Treatment of Oily Wastewater Using Dissolved Air Flotation Technique

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ABSTRACT

Oil/water emulsion is found in the wastewater effluent streams coming from various sources such as the petroleum refineries, the discharge of bilge and ballast water, workshops, petrol stations, rolling mills and from edible oil and soap factories. The oil recovery process adopted will depend on how the oil is present in the water stream. Oil can be found as free floating oil, as an unstable oil/water emulsion and also as a highly stable oil/water emulsion. Free oil in wastewater is readily removed by gravimetric separators while unstable oil/water emulsions can be mechanically or chemically separated. Stable emulsions and in particular those involving water soluble oily wastes require sophisticated methods to satisfy treated water legal requirements. This study is dedicated to the application of dissolved air flotation (DAF) for the removal of emulsified oils from oily wastewater. A dissolved air flotation unit has been designed for this purpose and the ultimate goal is to explore the technical viability of this technique. The design and then construction of the dissolved air flotation pilot plant has been conducted to treat 1.0 m^3/hr of oily wastewater. The performance of the DAF system has been investigated using synthetic oil emulsions and true wastewater where three different types of oil have been managed. The various operating conditions have been tested to define the most appropriate conditions for processing oil/water emulsions. The effect of coagulant addition on the oil separation in the presence of an emulsifying agent is investigated.

Keywords:

Wastewater, Oil, Dissolved air, Flotation.

Introduction:

Visible oil floating on the surface of rivers, lakes, and seas has always presented esthetic problems whether the quantity of oil is sufficient to interfere with beneficial uses of the water or not. Moreover, heavy films of oil interfere with the natural process of aeration and photosynthesis and thus directly contributing to organic pollution. Edible oils and soap industries are of the largest industrial sectors from which relatively large volumes of complex wastewater are originated. Also, a major part of the wastewater results from cleaning operations as the wash water of filtration equipment, floors and tanks. In the refining processes, the quantity of pollutants in the wash water varies with nature of the operation. Other sources may include spent liquors having chemicals that were used in solvent extraction. Wastewater is discharged either to municipal sewerage systems or directly into surface water receiving bodies. However, on the basis of the harm caused by this wastewater, its treatment must be considered so as to abide with the regulations imposed on water disposal which are becoming increasingly stricter (1).

The separation of oil from an effluent water stream depends on the state of the oil in the carrier stream and this is the main factor affecting the selection of the processing route to be taken to attain the required effluent quality (2,3). Oil can be present as free floating oil where the oil droplets dispersed in the bulk of the carrier fluid are susceptible to gravity separation. For practical purposes, this may be considered as oil having above 30 microns droplet diameter. On the other hand, oil may be present in water as an emulsion. A stable oil/water emulsion is a colloidal system of electrically charged oil droplets surrounded by an ionic environment. This emulsion is of two types; mechanically formed emulsions and chemically stabilized emulsions. The former can be considered as oil droplets of less than 30 μm caused by subjecting the carrier phase to violent mixing and/or mechanical shearing by pumps or pressure reducing valves while the latter occurs when the carrier phase contains surface active agents such as organic materials or cleaners which maintain a stable colloidal system. Anything smaller than the emulsion, can be considered as dissolved or in true solution. In this case the solution has properties less like a two-phase mixture and more like a solution with particle sizes between 0.001 to 1.0 μm (3).

Physical treatment process brings about a change in the properties of the contaminants while the chemical nature of the compounds remains unaffected. The physical properties of the contaminants are manipulated to facilitate the removal of pollutants from the bulk wastewater stream. The physical treatment processes employed for industrial wastewater treatment are gravity separation, air flotation, centrifugation, evaporation, filtration, activated carbon adsorption, air or steam stripping, oil coalescing and liquid/liquid extraction. Gravity separation is applied for the treatment of wastewater streams where contaminants can be separated from the bulk waste stream as a result of their specific gravities being higher or lower than that of water which is 1.0. Waste having a specific gravity in the range of 0.8 to 0.95 is separated into an upper floating layer while a specific gravity in the range of 1.05 to 2.6 is to settle into a bottom layer (4). The heavier or lighter the constituent the faster is its settling to the bottom or its floating to the surface.

In centrifugal separators a specific gravity difference between the pure components should at least be 0.01 and the droplet size of the dispersed phase should be at least 1μm. Evaporation and filtration are employed where the bulk waste stream contains a high concentration of solids. For droplets smaller than 10 μm in diameter, membrane filtration (ultra filtration) can be used where inorganic membranes such as alumina and porous stainless steel are advantageously used for oil/water separation (1,5). Adsorption involves the use of powdered activated carbon in complete–mix reactors or granular activated carbon in fixed or fluidized bed reactors (1) while extraction operations depend on using a suitable solvent.

Chemicals are commonly used for the treatment of oily wastewater to enhance mechanical treatment. It is used to precipitate emulsifying agents, to affect the interfacial tension, to neutralize electrical charges and to adjust the pH. In breaking emulsions, the stabilizing factors must be neutralized to allow the emulsified droplet to coalesce. The accumulated electric charges on the emulsified droplets are neutralized by introducing a charge opposite to that of the droplet. The chemical treatment of oily wastewater first involves the destruction of the emulsifying properties of the surface-active agent or the neutralization of the charged oil droplets followed by the agglomeration of the neutralized droplets into large separable globules.

Dissolved air flotation technique; Oily material entrained in wastewater can become mechanically emulsified by turbulent mixing, pressurization or centrifugal pumping. Emulsified material will not separate out rapidly because the material has been dispersed so finely into the bulk waste stream that a stable suspension occurs. This dispersed oil can be removed using dissolved gases in the form of micron-size bubbles which form agglomerates from finely dispersed particles. The introduction of air bubbles reduces the overall specific gravity of the agglomerates and thus the agglomerated material floats to the surface where it forms a scum layer that can be removed by skimming. Thus, dissolved air flotation (DAF) is an accelerated gravitational separation. In the DAF, air under pressure is introduced at the bottom of an open basin and as the air bubbles rise to the top of the basin, agglomerated material floats to the surface. In other DAF configurations, the wastewater itself is pressurized and supersaturated with air then the wastewater pressure is allowed to be reduced to atmospheric conditions causing the excess dissolved gases in the wastewater to float to the surface. Air flotation is most effective when the air bubble size is small – 2 mm is typical.

Air flotation is used to accelerate and enhance the gravitational technique bringing oil to the surface of oil–water mixtures. In this process, microscopic oil droplets are converted into microscopic air/oil bubbles that have a lower density than oil micelles and micro-emulsions. Air /oil bubbles therefore rise to the surface much more quickly than do emulsion droplets. There are two basic methods for dispersing air bubbles through waste streams; induced air flotation

(IAF) and dissolved air flotation (DAF). In the IAF, air is drawn down the shaft of a rotor in the flotation chamber where it is dispersed into the effluent through a diffuser pipe or an aspirator or through educators (1, 3). The air/water contact occurs essentially at atmospheric pressure and air bubbles are entrained in the water rather than being formed in the water. A motor driven self-aerating rotor mechanism is used. The spinning of the rotor acts as a pump which forces water through the dispersed ion creating vacuum in the standpipe. This vacuum sucks air into the standpipe and mixes it with the water. The typical bubble size in IAF system is 1000 μm and the residence time is between 4 and 6 minutes.

In dissolved air flotation systems (DAF), air is dissolved in the wastewater stream under pressure. The air solubility decreases when the pressure is released by entering the waste into the tank through a restriction orifice. The result is the formation of microscopic air bubbles and air/oil bubbles rise and collide with oil droplets speeding their recovery at the surface. Wastes are normally pressurized to about 2.06 to 2.76 bar and retained at this pressure for a minute. The size of the produced bubbles varies from 10 to 120 μm. These bubbles are effective at removing even smaller oil droplets, but require high residence time for efficient separation for as long as 20 to 30 minutes.

There are three basic flow systems for the DAF process. The first is a full flow pressurization system in which the entire influent feed stream is pressurized by a pressurizing pump and held in a retention tank. Another system is the partial flow pressurization without effluent recycle systems where only about thirty to fifty percent of the effluent feed stream is pressurized and held in a retention tank. Remaining portion of the influent stream is fed by gravity or low pressure pump to the inlet compartment of the flotation chamber where it mixes with the pressurized portion of the influent stream. There is also the recycle flow pressurization system in which a portion (15-30 %) of the clarified effluent from the flotation chamber is recycled, pressurized and supersaturated with air in the retention tank. The recycled flow is mixed with the unpressurized main influent stream just before admission into the flotation chamber with the result that the air bubbles come out of aqueous phase in contact with the suspended matter at the inlet of the flotation chamber and this is the flow system selected in this study.

Theoretical aspects of DAF operation:

According to Henry's law, the solubility of gas (air) in an aqueous solution increases with the increase in pressure. The influent feed stream is saturated at several times atmospheric pressure (25 to 70 psig) by a pressurizing pump. The pressurized feed stream is held at this high pressure for about (0.5 to 3 minutes) in a pressure retention tank designed to provide sufficient time for dissolution of air into the treated stream. Following the pressure retention tank, the stream is released backed to atmospheric pressure in the flotation chamber. Most of the pressure drop occurs after a pressure reducing valve and in the transfer line between the retention tank and the flotation chamber so that the turbulent effects of the depressurization can be minimized. The sudden reduction in pressure in the flotation chamber results in the release of microscopic air bubbles which attach themselves to suspended or colloidal particles in the processed water in the flotation chamber. This results in agglomeration which due to the entrained air gives a net combined specific gravity less than that of water causing the required flotation.

Flotation phenomena can occur by: (a) air bubbles adhering to the insoluble solids by electrical attraction (b) air bubbles becoming physically trapped in the insoluble solids or flocculent structure (c) air bubbles becoming chemically adsorbed to the insoluble solids or flocculent structure. The floated material rises to the surface of the flotation chamber forming a floating layer and skimming devices continuously remove the floated material. The surface sludge layer, which in certain cases attains a thickness of many inches, can be relatively stable and is drawn from the bottom of the flotation chamber recovered either for reuse or for discharge. The retention time in the dissolved air flotation chambers is usually about 3 to 6 minutes for modern flotation units and 20 to 60 minutes for conventional flotation units depending on the characteristics of the process water and the performance of the flotation unit.

Design of flotation chamber with a recycle flow pressurization system:

The design parameters for the flotation chamber are as follows:

I) Air to oil ratio (A/O);The performance of a dissolved air flotation unit will be mainly dependent on the ratio of the amount of gas applied to the unit to the amount of oil and grease. It thus controls the amount of air used and the design of the pressure vessel. It can be calculated according to following relation:

$$\frac{A}{O} = \frac{S}{C} . R.(FP-1) \qquad (3,5,6) \text{-----------------------} \{1\}$$

where:

A : Air released for flotation of oil and grease, mg/sec.

O : Mass flow rate of oil and grease entering the flotation system.

S : Solubility of air in the flotation effluent, mg / lit = 0.0209 (7)

C : Concentration of oil & grease in waste stream , mg/lit.

R : Recycle ratio (recycled rate per inlet flow rate).

F : Fraction of saturation of air in water in pressure vessel (Assumed to be 0.8 at STP (7).

P : Pressure applied in pressure vessel, 4.8 bar (3,7)

II) Hydraulic load; Dissolved air flotation is a process that uses minute air bubbles which upon attachment to a discrete particle reduce the effective specific gravity of the aggregate particle to less than that of water. Reduction of the specific gravity for the aggregate particle causes separation from the carrying liquid in an upward direction. Figure (1) suggests that the particle to be removed may have a natural tendency either to rise or to settle. Attachment of the air bubble to the particle induces a vertical rate of rise noted as V_T . Figure (2) illustrates the basic design considerations of the flotation unit. Since the influent feed stream must pass through the flotation chamber, the particle to be removed will have a horizontal velocity. Certain criteria have been established for the limits of the parameter V_H ,which sets the width and depth of the flotation chamber.

$$VH = (Q+R)/Ac \text{ ---------------------------- } \{2\}$$

where:

Q : Influent flow rate, m3/sec

A_c : Cross sectional area of flotation chamber, m^2

Figure (1) suggests that the effective length (L) of the flotation chamber is directly proportional to the horizontal velocity and depth and is inversely proportional to the vertical rate of rise of the particle to be removed. In the design of the flotation chamber, the procedure is to select th target oil to be removed with a rise rate of VT and design the chamber so that all oil and grease that have a rise rate equal to or greater than VT will be separated. The oil must have sufficient rise velocity to travel the effective depth (the distance from the bottom to the water surface of the flotation chamber) within the detention time in order to be floated. That is the rise rate VT must be at least equal to the effective depth divided by the detention time or equal to the flow divided by the surface area:

$$V_T = D/T = (Q+R)/A_s \text{ -------------------------------- } \{3\}$$

where:

V_T : Vertical rise rate of oil and grease, m /sec

D : Effective depth of flotation chamber, m

T : Detention time, sec

A_s : Surface area of flotation chamber, m^2

The ratio of $(Q+R)/A_S$ is also defined as the hydraulic loading rate. Theoretically, any particles having a rise rate equal to or greater than the hydraulic loading rate will be removed in an ideal flotation chamber.

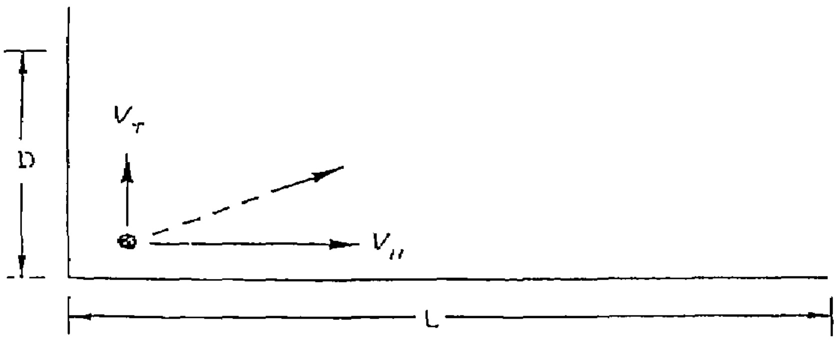

Figure (1) Basic design concept of flotation unit(V_T=vertical rate of rise, V_H= horizontal velocity and L= length of treatment unit)

For rectangular shape flotation chamber, The width (W) and effective length (L) can then be determined as follows:

$$W = A_C / D \text{ --- } \{4\}$$

$$L = (A_S / W)\ \eta = (V_H / V_T)\ \eta\ D \text{ ------------- } (5)$$

where:

η : Factor for short circuiting and turbulence, assumed as 1.4 (7)

The range of hydraulic load is 117,000 – 290,000 Lpd/m^2 (3) .The increasing of load leads to a higher floatation chamber and a higher efficiency.

III) Retention time in flotation chamber; The optimum retention time was found by laboratory scale experiments to be 20 minutes.(6)

Dissolved Air Flotation Pilot Plant:

Figure (2) shows the main components of the pilot plant containing the following items:

1- Flotation chamber

2- Retention chamber (pressure vessel)

3- Two storage tanks which include:

a- Influent storage tank

b- Effluent storage rank

4- Pumps for the (DAF) system which include:

a- Pressure pump between effluent tank and pressure vessel (Recycle pump).

b- Flow pump between influent tank and clarifier to adjust the flow of the wastewater stream to the floatation chamber.

Technical specifications of the pilot plant; The pilot plant was designed and constructed according to the following data:

Feed flow rate = 1 m^3/hr, Percent recycle = 30 % ,Hydraulic load = 120,000 Lbd/m^2, Air to oil ratio = 0.118 ,Retention time of flotation chamber = 20 min. and retention time of pressure vessel = 2.0 minutes

Accordingly, the established pilot plant has the following specifications:

Size of influent tank = 1.0 m x 1.0 m x 1.1 m

Rapid mixer installed in influent tank has the following specifications:

a- 1.5 HP motor (1400 rpm)

b- Paddle mixer diameter 13 cm

Size of flotation chamber = 0.5 m width x 1.0 m length x 1.6 m height

Size of effluent tank for treated water = 1.0 m x 1.0 m x 1.1 m

High pressure pump has the following specifications:

a- 0.5 HP motor,

b- Flow rate = 5 lit/min

Experimental Investigation:

In this study the dissolved air flotation system has been applied as an oil recovery technique from wastewater emulsions.

Procedure; The synthetic oil emulsion or the pretreated wastewater is to be prepared and the flow rate is adjusted as required by collecting a certain volume during a period of time (t) while the flow rate of air is adjusted as required by using a rotameter and a by-pass valve. The influent tank is filled with 900 liters of wastewater while the clarifier (flotation tank) is filled at the start of the run with about 450 liters of clean water and the effluent tank is filled with 75 liters of clean water. After 29 minutes from starting, all clean water in clarifier and effluent tank is replaced by treated water and the system then reaches steady state. Thus, samples of treated water could be collected and analyzed.

Experimental work; The experimental work for the wastewater treatment was conducted while varying the different parameters as shown in table (1)

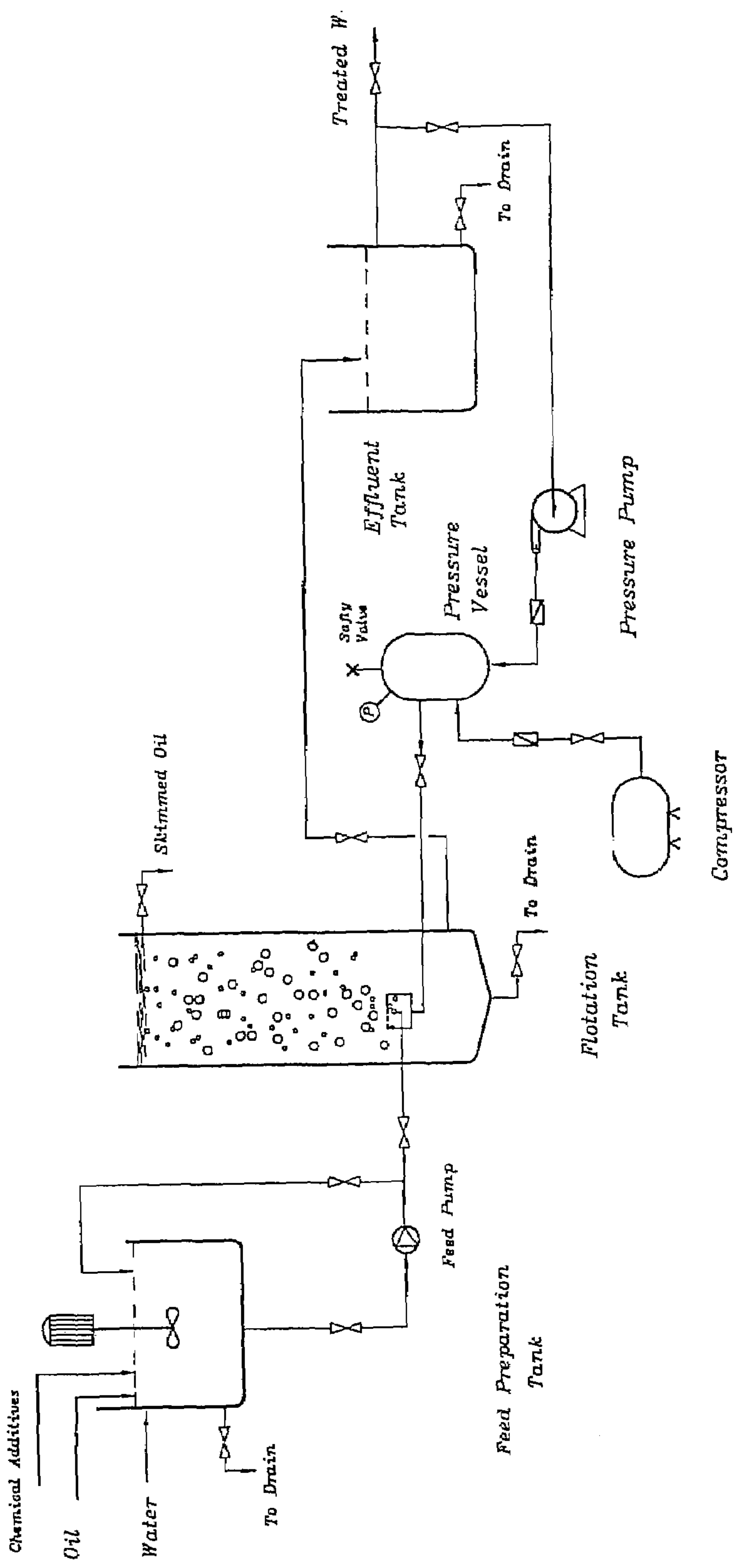

Figure (2) Pilot plant for dissolved air flotation experimental set up

Table (1) Parameters affecting the DAF performance

Parameter	Range	Notes
Oil concentration	100 – 1000 ppm	
Flow rate * Influent flow rate * Recycle flow rate	 4 – 17 lit/min. 1.2 – 5.1 lit/min.	Retention time in clarifier changes from 20 to 60 min. and in pressure vessel from 2.0 to 3.0 min.
pH value	1.5 - 12	Expected range for wastewater from oil and soap factories.
Soap content	0 – 300 ppm	
Alum dosage	0 – 150 ppm	Typical doses.
Oil type	Cotton oil, Corn oil, Car oil	Two vegetable oils and one mineral oil.

Analysis; Treated water is analyzed by measuring its chemical oxygen demand (COD) and its oil and grease (O&G) content. COD values were obtained by the closed reflux calorimetric method using the apparatus (HACH DR2000).

Oil and grease values were measured using the same calorimetric method. Measurement was based on the extraction of the remaining emulsified oil in the treated wastewater with 1-1-1, tri chloro ethane as a solvent, and then the O & G content in the solvent layer is measured.

Results and Discussion:

The effect of the operating variables; feed concentration, flow rate, pH, emulsifier concentration and alum addition on the efficiency of separation has been studied.

Effect of oil concentration; These experiments are executed at the designed flow rate 1.0 m^3/hr, pH 7, recycle 30%, retention time in clarifier 20 minutes while the time in the pressure vessel is 3 minutes. Results obtained are tabulated below:

Table (2): Effect of oil concentration in water on separation efficiency of cotton oil

Initial oil concentration, mg/lit	Initial COD, mg/lit	Final oil concentration, mg/lit	Final COD, mg/lit	Oil removal, %	COD variation, %
100	356	13	50	87	83
200	507	36	90	82	80
300	658	75	130	75	71
500	961	155	300	69	68
700	1265	252	586	64	54
1000	1718	400	810	60	52

Table (3): Effect of oil concentration in water on separation efficiency of corn oil

Initial oil concentration, mg/lit	Initial COD, mg/lit	Final oil concentration, mg/lit	Final COD, mg/lit	Oil removal, %	COD variation,%
100	405	31	154	69	62
200	770	64	316	68	61
300	940	105	395	65	58
500	1270	190	559	62	56
700	1605	280	770	60	52
1000	2105	430	1074	57	49

Table (4): Effect of oil concentration in water on separation efficiency of car oil

Initial oil concentration, mg/lit	Initial COD, mg/lit	Final oil concentration, mg/lit	Final COD, mg/lit	Oil removal, %	COD variation,%
100	290	20	70	80	76
200	465	44	126	78	73
300	740	75	215	75	71
500	980	145	314	71	68
700	1210	217	448	69	63
1000	1561	350	640	65	59

Referring to tables 2, 3 and 4, it is shown that the oil separation increases as oil concentration decreases for all types of oil; 60 to 87 % for cotton oil, 57 to 69 % for corn oil and 65 to 80 % for car oil. *It is clear that cotton oil has the best efficiency of separation.*

This is attributed to the specific gravity where cotton oil has the lowest specific gravity compared to that of water followed by car oil while corn oil has the nearest specific gravity to water (Fig.3).

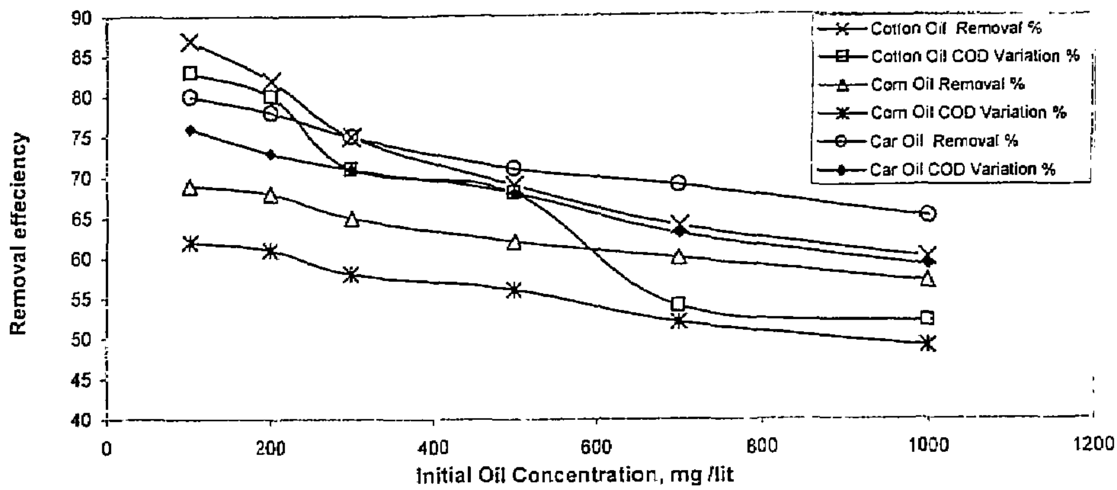

Figure (3): Effect of Initial Oil Concentration on Oil Removal Efficiency and on COD Value

Effect of pH; The effect of pH on the oil separation was studied where experiments were carried out at different pH values and at an initial oil concentration of 1000 mg/lit, initial COD 1718 mg/lit, influent flow rate $1m^3$, recycle 30 % and the obtained results are shown in tables (5,6 and 7).

Table (5): Effect of pH on cotton oil separation.(Initial oil content = 1000 mg/lit)

pH	Final oil concentration, mg/lit	Final COD concentration, mg/lit	Oil removal, %	COD variation , %
1.5	260	636	74	63
3	330	722	67	58
7	400	810	60	52
10	490	980	51	43
12	660	1117	44	35

Table (6): Effect of pH on corn oil separation. (Initial oil content = 1000 mg/lit)

pH	Final oil concentration, mg/lit	Final COD concentration, mg/lit	Oil removal, %	COD variation, %
1.5	290	737	71	65
3	360	968	64	54
7	430	1200	57	43
10	550	1347	45	36
12	630	1452	37	31

Table (7): Effect of pH on car oil separation. (Initial oil content = 1000 mg/lit)

pH	Final oil concentration, mg/lit	Final COD concentration, mg/lit	Oil removal, %	COD variation, %
1.5	180	375	82	76
3	240	515	76	67
7	350	640	65	59
10	470	812	53	48
12	600	983	40	37

It is observed that lowering the pH from the alkaline to the neutral medium remarkably increases oil separation. Further, the decrease of pH enhances the efficiency of separation in a small range. At a pH of 10, the separation efficiency is in the range 45 to 53 %. At normal pH the efficiency range from 57 to 65 % while at a pH of 3, it changes between 64 to 76 %.

Lowering the oil removal efficiency may be explained by the increase in the surface potential of the emulsion droplet on increasing the pH due to the absorption of $(OH)^-$ ions at the oil-water interface thereby increasing the repulsion between the surface and hindering of oil droplets in the clarifier (3 ,8) (Figure 4).

Table (8): Effect of flow rate on cotton oil separation

Influent flow rate, lit/min.	Recycle flow rate, lit/min	Retention time in clarifier, min.	Final COD, mg/lit	Final oil, mg/lit	Oil removal,%	COD variation,%
4	1.2	80	482	170	83	72
8	2.4	40	618	250	75	64
12	3.6	25	739	340	66	57
16	4.8	20	825	400	60	52

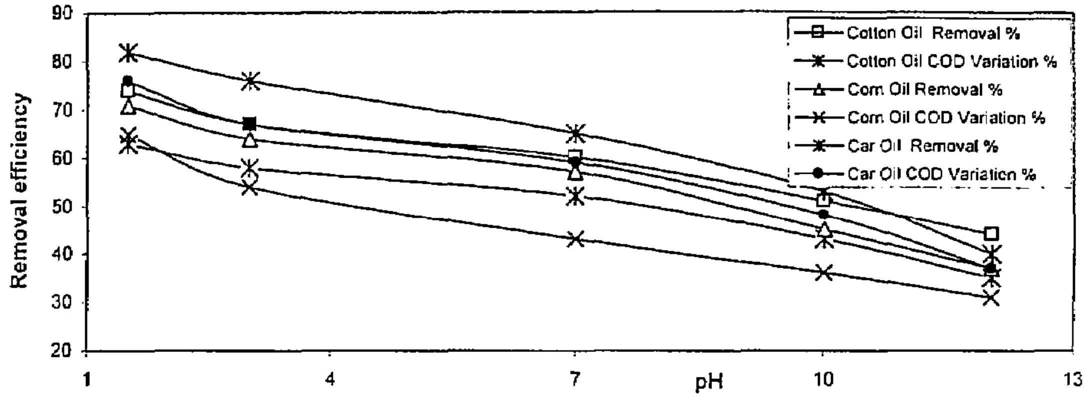

Figure (4): Effect of pH on Oil Removal Efficiency and on COD Value

Effect of flow rate; It is clear that the separation of oil droplets seems to be strongly affected by the flow rate and hence the retention time of flotation and this is shown in tables 8,9 and 10. Initial concentration is 1000 mg/lit and initial COD is 1718 mg/lit.

Table (9): Effect of flow rate on corn oil separation.

Influent flow rate, lit/min.	Recycle flow rate, lit/min	Retention time in clarifier, in	Final COD, mg/lit	Final oil, mg/lit	Oil removal,%	COD variation,%
4	1.2	80	505	130	87	76
8	2.4	40	758	210	79	64
12	3.6	25	926	320	68	56
16	4.8	20	1074	430	57	49

Table (10): Effect of flow rate on car oil separation.

Influent flow rate, lit/min.	Recycle flow rate, lit/min	Retention time in clarifier,min	Final COD, mg/lit	Final oil, mg/lit	Oil removal,%	COD variation,%
4	1.2	80	328	100	90	79
8	2.4	40	468	220	78	70
12	3.6	25	609	310	69	61
16	4.8	20	640	350	65	59

Variation of the flow rate from 16 lit/min. to 4 lit/min., increases the efficiency of separation from 60 to 83 % for the cotton oil, 57 to 87 % for the corn oil and 65 to 90 % for the car oil. Decreasing the flow rate, results in increasing the separation efficiency for the different oil types and thus enhances the DAF performance. If the flow rate is too high, oil will be entrained in the discharge flow instead of floating to the top of the chamber with the air (Figures 5).

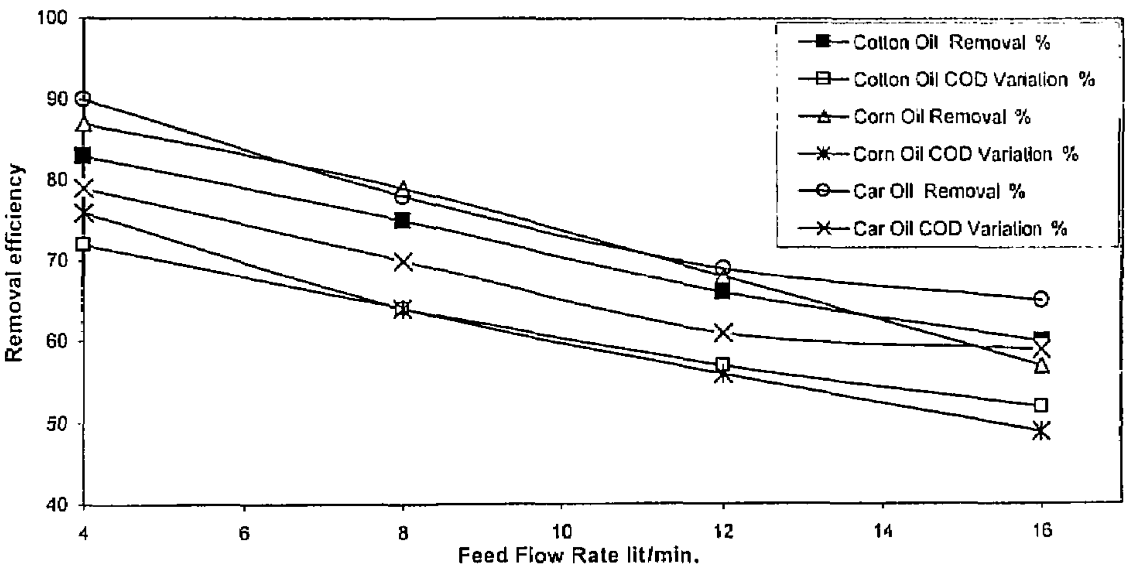

Figure (5): Effect of Flow Rate on Oil Removal Efficiency and on COD Value

Emulsifier effect; The initial oil content is 1000 mg/lit, pH is 7, influent flow rate is $1 m^3$ and recycle is 30%. The oil separation decreases on adding soap as an emulsifying agent as shown by the results obtained in tables 11,12 and 13. Increasing the dose of the emulsifier for both cotton seed oil and corn oil to 400 mg/lit, decreases the efficiency of separation to zero. This is attributed to the effect of soap on oil molecules forming a chemical emulsion that is hardly broken by the DAF system (Figure 6).

Table (11): Effect of emulsifier on cotton oil separation.

Soap content, mg/lit	Initial COD, mg/lit	Final oil content, mg/lit	Final COD, mg/lit	Oil removal, %	COD variation, %
0	1718	400	810	60	52
50	1724	470	1017	53	41
100	1730	520	1125	48	35
200	1757	600	1300	40	26
300	1795	900	1741	10	3
400	1810	1000	1810	0	0

Table (12): Effect of emulsifier on corn oil separation.

Soap content, mg/lit	Initial COD, mg/lit	Final oil content, mg/lit	Final COD, mg/lit	Oil removal, %	COD variation, %
0	2105	430	1074	57	49
50	2112	490	1309	51	38
100	2125	550	1509	45	29
200	2147	700	1760	30	18
300	2169	870	2044	13	7
400	2198	1000	2198	0	0

Table (13): Effect of emulsifier on car oil separation.

Soap content, mg/lit	Initial COD, mg/lit	Final oil content, mg/lit	Final COD, mg/lit	Oil removal, %	COD variation , %
0	1718	400	810	60	52
50	1724	470	1017	53	41
100	1730	520	1125	48	35
200	1757	600	1300	40	26
300	1795	900	1741	10	3
400	1810	1000	1810	0	0

Enhancing oil removal by adding a chemical de-emulsifier; In the presence of surfactants or other chemical pollutants, the oil separation using the DAF system is affected. To overcome this problem, alum is selected as a coagulant and the experiments for coagulant addition are conducted at the critical circumstances of separation encountered. The initial oil content is 1000 mg/lit, initial COD is 1718 mg/lit, influent flow rate is 1 m^3/hr and recycle is 30 %. The effect of coagulant addition is studied in absence and in presence of the emulsifier and results are as shown in tables 14, 15,16,17 and 18. In case of cotton oil, alum increases the separation from 60 to 90 % in case of mechanically emulsified oil in water while it increases the separation from 48 to 89 % for

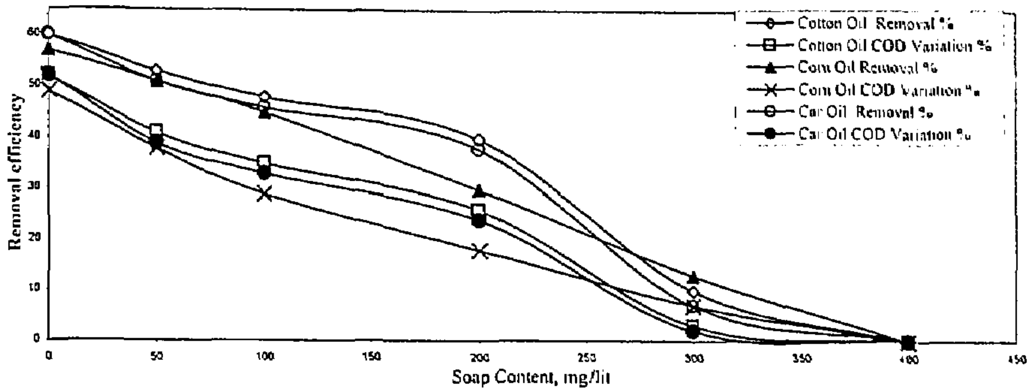

Figure (6): Effect of Soap Addition on the Oil Removal Efficiencyand on COD Value

Table (14): Effect of alum dose on cotton oil separation (No soap)

Alum dose, mg/lit	Final oil, mg/lit	Final COD, mg/lit	Oil separation, %	COD variation, %
0	400	810	60	52
25	320	704	68	59
50	200	550	80	68
75	160	412	84	76
100	100	326	90	81
150	180	498	82	71
200	250	636	75	63

Table (15): Effect of alum dose on cotton oil separation (100 mg/lit soap)

Alum dose, mg/lit	Final oil, mg/lit	Final COD, mg/lit	Oil separation, %	COD variation, %
0	520	1125	48	35
50	440	986	56	43
100	180	536	82	69
150	110	380	89	78
200	190	571	81	67
250	270	709	73	59

chemically emulsified oil due to the added soap. Figure (7) shows the effect of the coagulant addition without soap while Figure (8) shows the effect with addition of soap.

The effect of alum addition on corn oil separation was carried out using an initial oil content of 1000 mg/lit, , pH 7, influent flow rate 1 m^3/hr and recycle is 30 %. Alum increases the separation from 57 to 91 % for mechanically emulsified oil and has a critical alum dose of 150 mg/lit while in case the mixture is chemically emulsified with soap, the alum increases the separation from 45% to 89 % and the critical dose is 250 mg/lit.

Table (16): Effect of alum dose on corn oil separation (No soap)

Alum dose, mg/lit	Final oil, mg/lit	Final COD, mg/lit	Oil separation, %	COD variation, %
0	430	1074	57	49
25	330	947	67	55
50	260	863	74	59
75	200	674	80	68
100	140	568	86	73
150	90	421	91	80
200	160	631	84	70
250	230	779	77	63

Table (17): Effect of alum dose on car oil separation (100 mg/lit soap)

Alum dose, mg/lit	Final oil, mg/lit	Final COD, mg/lit	Oil separation, %	COD variation, %
0	550	1509	45	29
25	500	1445	50	32
50	360	1275	64	40
100	300	1105	70	48
150	250	1041	75	51
200	190	850	81	60
250	110	680	89	68
300	180	786	82	63

The alum addition has the effect of increasing separation of car oil from 65 to 92 % and from 19 to 80% for mechanically and chemically emulsified oils, respectively.

Alum ions are absorbed at the oil/water interface and this increases the hydrophobicity of the droplets at the surface. Consequently, the electrostatic potential at the aggregate surface is lowered in the presence of more hydrophobic ions decreasing the repulsive double layer interaction which acts as a barrier for flocculation. The decrease in the separation observed at higher alum dosages may be due to that more ions are absorbed_at the oil/water interface compared to the number of soap emulsifier ions (9). This recharging of the droplet interface promotes emulsion stability.

Table (18): Effect of alum dose on car oil separation

Alum dose, mg/lit	Oil separation without soap, %	Oil separation with soap, %	COD variation without soap, %	COD variation with soap, %
0	65	19	59	11
25	77	45	68	36
50	85	77	77	64
75	92	80	83	71
100	82	75	74	60
150	76	69	65	57

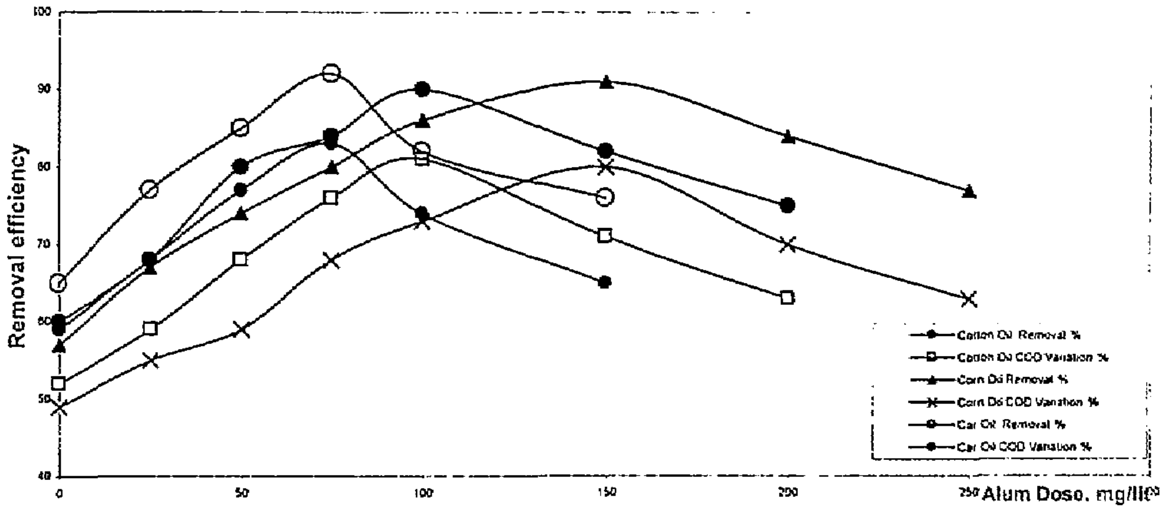

Figure (7): Effect of Alum Addition on Oil Removal Efficiency and on COD Value (No Soap)

Conclusions and Recommendations:

This work has been directed towards exploring the effect of different operating variables on the efficiency of oil coalescing systems. The study included bench–scale investigations for synthetic oily water and the investigated variables included oil concentration, flow rate , pH, chemical de-emulsifier additions in presence and absence of soap. Further, results have been tested using real oily wastewater and the findings were compared favorably well. Results revealed the following:

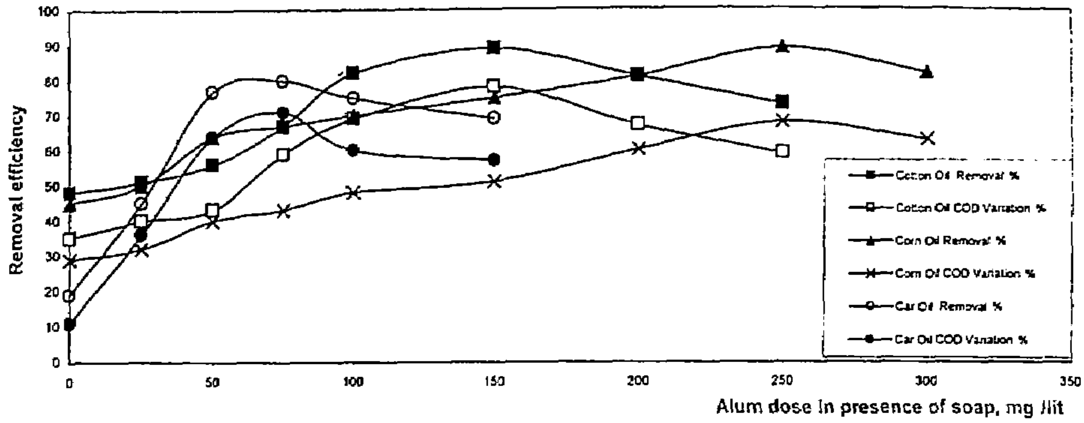

Figure (8): Effect of Alum Addition on Oil Removal Efficiency and on COD Value (100 mg soap/lit)

a- Oil concentration in water affects the oil removal and the investigation showed that the separation efficiency decreases by increasing the oil concentration.

b- Oil removal efficiency is directly affected by flow rate where the separation increases by decreasing the flow rate.

c- Oil separation efficiency tends to be enhanced in the neutral to acidic range.

d- An increase in soap concentration tends to decrease the oil separation efficiency of the DAF system due to the emulsifying effect of soap.

e- Addition of alum tends to improve the oil removal from wastewater.

Based on a case study for the wastewater obtained from the Egyptian Oil and Soap factory, a technical and economic evaluation for oily wastewater treatment is carried out. It proposed an oil recovery plant including: screen, equalization tank, gravity oil separator, coagulation unit and dissolved air flotation unit. Preliminary cost estimation for 1000 m^3/day for inlet concentration of 200 mg/lit oil indicates that the total capital investment is $ 500,000 and the operating cost per m^3 of wastewater is $ 0.22 (10,11).

REFERENCES:

[1] - Frank N. Kemmer; The Nalco Water Handbook, McGraw Hill, New York ,1993.

[2] - Pray, H.A.; Water Treatment Plant Design, American Water Work Association,1996.

[3] - Milos Krofta and Lawrence K. Wang; ;Design of DAF System, Technical paper presented at the International Meeting of ATCE, March,1983.

[4] – David H.F .and Bela G. Liptak ;Wastewater treatment, Lewis Publishers, New York, 2000.

[5] - Milos Krofta and Lawrence K.Wang; 'Flotation Technology and Secondary Clarification, Tappi Journal, April 1987.

[6] - James P. Malley; Laboratory Comparison of DAF with Conventional Treatment, Research and Technology, 1984.

[7] - Philip A. Schweitzer; Handbook of Separation Technique for Chemical Engineering', McGraw Hill, New York ,1986.

[8]- Ralph L. Stephenson; The Industrial Wastewater Systems Handbook, Lewis Publishers, New York, 1998.

[9]- Paul N. Cheremisinaff; Handbook of Wastewater Treatment, Marcel Dekker Inc.,1990.

[10] Perry, R .H. et al., Chemical Engineers Handbook,7Th edition, McGraw Hill, New York,1997.

[11]-Peters and Timmerhaus, Plant Design and economics for chemical engineers , McGraw Hill, New York 1991.