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SEWAGE WATER TREATMENT VIA ELECTROCOAGULATION USING IRON ANODE

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ABSTRACT

This work deals with the possibility of using elctrocoagulation method for sewage treatment. The effect of various operational parameters of the treatment efficiency were investigated and optimized. The treatment using iron sacrificial anode was affected by the initial pH, the current density, the amount of sodium chloride and initial dye concentration. The optimum operating conditions of pH 7.6, current density of 65mA/cm^2, electrolysis time of 30mins, 1g/l sodium chloride as supporting electrolyte and 3cm as electrode gap distance. The elctrocoagulation process is a very promising pre-treatment step for UF and RO process for the conversion of sewage water to high quality irrigation water or disinfected drinking water.

Keywords: iron electrode, elctrocoagulation, sewage, water treatment.

INTRODUCTION

Egypt suffers from water shortages, where Egypt's annual share of about 55 billion cubic meters since 1969 in spite of the escalating population growth. This leads to a lack of annual per capita water share which reached to 611 cubic meters in 2015 and this, of course, under the global water poverty line. Egypt is looking for new sources for water. The concept of recovery, treatment and re-use is one of the proposed solutions to resolve the problem of water scarcity in Egypt. The annually produced sewage which amounts to 8 billion cubic meters is considered one of the most important sources of permanent and processors that can be re-used for irrigation. Sewage, on the one hand, normally contained of biological, chemical and physical composition which is usually high in Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Suspended Solid (SS). So, direct discharge of raw or improper treated sewage into the water body is one of the main sources of pollution on a global scale [1]. There are two main objectives of wastewater treatment, one is protecting the environment and the other one is conserving fresh water resources [2]. Nowadays, many of the treatment plants use the biological process in treating sewage water but there are also disadvantages for that process because as the concentration of BOD increases, the higher oxygen volume by the aeration is needed resulting of higher capital, running, and energy cost to them. Besides, this conventional method also need to have huge treatment space, skilled technicians and required a long period to treat the sewage water. Simple, affordable, and efficient sewage water treatment systems are urgently needed in Egypt because most of the conventional technologies currently in use in industrialized nations are too expensive and complex [3]. Electrocoagulation is one of simple and cost-effective methods to treat wastewater efficiently [4]. This electrochemical treatment seems to be a promising treatment method due to its high effectiveness, its lower maintenance cost, less need for labor and rapid achievement of results [5]. Research, in the past few decades, have shown that the elctrocoagulation is a promising treatment method and effectively potential to treat verity type of wastewaters including dyes wastewater [6-10], tannery wastewater [11], restaurant wastewater [4], palm oil mill effluent [6], food wastewater [7], potato chip manufacturing wastewater [8], urban wastewater [11], and removing heavy metals [12–21]. Electrocoagulation treatment methods offer an alternative to the use of chemical coagulant such as metal salts or polymers for breaking the pollutants because during the elctrocoagulation process, the electrode can generate coagulated species and metal hydroxides that destabilize and aggregate the suspended particles and precipitate. The hydrogen gas released from cathode would also help to float the flocculated particles out of the water [22]. Treatment of sewage water by elctrocoagulation leading to secondary treated disinfected water. Several researchers have studied a domestic wastewater [23] and, reported that wastewater usually consists of a number of contaminants, such as TSS, TDS, COD, and colors. Wastewater sample is tested in experimental work, with EC after passing each current (0.12, 0.25 and 0.36) amp for each time period (5, 10, 15 and 20) minutes .The result of the study was shown that the maximum reduction of COD and TDS at 20 minutes for 0.25 amp. While Saleem [24], found that the application of 24.7 mA⁄cm^2 current density with an inter electrode spacing of 5 cm may provide 91.8%, 77.2% and 68.5% removal in turbidity, COD, and TSS within 30 min of EC treatment. Rodrigo [25], indicated that is a capability of removing ionic phosphorus and COD, when using conductive-diamond electrochemical oxidation and elctrocoagulation for persistent organic consumption, specifically regeneration of urban wastewater. The study stated that energy consumption is capable of removing at values lower than 4.5 kWh/m^3. The aim of the present study is to investigate the optimum conditions for the use of elctrocoagulation for treatment of the heavy load sewage water in Egypt as a pretreatment step for membrane post treatment to save irrigation water.

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EXPERIMENTAL METHODS

The sewage water was collected from Abou Rawash municipal sewage primary treatment plant in El Giza Governorate in Egypt. The total capacity of the plant is 1.2 million cubic meter per day. The characteristics of the raw sewage water used in this study are presented in Table-1. All chemicals used were of analytical grade. The elctrocoagulation cell consists of iron anodes and D.C. power supply (model GP4303D LG precision Co. Ltd, Korea). Iron electrodes of 2*2 cm were used, they were mechanically polished with different grade emery washed with distilled water and rinsed with acetone, and finally dried in a stream of air. The anode was weighed and supported vertically in a parallel position midway between the cathodes. The gap distance between each cathode and anode was 3cm. The elctrocoagulation cell was of 1.25liter capacity and filed with 0ne liter sewage in each experiment. All experiments were carried out under stirring and both of the voltage and current was measured using digital multimeter (kyoritus model 1008 Japan). Figure-1 shows the electrocagulation cell used for treatment of Abourwash municipal sewage water.

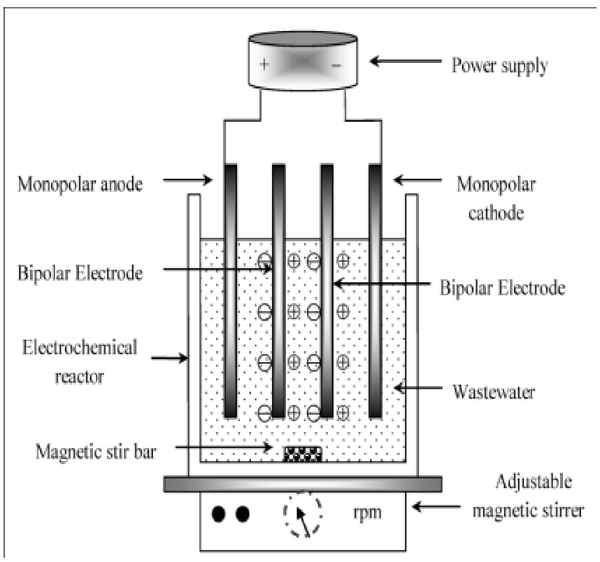

Figure-1. Electrocagulation cell used for Abourwash Sewage water treatment.

The elctrocoagulation experiments were carried out at the ambient temperature 25^{0}C at the beginning of the run, the sewage water was feed into the reactor and the pH and conductivity were adjusted to the desired value. The conductivity of the solution was raised by adding the desired amount of the supporting electrolyte and dissolved completely then the pH adjusted to the desired value. The elctrocoagulation cell then filed with one liter of the above characterized sewage. Stirring is starting and direct current is applied for the required time then the system is switched off. The particulates of colloidal ferric oxyhydroxides gave yellow brown color into the solution after elctrocoagulation and electrolytic flotation. The sludge was separated by filtration with Whatman filter paper (pore size 11μm). Then the liquid was subjected to analysis, and the dissolved iron weight was evaluated from the change in weights of the anode before and after the elctrocoagulation process. Then calculate anodic dissolution percentage from equation Anodic diss. Eff. = wt. diss. × 100/I (amp.)×t (sec) × ECE Where ECE is electrochemical equivalent of iron

Table-1. Shows the main characteristics of sewage water.

Parameter	unit	value
Color	Gray/black	
pH		7.6
S.S	Mg/l	507
COD	Mg O_2/l	760
BOD	Mg O_2/l	446
Electrical Conductivity		0.31
TDS	Mg/l	550

Analytical methods

Analysis or measurements continuously

pH measurements are performed by pH meter Consort C931 model with a glass electrode containing a solution of 4M KCl concentration. The pH meter is calibrated with standard solutions of phosphate, pH 4, 7, 10 and 12. The accuracy standards given by the supplier is ± 0.02 units at 20°C. The pH of each sample taken at the stirred reactor is taken immediately. The voltages are directly measured on the display of the power supply.

Analysis requiring sampling

At the end of elctrocoagulation, tests are performed on the samples. These include measurements of the dissolution of sacrificial metal (Fe) and indicators of pollution (COD, COD and BOD) and Determination of the concentration in dissolved metal. The measurement of the concentration of dissolved iron is done by taking the weight of iron anode before and after the elctrocoagulation process, the weight difference is the released iron weight during the experiment. COD was measured after decantation and adjustment of the supernatant to the pH of flocculation: The pH is of 6.5-7 for the treated effluent by aluminum electrodes and more than 6 for those treated with iron electrodes [26]. We used type Hanna's device instruments LP 2000 containing an infrared diode of wavelength 890 nm and a detector of reflected light which is a device with direct reading for the measure of the turbidity. The measure is based on the absorption or the distribution of rays of light by particles in suspension. The COD is defined as an expression of the amount of dissolved oxygen required to oxidize by chemical means, without the intervention of living things, all oxidizable substances. It is expressed as mg O_2 per liter of solution. The BOD measurements were carried out according to APHA [27 and 28].

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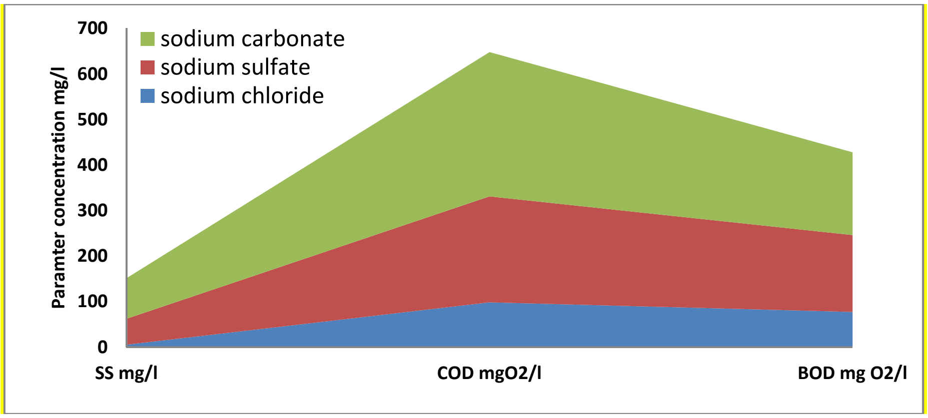
The optimum operating conditions for the elctrocoagulation processes

Several parameters were studied to investigate the optimum conditions for the elctrocoagulation of sewage water. The studied operating conditions were supporting electrolyte concentration which affecting solution conductivity, effect of pH, effect of applied current density, effect of electrolysis time, effect of anode to cathode gap distance.

RESULTS AND DISCUSSIONS

Effect of supporting electrolyte type



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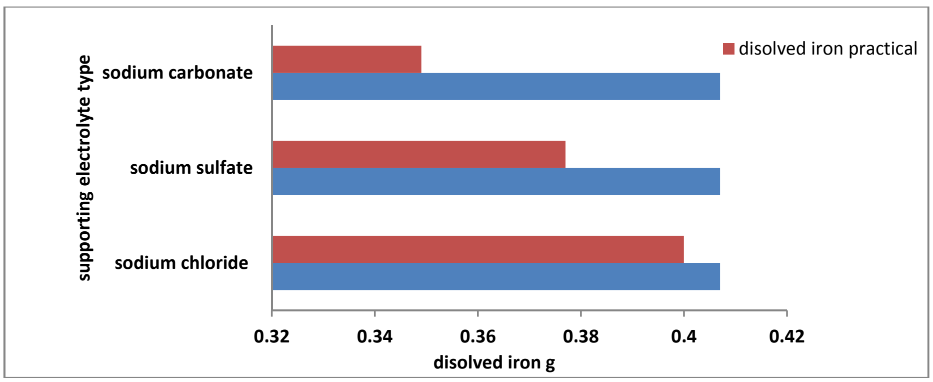


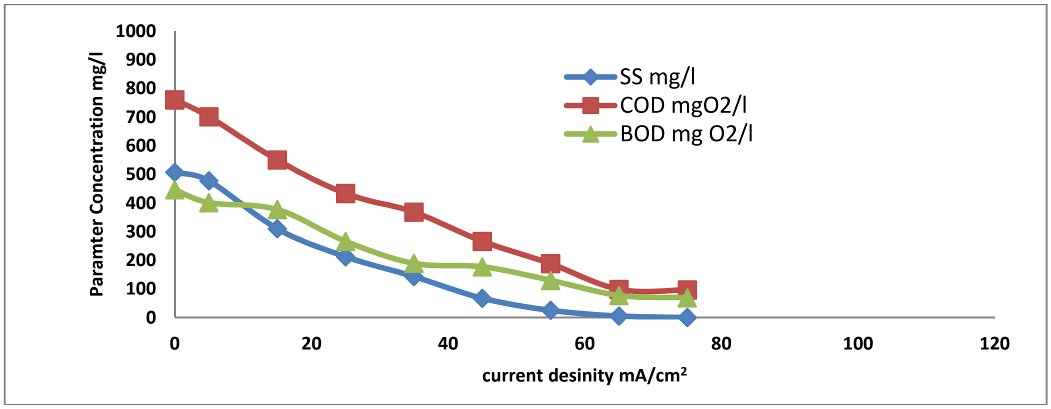
(B)

Figure-2. (A) Effect of supporting electrolyte type on sewage water, and Figure-2 (B) Effect of supporting electrolyte type on the dissolved iron weight during sewage water elctrocoagulation, at elctrocoagulation at current density 65mA/cm^2 pH7.6, electrolysis time 30min, supporting electrolyte 1g/l, electrode gap distance 3cm.

Figures-2(A) and (B) shows the effect of supporting electrolyte type on the treatment of sewage water by elctrocoagulation using iron anode and the dissolved iron weight at the following conditions: current density 65mA/cm2 pH7.6, electrolysis time 30min, supporting electrolyte 1g/l, electrode gap distance 3cm**.** As it is clear from Figure-2(A) that, sodium chloride showing the maximum removal of S.S, COD, and BOD while they decreased from 507mg/l, 760mgO$_2$/l, and 446mgO$_2$/l to 5mg/l, 98mgO$_2$/l, and 77mgO$_2$/l respectively. While in case of sodium sulfate and sodium carbonate they decreased to 57ng/l, 233mgO$_2$/l, and 169mgO$_2$/l for sodium sulfate and 89mg/l, 317mgO$_2$/l, and 182mgO$_2$/l for sodium carbonate. Figure-2 (B) show the released iron weight during the elctrocoagulation of sewage water by using sodium chloride, sodium sulfate and sodium carbonate as supporting electrolytes, in case of sodium chloride released iron reaches to 0.4g while in case of sodium sulfate and sodium carbonate it reaches to 0.337g and 0.349g, respectively. From the above mentioned it was found that sodium chloride will be taken as the optimum supporting electrolyte for the sewage water treatment using elctrocoagulation via iron anode.

Effect of current density

The current density is the most important parameter in all electrochemical processes. The current density determines the amount of Fe^{3+} or Fe^{2+}ions released from the electrodes. Fig.3a shows the effect of current density at 5, 15, 25, 35, 45, 55, 65, and 75mA/cm^2 on SS, COD, and BOD of the treated sewage water by elctrocoagulation using iron anode, while Figure-3 (B) shows the effect of current density on the obtained dissolved iron weight during the elctrocoagulation process. The process was carried out at the operating conditions of, pH7.6, electrolysis time 30min, sodium chloride as supporting electrolyte 1g/l, electrode gap distance 3cm. The results show that the optimum current density should be constant at 65 mA/cm^2 which gives maximum removal of S.S., COD, and BOD where these values decreased from 507mg/l, 760mgO_2/l, and 446mgO_2/l to 5mg/l, 98mgO_2/l, and 77mgO_2/l respectively. Also the amount of released iron increases as the applied current density increases but the S.S., COD, and BOD nearly became constant at more current density above 65mA/cm^2, so 65mA/cm^2 was taken as the optimum applied current density for sewage elctrocoagulation.



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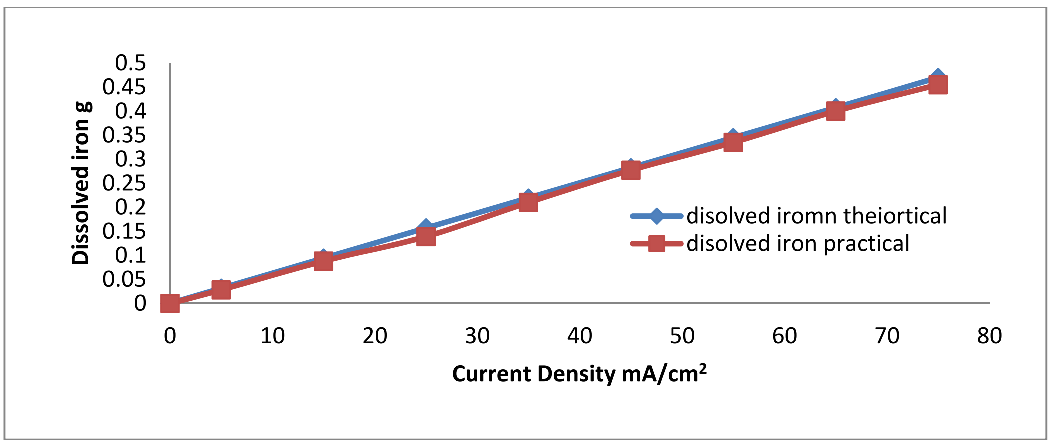

(B)

Figure-3. (A) Effect of current density on sewage water elctrocoagulation at operating conditions: pH7.6, electrolysis time 30min, supporting electrolyte 1g/l, electrode gap distance 3cm and Figure-3(B) effect of current density on the dissolved iron weight during sewage water elctrocoagulation at the same operating conditions.

Effect of sewage water pH

Figure-4(A) describes the effect of sewage pH on the remaining S.S., COD, and BOD at elctrocoagulation operating conditions of: current density65mA/cm^2, electrolysis time 30min, sodium chloride as supporting electrolyte 1g/l, electrode gap distance 3cm, while Figure-4 (B) represents the relation between pH and the amount of the dissolved iron at the same operating conditions mentioned before. The results show that the S.S, COD, and BOD decreased as the pH decreased reaching its minimum values at pH8 then with the increasing of the pH the S.S, COD, and BOD increases. Also the results show that as the pH increases the amount of the released iron decreases. So based on the above pH 7.6 was taken as the optimum value for sewage water treatment using elctrocoagulation by iron anodes.

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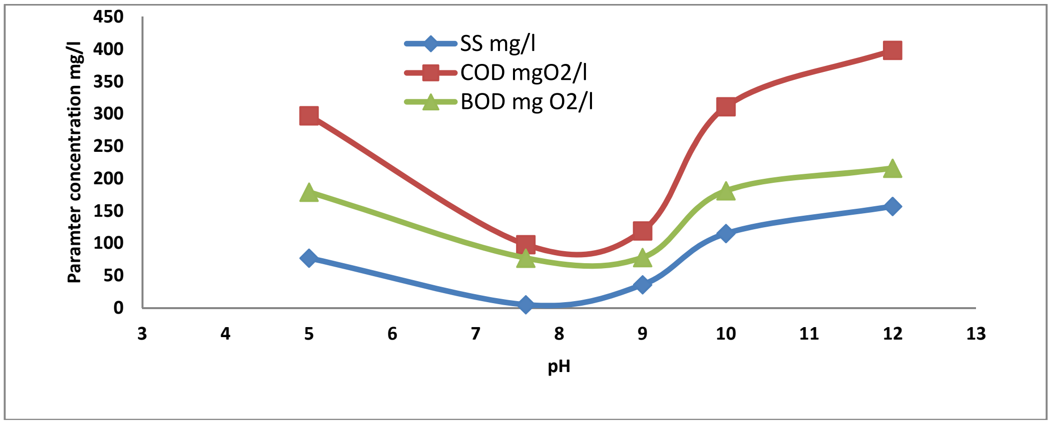

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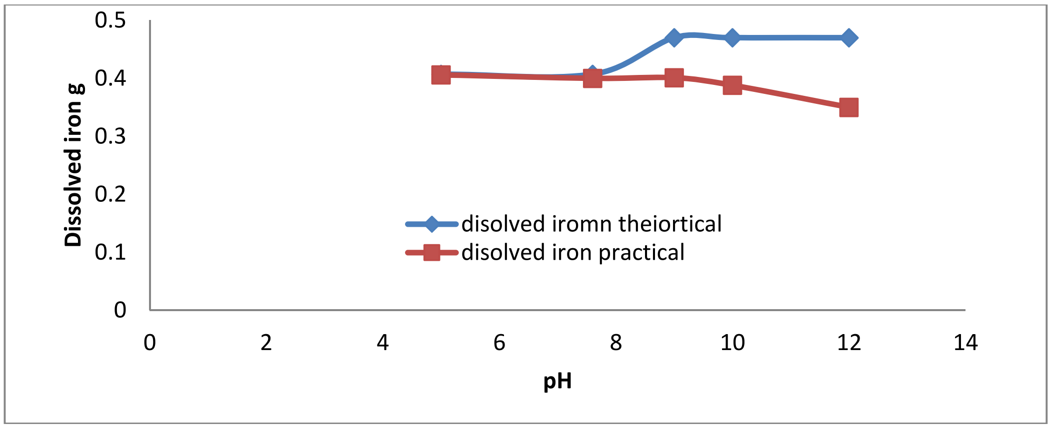

(B)

Figure-4. (A) Effect of pH on elctrocoagulation of sewage water at operating conditions current density65mA/cm^2, electrolysis time 30min, supporting electrolyte 1g/l, electrode gap distance 3cm, and Figure-4 (B) Effect of pH on dissolved iron during sewage water elctrocoagulation at the same operating conditions

Effect of electrolysis time on sewage water elctrocoagulation

Figure-5(A) and Figure-5(B) represent the effect of time of electrolysis on remaining S.S, COD, and BOD and the weight of dissolved iron at the operating conditions of elctrocoagulation process which they are current density65mA/cm^2, sodium chloride as supporting electrolyte 1g/l, pH 7.6, gap distance 3cm. From these results; it is clear that as the electrolysis time increases the remaining S.S, COD, and BOD decreases and then removal efficiency increased. This is attributed to during electrolysis, anodic dissolution leads to the release of coagulating species. The removal efficiency depends directly on the concentration of metal ions released from the anode surface. When the electrolysis time is increased, the concentration of metal ions and their hydroxide flocs increased [21]. At 30 min. maximum removal efficiency is reached, after that it no significant change was obtained.

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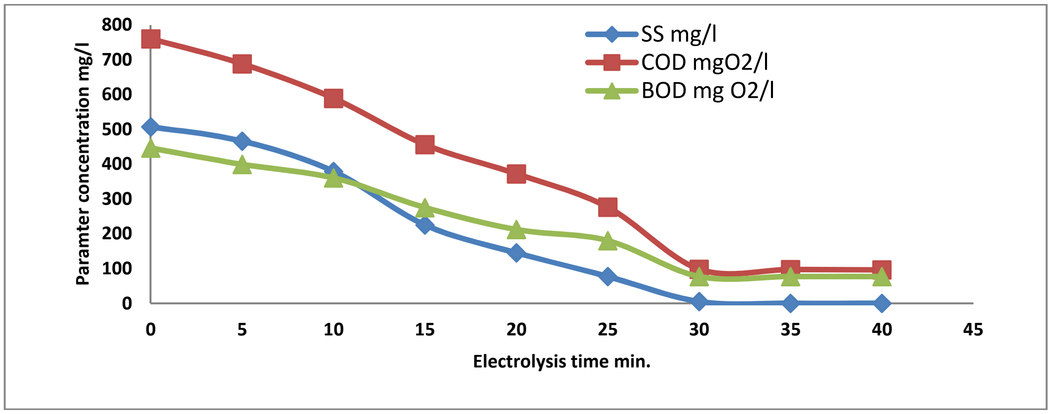

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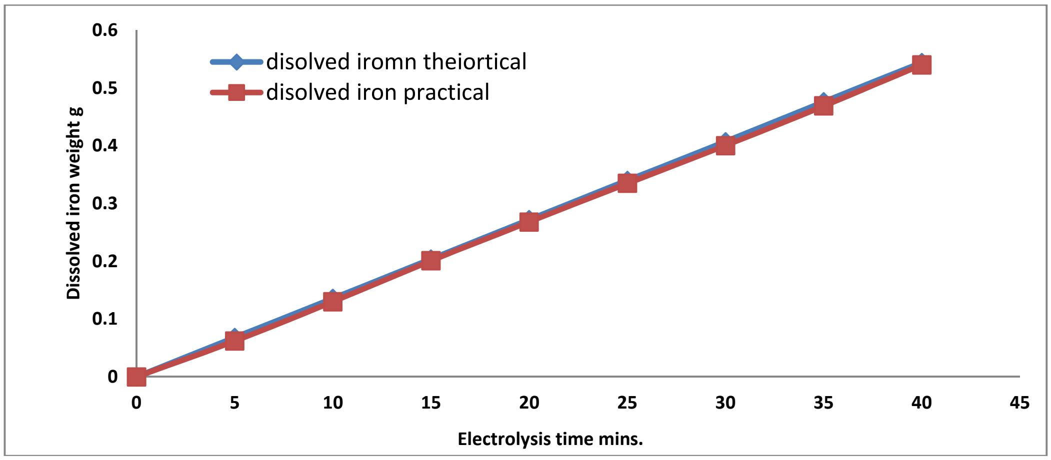

(B)

Figure-5. (A) Effect of electrolysis time on sewage water elctrocoagulation, current density65mA/cm^2, pH 7.6, sodium chloride as supporting electrolyte 1g/l, and gap distance 3cm. and Fig. 5 (B) Effect of electrolysis time on the dissolved iron weight during sewage water elctrocoagulation.

Effect of supporting electrolyte concentration

Figure-6 (A) and Figure-6 (B) show the effect of supporting electrolyte concentration NaCl on remaining S.S, COD, and BOD and weight of dissolved iron during elctrocoagulation of sewage water at 300 min. time of electrolysis, pH7.6, current density at 65 mA/cm^2, and. It can be seen that in the presence of NaCl, the removal efficiency of S.S. COD, and BOD were increased with a subsequent decrease in the applied voltage. This could be attributed The results show that, as the supporting electrolyte concentration increased, the dissolved iron weight increased due to the increment of the electrical conductivity reaching the maximum value at 1g/l NaCl. However, with the increase in NaCl concentration > 2 g/l no significant change in the removal efficiency of the S.S, COD, and BOD were obtained. This behavior may be explained as at constant voltage with increasing of electrolyte concentration, conductivity of sewage water increases and resistance decreases, so the current passed increases and the produced amount of metallic hydroxide also increases [9]. So, increase in pH value may be occurred and iron may precipitate in the oxide form

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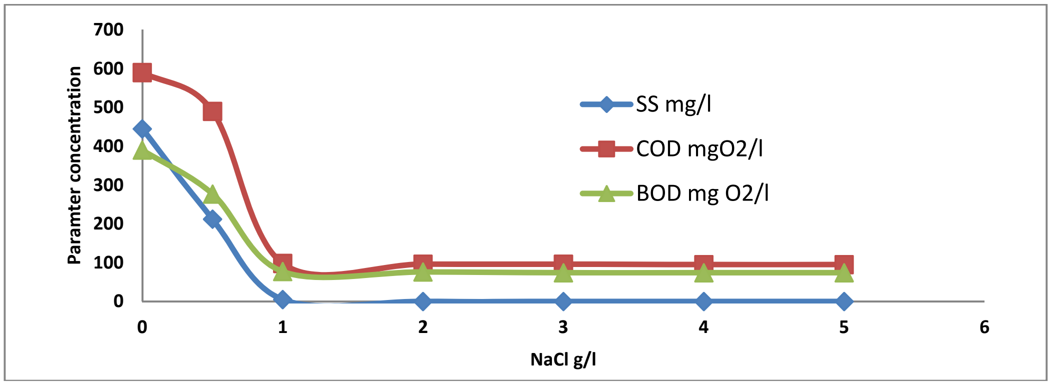

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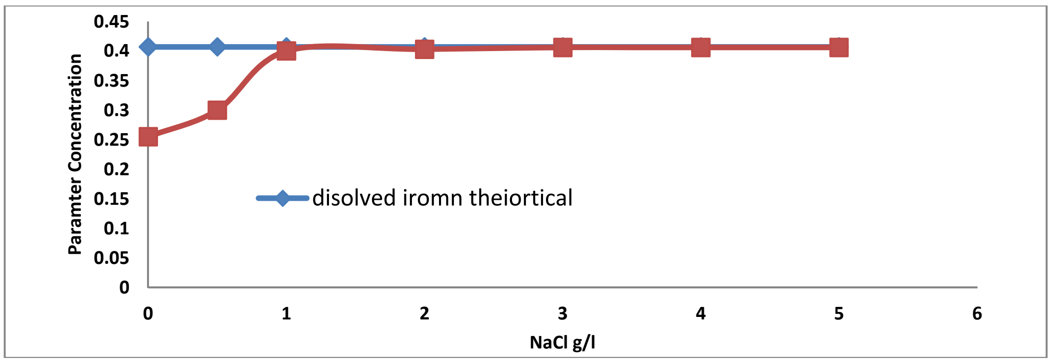

(B)

Figure-6. (A) Effect of sodium chloride concentration on sewage water elctrocoagulation current density 65mA/cm^2, electrolysis time 30min, pH7.6, and gap distance 3m. Figure-6 (B) Effect of sodium chloride concentration on the dissolved iron weight during sewage water elctrocoagulation

Effect of electrode gap distance

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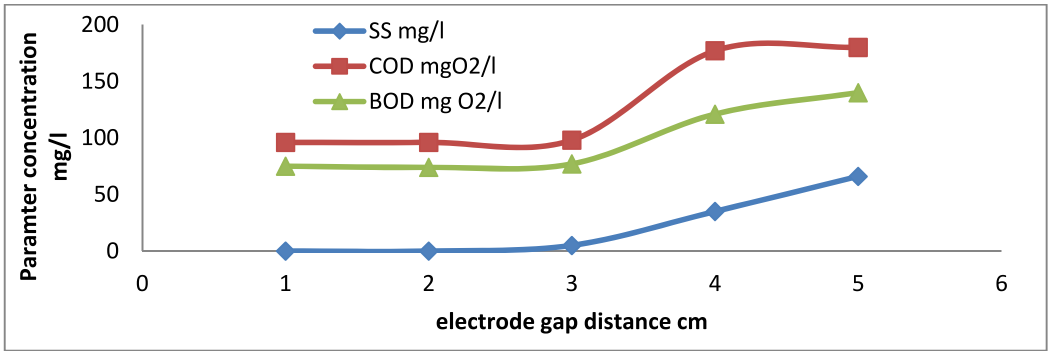

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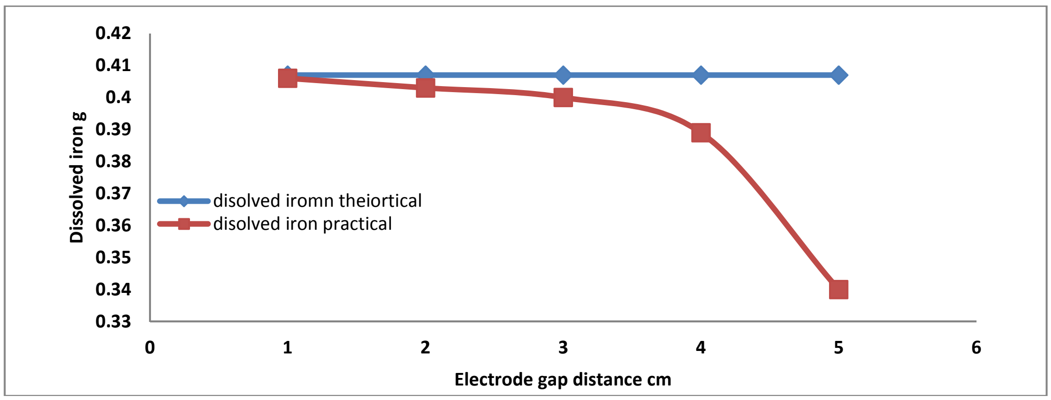

(B)

Figure-7. (A), and Figure-7 (B) Effect of electrode gap distance on sewage water elctrocoagulation, and the dissolved iron weight at: current density65mA/cm^2, pH 7.6, electrolysis time 30min, supporting electrolyte 1g/l.

Figure-7 (A), and Figure-7(B) show the effect of electrode gap distance on both the S.S., COD, BOD, and the released iron weight during the sewage water elctrocoagulation process at the operating conditions: current density65mA/cm^2, pH 7.6, electrolysis time 30min, supporting electrolyte 1g/l. it was found that, as the electrode gap distance increases from 1cm to 3cm, no significant change on the S.S, COD, BOD, and released iron weight were obtained, while at gap distance more than 3cm, the removal efficiency of S.S, COD, and BOD also the released iron weight starts to decreases due to the loss of electrical conductivity which required more consumption of power to get the successful elctrocoagulation process. On the other hand the closest distance may be make industrial problem due to the difficulty of electrode cleaning also the fast blocking of the electrode surfaces due to the huge amount of the iron oxide deposited over electrode surfaces. So based on the above 3cm electrode gap distance was selected as the optimum electrode gap distance for sewage water elctrocoagulation.

Based on the effect of the above operating conditions of sewage water elctrocoagulation it was found that the optimum operating conditions for the maximum removal of suspended solids, chemical oxygen demand, and biological oxygen demand were applied current density of 65mA/cm2, pH 7.6, electrolysis time 30min, sodium chloride of 1g/l as supporting electrolyte, and 3cm as electrode gap distance between the cathode and iron anode.

CONCLUSIONS

Elctrocoagulation has been applied successfully to investigate the optimum treatment operating conditions of Abu Rwash sewage water in Giza, Egypt using iron electrode as anode and graphite cathode. The optimum operating conditions for the effective removal of S.S, COD, and BOD were: pH 7.6, applied current density of 65 mA/cm^2, electrolysis time of 30 min., and sodium chloride as supporting electrolyte concentration of 1g/l and electrode gap distance of 3cm. The S.S, COD, and BOD decreased from 507, 670, and 446 to 5, 98, and 77 mg/l at these optimum conditions. Electrocoagulation could be ideal pre-treatment step for sewage water treatment, recovery and reuse as irrigation water by UF filtration and also for UF/RO system for production of disinfested drinking water.

REFERENCES

[1] Gijzen H. 2002. Anaerobic digestion for sustainable development: a natural approach. Water Science and Technology. 45: 321-28.

[2] Bukhari A. A. 2008. Investigation of the electro-coagulation treatment process for the removal of total suspended solids and turbidity from municipal wastewater. Bioresource Technology. 99: 914-21.

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

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

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

[6] Phalakornkule C., Mangmeemak J. and Intrachod K. 2010. Pretreatment of palm oil mill effluent by elctrocoagulation and coagulation. Scienceasia. 36: 142-49.

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

[8] Kobya M., Hiz H., Senturk E., Aydiner C. and Demirbas E. 2006. Treatment of potato chips manufacturing wastewater by elctrocoagulation. Desalination. 190: 901-211.

[9] Hussein HS1, Sabry R, Hassan N1, Morsi MS and H.H. Shaarawy. 2014. Removal of Reactive Blue Dye 19 from Textile Wastewater by Elctrocoagulation Using Iron Electrodes. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 2014 RJPBCS. 5(3): 2091-2105.

[10] HH Shaarawy. Removal of Kongored from its Solutions using Electrocoagulation via Anodically Generated Aluminum. Afinidad 65 (538).

[11] Pouet M. F. and Grasmick A. 1995. Urban wastewater treatment by elctrocoagulation and flotation. Water Science and Technology. 31: 275-283.

[12] Kabdaşli I., Arslan T., Olmez-Hanci T., Arslan-Alaton I. and Tünay O. 2009. Complexing agent and heavy metal removals from metal plating effluent by elctrocoagulation with stainless steel electrodes. Journal of hazardous materials. 165: 838-45.

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

[14] Hanay Ö. and Hasar H. 2011. Effect of anions on removing Cu^{2+}, Mn^{2+} and Zn^{2+} in elctrocoagulation process using aluminum electrodes. Journal of hazardous materials. 189: 572-6.

[15] Shafaei A., Pajootan E., Nikazar M. and Arami M. 2011. Removal of Co (II) from aqueous solution by elctrocoagulation process using aluminum electrodes. Desalination, (2011), 279, no. 1–3, pp. 121-6.

[16] Shafaei A., Rezayee M., Arami M. and Nikazar M. 2010. Removal of Mn2+ ions from synthetic wastewater by elctrocoagulation process. Desalination. 260: 23-8.

[17] Al Aji B., Yavuz Y. and Koparal A. S. 2012. Electrocoagulation of heavy metals containing model wastewater using monopolar iron electrodes. Separation and Purification Technology. 86: 248-54.

[18] Shafaei A., Rezaie M. and Nikazar M. 2011. Evaluation of Mn2+ and Co2+ removal by elctrocoagulation: A case study. Chemical Engineering and Processing: Process Intensification. 50: 1115-21.

[19] Heidmann I. and Calmano M. 2008. Removal of Zn (II), Cu (II), Ni (II), Ag (I) and Cr (VI) present in aqueous solutions by aluminum elctrocoagulation. Journal of hazardous materials. 152: 934-41.

[20] Meunier N., Drogui P., Mercier G. and Blais J.-F. 2009. Treatment of metal-loaded soil leachates by elctrocoagulation. Separation and Purification Technology. 67: 110-6.

[21] Merzouk B., Gourich B., Sekki A., Madani K. and Chibane M. 2009. Removal turbidity and separation of heavy metals using elctrocoagulation - electroflotation technique a case study. Journal of hazardous materials. 164: 215-22.

[22] Kobya M., Demirbas E., Can O. T. and Bayramoglu M. 2006. Treatment of levafix orange textile dye solution by elctrocoagulation. Journal of hazardous materials. 132: 183-8.

[23] Sarala C. 2012. Domestic Wastewater Treatment by Electrocoagulation with Fe-Fe Electrodes. India: Andhra Pradesh. 4: 530-533.

[24] Saleem M. Bukhari A.A. and Akram M.N. 2011. Electrocoagulation for the Treatment of Wastewater for Reuse in Irrigation and Plantation. Journal of Basic and Applied Sciences. 7(1): 11-20.

[25] Rodrigo M.A.; Cañizares P.; Lobato J.; Sáez C. 2010. Modeling of Electrochemical Process for the Treatment of Wastewater Containing Organic Pollutants. In Electrochemistry for the Environment; Comniellis, C., Chen, G.H., Eds.; Springer: New York, NY, USA. pp. 99-124.

[26] Zongo I, Maiga A.H., Wéthé J, Valentin G, Leclerc J.-P., Paternotte G, Lapicque F. 2009. Journal of Hazardous Materials. 169: 70-76.

[27] APHA (American Public Health Association). 1985. Standard Methods for the Examination of water and wastewater, 16h ed. APHA, New York, N.Y., USA.

[28] APHA (American Public Health Association). 1992. Standard methods for the Examination of Water and Wastewater, 18th, ed. Washington D.C., U.S.A.