Treatment of Municipal Wastewater by using Electro-coagulation at Gharbyia Govenorate, Egypt

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Abstract—The treatment of wastewater has become necessity. An innovative effective and cheap method of purifying and cleaning wastewater before discharging into any other water systems is needed. A wide range of wastewater treatment techniques are known which include biological processes and physicochemical processes. A techniques based on electrochemical technology are being developed and improved to reduce less chemical additions. The present study was conducted to investigate the applicability of the electro-coagulation technique for the treatment of municipal wastewater at Gharbyia governorate. Electro-coagulation is the process of passing an electrical current through a liquid, using anode and cathode. In present study iron and aluminum electrodes are used and the sample is made up to run at different retention time i.e., 10, 20,30,40 , 50 and 60 minutes and different applied electricity current is passed in the liquid (0.15, 0.30 , 0.40A). The study found that, the domestic wastewater showed that only current(C) and retention time (t) have correlation with each other. It observed that the batch which is operated at 0.30 A for 60 minutes has maximum removals efficiency of COD, BOD, TSS, and oil & grease.

Keywords --- wastewater treatment; electro-coagulation; iron and aluminum electrodes, chemical oxygen demand.

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1. INTRODUCTION

Electro-coagulation is an alternative technology for wastewater treatment in addition to its other conventional applications. The advantages of electro coagulation over other conventional techniques, as chemical coagulation and adsorption have no generation of secondary pollution, and compact equipment. The earlier studies have reported the potential of electro coagulation to treat both of industrial and domestic wastewater [1, 2, 3].

Electrochemical treatment seems to be a promising treatment method due to its high effectiveness, its lower maintenance cost, less need for labour and rapid achievement of results [4,5]. Electrocoagulation-flotationtreatment is investigated, as it has greater ability for the removal of COD and TSS from effluents in comparison with treatment by conventional coagulation [6, 7].

At the end of the studies identifying the most appropriate treatment alternatives, electro coagulation (EC) is shown to be one of the best methods for the wastewater. Reusing of wastewater has become an absolute necessity, so there is an urgent need to develop inventive, more effective and low-cost techniques for treatment of wastewater [7, 8].

Removal mechanisms of the EC process include coagulation, adsorption, precipitation, and flotation[10]. Similarly, the effect of DC electric fields on COD in aerobic mixed sludge processes has been investigated, and optimum operational conditions were determined [11]. In another study, removal of nitrogen compounds has been successfully realized using a rotating electro-biological contactor; an interesting study, in which over 83% efficiency of the de-nitrification was observed at a nitrification efficiency of 68.9% [12, 13].

In the environmental field, electro coagulation is one of the main applications of electrochemical reactor technology for the treatment of water and wastewater. EC is a complicated process that involves many chemical and physical phenomena using consumable electrodes (Fe/Al) to supply ions into the water stream. During the late nineteenth century, EC was applied in several large-scale water treatment plants in London [13, 14], while electrolytic sludge treatment plants were operated as early as 1911 in various parts of the United States [15, 16].

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Fe or Al is dissolved from the anode generating the respective metal ions, which immediately hydrolyse to polymeric iron or aluminium, and finally, generate the respective hydroxide. These polymeric hydroxides are excellent coagulating agents. The consumable (sacrificial) metal anodes are used to continuously produce polymeric hydroxides in the vicinity of the anode [17, 18].

Coagulation occurs when these metal cations combine with the negative colloidal particles carried toward the anode by electrophoretic motion. Contaminants present in the wastewater stream are treated either by chemical reactions and precipitation or by physical and chemical attachment to colloidal materials being generated by the electrode erosion. They are then removed by flotation, sedimentation and filtration. In conventional coagulation process, coagulant chemicals are added. By contrast, these coagulant agents are generated in situ in the EC process. The destabilization mechanism of the contaminants, particulate suspension, and breaking of emulsions taking place in an EC reactor may be summarized as follows [19, 20]:
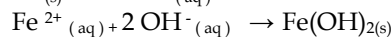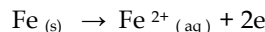
- Compression of the diffuse double layer around the charged species by the interactions of ions generated by oxidation of the sacrificial anode;
- Charge neutralization of the ionic species present in wastewater by counter ions produced by the electrochemical dissolution of the sacrificial anode. These counter ions reduce the electrostatic inter-particle repulsion to the extent that the van der Waals attraction predominates, thus causing coagulation. A zero net charge results in the process;
- Floc formation: the floc formed as a result of coagulation creates a sludge blanket that entraps and bridges colloidal particles that are still remaining in the aqueous medium.

Water is also electrolyzed in a parallel reaction, producing small bubbles of oxygen at the anode and hydrogen at the cathode. These bubbles attach to the flocculated particles and make them float to the surface through natural buoyancy. In addition, the following physicochemical reactions may also take place in the EC cell [20, 21]:
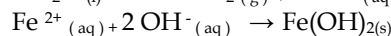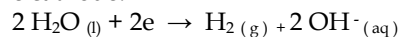
- Electrophoretic migration of the ions in solution.
- Cathodic reduction of impurities present in wastewater.
- Reduction of metal ions at the cathode; and Other complex electrochemical reactions.

Although the above reactions suggest the evolution of oxygen at the anode, Donini et al.,(1994) [13] presented experimental evidence that oxygen is not generated at the cathode, as claimed by reaction 2.Upon oxidation in an electrolytic system, iron produces ferrous hydroxide Fe(OH)2or ferric hydroxide Fe (OH)3, depending on the pH of the electrolyte. A mechanism has been proposed by Canizares et al., (2007) [8] for the production of iron hydroxide in the absence of oxygen
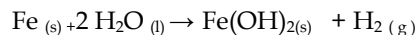
At the anode:

$$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e$$
$$Fe^{2+}_{(aq)} + 2\,OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}$$

At the cathode:

$$2\,H_2O_{(l)} + 2e \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$$
$$Fe^{2+}_{(aq)} + 2\,OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}$$

Overall reaction

$$Fe_{(s)} + 2\,H_2O_{(l)} \rightarrow Fe(OH)_{2(s)} + H_{2(g)}$$

The iron hydroxide formed remains in the aqueous stream as a gelatinous suspension, which can remove the pollutants from wastewater either by complexation or by electrostatic attraction, followed by coagulation.

The$H_{2(g)}$ produced as a result of the redox reaction may remove dissolved organics or any suspended materials by flotation. However, the Fe3+ions may undergo hydration and depending on the pH of the solution.
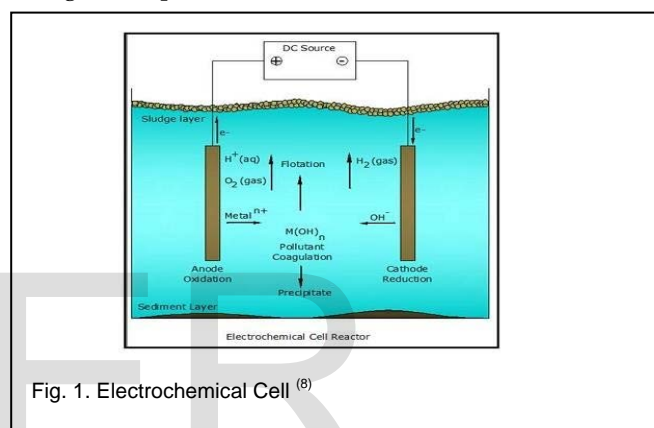

Fig. 1. Electrochemical Cell [8]

2 MATERIAL AND METHODES

2.1 sampling

The samples are taken from the influent of Tanta Waste Water Treatment Plant (WWTP) and kaferEl-Zayaat waste WWTP in Gharbyia governorate.

2.2 Experimental setup

A smaller, laboratory-scale EC system was designed, built, and used. Electrode plates made of Al, Fe, and stainless steel SS were manufactured and used in this EC system. The dimensions of the plates were 10 mm x 50 mm x 50 mm. After each experiment,the electrodes and the glass EC cylinder were rinsed with hot tap water and submerged in 1.5 M nitric acid solution for a short time. The electrodes were then mechanically cleaned and rinsed thoroughly with de-ionized water. After this, a precise scale was used to weigh the oven-dried anode plates. A magnetic stirrer was used to mix the water in the glass cylinder. Effective electrode surface area was 50.0 cm2 and the distance between electrodes was fixed at 7 cm. In each run, approximately 500 ml of total volume of sample placed in the reactor. The electrodes were connected directly to DC power supply (0-60V, 0-6.0A). The magnetic stirrer was also used in this experiment to ensure a good mixing where the mixing rate was set constant at 100 rpm.

2.3 Experimental method

Performance of the EC process was evaluated. The raw wastewater influent (850 mg COD/L) with high organic load, the electrical current densities were (0.13 A– 10 V, 0.24 A–20 V and 0.38 A–30 V).

Experimental steps were applied as sampling, and analysis. For the analysis methods, Merck and BDH analytical quality chemicals were used in the preparation of reagents, All the sampling and analysis procedures were adopted from Standard Methods for the Examination of Water and Wastewater 22ed(2012)[27].Each experimental application was carried out with 500 ml of sample at room temperature. In the beginning, the experiments commenced for the unadjusted raw sample (pH = 7.0). After electrolysis, settling ensued for 1 h, then the samples taken from the liquid phase and analyzed for COD (as total),TSS, BOD and Oil and Grease. Meanwhile, the present sludge percentage was recorded. Consequently, the performance of the EC process on DWW samples was analyzed based on current intensity and electrolysis time.

3. Results and Discussion

The effluent treated with iron electrode as anode, appeared greenish first and then turned yellow and turbid. This green and yellow colour resulted from $Fe^{2+}$and Fe^{3+}ions generated during the EC process. $Fe^{2+}$is the common ion generated in situ of electrolysis of iron electrode. It has relatively high solubility at acidic or neutral conditions and can be oxidized easily into $Fe^{3+}$by dissolved oxygen in water. Electrical conductivity decreased with increase in the time. A slight increase in the pH was observed with time during the process which was within the regulatory drinking water standards.Chlorides and alkalinity also decreased with reaction time for different current amperes the influent wastewater quality summarized in Table (1).

TABLE 1
TANTA AND KAFER EL-ZAYAAT WASTE WWTP INFLUENTS
WASTEWATER QUALITY

Parameter	Units	Tanta		Kafer Elzyate	
		Inf.	TW	Inf.	**TW**
pH	----	7.8	8.9	7.6	8.9
COD	mg/l	850	26	800	30
BOD	mg/l	600	7	550	11
TSS	mg/l	500	4	480	6
O & G	mg/l	6	0.05	5	0.04
Chloride	mg/l	80	52	77	42
Cond.	µs/cm	860	570	1450	1234
TDS	mg/l	473	313	769	679

3.1 Tanta WWTP

3.1.1 Chemical oxygen demand (COD).

Figure (2); shows the relations between the removal % of COD and the current at various retention times. The study showed that, the COD levels decreased with increasing the applied electric current and retention time. The removal percentages of COD observed at retention time (15 minutes) with applied electric current of 0.13, 0.24 and 0.36 A), and the removal % were 35 %, 38 % and 48 %, respectively. A higher removal percentages observed after 60 minutes retention time with applied electric current 0.13, 0.24 and 0.36 A, the removal percentages were 62 %, 75 % and 95 %, respectively, as indicated in Figure (2).

Bensadok *et al.,* (2008) [4] investigated the removal of pollutants from a petroleum refinery's sulphides spent caustic wastewater, which is highly alkaline and black in colour by EC. Fe anodes were found clearly more efficient than Al anodes in this application. Interestingly, when a second successive EC unit was used to treat the solution optimally treated (t = 30 min, i = 212 A/m²) by the first unit, removal percentages rose from about 85% to more than 98% for both sulphide and organics (COD). The initial values of sulphide and COD had been extremely high, 34517 mg/L and 72450 mg/L, respectively. Heavy metals could be removed nearly completely by the first EC unit. EC was concluded to be highly efficient and relatively fast compared with conventional existing techniques for treating such waste.
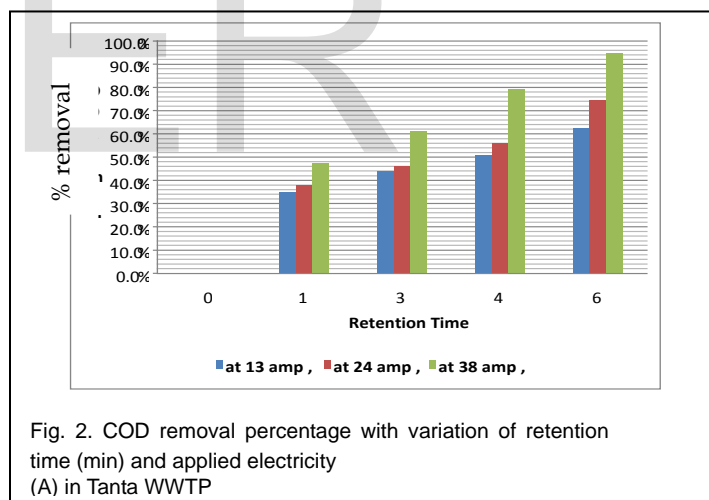

Fig. 2. COD removal percentage with variation of retention time (min) and applied electricity
(A) in Tanta WWTP

3.1.2 Biochemical oxygen demand (BOD).

Figure (3); shows the removal percentages of BOD of Tanta WWTP using electro-coagulation techniques, the BOD values were decreasing with increasing both applied electric current and retention time. The study found that, the BOD at a contact time of 15 minutes and applied electric current0.13, 0.24 and 0.36 A, the removal percentages were 36 %, 44 % and 47 %, respectively. at 60 minutes contact time and applied current 0.13, 0.24 and 0.36 A, the removal percentages were 59 %, 73 % and 96 %, respectively as indicated in Figure (3).

In this work, Fe-based EC was found to cause a larger increase in pH than Al-EC with similar solutions. Similar results have been reported by, Canizares et al. (2008). One explanation for this could be that aluminium complexes more hydroxide ions than iron, thus resulting in a lower final pH value. Similar

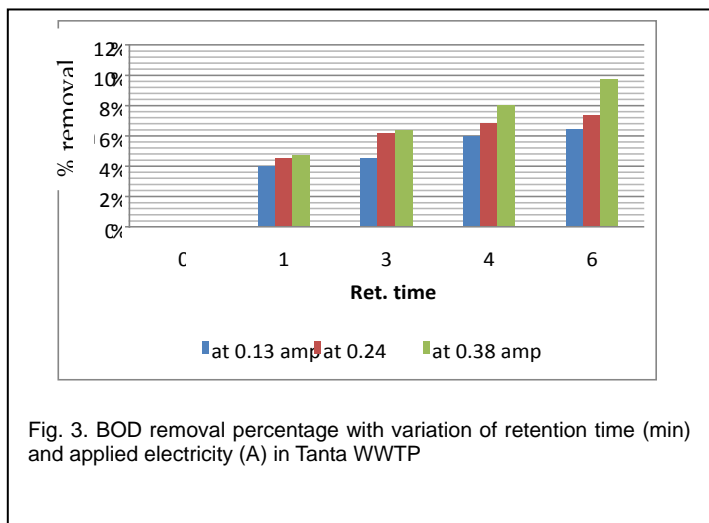observation were found, the removal percentages of BOD were reached to 96% [8, 9].

Fig. 3. BOD removal percentage with variation of retention time (min) and applied electricity (A) in Tanta WWTP

3.1.3 Total suspended solids (TSS).

TSS levels were decreased with the increased both of the applied electric current and retention time as shown in Figure (4).At retention time 15 minutes, the TSS levels were decreased at applied electric current0.13 , 0.24 and 0.36 A, the removal percentages were 41 % , 56 % and 62 %, respectively. A 60 minutes retention time and applied electric current0.13 , 0.24 and 0.36 A, the removal percentages, the removal percentages were 74 % , 83 % and 99 %, respectively, as shown in Figure (4).

Jiang et al.,(2002) [20] studies obtained high removal of colour and TSS with aluminium electrodes, while iron was more effective than aluminium in reducing TSS, BOD and COD from industrial wastewater. A combination of iron and aluminium gave good efficiencies for the removal of the colour, 71%, and COD, 69%.Similar results were obtained for the treatment of paper mill wastewaters using various aluminium and iron electrode combinations [20].
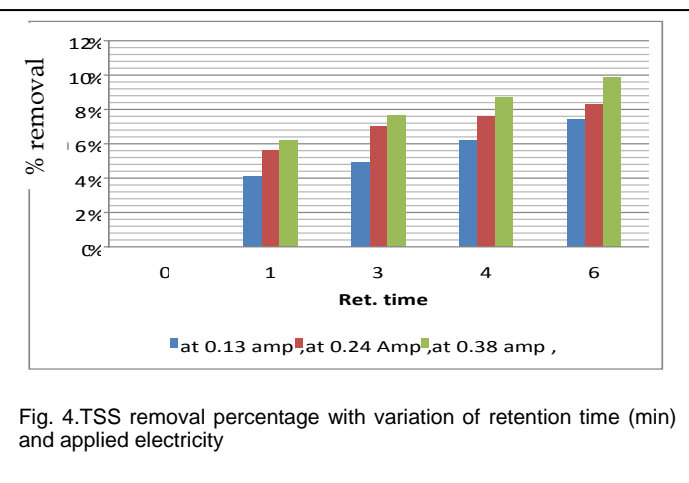

Fig. 4.TSS removal percentage with variation of retention time (min) and applied electricity

The data presented in Figure (5), shows the removals percentages of oil& grease and the applied electric current at various contact times. Oil& grease values were decreased with in-

creased values of both electric current and retention time. Oil & grease values at a contact time of 15 minutes and applied electric current 0.13 , 0.24 and 0.36 A were decreased and the removal percentages were 62 % , 76 % and 78 %, respectively, as shown in Figure (5). After 45 minutes retention time and applied electric current 0.13 , 0.24 and 0.36 A, the removal percentages were 84 % , 99 % and 99 %, respectively.

Several studies have been reported in the literature on the treatment of oily wastewaters. These studies indicate that electro-coagulation is a feasible technique to destabilize oil-in-water emulsions. Although several anode materials were proven effective, aluminium electrodes showed the best removal performance. For example, Virkutyte et al (2010) [26] used iron or aluminium electrodes to treat solutions containing oil concentrations of 50, 200 and 500 mg L-1. The removal efficiency was as high as 100% for all experiments when aluminium electrodes were used, probably because of high adsorption capacity of hydrous aluminium oxides. MOLLAH et al.(2004),[24] presented an extensive study on the treatment of wastewater from restaurants in Hong Kong, containing high levels of oil and grease. Aluminium electrodes were used and the effect of several parameters was investigated. The loading charge and the electro-coagulation time were identified as the most important factors for an efficient treatment.
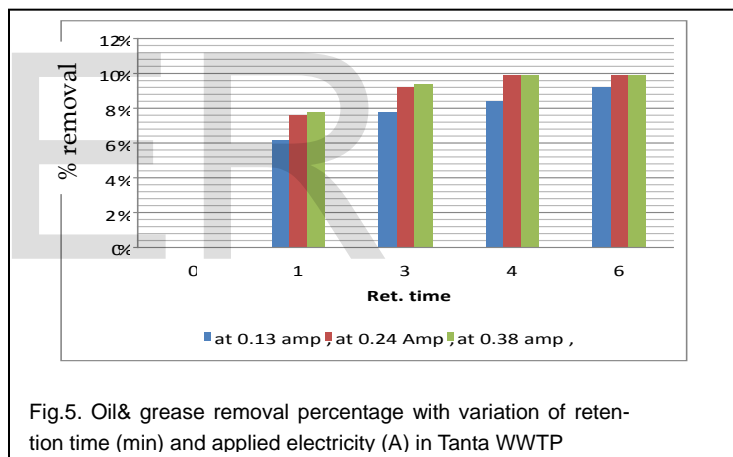

Fig.5. Oil& grease removal percentage with variation of retention time (min) and applied electricity (A) in Tanta WWTP

3.2 Kafer Elzyate WWTP
3.2.1 Chemical oxygen demand (COD).

The data presented in Figure (6),shows the removal percentages of COD of Kafr El Zayaat WWTP and different applied electric current and various retention times. The study found that the values of COD decreased with the increasing the applied electric current and retention time. At a retention time of 15 minutes and at applied electric current0.13 , 0.24 and 0.36 A, the removal percentages were 37 % , 40 % and 49 %, respectively, as shown in Figure (6). After 60 minutes retention time and applied electric current0.13 , 0.24 and 0.36 A, the removal percentages were 65 % , 77 % and 96 %, respectively.

Domestic wastewater may be categorized into two parts, namely black water toilet flushing) and greywater, which is less polluted but is generated at a greatly higher rate. Thus, recycling and reuse of treated grey water for, e.g., gardening or toilet flushing may be of great significance in the future. About 70% of the COD (initial value 320–733 mg/L) and 99.9% of the pathogens could be removed by Al EC from

greywater derived from an Indian middle-class household, with OC and EEC values of about 0.15 €/m3 and 0.3 kWh/m3, respectively [22, 23, 24].

Both electrode combinations were found to perform well and the results were similar. However, using Al as the anode material was chosen as optimal, mainly due to the possible coloration of water by Fe. Similarly to the results were found, the initial pH value enhanced pollutant removal. However, the differences were clearly more significant here. It should be noted that this kind of behaviour is usual in common chemical aluminium coagulation practice, where initial solution pH is typically adjusted to 5–6. Furthermore, these results are in good accordance with those presented in the works of, MOLLAH *al.* (2001) [25].

In the end, 90% COD Mn and 80% DOC removal efficiencies were achieved. Optimum process conditions for the SWW treatment were found to be: anode/cathode = Al/Fe, initial pH = 4, i= 100 A/m2, and t = 10 min[25].
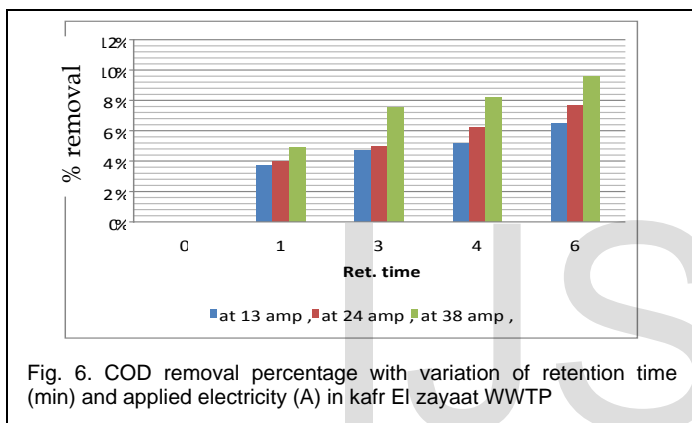

Fig. 6. COD removal percentage with variation of retention time (min) and applied electricity (A) in kafr El zayaat WWTP

3.2.2 Biochemical oxygen demand (BOD).

The data presented in Figure (7)shows the removal percentages of BOD with variation of applied electric current and retention times. The BOD values were decreased with increasing of retention time (15 minutes) at applied electric current 0.13 , 0.24 and 0.36 A, the removal percentages were 40 % , 45 % and 47 %, respectively as shown in Figure (7). After 60minutesretention time and at applied electric current 0.13 , 0.24 and 0.36 A, the removal percentages were 64 % , 74 % and 97 %, respectively.
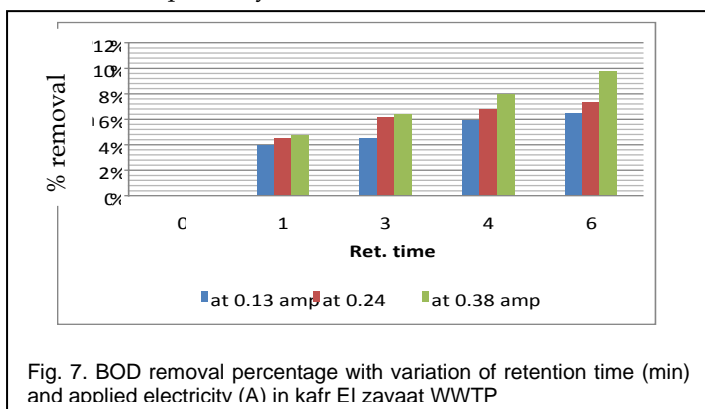

Fig. 7. BOD removal percentage with variation of retention time (min) and applied electricity (A) in kafr El zayaat WWTP

The data presented in Figure (8) shows the values of TSS decreased with increasing both of applied electric current and

retention times. The values of TSS decreased at contact time of 15minutes and applied electric current 0.13 , 0.24 and 0.36 A and the removal percentages of TSS were 42 % , 54 % and 66 %, respectively. After 60 minutes retention time and applied electric current 0.13 , 0.24 and 0.36 A, the removal percentages were 77 % , 80 % and 99 %, respectively.
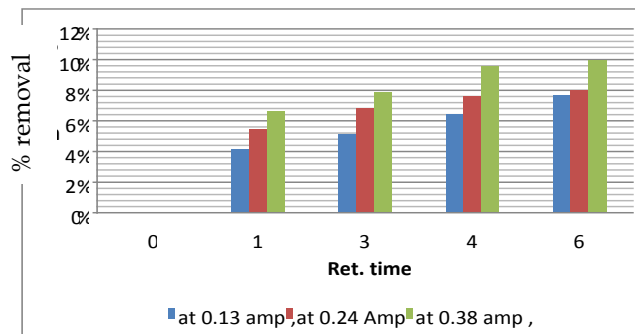

Fig. 8. TSS removal percentage with variation of retention time (min) and applied electricity (A) in kafr El zayaat WWTP

3.2.4 Oil and Grease (O&G).

The data presented in Figure (9) shows the removal percentages of oil & grease with variation of applied electric current and retention times. At retention time (15 min), the values of oil & grease decreased with increased applied electric current 0.13 , 0.24 and 0.36 A, the removal percentages were 64 % , 78 % and 80 %, respectively. After 45 minutes and applied electric current0.13 , 0.24 and 0.36 A, the removal percentages were 90 %, 99 % and 100 %, respectively.
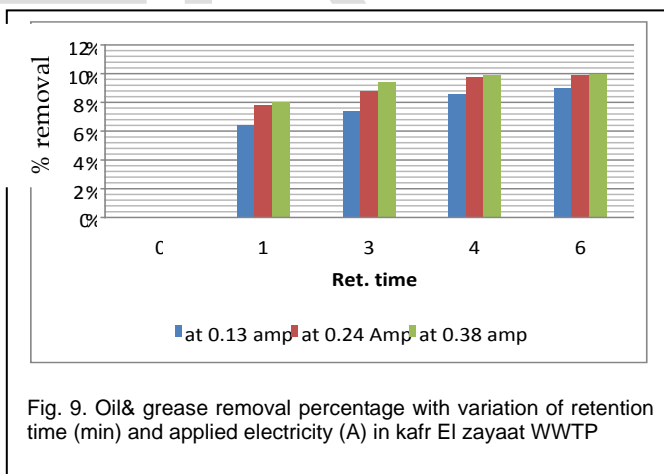

Fig. 9. Oil& grease removal percentage with variation of retention time (min) and applied electricity (A) in kafr El zayaat WWTP

4 CONCLUSION

From the present study, it was concluded that the treatment process had shown feasible activity in removing the impurities present in the wastewater. In this process with-

out using any chemicals, it does not leave any additional chemicals in the sample. In this process, suspended solids formed after electro coagulation process removed by filtration and chemical oxygen demand COD decreased to 95 % with increase of contact time for different currents, maximum reduction of COD is observed at 60 minutes for 0.38A. The maximum reduction of TSS was 99 % at 60 minutes for 0.38A. The maximum reduction of oil and grease is 99 % at 45 minutes for 0.24A.The maximum reduction of BOD was98 % at 60 minutes for 0.38A

A successful application of electro-coagulation (EC) technique for the removal of suspended solids from wastewater would address the environmental needs of reduction in the operational costs and potential saving in processing unit. Electro coagulation method offers a special attraction due to its ecologically friendly, safety, simplicity and lower operating costs.

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