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Electro- Flotation Treatment Technique (EFTT) of Some Industrial wastewater

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Abstract

Flotation is an important process in water technology for liquid- solid separation in industrial wastewater treatment. Electro- Flotation Treatment Technique (EFTT) can be used for many industrial wastewater. The objective of this work is to study the efficiency of electro- flotation (EF) technique compared with other ordinary classical methods. The water quality parameters resulted from using this treatment technique were confide with local environmental legislation. Pollutants removal efficiency was reached 57-85%. Parameters used in this study include: Hydrogen Ion Concentration (pH), Total Dissolved Solid (TDS), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), oil and grease, total phosphorus, salinity, conductivity and bacteria total count.

Keywords: Electro- Flotation Treatment Technique (EFTT), industrial wastewater treatment, pH, TDS, COD, BOD, DO.

Introduction

Suspended solids with a density close to or less than that of water can't be removed by sedimentation such solids would sediment only very slowly or would remain suspended. Air flotation (Fig.1), in all its variations, is an efficient way to separate light particulates and oils from wastewater. Particulates that adhere to an air bubble, either by adsorption or absorption, can be floated from the liquid phase. Adsorptive bubble separation processes make use of the selective adsorption of impurities at the gas/liquid or gas/solid interfaces of rising bubbles. The adsorbed impurities, which can be in soluble or insoluble form, are carried out to the top of the bubble separation reactor, where they can be removed from the aqueous system. Air flotation units are capable of removing most of the emulsified oil in addition to the free oil. (Wang et al, 2010)

Air flotation is used in the beneficiation of ores. Its first application in the wastewater-treatment field was in the flotation of suspended solids (SS), fibers, and other low-density solids. **(George and Kostas,2014).**

Flotation also is used for the thickening of activated sludge (4 and flocculated chemical sludge**.** More recently, air flotation has been applied to the removal of oils and greases from wastewater because it is a practical, reliable, and efficient treatment process (Alkhatib and Thiem 1991)

The process of flotation consists of four basic steps (Fig.2). Firstly, Bubble generation in the wastewater. Secondly, Contact between the gas bubble and the particle or oil droplets suspended in the water. Thirdly, Attachment of the particle or oil droplet to the gas bubble and then rise of the air/solids combination to the surface where the floated material are skimmed off Flotation utilizes the differential density between the bubbles to which the small solid particles and oil droplets become attached, and the water, to effect separation. Since the agglomerates have a lower density than the medium in which they are immersed, they rise to the surface where they are removed. There are essentially five different types of flotation systems, their classifications based on the method of bubble formation in the dissolved air, Induced (dispersed) air, Froth, Vacuum and Electrolytic. (Shammas et al, 2010)

In recent years, electroflotation seems to be a fast growing method in wastewater treatment as it offers immediate saving in operating and capital costs over air flotation in many situations. In comparison to other flotation system electroflotation has many advantages. Firstly, it is characterized by a fast rate of removal pollutant particles. Secondly, it is able to achieve simultaneous flotation and coagulation, with less sludge produced. Thirdly, the electroflotation equipment is very compact and thus suitable for installation where the available space is rather limited. Furthermore, the convenience of dosing control only by adjusting the current makes automation quite easy operation and offers simplicity and low capital and operating costs (Hosny et al, 1992 Calvin et al, 1997). Lastly, Ben Mansur and Chalbi (2006) examined the effect of operating parameters such as current density, oil concentration, flotation time and coagulant concentration on the performance of the electroflotation cell. Oil removal reached 75% under optimum conditions:

Key design variables in the system controlling efficiency of removal are, Gas input rate and volume of gas entrained per unit volume of liquid , Bubble-size distribution and degree of dispersion ,Surface properties of the suspended matter ,Hydraulic design of the flotation chamber, Concentration and type of dissolved materials, Concentration and type of suspended matter and oils, Chemicals added, Temperature, Residence time ,Recycle ratio and pH (Krofta M, Wang LK (2000), Sansalone V. J and Srinivasan. V (2001), Wang L. K, Fahey EM, Wu Z (2005))

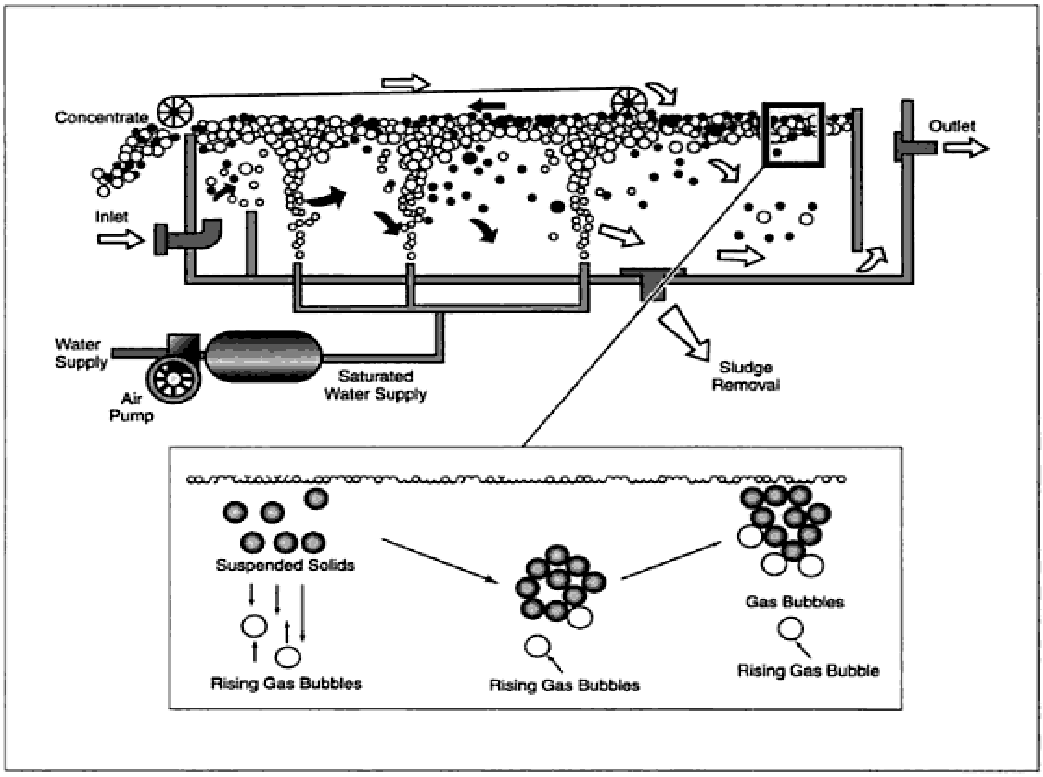

Fig 1: An Air Flotation System in which air bubbles are attached to tiny particles and move with them to the surface (1998)

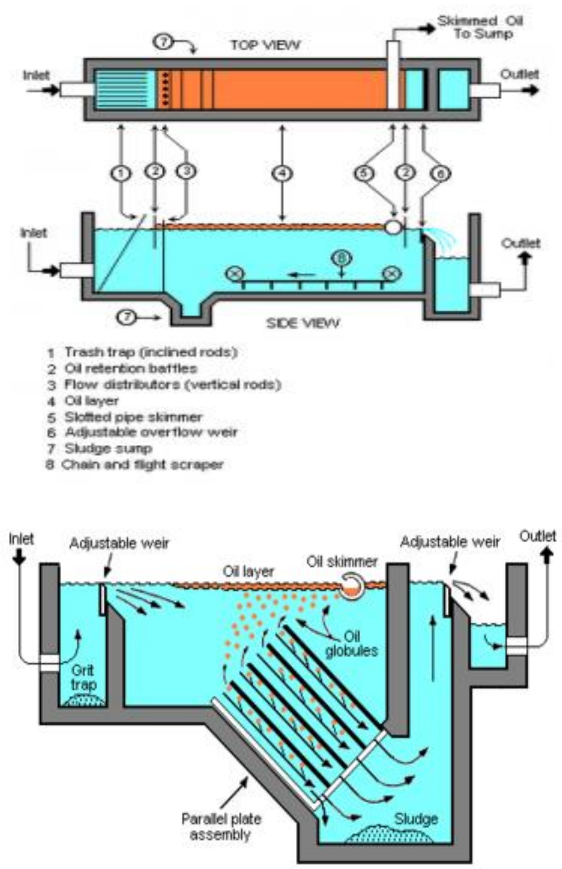

Fig. 2: Electro- Flotation Treatment unit (2004)

Materials and methods:

Collection of samples:

Water samples were collected for a yearlong period, seasonally (Starting from winter 2014, spring 2014, summer 2014 and to autumn 2014) from three plants in Damietta port. The three plants were selected on the basis of their positions and treatment technique that these plants treated all wastewater in the port, as plant 1 use EF technique , plant 2 use DAF technique and plant 3 use both technique . Water samples were collected in high density polyethylene (HDPE) bottles that were routinely acid-treated with a solution (0.5 N HCl) and well rinsed with de-ionized water prior to use, dried, and stored with the caps on to prevent contamination. The bottles were rinsed with sample water prior to actual sample collection.

Physical and chemical analysis of water samples

In the present study, the collected water samples were analyzed for both physical and chemical **(Table.1)** which include: pH, Turbidity, Dissolved Oxygen (DO) Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Phosphorus (TP), Total Dissolved Solids (TDS), Nitrite, Nitrate, sulfate, Electrical conductivity (E.C), Total suspended solids (TSS), Oil and grease, and salinity have been determined according to Standard Method **(APHA, 1992)**. Samples of wastewater were collected examined within 2 – 6 hours of collection.

Temperature and pH were determined in the field. Preservation methods were limited to pH control, chemical addition, refrigeration, and freezing (EPA, 1983). pH value of the samples was measured directly by pH Meter (model, 211 HANNA,.USA) according to electrometric method. (APHA, 1992) .While Turbidity of samples was measured Nby Nephelometric Method using (Al 1000 Turbidimeter, aqualytic, Germany with measuring 0-200 NTU) according to (APHA, 1992).

Where Total dissolved solids (TDS), Salinity and Electrical conductivity (EC) was measured by TDS meter (Digital Portable TDS/ Conductivity meter Model. 8033 HANNA, USA) as TDS expressed as ppm (mg/l) and E.C expressed as dS/m. But Total suspended solids (TSS) were determined according to (APHA, 1992).

Dissolved oxygen (DO) in water sample was detected according to Winkler with Azide Modification Method (APHA 1992) but Biological Oxygen Demand (BOD) of the samples was determined according to (Adams1990) where Chemical Oxygen Demand (COD) of the samples was determined by Manual Method: Dichromate Reflux according to (EPA, 1983).

On the other hand Sulfate, Nitrate and Nitrite ions were determined according to (Rump Method 1999) but Total Phosphorus (TP) of the samples was detected according to Ascorbic Acid Method (APAH 1992). However Oil and grease was measured by Liquid-liquid extraction with hexane, treatment with silica gel (for Mineral Oil and Grease only) and gravimetric determination (PBM). (EPA, 1983).

Biological analysis of water samples

Total Bacterial Counts (TBCs) were determined by using the spread plate method and incubated at 35-37˚C for 48 hrs. (APHA, 1989).

Results and Discussion

The removal efficiency is defined here as the ratio of the amount of the removed pollutant to the initial amount in the feed, and was examined as function of time. The removal rate and the process effectiveness were easily deduced from this study. Key design variables in the system controlling efficiency of removal are, Gas input rate and volume of gas entrained per unit volume of liquid, Bubble-size distribution and degree of dispersion, Surface properties of the suspended matter, Hydraulic design of the flotation chamber, concentration and type of dissolved materials, concentration and type of suspended matter and oils, chemicals added, temperature, residence time, recycle ratio and pH. The removal efficiency data was presented in (Table 2).

It was found that the removal efficiency of Oil & Grease with time as function of initial Oil & Grease concentration where pH (8.8-9.5) and temperature (19-21) ^{0}C .Removal efficiency of this parameter ranged from 57% (least value) which recorded in August and 81.7 % in March (highest value) (Fig. 3), and that related to variable conditions affect system operation over time, as the Concentration and type of dissolved materials differed seasonally according to factories waste load. Same case occurred to the removal efficiency of Turbidity with time .Removal efficiency of it ranged from 43.7% (least value) which recorded in April and 78.2 % in February (highest value). (Fig. 8)

The removal efficiency of Biological Oxygen Demand (BOD) with time as function of initial Biological Oxygen Demand concentration illustrated in (Fig. 4) where pH (8.8-9.5) and temperature (19-21)^{0}C. Removal efficiency of this parameter ranged from 15.2% (least value) which recorded in April and 73.3 % in December (highest value) and that due variable conditions affect system operation over time as The main reason detected for this variation in removal efficiency through different seasons was work duration of plant which affect aeration directly, which also affect the removal efficiency of Chemical Oxygen Demand (COD) with time (Fig. 5). Removal efficiency of this parameter ranged from 25% (least value) which recorded in April and 60% in December (highest value)

(Fig. 6) and (Fig. 7) illustrated the removal efficiency of Total Dissolved Solid (**TDS)** and Total Suspended Solid (**TSS)** with time where pH (8.8-9.5) and temperature (19-21) ^{0}C .Removal efficiency of **TDS** ranged from 1.13% (least value) which recorded in January and 11.4 % in February (highest value) where **TSS** removal efficiency ranged from 64.8% (least value) which recorded in August and 77.5 % in December (highest value) and that related directly to Surface properties of the suspended matter, Concentration and type of dissolved materials ,concentration and type of suspended matter and oils and chemicals added which varied over time according to industrial operations in different factories.

On the other hand (Fig. 9) illustrated the removal efficiency of sulfate with time .Removal efficiency of this parameter ranged from 1.4% (least value) which recorded in (April& February) and 21.4 % in December (highest value) and also (Fig. 10) and (Fig. 11) illustrates the removal efficiency of Nitrate and Total Phosphorus (TF). where Removal efficiency of Nitrate ranged from 0% (least value) which recorded in November and 56.4 % in January (highest value), but Removal efficiency of total phosphorus (TF) ranged from 16.6% (least value) which recorded in June and 33.3 % in (May & December) (highest value) and that due variable conditions affect system operation over time.

Removal of Total Bacterial Counts (TBCs)

(Fig. 12) illustrates the removal efficiency of Total bacteria count with time as function of initial Oil & Grease concentration where pH (8.8-9.5) and temperature (19-21) ^{0}C .Removal efficiency of this parameter ranged from 33.5% (least value) which recorded in September and 48.6 % in February (highest value) .

Table 1: Results of Physico-chemical and biological analysis of water samples

Parameter	Jan		Feb		Mar		Apr		May		June	
	before	**after**	**before**	**After**	**before**	**after**	**before**	**after**	**before**	**after**	**before**	**after**
T ^{0}C	19	19	19	19	20	20	20	20	20	20	20	20
TDS (mg/l)	529	523	245	217	387	370	387	370	520	510	640	625
TSS (mg/l)	80.04	18.228	65.32	15.88	47.9	14.7	65.3	15.8	80	19	84.1	21.5
ES (mg/cm)	929	923	406	365	667	644	669	644	925	920	939	936
Salinity ‰	0.5	0.5	2.5	2.2	1.5	1.35	1.4	1.1	0.5	0.5	0.5	0.5
Turbidity (nTu)	59.8	28.8	108	23.5	83.9	26.15	49.8	28	60	29	71	39
pH	9.39	9.36	9.22	9.05	9.1	9	8.9	8.8	9.39	9.3	9.5	9.4
DO (mg/l)	4	4.8	2.4	4	3.2	4.4	3.9	4.3	4	4.1	2.5	3.2
BOD (mg/l)	1000	463.4	800	370.72	900	417	850	720	1000	463.4	1400	540
COD (mg/l)	2000	1000	1600	800	1800	900	1600	800	2000	1000	2600	1300
Oil &Grease mg/l	1801.8	563	1450.4	320	1626	297	1808	562	1900	580	1870	745
Sulfate mg/l	150	135	136	134	75.5	68.7	13.6	13.4	130	125	152	148
Nitrate (mg/l)	32.8	14.3	16.25	8.5	13.2	11.4	16.5	8.5	16	8	14.8	9
TP (mg/l)	45.7	32.8	40.8	30.9	43.2	31.85	3.2	2	3	2	12	10
Total count bacteria(T.C.B)	80×10^3	64×10^3	120×10^3	40×10^3	100×10^3	52×10^3	108×10^3	72×10^3	120×10^3	40×10^3	124 x10^3	80×10^3

Table 2: Continued Results of Physico-chemical and biological analysis of water samples

Parameter	July		Aug		Sept		Oct		Nov		Dec	
	before	**after**	**before**	**After**	**before**	**after**	**before**	**after**	**before**	**after**	**before**	**after**
T ^{0}C	20	20	21	21	21	21	20	20	20	20	19	19
TDS mg/l	645	629	647	630	648	625	600	570	600	579	530	520
TSS mg/l	90	30	91	32	92	35	84	25	82	27	89	20
ES mg/cm	944	940	945	940	950	940	935	930	935	932	929	923
Salinity %	0.5	0.5	0.5	0.5	1.5	1.3	0.5	0.5	0.5	0.5	0.5	0.5
Turbidity (NTU)	71	39	75	40	80	42	62	32	65	34	60	27
Ph	9.1	8.9	9	8.9	9	8.8	9	8.8	8.9	8.8	9	8.5
DO (mg/l)	2	3	1.8	2.9	1.7	2.6	3	3.3	3.1	3.5	1.9	4.5
BOD (mg/l)	1600	640	1640	670	1650	670	1200	483	1250	4800	1500	400
COD (mg/l)	2650	1400	2700	1450	2750	1460	2100	1100	2200	1000	2000	800
Oil & Grease mg/l	1750	740	1810	780	1850	785	1700	580	1700	575	1805	503
Sulfate (mg/l)	157	140	158	140	160	142	135	121	130	120	140	110
Nitrate mg/l	15	12	17	14	16	15	11	10	10	10	14	12
TP mg/l	17	12	18	13	17	13	9	7	9	6.5	45	30
Total Bacterial Counts (TBCs)	136×10^3	100×10^3	132×10^3	108×10^3	136×10^3	112×10^3	128×10^3	52×10^3	112×10^3	48×10^3	84×10^3	48×10^3

Table 3: Pollutant removal efficiency

Parameter %	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
TDS	1.13	11.4	4.3	4.3	1.9	2.3	2.4	2.6	3.5	5	3.5	1.8
TSS	77.2	75.6	69.3	75.8	76.2	74.4	66.6	64.8	61.9	70.2	67	77.5
Turbidity	51.8	78.2	68.8	43.7	51.6	45	45	50	47.5	50	47	55
BOD	53.6	53.6	53.6	15.2	53.6	61.4	60	59.1	59.3	59.7	61.6	73.3
COD	50	50	50	25	50	50	47.1	46.2	46.9	47.6	54.5	60
Oil & Grease	68.7	77.9	81.7	68.9	69.4	60.1	57.7	56.9	57.5	65.8	66.1	72.1
Sulfate	10	1.4	9	1.4	3.8	2.6	10.8	11.3	11.2	10.3	7.6	21.4
Nitrate	56.4	47.6	13.6	48.4	50	39.1	20	17.6	6.2	9	0	14.2
TP	28.2	24.2	26.2	37.5	33.3	16.6	29.4	27.7	23.5	22.2	27.7	33.3
Total Bacterial Counts (TBCs)	20	66.6	48	33.3	66.6	35.4	26.4	18.1	17.6	59.3	57.1	42.8

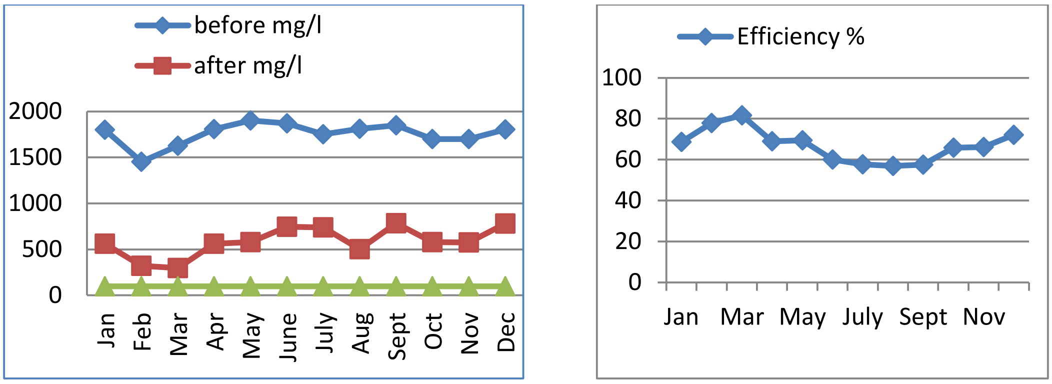

Fig 3 : Removal efficiency as a function of Oil & Grease concentration and time

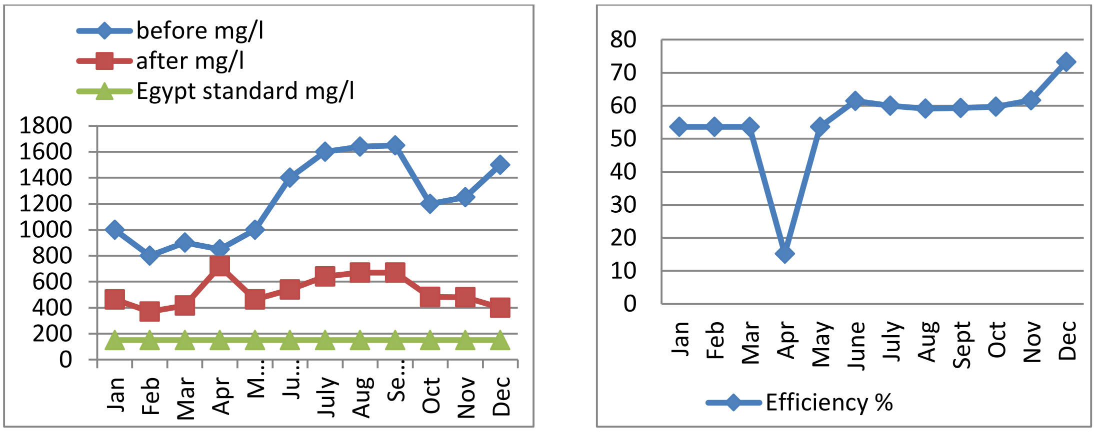

Fig 4 : Removal efficiency as a function of BOD concentration and time

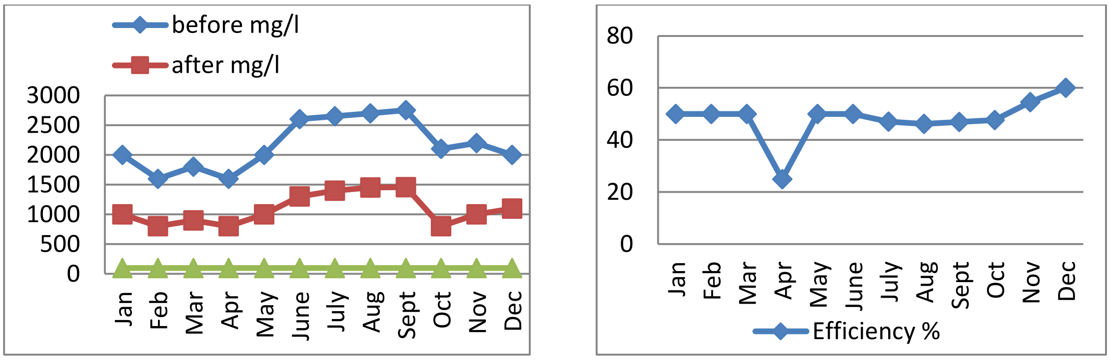

Fig 5 : Removal efficiency as a function of COD concentration and time

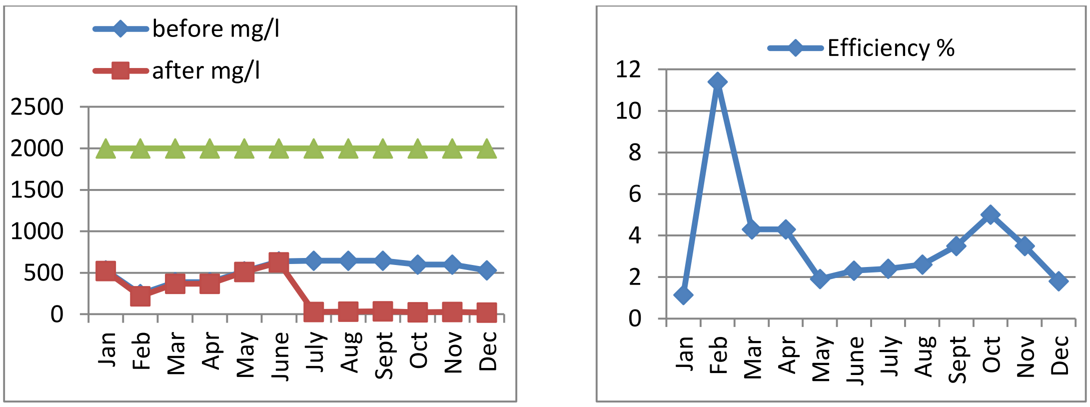

Fig 6: Removal efficiency as a function of TDS concentration and time

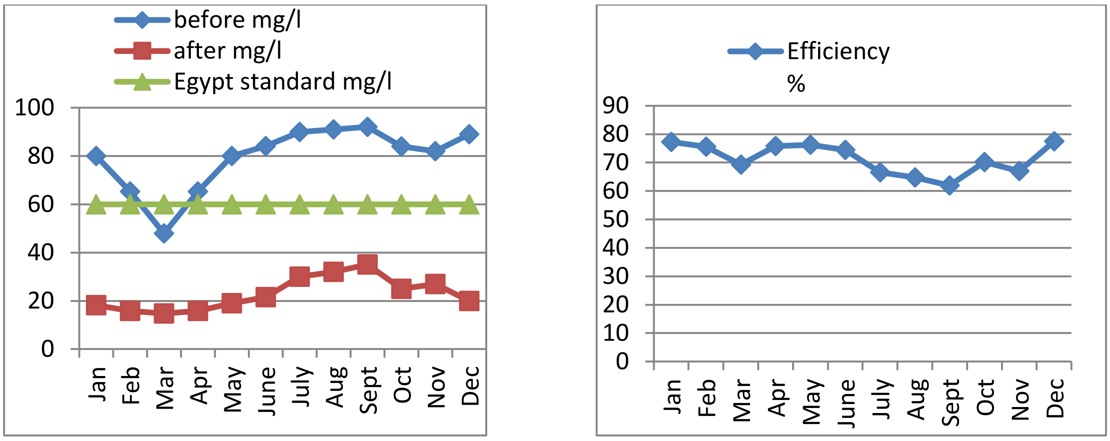

Fig 7 : Removal efficiency as a function of TSS concentration and time

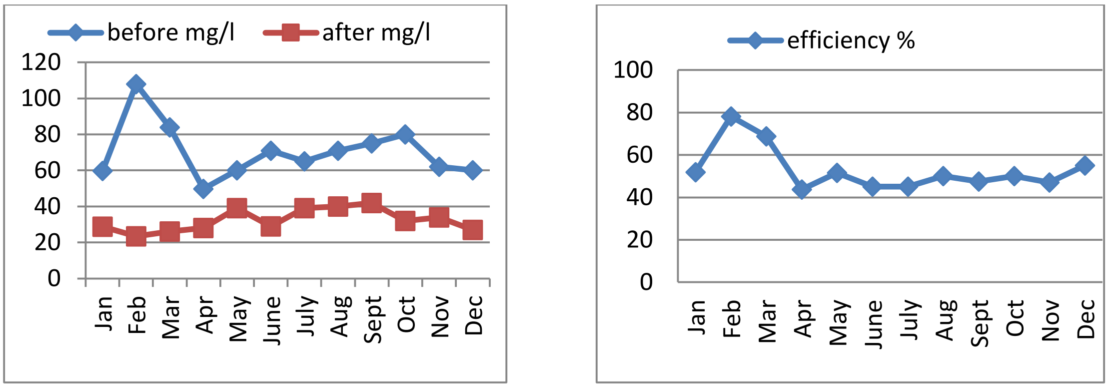

Fig 8 : Removal efficiency as a function of turbidity concentration and time

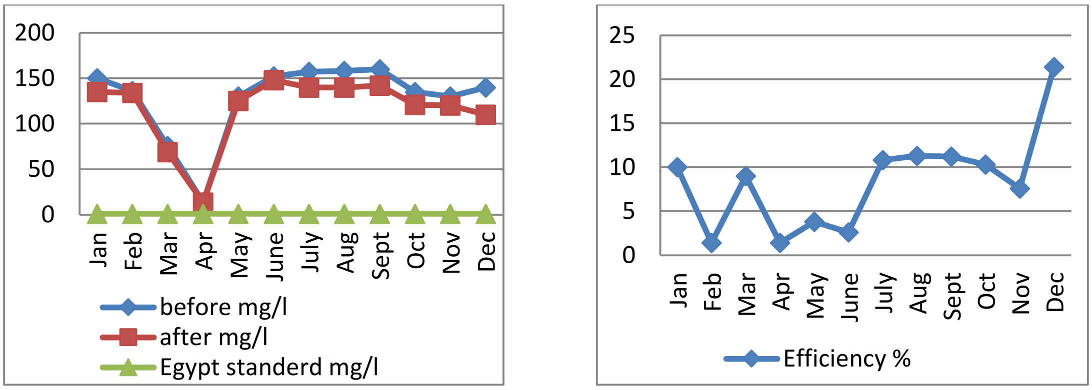

Fig 9: Removal efficiency as a function of sulfate concentration and time

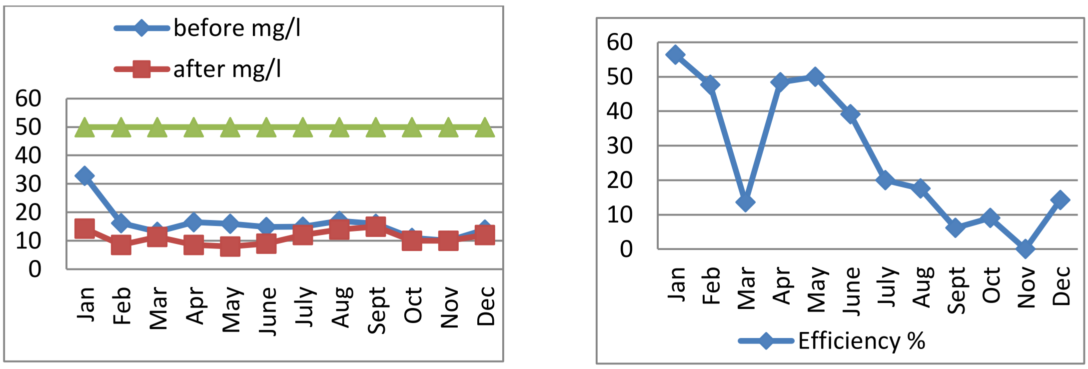

Fig 10 : Removal efficiency as a function of nitrate concentration and time

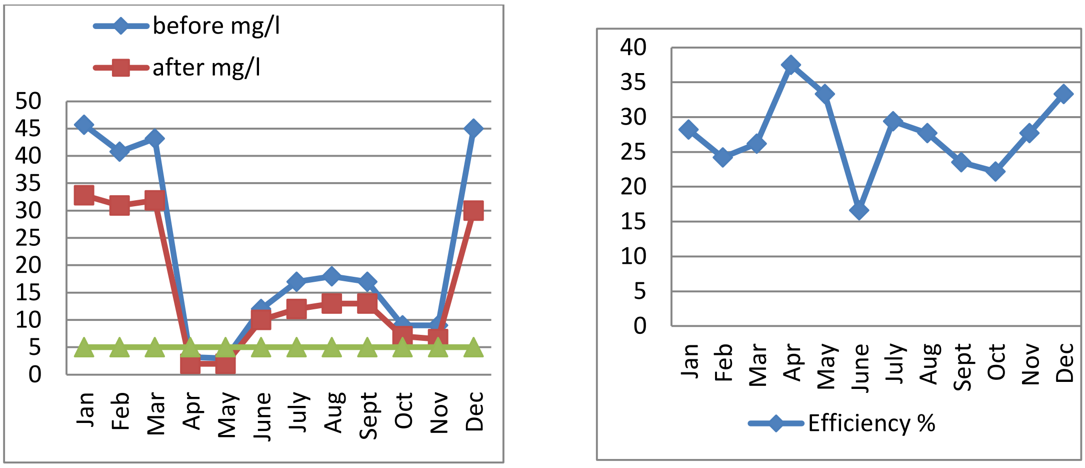

Fig 11 : Removal efficiency as a function of total phosphorus concentration and time

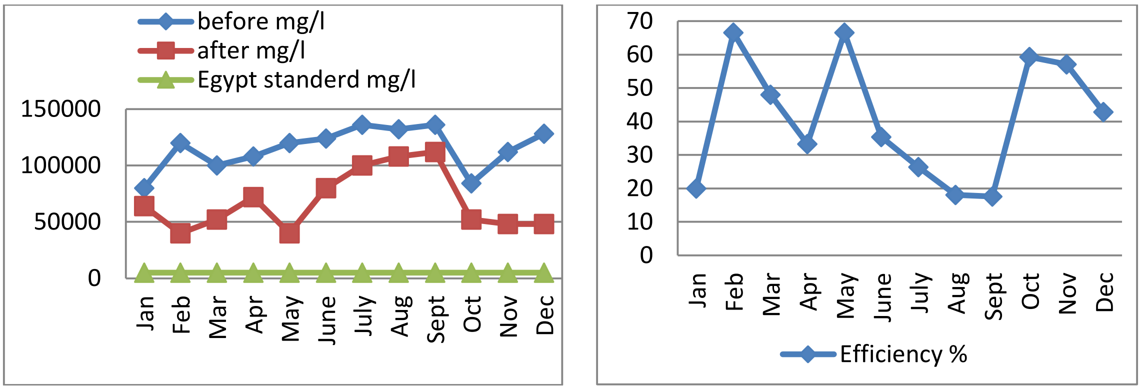

Fig 12 : Removal efficiency as a function of total bacteria count and time

Conclusions

The results obtained in this study suggested an opportunity for the application of Electro-Flotation Treatment Technique (EFTT). It concluded that the treatment of industrial wastewater by EFTT is an effective Technique. The use of EFTT to industrial wastewater treatment under the optimal operating conditions gave a removal of turbidity reached to 78.2% at pH 9, while oil, grease, BOD, COD removal efficiency reached 81.7 %. 73.3% and 60% respectively. But the removal efficiency of sulfate, nitrate and total phosphorus reached 81%. On the other hand the removal efficiency of bacteria reached 66%. Based on the physicochemical and biological characteristics of the treated water, Electro-Flotation Treatment Technique (EFTT) can be used for much industrial wastewater treatment and it offers immediate saving in operating and capital costs over air flotation in many situations

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We would also like to express our deepest appreciation to all those who provided us the possibility to complete this research.

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الملخص العربي

عنوان البحث: معالجة مياه الصرف الصناعي باستخدام تقنية الطفو الكهربي

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اختصت هذه الدراسة بدراسة كفاءة معالجة تقنية الطفو الكهربي لمعالجة بعض مياه الصرف الصناعي . هذة الطريقة تتم عن طريق نقل أجسام التلوث العالقة من السائل الي سطحه في فقاعات الغاز التي تتكون بالتحلل الكهربى لمياه الصرف أثناء عملية التحلل الكهربى حيث يتصاعد غاز الهيدروجين عند الكاثود والأكسجين على الآنود والدورالرئيسي في طفو الحبيبات يتم بالفقاعات التي تتكون . لزيادة طرق التقنية بالطفو تضاف عوامل مساعدة خاصة إلى المياه التي يتم معالجتها وهي مواد التجميع .اجريت بعض القياسات البيئية لدراسة الصفات الكيميائية والفيزيائية والبيولوجية للمياه المعالجة لتحديد كفاءة هذه التقنية لمعالجة بعض مياه الصرف الصناعي مثل الأس الهيدروجيني – العكارة – الملوحة – المواد العالقة – المواد الذائبة – الأكسجين الحيوي – الأكسجين الكيميائي –الكبريتات – النترات – الفسفور – الزيوت والشحوم والعدد الكلي للبكتريا .وقد وجد من هذه الدراسة ان نسبة الكفاءة للمعالجة بهذه التقنية تراوحت بين ٥٧-٨٥ %.