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Treatment of Oily Wastewater by Induced Air Flotation

Dr Thamer .J.Mohammed
Chemical Engineering Department, University of Technology/Baghdad
Email:thamer_jasim@yahoo.com
Shahad .S. Mohammed
Chemical Engineering Department/ University of Anbar /Iraq
Zaidoon khalaf
Petroleum Research and Development Center, Ministry of Oil/Baghdad

ABSTRACT

In this study induced air flotation (IAF) through Perspex glass column (ID 10cm and 150 cm heights) has been studied experimentally to treat the oily wastewater of Iraqi North Oil Company. The column operated in a semi-batch mode (batch wastewater, continuous air injection).

Different samples of oily wastewater (30,100,800ppm) were used. Air introduced at different superficial gas velocity through porous (pore size 120µm) distributor which located at the bottom of column. Different speed of the stirrer (50 to 250) rpm was used to indicate it effect on the removal efficiency of oil from water.

The study showed that the removal efficiency of oil was increased with increasing initial oil concentration, it reached up to 76 %. While it became 89% when using stirrer.

The experimental results were translated to a computer program to predicate empirical correlation.

Keywords: Oily, Flotation, Initial Concentration, Stirrer.

معالجه المياه الملوثه بالنفط بطريقه التطويف

الخلاصه

في دراسه عمليه التطويف المستحث من خلال عمود التطويف (القطر الداخلي 10 سم وبارتفاع 150 سم) تمت عمليه معالجه الماء الملوث بالنفط لشركه نفط الشمال العراقيه. العمود يعمل بنظام شبه وجبه (وجبه من الماء الملوث وضخ للهواء مستمر).

تم اخذ عينات مختلفه من الماء الملوث بالنفط بتراكيز(30,100,800) جزء بالمليون. الهواء الداخل بسرع مختلفه من خلال الثقوب (حجم الثقب 120 مايكرومتر) حيث ان الموزع يقع في نهايه العمود. سرع مختلفه من الخلاط المستعمل تتراوح من (50الى 150)دوره بالدقيقه لمعرفه مدى تاثير هذه السرع على كفاءه ازاله النفط من الماء.

الدراسه بينت ان كفاءه الفصل للنفط تزداد بزياده التركيز الابتدائي للنفط , وقفزن من 76% الى 89% باستخدام الخلاط. النتائج العمليه ترجمت بواسطه انظمه الحاسوب لاسناد الارتباط التجريبي.

الكلمات الفتاحيه: نفطي , تطويف, التركيز الابتدائي, الخلاط

INTRODUCTION

The type of oil-water mixture may be classified as oil and present as free oil, grease, dispersed oil, emulsified oil or dissolved oil. Free oil is usually characterized by an oil-water mixture with droplets greater than or equal to (150µm) in size (API, 1969). While a dispersed oil mixture has a droplet size range between (20-150µm), and the emulsified oil mixture will have droplet size smaller than(20µm) (Francis & Eric 1983). A wastewater with an oil-water mixture where the oil is said to be soluble is a liquid where oil is not present in the form of droplets the oil particle size would be typically less than (5µm) (Patterson, 1985). Free oil is not dispersed and float on the surface, the oily layer can be skimmed. Soluble oil requires the use of ion-exchange technology (Zoubolils & Arranas, 2000). Carbon adsorption or membrane filtration treatment is very effective to remove emulsified oil (Wemco, 1982and Salahi et al., 2010)).

Non-emulsified dispersed oil can be removed by gravity separation, e.g. hydro cyclones, gravity filter or sedimentation or flotation, where oily droplets larger than 40µ are removed by flotation techniques(Zoubolils & Arranas,2000). Zhang et al., 2011 studied the treatment oily wastewater by coagulation floating combination process. They show that, the removal rate of oil can reach 98% in optimization condition of flotation process, with PAFC of 250ppm.

Thamer&Eman, 2007, studied the effect of coagulant (alum, clay) on removal efficiency of oily wastewater treatment by dissolved air flotation. They found that the removal efficiency of oil increase with alum until reaching the optimum dosage (25, 40, 70) ppm for initial oil concentration (30, 58, 136) ppm respectively, and the over dosage causes a decrease in the oil removal efficiency, but the other coagulant (clay) having higher removal efficiency of oil the optimum dose of it was (2.5, 5, 9) ppm for the same initial oil concentration, but disadvantage of higher amount of sludge caused. Shanmugam et al, 2008, studied the effect of various parameters like superficial gas velocity and speed of stirrer (N) on fractional gas hold up in bubble column of 0.14m ID and 2m height. They concluded that fractional gas hold up increased with increasing superficial gas velocity and speed of the stirrer. Budhi et al, 2011, their aimed is to investigate feasibility of the aerobic biological process to treat oily wastewater from palm oil food industry. Effect of aeration and sludge concentrations were studied. Raw sludge and raw wastewater were mixed and acclimatized for five days in a stirred tank reactor, it was found the higher aeration results a high COD removal and oil & grease removal. The effect of different initial concentrations of oil and of different speeds of stirrer on the removal efficiency of oil were conducted.

MATERIALS

- Surfactant sodium laurel sulfate (SLS) was used as anionic emulsifier, its molecular weight is equal to 288.38 gm/mole and its purity is 90%.
- Aluminum sulfate (Alum) Commercial alum was used in the experiments, it is a white dry powder, has a formula of ($Al_2(SO_4)_3.18H_2O$) and molecular weight of (594.4 gm/mole).
- Surfactant camper (Cocamidopropylamine Oxide) it is an amphoteric surfactant, its yellow oil with the molecular weight of 309.

- pH adjustment was done by using (NaOH molecular weight is 40 gm/mole and purity of 100% and HCl molecular weight is 98.08 gm/mole and purity of 100%).
- Normal Hexane was used as a solvent and Anti-Foam.
- Carbon tetra chloride.
- Distilled water.

EXPERIMENTAL WORK

The experiment apparatus is shown schematically in Figure (1). The oily wastewater treatment was operated by dispersed air in flotation column. The column made of a cylindrical Perspex glass column with the dimensions (10 cm I.D and 150 cm in height) and operated in a semi- batch mode (Batch wastewater, continuous air). Oily water with different concentration (30, 100 and 800 ppm) was poured gently at the top of the column. The drop oil sizes distribution was found by using microscope and the mean drop diameter was found to be equal to (44) μm. The analysis of wastewater samples after treatment were carried out by using (UV type 1100) to measure residual oil content and removal efficiency.

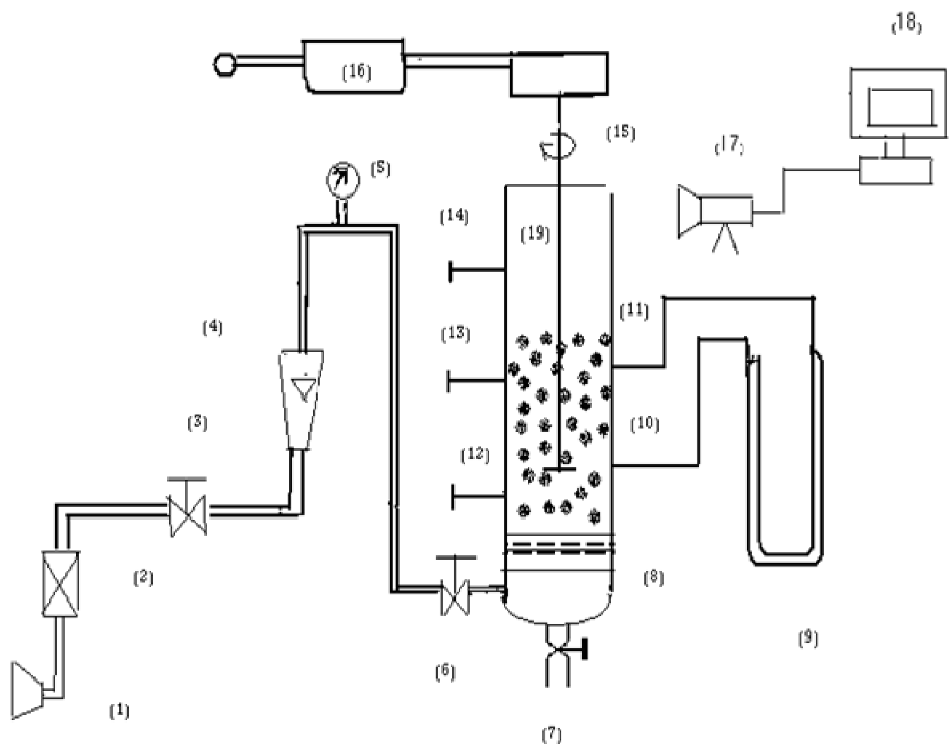

Figure (1) **Schematic diagram for the experimental apparatus.**

(1)Air compressor	(9)monometer
(2) filter	(10)&(11)Pressure taps
(3) needle valve	(12)&(13)&(14)sampling valves
(4)Rota meter	(15) stirrer
(5)pressure gage	(16) motor
(6)check valve	(17) camera
(7)drain valve	(18) computer
(8)distributor	

RESULTS AND DISCUSSION

Effect of Initial Oil Concentration

The removal rate of oil at various initial oil concentrations (30 to 800 ppm) was studied and it was found that the removal rate increases with increasing initial oil concentration that because when the concentration of oil increased the contact of air bubble and oil droplet was increased. This is shown in Figures (2and 3) at which show the relationship between removal efficiency (R %) with time of flotation at different concentrations (100-800ppm) of oily wastewater. Also these experimental results are represented in three dimensions curve as shown in Figure (3b). This Figure shows the combined effect of time flotation and concentration of oily wastewater on removal efficiency. Three dimensional representations in this work is mainly to show the classification of the optimum surface shape of two parameters which give higher removal efficiency. The removal rate constants at various initial oil concentrations were found and plotted as $\log(C/C_o)$ against time in Figure (4). The slope of the lines gives the rate constants and their values are tabulated in Table (1).

Table (1) Rate constants at various initial oil concentrations.

C_o (ppm)	K (1/sec)	n
100	0.012	1.05
200	0.0223	0.87
400	0.0446	0.66
600	0.0493	0.51
800	0.177	0.47

It was found that the fastest removal of oil occurred at the highest initial concentration.

An empirical correlation from the experimental results was found by computer programming as shown in Eqn. 1, for initial oil concentration (100-800), with R^2=0.98, to make comparison between the experiment and predicted results as shown in Figure (5),

$$R\% = 0.053Co + 33.9 \quad \text{... (1)}$$

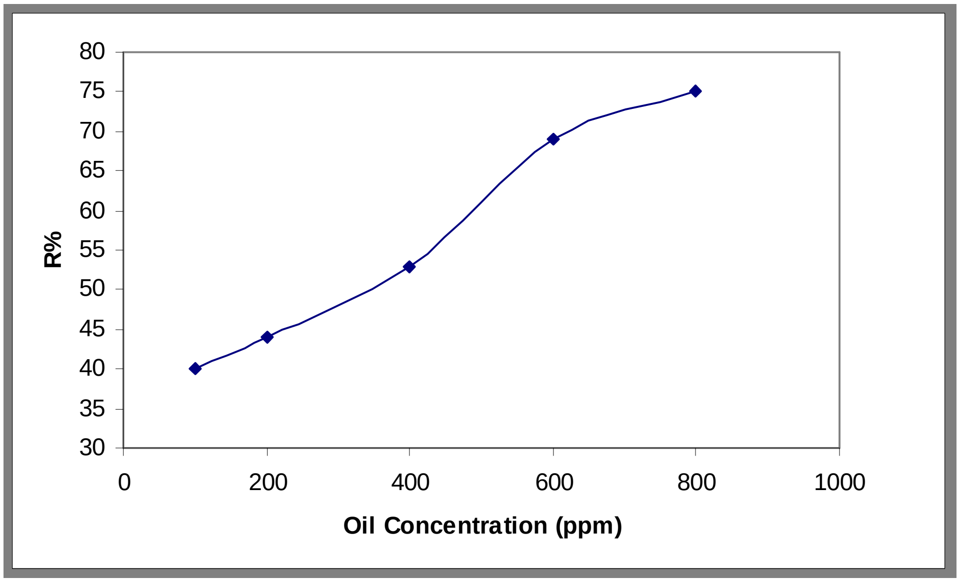

Figure (2) Effect of the initial oil concentration on the removal efficiency, pH=7.2, Q= 0.0113 m^3/min, t=1500 sec.

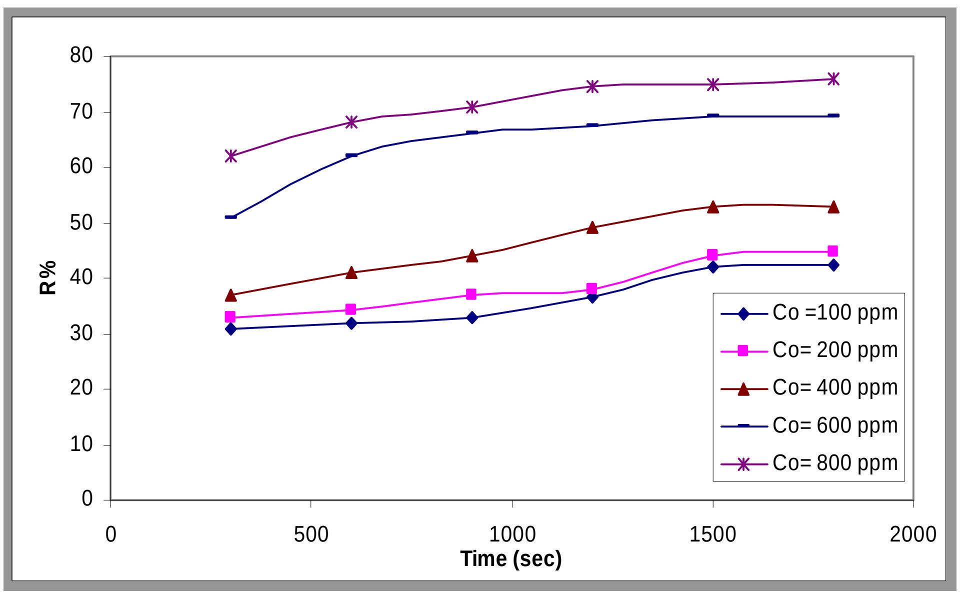

Figure (3a) Effect of the initial oil concentration on the removal efficiency, pH=7.2, Q= 0.0113 m^3/min, as function of time.

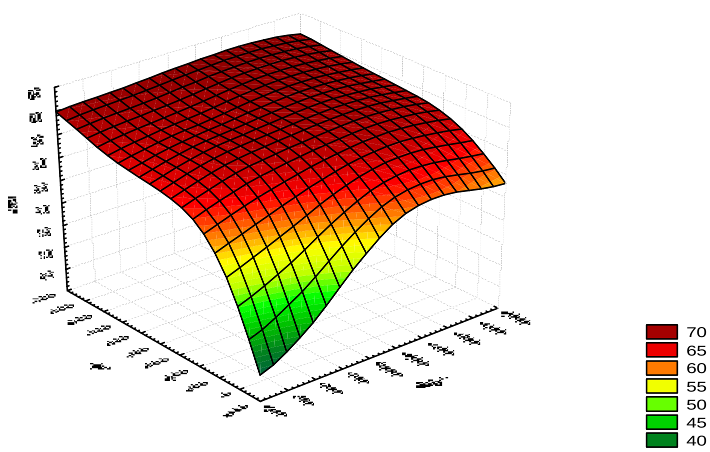

Figure (3 b) Effect of the initial oil concentration on the removal efficiency in a 3D plot, pH=7.2, Q= 0.0113 m^3/min, as function of time.

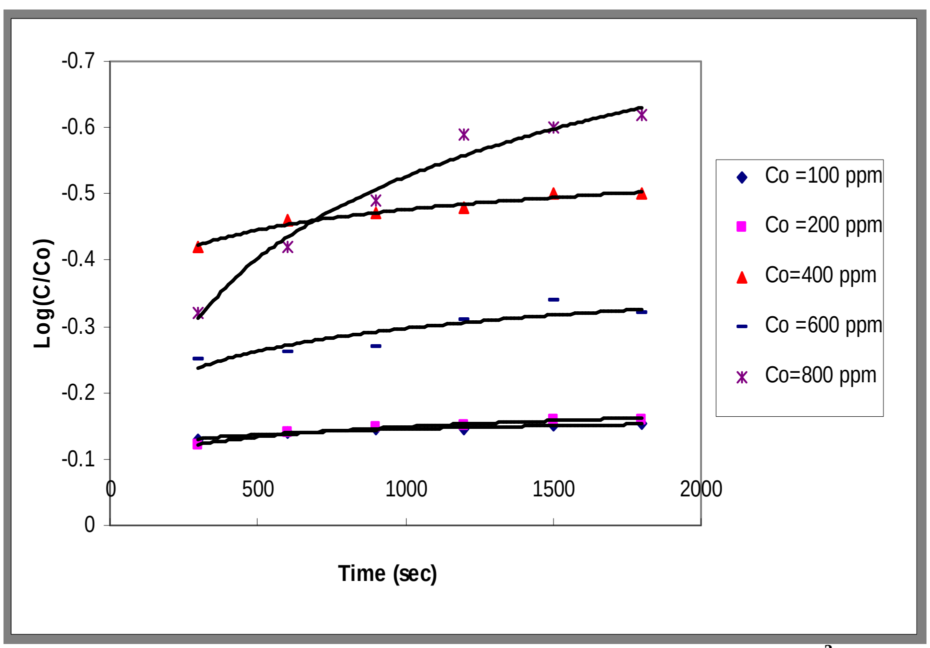

Figure (4) Log(C/C_o) versus time at different C_o values, Q=0.0113m^3/min, t=1500 sec, and Co=800 ppm, H=70 cm.

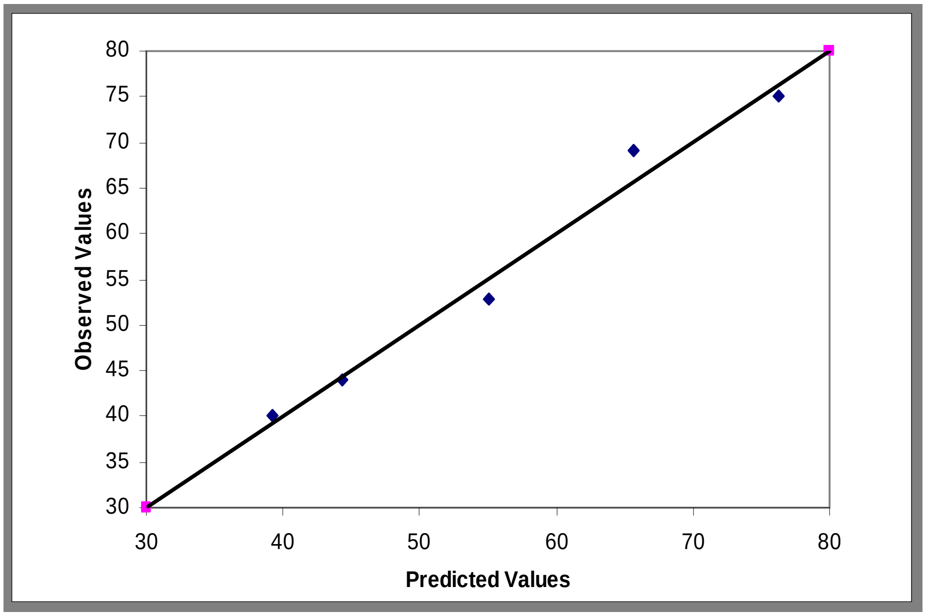

Figure (5) Comparison between the observed vales of removal efficiency of oily wastewater and the predicted vales.

Effect of Mixing

Figure (6) shows the effect of different speeds of the stirrer (50-250) rpm(22.6-253sec^{-1}) on the gas hold up, where the gas hold up increases when increasing the speed of the stirrer, Figure (7). Shows the comparison between the gas hold up with and without stirrer and found that the gas hold up with stirrer was higher than without stirrer. This may be due to the formation of larger gas bubbles where the stirrer plays a vital role in breaking of large bubbles; thereby increasing the gas hold up, this result is in agreement with Shamugam, 2008. Figure (8). Show the effect of the mixing on the oil removal efficiency at different time.

It can be noticed at the range (50-250) rpm that the removal efficiency increased slowly and the high removal efficiency can be obtained at 200 rpm and the removal efficiency decreased slowly compared with 200 at 250 rpm. This system is called (MIAF) and R% in it was higher than (IAF). This result can be explained that the size of oil droplets increases due to the sweep flocc coagulation from the presence of alum content and thus accelerates the separation flotation process Figure(9). shows the effect of stirrer on the bubble size; also a correlation has been developed as shown in Eqn. 2 for fractional gas hold up for stirred flotation column based on computer programming(statistical) with statistical method.

$$\varepsilon_g = 0.39\,(U_g)^{0.0163}\,(H/D)^{0.157}\,(N/\rho_L)^{0.473} \quad \ldots (2)$$

The comparison between the observed and the predicated results is shown in Figure(10), where the average error was 2%, and the correlation coefficient was 0.98.

Figure (11), shows a comparison between the removal of oil in the Jar-test and in the flotation column in the same initial oil concentration equal to 800 ppm and the same dose of additive 24 SLS+80 alum and at 50 rpm, the results shows that the removal efficiency in the flotation column is higher than the Jar-test and that is in agreement with Puget&Massrani, 2000.

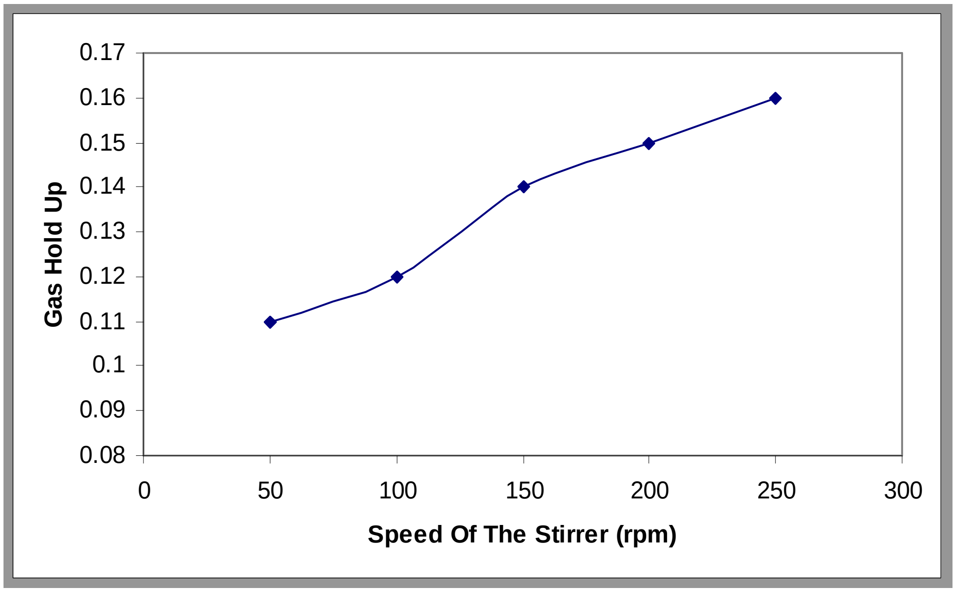

Figure (6) Effect of the speed of the stirrer on the gas hold-up, H=70 cm, C_o=800 ppm.

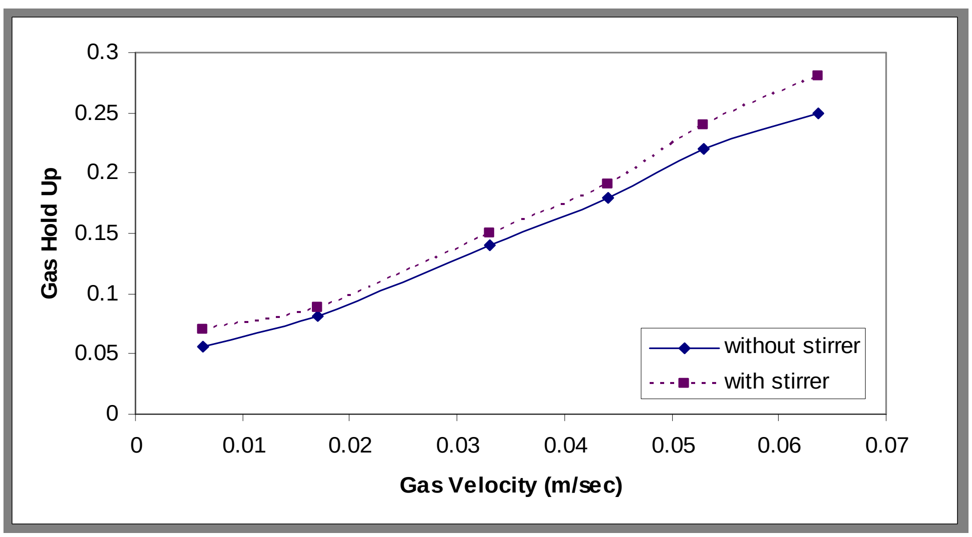

Figure (7) the comparison in gas hold up values, H=70 cm, C_o=800 ppm.

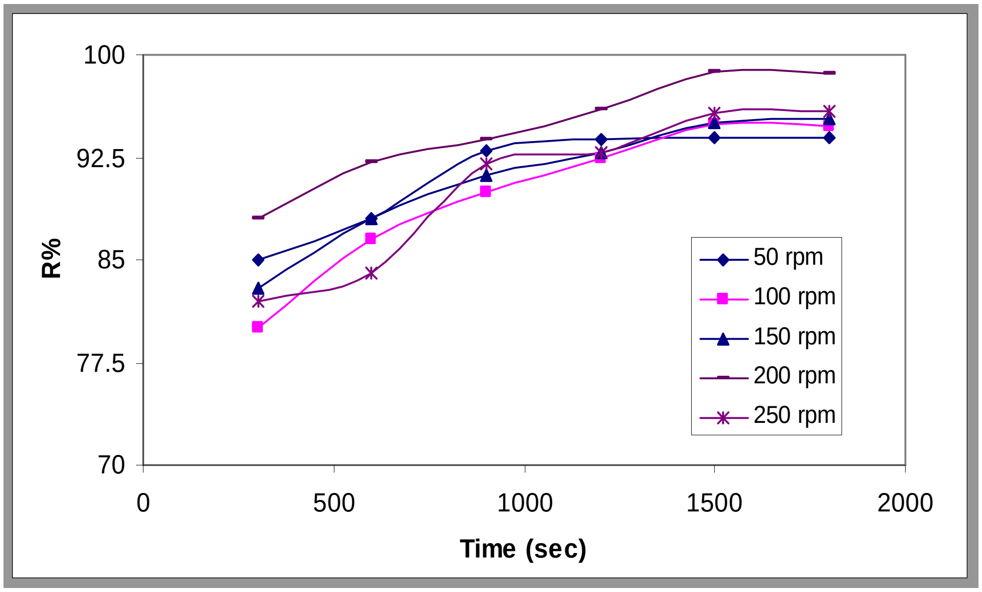

Figure (8) Effect of the speed of the stirrer on the removal efficiency, pH=7.2, Q=0.0113 m^3/min, C_o=800 ppm , 64 sls+240 alum .

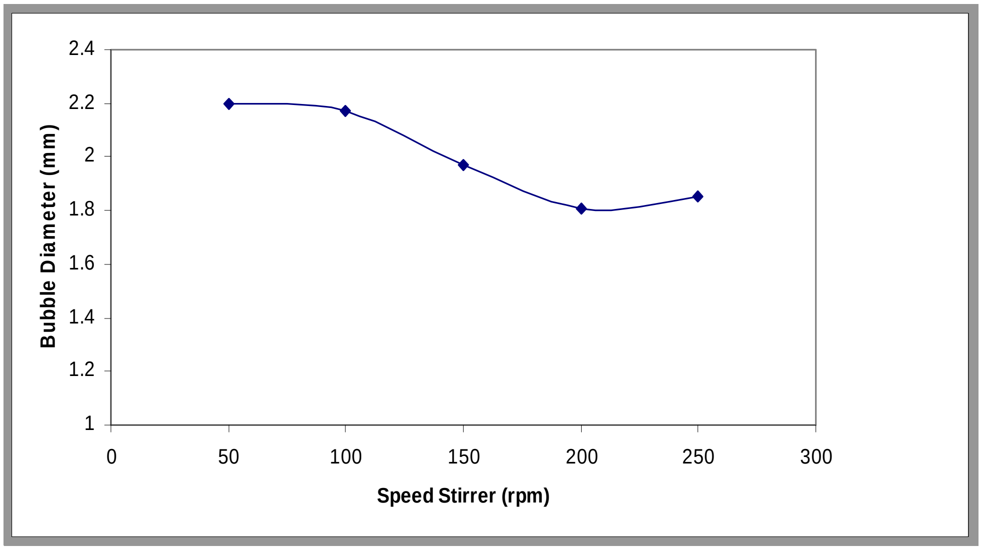

Figure (9) Effect of the speed of the stirrer on the bubble size, H=70 cm, C_o=800 ppm.

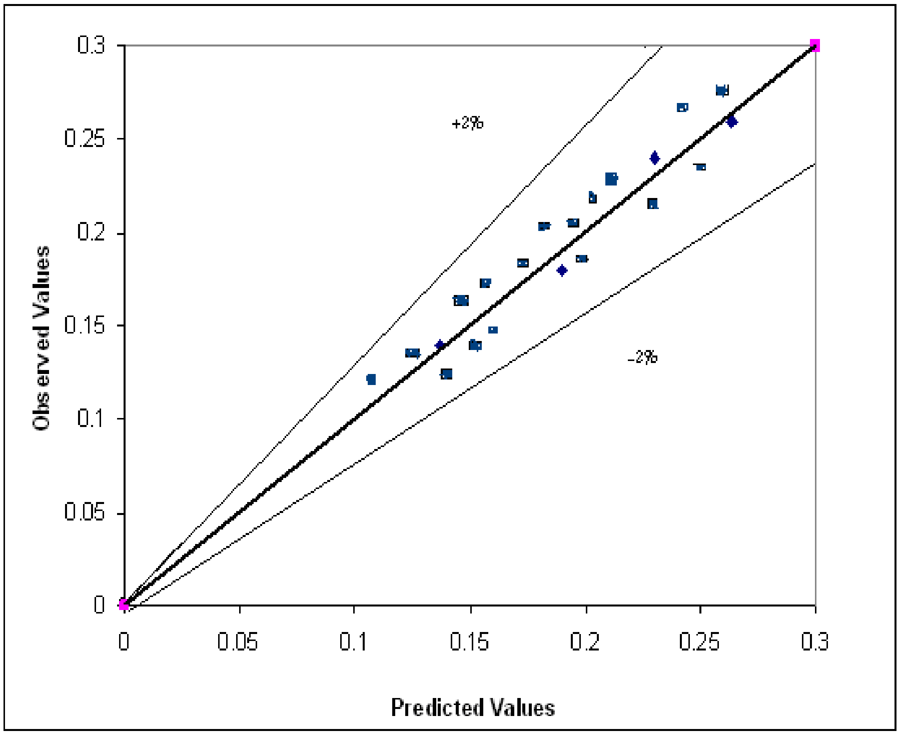

Figure (10) Predicted versus observed gas hold up of Eqn. 2.

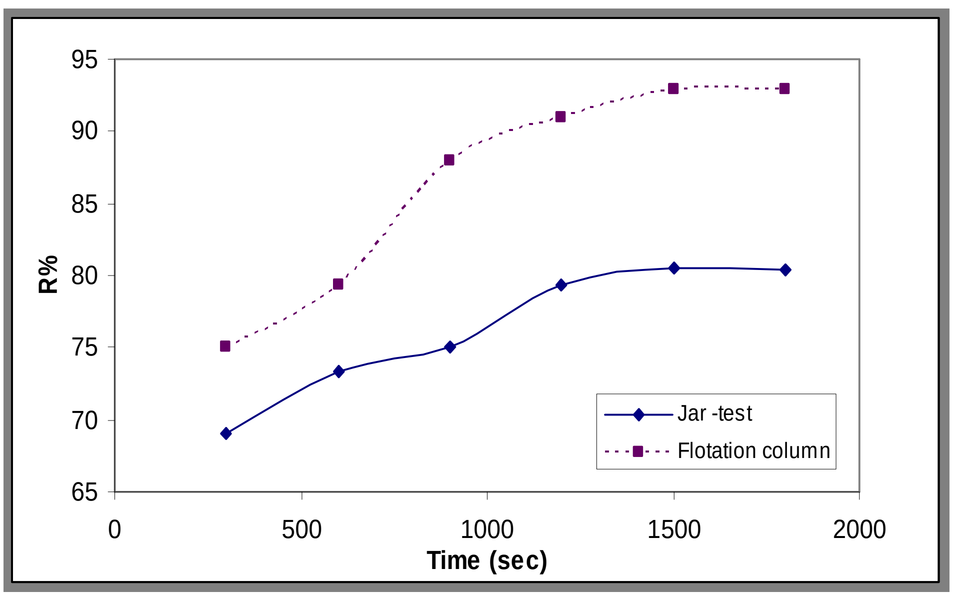

Figure (11) A comparison between flotation column and the Jar-test, Co=800 ppm.

CONCLUSIONS

In this work, treatment of oily wastewater with flotation column was investigated. According to the results, it can be concluded that the following:

- The emulsified oil with concentration (30-800 ppm) can be removed by dispersed air flotation; high percentage was achieved from 20 to 25 minutes.

- Induced air flotation (IAF) and modified induced air flotation (MIAF) were applied and analyzed in term of treatment efficiency; the removal efficiency obtained with IAF processes was smaller than obtained in MIAF.
- The gas hold up increased with the increase of gas velocity and also increased when adding surfactant, when using the stirrer. The gas hold up was correlated according to the following equation:

$$\varepsilon_g = 0.39\,(U_g)^{0.0163}\,(H/D)^{0.157}\,(N/\rho_L)^{0.473}$$

NOTATION

Co Initial oil concentration, ppm
C Final oil concentration, ppm
D Diameter of the column, cm.
H Liquid height inside the column, cm
k Rate constant, sec^{-1}.
n Order of the reaction.
N Speed of the stirrer.
Q Gas flow rate, m^3/min
t Time, sec.
IAF Induced air flotation
U_g Gas Velocity, cm/sec.
r_l Density of the liquid, g/cm^3.
e_g Volume fraction of gas or gas holdup, (-).

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