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Study the Performance of Dissolved Air Flotation as Industrial Wastewater Treatment Method

Abstract-*This research aimed to study the removal efficiency of oil pollutant from industrial wastewater by dissolved-air flotation (DAF) with and without chemical coagulants. The sample test of wastewater is discharged from Daura Refinery. The performance of dissolved air flotation for example saturation pressure and recycle ratio were studied. The industrial wastewater treated by DAF is carried out with two types of chemical coagulants: Alum and Polyacrylamid. The treatment method of wastewater by DAF with and without chemical coagulants and their effect on the removal efficiency of oil, results were obtained at different parameters such as saturation pressure (2,5-5.5atm) and recycle ratio (20-50). It has been found the oil removal efficiency (R %) increases with increase in recycle ratio (R.R) and saturation pressure (P). The maximum oil removal efficiency in DAF unit without coagulants is found to be equal to 60%, while with polyacrylamide coagulants is equal to 94, 90 %, while with alum coagulants is equal to 89, 82 % and with combination of alum+ polyacrylamide coagulants is equal to 98.96, 95.5 % for initial oil concentration (C_o) 50, 200 ppm respectively. The experimental results were indicated the removal efficiency of oil by using polyacrylamide as alone is more effective than adding alum but combination of them, resulted improvement in removal efficiency. The experimental results of DAF process with coagulants are expressed in develop general empirical correlation by chemical cad in computer program.*

Keywords- *Dissolved Air Flotation, industrial wastewater treatment.*

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1. Introduction

Oil in the wastewater can be removed by the use of commonly recognized methods. As the removal depends on the conditions of the oil-water mixture, the type of apparatus must be carefully chosen [1]. The type of oil-water mixture may be categorized as free oil, dispersed oil, emulsified oil or dissolved oil. Free oil is usually characterized with droplets greater 150 microns while a dispersed oil mixture has a droplet size range between 20 and 150 microns, and an emulsified oil mixture will have droplet sizes smaller than 20 micros, [2]. DAF is water treatment method that clarifies wastewater by removal of suspended matter. The removal is done by dissolving air in the water or wastewater under pressure and then releasing the air at atmospheric pressure in a floatation tank.
The released air from tiny bubbles which adhere to the suspended mater causing the suspended matter to float to the surface of wastewater where it may then be removal by a skimming device,[3]. The roles of aluminum and ferric sulphate as destabilizing agent for oil-water emulsions that were stabilized by an anon-ionic surfactant which is examined in terms of oil removal [4]. They considered the effect of coagulant dose, pH, and the duration and intensity of both slow and fast mixing. Electro kinetic tests show that oil droplets have a negative zeta potential, which is weakly dependent on pH values. The selected coagulants are displayed to be effective in decreasing the zeta potential of the oil droplets and charge reversal was observed for aluminum sulfate, oil removal up to 99.3 % at pH 8 seen for aluminum sulfate and ferric sulphate respectively [5]. Fast mixing times (120 s) and flocculation times from 15 to 20 min. appear to be optional for the DAF separation. It can be observed that relatively low average mixing speeds for coagulation and flocculation are needed for effective operation, [6]. A study was investigated

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the best oil content removal from produced water when using of 15 mg/l of ferric chloride as coagulant with different concentrations of polyelectrolyte (0.5, 1, 1.5 mg/l) decrease the oil content from 46.6 mg/l to 4.7, 4.5 , and 4.3 mg/l ,respectively [7]. The experimental results showed of treatment Iraqi oil field produced water by dissolved air flotation column that the oil removal efficiency increases with increasing the flow rate of produced water, the flotation time and coagulant dosage of alum, [8]. The experimental results were showed that $Al_2(SO_4)_3$ was a more effective coagulating agent than lime for oil removal from industrial wastewater using mechanically flotation technique [9]. The study of flotation technique was applied an Induced Air Flotation (IAF), then applied Modified Induced Air Flotation (MIAF) and made a comparison between them for treating oily wastewater [10]. The current work displayed that the removal efficiency of oil, COD, and BOD were correlated to the additive dose of alum and sodium laurel sulfate (SLS), and flotation rate increase after using alum and surfactant together to obtained removal efficiency 98% when the initial oil concentration was 800ppm.The creation of coagulant mixtures in wastewater. That will aid to coagulate contaminants and generate bubbles in favor of mixing and elimination of oil and solids by flotation [11]. Oil removal rates were observed to increase greater levels of aeration and agitation in the flotation process [9].

2. Materials and Experimental Methods

The following procedure of experimental work on the flotation Jar Test and this equipment are shown in Figures 1 and 2, and the more details of the procedure are shown in reference [12].

- Aluminum sulfate (Alum) was used in the tests; it is a white dry powder $(Al_2(SO_4).18H_2O)$ with a molecular weight of (594.4 gm/mole).
- Polyacrylamide (PAAM); propenamide homopolymer cyanamer [American Cyanamid].
- The amount of natural wastewater sample for test experimental was taken from Daura Refinery.

The experimental work was carried out by applying two methods, flotation without coagulant and with chemical coagulants. The common first step for two methods is prepared Saturator (pressure chamber Figure 2) to desired operating pressure and it filled with water to two-third full. The second step, the saturated water was fed into the Jar-tester, which contains a sample of wastewater. Leave the air supply on and allow the saturator to stand 5-10 minutes. The third step is treatment flotation of wastewater with selected operating variables recycle ration (R.R%) by Control Synchronized Recycle (SRC Figure 2).

If the water is saturated, then a dense milky air cloud will be seen in the water at the end of the flotation test. Therefore, Jars were drained to take a wastewater sample to measure oil content and removal efficiency. But the experimental tests for the second method flotation with chemical coagulants was carried out as following: the same procedure above was repeated and follow, the sample wastewater added to Jars and it can be mixed vigorously at one of the speeds and then drive was energized, 400 rpm, chemical coagulants at a dose can then be added simultaneously and the mixing time can be set on the process timer and energized, timer was energized, and the slow speed required to set at 40 rpm. The flocculate speed can be quantified in term of velocity gradient value (G) [12]. The recycles water, and hence micro bubbles of air were introduced to the base of the Jars. At the end flotation time, a sample of wastewater was drawn to measure oil content and obtain removal efficiency.

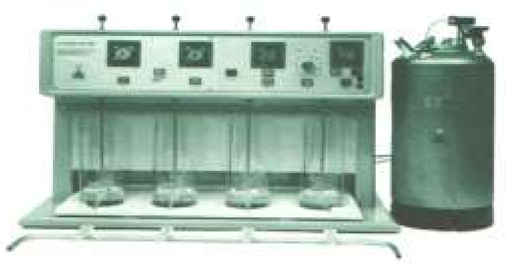


Figure 1: Flotation Jar-Test Equipment

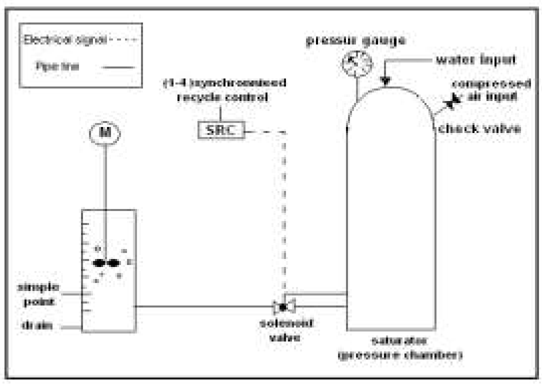


Figure 2: The flotation Jar-Test laboratory equipment

3. Results and Discussion

The experimental results of flotation without and with coagulants as alum and polyacrylamide were carried out at different parameters such as saturation pressure and recycle ratio. The discussed of results as shown in the following paragraphs.

I. Effect of Saturation Pressure on Oil Removal Efficiency, Without Coagulants

For flotation results without coagulants, and effect of saturation pressure (R.R) at initial oil concentration C_O=50,200ppm on oil removal efficiency (R%) as shown in Figures. 3 to 4, respectively. The results indicated that the removal efficiency of oil increases with increasing saturation pressure, this due to the mass transfer increase of the liquid phase and the shaping action of hydrocarbon increases [13]. The range of pressure was used between (2.5-5.5) atm because the over range causes increasing in cost process.

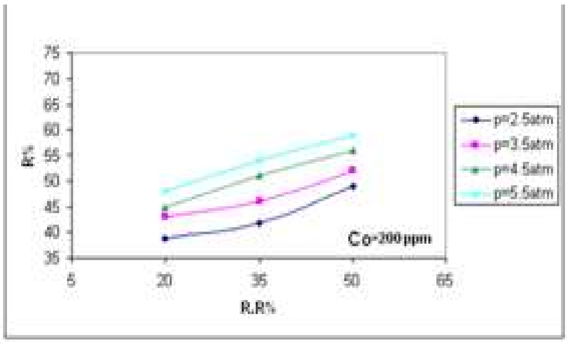


Figure 3: Effect of recycle ratio on oil the removal efficiency without coagulants

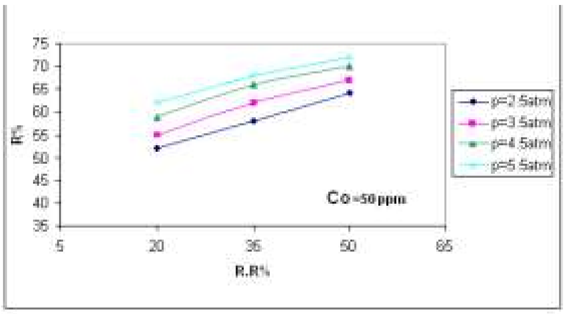
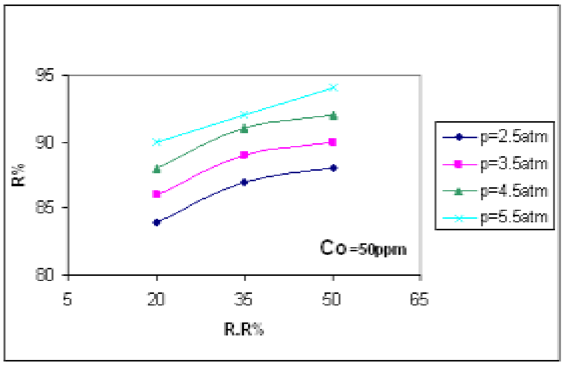


Figure 4: Effect of recycle ratio on oil the removal efficiency without coagulants

II. Effect of Recycle Ratio With alone coagulant as Alum or Polyacrylamide on Removal Efficiency

Figures 5-6 show the experimental results of dissolved air flotation by using 25ppm of polyacrylamide as the best dose [12] at different recycle ratio and pressure. The addition of coagulant with solution improves the removal efficiency for example at R.R=50%, and press=5.5 atm with stirring at 400 rpm (375 s^{-1}) the C_o=50 ppm, obtained about R%=94, but without coagulant R%=73, therefore an improvement in efficiency about 21%. But when using C_o=200ppm with the same above condition, decreasing removal efficiency to R%=90, as shown in Fig.6. but still, R% more than without coagulant as shown in Figure 3. This results show that the size of oil droplets increase because of the sweep flocs coagulation from the presence of high molecular weight of polyacrylamide accelerate the separation flotation process. This



phenomenon improves efficiencies explained based on by either a charge or a size mechanism [14].

Figure 5: Effect of recycle ratio on oil the removal efficiency by using (polyacrylamide 25 ppm) Dose

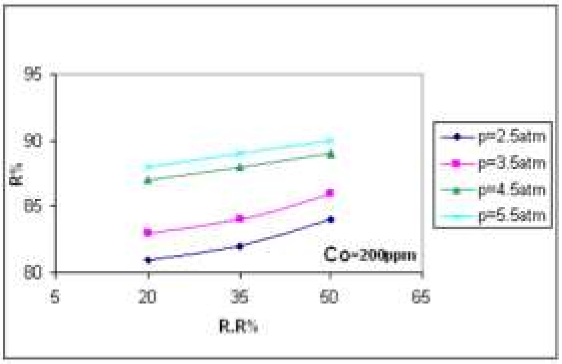


Figure 6: Effect of recycle ratio on oil the removal efficiency by using (polyacrylamide 25 ppm) Dose

Figures 7-8 show the experimental results of dissolved air flotation by using the best condition of alum dose 30ppm [12], at different recycle ratio and pressure. The addition of coagulant of alum with solution improves the removal efficiency for example at the same above operating condition with C_o=50ppm, obtained R%=89, but flotation without coagulants R%=73 (i.e. efficiency increases R%=16) as shown in Figs. 3 and 7 as respectively. When increasing oil concentration to C_o=200ppm, result decreasing in R%=82, as shown in Figure 8, but still efficiency more than flotation without coagulant as shown in Figure 4 when comparison with the results shown in Figure 8.

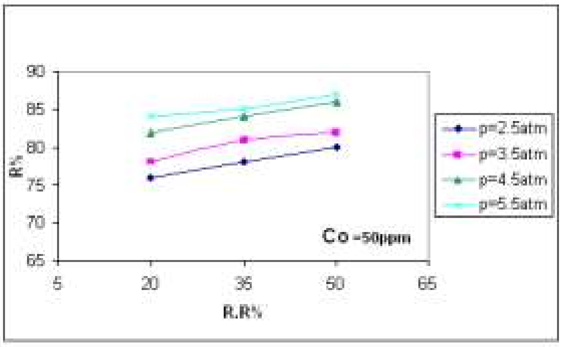


Figure 7: Effect of recycle ratio on Oil the removal efficiency by using Alum coagulant 30ppm Dose

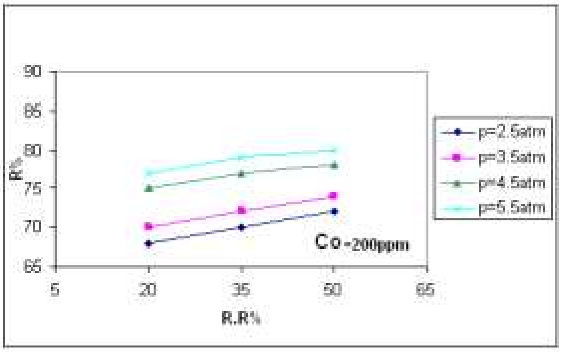


Figure 8 : Effect of recycling rati on oil the removal efficiency by using Alum coagulant 30ppm Dose

From Figures 5 and 6 that found that treatment of wastewater by flotation with using polyacrylamide coagulant is more efficiency on oil removal than flotation with alum coagulant because the technically important water polymer that has two functional groups are active double bond and an amid group its anionic and cationic derivatives.

III. Effect of Recycle Ratio with combination addition of coagulants as Alum and Polyacrylamide on Removal Efficiency

Figures 9-10 show the experimental results of DAF with use combination addition of the best [10] coagulants dosages of 15ppm alum +15ppm polyacrylamide, to obtain maximum removal efficiency of oil R%=98.96, at C_o=50ppm, and R%=95.5, at C_o=200ppm, as shown in Figs. 9 and 10 as respectively. When comparison these results with DAF without coagulants, the removal efficiency is increasing about to 26% for C_o=50ppm, at the same conditions.

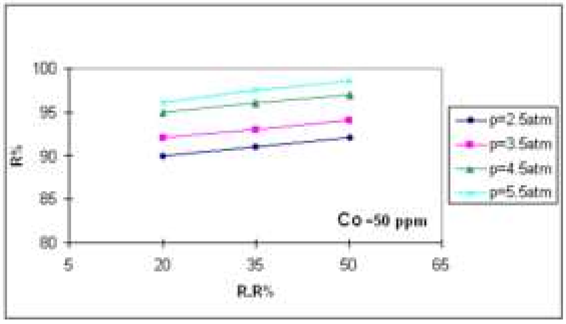


Figure 9: Effect of recycle ratio on oil the removal efficiency by using Alum 15ppm+ polyacrylamide 15ppm, Dose

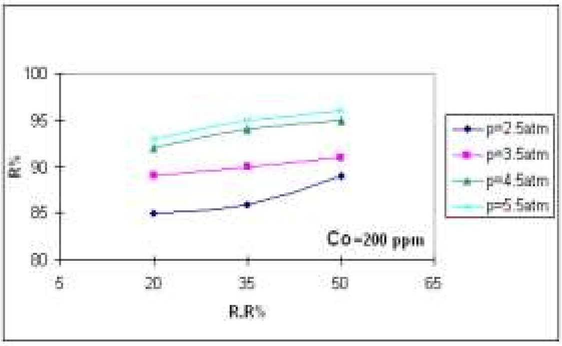


Figure10: Effect of recycling ratio on oil the removal efficiency by using Alum 15ppm+polyacrylaimde 15 ppm, Dose

The results of that best operating conditions of DAF to obtain maximum removal efficiency of oil can be represented in three dimensions, as shown in Figs.11 and 12. These figures are useful to show the interaction of two variables; different recycle ratio and saturation pressure, which effect on oil removal efficiency. Therefore the optimum conditions for multi-variables can be noticed quickly from figures which show the best location as maximum removal efficiency.

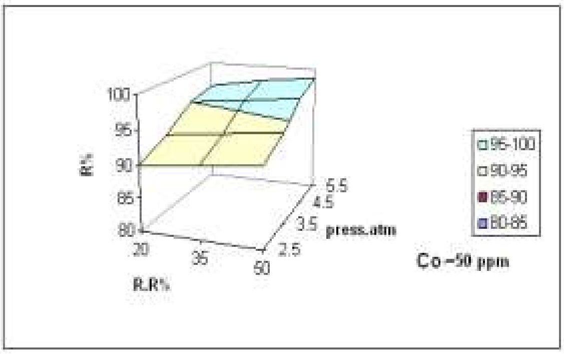


Figure 11: Effect of saturation pressure and recycle ratio on oil the removal efficiency by using Alum 15 ppm+ polyacrylamide 15 ppm.

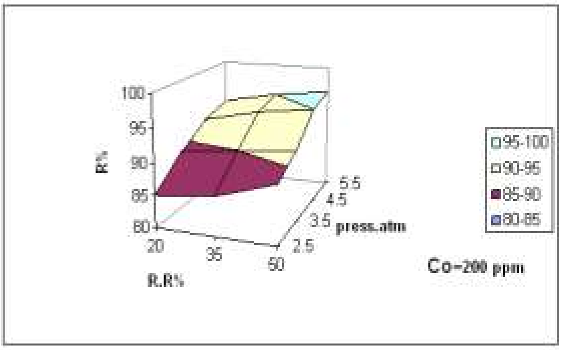


Figure 12: Effect of saturation pressure and recycle Ratio on oil the removal efficiency by using Alum15 ppm+ polyacrylamide 15 ppm

IV. Empirical Correlation

DAF results are analyzed to develop empirical correlation by using the statistical program in chemical cad. The process of developing the current model is by presenting equations of different forms into a computer program. The dependent and independent variables are compared with actual values, and the process is repeated until an excellent agreement is obtained Eq.1 represent the oil removal efficiency with recycling ratio-pressure and influent oil concentration for DAF with coagulants. The absolute average error is equal to 5.193% and correlation coefficient =0.934 of Eq.1.

$$R\% = a_o \left[\frac{(R.R)^{a1} (P)^{a2}}{(Co)^{a3}} \right] \quad (1)$$

Where R%=removal efficiency, R.R=recycle ratio, P=saturation pressure, C_o=initial oil concentration (ppm). a_o=67.89, a1=0.089, a2=0.345, a3=-0.186.

4. Conclusions

The following conclusions can be drawn:

a. The maximum removal efficiency of oil R%=73 (C_o=50ppm) from wastewater was obtained for DAF without adding coagulants, but it decreases with a higher initial concentration of oil fed.

b. For DAF with addition coagulants, the maximum removal efficiency of oil is equal =94% with uses polyacrylamide as a chemical coagulant is more than DAF with uses alum coagulant R%=89, for C_o=50ppm and alum dosage=30ppm. But the treatment of wastewater by DAF with addition combination of coagulants polyacrylamide 15ppm+alum 15ppm improvement removal efficiency of oil to R%=98.96 .

c. Removal oil from wastewater by DAF with adding chemical coagulants, resulted water have residual oil concentration less than 1ppm, agreement with an allowable limit which decided by WHO, then this water can be reuse or discharge to the river.

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