagulation-floccculationin water and wastewater treatment - A review. *International Journal of Research and Reviews in Applied Sciences,* 18**,**285-294.

Un, U. T. & Aytac, E. 2013. Electrocoagulation in a packed bed reactor-complete treatment of color and cod from real textile wastewater. *Journal of Environmental Management,* 123**,** 113-119.

Un, U. T., Koparal, A. S. & Ogutveren, U. B. 2009. Electrocoagulation of vegetable oil refinery wastewater using aluminum electrodes. *Journal of Environmental Management,* 90**,** 428-433.

Un, U. T., Koparal, A. S. & Ogutveren, U. B. 2013. Fluoride removal from water and wastewater with a bach cylindrical electrode using electrocoagulation. *Chemical Engineering Journal,* 223**,** 110-115.

Un, U. T. & Ocal, S. E. 2015. Removal of heavy metals (Cd, Cu, Ni) by electrocoagulation. *International Journal of Environmental Science and Development,* 6**,** 425-429.

Valente, G. D. F. S., Mendonca, R. C. S. & Pereira, J. A. M. 2015. The efficiency of electrocoagulation using aluminum electrodes in treating wastewater from a dairy industry. *Ciência Rural,* 45**,** 1713-1719.

Valero, D., García-García, V., Expósito, E., Aldaz, A. & Montiel, V. 2015. Application of electrodialysis for the treatment of almond industry wastewater. *Journal of Membrane Science,* 476**,** 580-589.

Valero, D., Ortiz, J. M., García, V., Expósito, E., Montiel, V. & Aldaz, A. 2011. Electrocoagulation of wastewater from almond industry. *Chemosphere,* 84**,** 1290-1295.

Vasudevan, S., Kannan, B. S., Lakshmi, J., Mohanraj, S. & Sozhan, G. 2011a. Effects of alternating and direct current in electrocoagulation process on the removal of fluoride from water. *Journal of Chemical Technology and Biotechnology,* 86**,** 428-436.

Vasudevan, S., Lakshmi, J. & Sozhan, G. 2011b. Effects of alternating and direct current in electrocoagulation process on the removal of cadmium from water. *Journal of Hazardous Materials,* 192**,** 26-34.

Vasudevan, S., Lakshmi, J. & Sozhan, G. 2013. Electrochemically assisted coagulation for the removal of boron from water using zinc anode. *Desalination,* 310**,** 122-129.

Vasudevan, S., Sheela, S. M., Lakshmi, J. & Sozhan, G. 2010. Optimization of the process parameters for the removal of boron from drinking water by electrocoagulation—a clean technology. *Journal of Chemical Technology and Biotechnology,* 85, 926-933.

Vegini, A. A., Meier, H. F., Iess, J. J. & Mori, M. 2008. Computational fluid dynamics (CFD) analysis of cyclone separators connected in series. *Industrial & Engineering Chemistry Research,* 47, 192-200.

Vepsäläinen, M. 2012. *Electrocoagulation in the treatment of industrial waters and wastewaters*, PhD Thesis, VTT Technical Research Centre of Finland.

Vepsäläinen, M., Kivisaari, H., Pulliainen, M., Oikari, A. & Sillanpää, M. 2011. Removal of toxic pollutants from pulp mill effluents by electrocoagulation. *Separation and Purification Technology,* 81, 141-150.

Vepsäläinen, M., Pulliainen, M. & SILLANPää, M. 2012. Effect of electrochemical cell structure on natural organic matter (NOM) removal from surface water through electrocoagulation (EC). *Separation and Purification Technology,* 99, 20-27.

Verma, A. K., Dash, R. R. & Bhunia, P. 2012. A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters. *Journal of Environmental Management,* 93, 154-168.

Verma, S. K., Khandegar, V. & Saroha, A. K. 2013. Removal of chromium from electroplating industry effluent using electrocoagulation. *Journal of Hazardous, Toxic, and Radioactive Waste*, 17, 146-152.

Vilhunen, S., Vilve, M., Vepsäläinen, M. & Sillanpää, M. 2010. Removal of organic matter from a variety of water matrices by UV photolysis and UV/H_2O_2 method. *Journal of Hazardous Materials,* 179, 776-782.

Wachinski, A. 2012. *Membrane processes for water reuse*, McGraw Hill Professional, New York. USA.

Wang, A., Qu, J., Liu, H. & Ge, J. 2004. Degradation of azo dye Acid Red 14 in aqueous solution by electrokinetic and electrooxidation process. *Chemosphere,* 55, 1189-1196.

Wang, C. T., Chou, W. L. & Kuo, Y.M. 2009a. Removal of COD from laundry wastewater by electrocoagulation/electroflotation. *Journal of Hazardous Materials,* 164, 81-86.

Wang, H., Jiang, J.Q., Xu, R. & Li, F. 2012. Treatment of landscape water (LSW) by electrocoagulation process. *Desalination and Water Treatment,* 37, 62-68.

Wang, J. X., Inada, H., Wu, L., Zhu, Y., Choi, Y., Liu, P., Zhou, W.P. & ADZIC, R. R. 2009b. Oxygen reduction on well-defined core - shell nanocatalysts: Particle size, facet, and Pt shell thickness effects. *Journal of the American Chemical Society,* 131**,** 17298-17302.

Wang, Y., Chan, K., Li, X. & So, S. 2006. Electrochemical degradation of 4-chlorophenol at nickel–antimony doped tin oxide electrode. *Chemosphere,* 65**,** 1087-1093.

Wei, M.C., Wang, K.S., Huang, C. L., Chiang, C.W., Chang, T.J., Lee, S. S. & Chang, S. H. 2012. Improvement of textile dye removal by electrocoagulation with low-cost steel wool cathode reactor. *Chemical Engineering Journal,* 192**,** 37-44.

Weyns, G., Nelissen, G., Pembery, J., Maciel, P., Deconinck, J., Deconinck, H., Patrick, M. & Wragg, A. 2009. Turbulent fluid flow and electrochemical mass transfer in an annular duct with an obstruction. *Journal of Applied Electrochemistry,* 39**,** 2453-2459.

Xiang, Y. 2014. *Mass transfer phenomena in rotating corrugated photocatalytic reactors.*Masters thesis,University of Ottawa.

Xu, X. & Zhu, X. 2004. Treatment of refectory oily wastewater by electro-coagulation process. *Chemosphere,* 56**,** 889-894.

Yahiaoui, O., Lounici, H., Abdi, N., Drouiche, N., Ghaffour, N., Pauss, A. & Mameri, N. 2011. Treatment of olive mill wastewater by the combination of ultrafiltration and bipolar electrochemical reactor processes. *Chemical Engineering and Processing: Process Intensification,* 50**,** 37-41.

Yan, M., Wang, D., Ni, J., Qu, J., Chow, C. W. & Liu, H. 2008. Mechanism of natural organic matter removal by polyaluminum chloride: Effect of coagulant particle size and hydrolysis kinetics. *Water Research,* 42**,** 3361-3370.

Yang, C. L. & Dluhy, R. 2002. Electrochemical generation of aluminum sorbent for fluoride adsorption. *Journal of Hazardous Materials,* 94**,** 239-252.

Yang, C.L. & Mcgarrahan, J. 2005. Electrochemical coagulation for textile effluent decolorization. *Journal of Hazardous Materials,* 127**,** 40-47.

Yavuz, Y., Öcal, E., Koparal, A. S. & Öğutveren, Ü. B. 2011. Treatment of dairy industry wastewater by EC and EF processes using hybrid Fe-Al plate electrodes. *Journal of Chemical Technology and Biotechnology,* 86**,** 964-969.

Yildiz, Y., Koparal, A. & Keskinler, B. 2008. Effect of initial pH and supporting electrolyte on the treatment of water containing high concentration of humic substances by electrocoagulation. *Chemical Engineering Journal,* 138**,** 63-72.

Yilmaz, A. E., Boncukcuoğlu, R., Kocaker, M. M. & Kocadağistan, E. 2008. An empirical model for kinetics of boron removal from boroncontaining wastewaters by the electrocoagulation method in a batch reactor. *Desalination,* 230**,** 288-297.

Yilmaz, A. E., Boncukcuoğlu, R., Kocakerim, M. M. & Keskinler, B. 2005. The investigation of parameters affecting boron removal by electrocoagulation method. *Journal of Hazardous Materials,* 125**,** 160-165.

Yilmaz, A. E., Boncukcuoğlu, R., Kocakerim, M. M., Yilmaz, M. T. & Paluluoğlu, C. 2008. Boron removal from geothermal waters by electrocoagulation. *Journal of Hazardous Materials,* 153**,** 146-151.

Yuksel, E., Eyvaz, M. & Gurbulak, E. 2013. Electrochemical treatment of colour index Reactive Orange 84 and textile wastewater by using stainless steel and iron electrodes. *Environmental Progress & Sustainable Energy,* 32**,** 60-68.

Zaied, M. & Bellakhal, N. 2009. Electrocoagulation treatment of black liquor from paper industry. *Journal of Hazardous Materials,* 163**,** 995-1000.

Zaroual, Z., Azzi, M., Saib, N. & Chainet, E. 2006. Contribution to the study of electrocoagulation mechanism in basic textile effluent. *Journal of Hazardous Materials,* 131**,** 73-78.

Zaviska, F., Drogui, P., Blais, J.F. & Mercier, G. 2009. In situ active chlorine generation for the treatment of dye-containing effluents. *Journal of Applied Electrochemistry,* 39**,** 2397-2408.

Zaviska, F., Drogui, P., Blais, J.F., Mercier, G. & De La Rochebrochard D'auzay, S. 2012. Electrochemical oxidation of chlortetracycline using Ti/IrO_2 and Ti/PbO_2 anode electrodes: Application of experimental design methodology. *Journal of Environmental Engineering,* 139**,** 810-821.

Zhao, X., Zhang, B., Liu, H. & Qu, J. 2011. Simultaneous removal of arsenite and fluoride via an integrated electro-oxidation and electrocoagulation process. *Chemosphere,* 83**,** 726-729.

Zhou, M., Dai, Q., Lei, L., Ma, C. A. & Wang, D. 2005. Long life modified lead dioxide anode for organic wastewater treatment: Electrochemical characteristics and degradation mechanism. *Environmental Science & Technology,* 39**,** 363-370.

Zidane, F., Drogui, P., Lekhlif, B., Bensaid, J., Blais, J.F. & Belcadi, S. 2008. Decolourization of dye-containing effluent using mineral coagulants produced by electrocoagulation. *Journal of Hazardous Materials,* 155**,** 153-163.

Zodi, S., Louvet, J.N., Michon, C., Potier, O., Pons, M.N., Lapicque, F. & Leclerc, J.P. 2011. Electrocoagulation as a tertiary treatment for paper mill wastewater: Removal of non-biodegradable organic pollution and arsenic. *Separation and Purification Technology,* 81**,** 62-68.

Zodi, S., Potier, O., Lapicque, F. & Leclerc, J.P. 2009. Treatment of the textile wastewaters by electrocoagulation: Effect of operating parameters on the sludge settling characteristics. *Separation and Purification Technology,* 69**,** 29-36.

Zodi, S., Potier, O., Lapicque, F. & Leclerc, J.P. 2010. Treatment of the industrial wastewaters by electrocoagulation: Optimization of coupled electrochemical and sedimentation processes. *Desalination,* 261**,** 186-190.

Zongo, I., Maiga, A. H., Wethe, J., Valentin, G., Leclerc, J.P., Paternotte, G. & Lapicque, F. 2009. Electrocoagulation for the treatment of textile wastewaters with Al or Fe electrodes: Compared variations of COD levels, turbidity and absorbance. *Journal of Hazardous Materials,* 169**,** 70-76.