Pulp and Paper Wastewater Treatment and Fiber Recovery Using a Flotation System

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ABSTRACT

This work is concerned with applying a dissolved air flotation technique for the treatment of wastewater obtained from the pulp and paper industry factories. Experiments have been done on the pilot scale unit to determine the optimum operating conditions that the dissolved air flotation (DAF) process should be held at. The factors on which the effectiveness of the flotation process depends are the inlet air flow rate, air pressure, wastewater fiber content and the coagulant added to the wastewater. The mostly used coagulants in the water treatment processes are aluminum sulfate (Alum) [$Al_2(SO_4)_3.18H_2O$], ferric chloride [$FeCl_3$] or anionic polyelectrolyte. The impact of these factors on both the percentage removal from the wastewater and the outlet water characteristics such as total suspended solids, settleable solids, turbidity, conductivity and dissolved solids were determined for monitoring the treating system. This work investigated a case study for the treatment of wastewater from a paper production company in Egypt and also the cost of this treatment.

Keywords: Wastewater, fiber, air flotation.

Introduction

All over the world there exist industries involving the release of large quantities of wastewater. In the past, this wastewater was drained to sewage networks or to surface receiving waters as rivers, canals or seas. But after the great technology progress taking place and due to the restrictions imposed by the environmental government laws, studies have been undertaken to analyze the water to determine its content and its consequent effect and then further to decide how to manage this water. In many cases industrial water was found to be rich in valuable material that can be separated and recycled[1].

On the other hand, other industries have wastewater containing toxic matter that must be treated and drained to sewage. Re-use of treated wastewater in various industries is becoming very popular being a cheaper source of water supply and can also be used for irrigation[2].

Work aiming at separation of different materials from wastewater has developed various techniques as sedimentation, screening, filtration and dissolved air flotation (DAF) methods. The dissolved air flotation is a process for the removal of fine suspended material from an aqueous suspension. It is a gravity separation system that uses air bubbles in a wastewater holding tank to help the flotation of insoluble material to the surface after which such material is removed.

Dissolved air flotation provides the needed energy for effective flotation in the form of extremely fine air bubbles which become attached to the suspended material. The attraction between the air bubbles and the particles is a result of being physically entrapped in the particle or due to adsorption forces that are a function of the characteristics of the particle surface. This attachment of bubbles to the particles reduces the density of the particles resulting in an increase in buoyancy causing flotation.

The most reliable method for producing bubbles of the proper size is to dissolve air into water under pressure and then the pressure of the solution is reduced where air comes out of solution in the form of micro size bubbles leading to the flotation of the fine particles to the surface in the clarifier. The DAF unit can be used where water treating applications will be required as in case of algae removal, chemical processing plants, heavy metal recovery or in pulp and paper, textile and pharmaceutical industries[3].

To design any treating unit, the complete analysis of the wastewater is needed and thus the characteristics of this water are to be determined. Accordingly, the undesirable pollutants present are determined. Industrial wastewater discharged from industries and associated processes result in large quantities of water. Water is used in industrial cooling, product washing, product generation and other processes [1]. Water used for process operations (non-cooling purpose) can become degraded by introducing nutrients, suspended sediments, bacteria, oxygen-demanding matter and toxic chemicals. The extent of pollutant (contaminant) loading depends on the nature of the industry[7].

The wastewater contains undesirable constituents as soluble organics which cause the consumption of dissolved oxygen. The suspended solids in wastewater impair the normal aquatic life and will undergo progressive decomposition resulting in oxygen depletion and the production of toxic gases.

The origin of wastewater from the pulp and paper industry using recycled paper may be from mixing with water, refining, fiber washing and screening. The major characteristics are dissolved solids, suspended and colloidal particles and the color. The most important characteristics of wastewater is its total solids content which is composed of the floating , settleable, colloidal and the dissolved matter. The typical range of suspended solids for wastewaters from the pulp and paper industries is 11.5 – 26 kg/ton [2]. Total solids, suspended solids, biological oxygen demand (BOD) and chemical oxygen demand (COD) are common parameters to be detected. Other important physical characteristics are odor, color, temperature and turbidity.

The total solids content in wastewater is all the matter that remains in the water while settleable solids are those solids that settle to the bottom of a cone-shaped container (Imhoff cone) in 60 minutes period. The colloidal fraction consists of the particulate matter with an approximate size of 0.001 to 1 μm. The dissolved solids portion consists of both organic and inorganic molecules and ions. Turbidity is a measure of the light– transmission of water and is used as another test to indicate the quality of wastewater discharges as well as natural waters with respect to colloidal and suspended matter[6].

Mechanical treatment operations are used to retain the coarse solids found in wastewater using screening elements. Different types of screens are designated as coarse or fine according to the size of their openings [3]. Corrugated plate interceptors CPI are replacing API (American Petroleum Institute) separators being more efficient for oil-water separation in many industries. Sedimentation is used as a physical treatment for the separation of suspended particles (organic and inorganic) heavier than water by gravity settling; separation of grit and particulate matter in the primary settling basin, biological floc in the activated sludge settling basin and chemical floc when the chemical coagulation is used in thickeners. The settling of suspended particles depends on their nature, concentration and the condition of the settling device. Coalescence is used to remove low concentrations of free and emulsified oil where the device is composed of beds of oleophilic material as resins, shells or plastics. This oleophilic material attracts oil droplets and coalesces the oil into large drops which rise to the surface [4].

Industrial wastewater often contains acidic or alkaline components which require neutralization before discharge. A pH between 6 and 9 is specified for water by regulating agencies before its discharge into receiving waters. Neutralization is accomplished through the use of waste streams or cheap chemicals. Controlled sulfuric acid additions or caustic soda solutions can be used. Oxidants are used in wastewater treatment to oxidize organics as a first step in the removal of heavy metals or as a last step to oxidize compounds such as hydrogen sulfide or inorganic compounds such as cyanides. Air is the least expensive and most common oxidant. Coagulation used for water treatment takes place in a rapid or in a flash mix basin where the coagulant is dispersed so that it comes into contact with all of the wastewater. The chemical theory assumes chemical reactions between colloidal particles and the chemical coagulant added while the physical theory proposes that the reduction of forces tending to keep colloids apart occurs through the reduction of electrostatic forces. Chemical precipitation in water treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids facilitating their removal by sedimentation. Biological treatment of wastewater includes five major processes; aerobic, anoxic, anaerobic, combined aerobic anoxic and anaerobic/aerobic [2]. An auxiliary operation is the disinfection which aims at the selective destruction of disease-causing organisms. Disinfecion takes place by the use of chemical agents as chlorine, physical agents as heating or lightening and by the use of radiations as electromagnetic gamma rays [1].

Laws regulate the discharge of wastewater according to environmental regulations. These laws aim to protect the environment, seashores and ports from pollution hazards in all their forms as well as to protect the natural resources. Laws also compensate any natural or juridical person for any damage caused due to the pollution of the water. Limits for pollutants in wastewater vary depending on the type of the receiving water body. The parameters that should be determined are pH, temperature, biochemical oxygen demand BOD, chemical oxygen demand COD, total suspended solids TSS, total dissolved solids TDS, oil and grease O&G content and residual chlorine[3].

Dissolved air flotation:

Flotation is used to separate solid or liquid particles from a liquid by introducing gas into the liquid phase. The air-solids mixture has a specific gravity less than water. Air bubbles are formed by introducing the gas phase directly into the liquid phase from a revolving impeller through diffusers. Once the particles have been floated to the surface, they can be collected by skimming using a rotating skimmer blade that removes the floating matter from the surface of the vessel [1]. The advantage of flotation is that very small or light particles that settle very slowly can be removed more completely and also in a shorter time. In the DAF system, air is contacted with an aqueous stream at high pressure. The pressure on the liquid is then reduced through a backpressure valve and hence releasing micro-sized bubbles that sweep suspended solid and oil from the polluted stream to the surface of the air flotation unit. To dissolve air for flotation, three types of pressurized systems may be used of which there is the full-flow (total pressurization) and is used when the wastewater contains large amounts of separable material and intense mixing has no effect on the treatment results. There is the partial-flow pressurization used where the required separation is moderate and the recycle-flow pressurization used for the treatment of material that would degrade by the intense mixing. DAF units may be equipped with a lamella plate which increases the separation area to ensure that even the smallest flocs are removed from the water [4].

Defining the problem:

In the pulp and paper industry a large amount of fibers is wasted into the wastewater which is directly drained and disposed into canals and seas causing environmental problems in addition to its being an economic loss. The DAF unit was to be used for the recovery of the lost fibers from the water. The outlet wastewater from El-Ahlya Company for paper production is discharged to non-agricultural drains and is discharged after that to Mediterranean Sea through Abu Quir rising station. In this work, we study the use of the DAF system for recycling of the fiber and hence the treatment of this waste stream.

Experimental work

Design of the dissolved air flotation system (DAF) system:

The DAF unit consists mainly of an influent tank equipped with a mixer, pipe flocculator, clarifying chamber, an effluent tank and a pressure retention vessel in addition to two pumps (Fig. 1). The first pump is installed between the feed tank and the clarifying chamber while the second pump is installed between the effluent tank and the retention vessel [5]. In order to design a flotation chamber, parameters as the air to solid ratio, hydraulic load and retention time are to be considered. To control the air/solid ratio in the flotation chamber, the operator has to adjust the recycle flow or the operating pressure or both. The retention time is within the range 3-60 minutes[5,9]. The DAF unit was designed to be used as a separation technique for the pulp and paper industry's wastewater. The designed pilot DAF unit sufficient for an operation handling one cubic meter per hour is as follows:

Influent tank: A cubic tank with a side length of 1 m and equipped with a rapid mixer. The mixer has an impeller with a paddle mixer 13 cm diameter, a HP of 1.5 and a speed of 1400 rpm.

Pipe flocculator: Two poly propylene U- tubes connected in series with 2.0 cm nominal diameter.

Flotation chamber: The chamber has a cross sectional area having the dimensions 0.5 x 0.5 m and its height is 2 m.

Effluent tank: Is a regular cubic tank having a side length of 1 m.

Pressure vessel: The vessel is designed according to the minimum concentration encountered. As the volume is inversely proportional to the concentration, a 11 liter stainless steel vessel of thickness 3/16 inch that can withstand up to 10 atmosphere pressure is used.

Supply pumps: The first pump is used to supply a flow rate of one cubic meter of water per hour and is an ordinary pump as that used in washing machines. The second pump supplies the recycle stream to the pressure vessel and has a 0.5 HP, a flow rate 5 lit./min. and a pressure head of 70 psi.

Investigated parameters:

Several parameters have been investigated and the ranges of their variation studied to determine their optimum values are as shown in Table (1) below:

Table (1): Investigated parameters and their ranges applied

Parameter	Range of Variation
Air flow rate	30 - 180 lit/min
Air pressure	2.5 - 5.0 bar
Inlet concentration	650 - 2100 mg/lit
Alum dose	0.4 - 0.6 lit/m^3
Ferric chloride dose	0.3 - 0.5 lit/m^3
Polyelectrolyte dose	0.5- 1.5 lit/m^3

Air flow rate: The flow rate is adjusted by tightening or releasing the valve of the compressor. The influent tank is filled with a suspension and rapid agitation is applied to achieve uniformity of the suspension. The inlet water concentration is determined and is the sum of the TDS and the TSS for a well shaked sample and this concentration as well as the rest of parameters are held constant throughout the experiments in which the air flow rate is changed. The suspension flows to the flotation chamber passing through the diffuser and when the liquid reaches a certain level (3/4 of the height), the air-water pressurized mixture is let to enter the chamber. After about 10 minutes of applying compressed air, the air valve is turned off and the suspension is left for another 10 minutes before taking the sample. The point at which samples were taken was near the chamber bottom. Analysis of this outlet sample was done to determine the outlet TSS, TDS, settleable solids, turbidity, concentration and conductivity. According to the TSS, the removal efficiency is calculated as follows:

$$\text{Removal efficiency} = (TSS_{in} - TSS_{out}) / TSS_{in} \; X \; 100 \; (\%) \quad \text{.........(1)}$$

This procedure was repeated using different air flow rates so as to determine the optimum value.

Air pressure: The air flow rate was held constant at the optimum value determined from the previous procedure. The air pressure was changed in each run and the same previous procedure is repeated to detect the optimum air pressure.

Inlet concentration: Air flow rate and air pressure were held at their optimum values and the same procedure was repeated while changing the inlet concentration of the suspension. This procedure was further repeated to determine the optimum amounts of alum and ferric chloride dose.

Analysis of wastewater:

The total suspended solids value is detected using the Direct Reading Spectrophotometer (DR/2000) in mg/lit. The absorbtometric method used to determine the turbidity of the wastewater measures an optical property of the water sample which results from the scattering and absorbing of light by the particulate matter present and the same device mentioned above is used to determine this characteristic [2]. Settleable solids are also tested and these are solids that will settle to the bottom of a cone-shaped container (Imhoff cone) in a 60 minute period. The conductivity of the sample is measured in μs/cm using a conductivity meter. The total dissolved solids consist of minerals, organic matter and nutrients that are dissolved in water in the form of ions and compounds which can not be observed in water. The value of the total dissolved solids is calculated by multiplying the value of the conductivity of the wastewater sample by a factor of 0.55 according to the calibration curve between the total dissolved solids (TDS) and the electrical conductivity.

Results and discussion

The experiments have been done in order to determine the optimum operating conditions that the DAF process should be held at. The following tables and graphs show the effect of the different factors on each of the treated wastewater characteristics as the removal efficiency, concentration, suspended solids, turbidity, conductivity and dissolved solids.

Effect of air flow rate on the effectiveness of the DAF unit:

The optimum air flow rate required to float solids in a suspension to get a high separation is that which will reduce the density of the resulting air/particle composite below that of water. Table (2) represented on figure (2) shows the effect of the air flow rate on the different characteristics of the outlet water. The percentage removal efficiency (based on the total suspended solids) increases with air flow rate until it reaches a point after which it decreases with air flow rate. This value represents the optimum air flow rate at which the unit should be operated. At this point (90 liter/min) the removal efficiency reaches 75.5%. Furthermore, the total solids TS in the treated wastewater (sum of total suspended and dissolved solids) decreases with air flow rate until it reaches a point after which the outlet concentration increases with air flow rate. This point represents the optimum air flow rate at which the unit should be operated. At this point (90 lit/min), the outlet TS reaches a minimum of 475 mg/lit when the inlet TS is 1230 mg/lit. The air flow rate has a similar effect on the outlet TSS as that on the TS and at the 90 lit/min flow rate, the outlet TSS reaches 245.2 mg/lit. (ppm). The effect of air flow rate on the outlet settleable solids shows some deviation where the optimum air flow rate for this variable is 150 lit/min. however, priority is given to the removal efficiency, and the outlet TS because the settleable solids is relatively of minor importance. The figure shows that the turbidity of the treated wastewater is nearly constant when air flow rate changes from 90 to 120 lit/min where it is minimum at 90 lit/min thus it is better to operate at this flow rate to abide with the removal efficiency and the outlet concentration.

Table (2): Relation between the air flow rate and the characteristics of the outlet water.

Inlet							Outlet						
Air flow rate, lit/min	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity, ms/cm	TDS, ppm	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity ms/cm	TDS ppm	% age Removal
30	1215	1000	220	263.5	430	215	791	576.3	125	150.0	430	215	42.4
60	1230	1000	220	250.0	455	228	735	507.1	88	127.1	455	228	49.3
90	1230	1000	225	262.0	460	230	475	245.2	42	119.8	460	230	75.5
120	1240	1000	220	300.0	490	245	545	300.0	30	120.0	490	245	70.0
150	1230	1000	230	260.0	460	230	575	350.0	16	150.0	450	225	65.0
180	1225	1000	230	255.0	450	225	935	710.0	70	182.7	450	225	29.0

Effect of air pressure on the effectiveness of the DAF unit:

Super saturated air is introduced into the wastewater under a certain pressure, followed by its sudden release to atmospheric pressure causing a froth of bubbles that brings the suspended solids to the surface. The choice of air pressure plays a great role in determining the quality of the effluent leaving the flotation cell. It can be noted from table 3 shown on figure (3) that the percent removal efficiency (based on total suspended solids) increases with the air pressure until it reaches a point after which it decreases with the air pressure. The inflection point represents the optimum air pressure at which the unit should be operated. At this point of 4 bar pressure, the removal efficiency reaches 77.8%. As for the outlet TS, it decreases with the air flow rate until it reaches a point after which the outlet concentration is proportional to the air pressure. This point represents the optimum air pressure at which the unit should be adjusted. At this point (4 bar), the outlet concentration is of minimum value 525 mg/lit while the entering wastewater concentration is 1314 mg/lit. The air pressure has a similar effect on both the outlet TSS and settleable solids as that effect on the concentration and at the 4 bar point, the outlet TSS reaches 222mg/lit.(ppm) and the settleable solids reaches 22 mg/lit. At this optimum air pressure (4 bar), the outlet turbidity reaches 54 N.T.U.

Table (3): Relation between the air pressure and the outlet water characteristics.

Inlet							Outlet						
Air pressure, bar	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity,ms/cm	TDS, ppm	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity ms/cm	TDS ppm	% age Removal
2.5	1230	1000	230	260	520	286	630	350	42	95	510	280.0	65.0
3.0	1302	1000	200	207	550	302	620	334	30	91	520	286.0	66.6
3.5	1292	1000	210	200	530	292	600	297	25	80	550	303.0	70.3
4.0	1314	1000	225	192	570	314	525	222	22	54	550	303.0	77.8
4.5	1297	1000	220	220	540	297	590	304	25	70	520	286.0	69.6
5.0	1294	1000	230	212	535	294	660	368.5	30	86	530	291.5	63.2

Effect of inlet concentration on the effectiveness of the DAF unit:

The optimum influent concentration is that which gives a high percentage removal. Table (4) as shown by figure (4) represents the effect of varying the inlet concentration of the wastewater. The percent removal efficiency (based on total suspended solids) is proportional to the inlet concentration until it reaches a point after which there is a drop encountered. This point represents the optimum inlet concentration at which the unit should be operated. At this point of inlet concentration (1781.1 mg/lit), the removal efficiency reaches 87.05 %.

Considering the outlet concentration (sum of total suspended and dissolved solids), it is nearly constant with the change in the inlet concentration until it reaches a zone where it decreases and then a point is reached after which the outlet concentration is proportional to the inlet concentration. At this point (1781.1 mg/lit), the outlet concentration is of minimum value 495.2 mg/lit. A similar effect is shown for the total suspended solids where at 1781.1 mg/lit, the outlet TSS is of minimum value 187.2 ppm while the entering wastewater TSS is 1445.6 ppm. The outlet settleable solids value decreases with the inlet concentration until it reaches a point after which the settleable solids is proportional to the inlet concentration. This point shows deviation from the previously determined optimum inlet concentration, but settleable solids is still of minor importance relative to the removal efficiency and the outlet concentration. At the point 1535.8 mg/lit , the outlet settleable solids value reaches 15 mg/lit. At the optimum inlet concentration 1781.1 mg/lit, the outlet turbidity reaches 74 N.T.U.

Table (4): Relation between the inlet concentration and the outlet water characteristics.

Inlet						Outlet						
Conc. mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity ms/cm	TDS, ppm	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity ms/cm	TDS ppm	% age Removal
658.6	413.6	86	83.3	490	245.0	508.0	263.0	31	60.0	490	245.0	36.4
911.5	625.5	120	113.0	520	286.0	562.0	276.8	27	65.0	520	286.0	55.8
1314.0	1000.0	225	192.0	570	314.0	565.0	262.8	22	54.0	550	303.0	73.7
1535.8	1220.8	250	205.6	580	315.0	601.8	286.9	15	53.6	580	315.0	76.5
1781.1	1445.6	260	220.0	610	335.5	495.2	187.2	25	74.0	560	308.0	87.1
2022.3	1675.8	275	200.8	630	346.5	584.0	242.9	30	78.0	610	335.5	85.5

Effect of chemicals addition on the DAF unit effectiveness:

The percentage removal efficiency is proportional to the dosage of the chemicals added so there is no optimum chemical dosage to be used and it will depend on economic considerations. According to tables 5, 6, and 7, figures 5, 6 and 7 illustrate the effect of different dosages of alum, ferric chloride and polyelectrolyte on the different characteristics of the effluent stream. Taking into consideration the economic factors, the average amount of alum that may be used is 0.6 liter (from a solution of 50 % concentration) for every cubic meter of the feed. The recommended polyelectrolyte dosage that may be used is 1.5 liter (from a solution 1 ppm concentration) for every cubic meter of the feed.

Table (5): Relation between the alum dosage and the outlet water characteristics.

Inlet							Outlet						
Alum dosage, mg/lit	Conc., mg/lit	TSS, ppm	Settle-able solid, mg/lit	Turbidity, NTU	Conductivity, ms/cm	TDS, ppm	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity, ms/cm	TDSppm	% age Removal
0.4	178.1	1445.6	260	220	610	335.5	624.5	162.5	35	25.0	840	462.0	88.8
0.5	178.1	1445.6	260	220	610	335.5	610.3	153.8	27	14.8	830	456.5	89.4
0.6	178.1	1445.6	260	220	610	335.5	578.6	143.6	18	9.4	790	435.0	90.1

Table (6): Relation between the ferric chloride dosage and the outlet water characteristics

ılet							Outlet						
ːrric ıloride g/lit	Conc., mg/lit	TSS, ppm	Settle-able solid, mg/lit	Turbidity, NTU	Conductivity,ms/cm	TDS, ppm	Conc., mg/lit	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity ms/cm	TDS ppm	% age Removal
.3	178.1	1445.6	260	220	610	335.5	841.8	175.0	55	33.1	985	541.8	87.9
.4	178.1	1445.6	260	220	610	335.5	773.9	163.6	37	24.9	1050	577.5	88.7
.5	178.1	1445.6	260	220	610	335.5	747.3	149.3	28	15.7	1085	596.8	89.7

Table (7): Relation between the polyelectrolyte dosage and the outlet water characteristics.

ılet							Outlet						
olyele trolyte ose, ıg/lit	Conc., mg/lit	TSS, ppm	Settle-able solid, mg/lit	Turbidity, NTU	Conductivity,ms/cm	TDS, ppm	Conc.,mg/li	TSS, ppm	Settleable solid, mg/lit	Turbidity, NTU	Conductivity ms/cm	TDS ppm	% age Removal
.5	178.1	1445.6	260	220	610	335.5	575.5	130.0	25	19.8	810	445.5	91.0
.0	178.1	1445.6	260	220	610	335.5	523.7	105.7	18	8.5	760	418.0	92.7
.5	178.1	1445.6	260	220	610	335.5	445.8	55.3	10	7.0	710	390.5	96.2

Case Study

In this study, we are dealing with a typical case; wastewater from El-Ahleya Co. for paper which is located in Abou-Quir (Alexandria) and the DAF system is to be applied. The problem is that a large amount of fibers is wasted with the wastewater and is thus an economic loss and being directly drained into the Mediterranean Sea many environmental problems result.

The wastewater discharged from the company has the following characteristics

Flow rate 10 m^3/hr

Total Solids 1781 mg/l

The suggested treatment scheme (Fig. 8) consists of the following equipment having the following specifications[9,11,13]:

Feed Tank

It is an underground equalization tank used to prepare the water for treatment in the DAF cell. The tank has the following specification:

Material of construction Concrete coated with epoxy material to make it impermeable.

Maximum flow rate	:	10 m^3 / hr
Side length	:	3 x 3 m
Height	:	2.2 m

Flotation Tank

A diffuser is placed in the center of the bottom of the tank to allow smooth and even distribution over the flotation cell:

Material of construction	:	Stainless Steel
Maximum flow rate	:	10 m^3 / hr
Effective flotation diameter:		60 cm
Height	:	4 m

Effluent Tank

Cylindrical tank for collecting the clarified water from flotation cell , with the following specifications :

Material of Construction	:	Stainless Steel
Maximum flow rate	:	13 m^3 / hr
Inside diameter	:	2 m
Height	:	3.2 m

Air Saturation Chamber

This allows to reach an air saturation efficiency higher than 95 % even when treating raw wastewater is with a high content of suspended solids. Air enters at the same time with recycled water from effluent tank to be dissolved to obtain air micro –bubbles. It has the following specifications:

Material of Construction	:	Stainless Steel
Maximum Operating pressure	:	13 bar
Max. Flow rate	:	3 m^3 / hr
Inside diameter	:	50 cm
Length	:	1 m

The vessel is equipped with the following :

An air pressure reducer with pressure gauge.

An air feed flow- meter with a control needle valve.

An air feed back check valve placed in air feed pump.

A pressure gauge to indicate the pressure inside the reactor

An air bleed-off ball valve.

Chemicals Tanks

Four standard P.V.C. chemicals tanks of 500 liters capacity each for the coagulant, flocculants, acid and the alkali.

Accessories:

Lifting Pumps

Three submersible lifting pumps should be supplied and installed in the equalization tank . Each pump shall have a guide rail for lifting the pump up for maintenance by means of a manual crane to be erected on the top of the tank .Each pump shall have the following specification :

Flow rate : 15 m^3 / hr

Head : 11.5 m

Motor : 3.5 KW

Pressurization pump and pressurization loop

Pipes in AISI 304 , flanges in aluminum , valves and bolts in galvanized carbon steel.

Type : Centrifugal horizontal axes.

Flow rate : 3 m^3 / hr.

Head : 50 m.

Motor : 3 KW

Coagulant, Polymer, Sulphuric acid and Caustic soda dosing pumps

Type : Diaphragm.

Flow rate : 30 1 / hr.

Pressure : 10 bar max.

Power : 90 W

Air Compressor

Tank : 200 liters

Air pressure : 8 bar

Power : 3 hp

pH Controller

The pH controller probe has to be installed in feeding pipe . The electronic component of the system will be located inside the control panel .It supplies a 4-20 mA signal in order to allow a proportional dosage of acid and soda.

Cost estimation for the treatment plant:

Wastewater amounting to 10 m^3/hr is treated while the unit is operated 10 hours per day, 300 working days per year. Knowing that the inlet wastewater concentration (TS) is 1781 mgm/lit. and the outlet concentration is 445 mgm/lit., then the total income due to the fiber recovered from wastewater is EGP 80,000 (EGP 2000/ ton). The preliminary cost estimate using procedure of standard references [8,10] concluded the following:

Total capital investment EGP 754,000

Total treatment cost EGP 263,000/ year

Net treatment cost after considering the recovered fiber EGP 183,000/year (for 30,000 m^3 /year of treated wastewater).

Net treatment cost per m^3 of wastewater EGP 6.1

Conclusions and recommendations

This work has been directed towards exploring the effect of different operating variables on the performance efficiency of a wastewater separation system. The study involved bench-scale investigations for fibers removal from wastewater streams. The investigated variables include influent fiber concentration, air flow rate, air pressure, alum and ferric chloride dosages as coagulants and the use of polyelectrolyte as a flocculent. Results revealed the following:

- The DAF unit was designed to be used as a successful separation technique for the treatment of the pulp and paper industry's wastewater.
- Fiber concentration in wastewater affects the removal efficiency where the efficiency increases to a certain maximum value and then starts to decrease again and so an optimum value is obtained.

- Fiber removal efficiency is directly affected by the air flow rate as it increases to a certain extent of flow and then started to decrease and thus an optimum value is considered for the flow rate.
- Addition of alum and ferric chloride tend to improve the fiber removal. Although the addition of ferric chloride greatly enhances the fiber removal efficiency, it causes corrosion of the treating equipment and gives the treated water a red color appearance.
- Results have been tested using an actual fiber wastewater stream (having fibrous material) and the findings have compared favorably with other alternatives.

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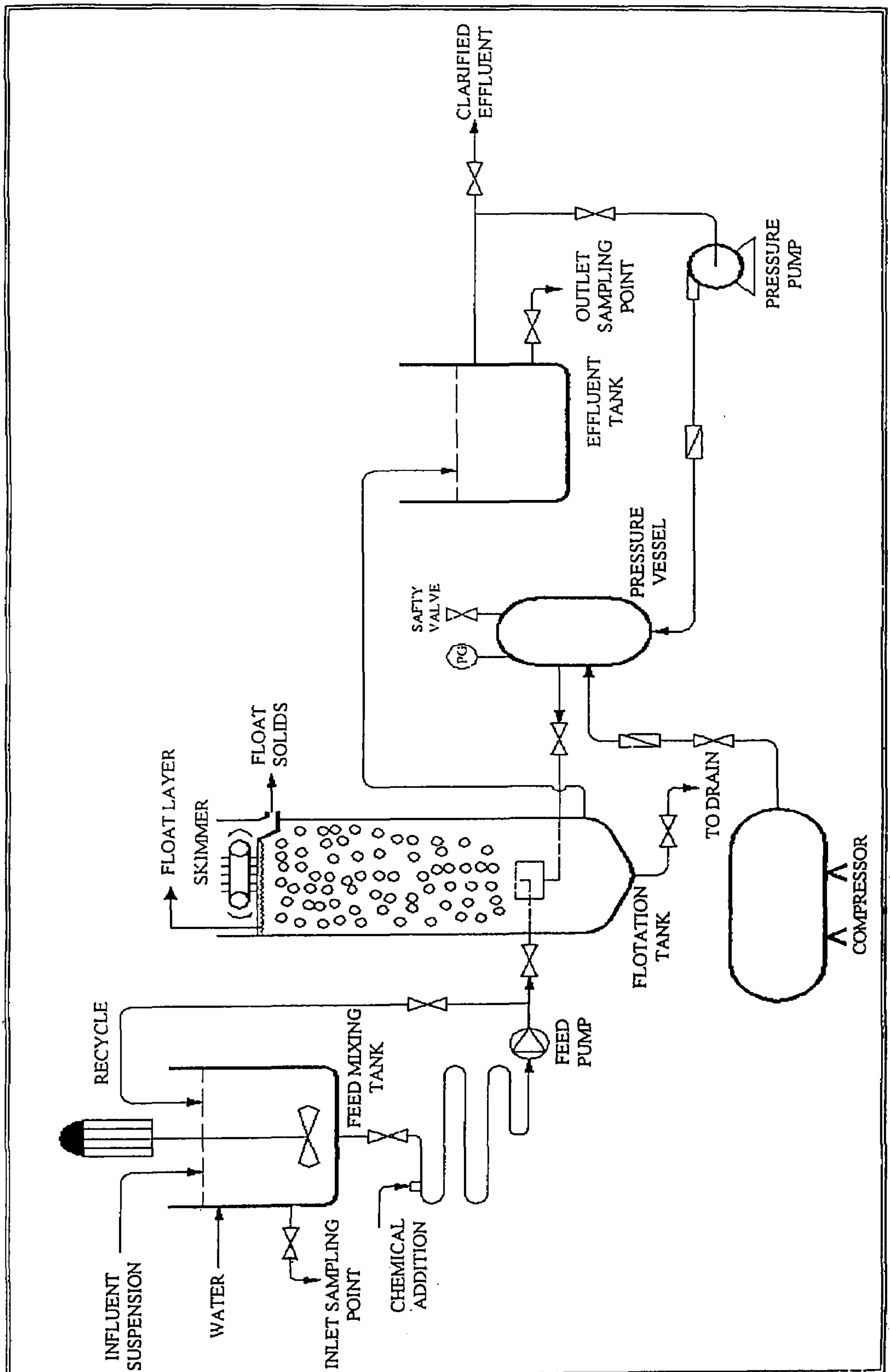


Figure (1): Pilot scale of DAF experimental set-up

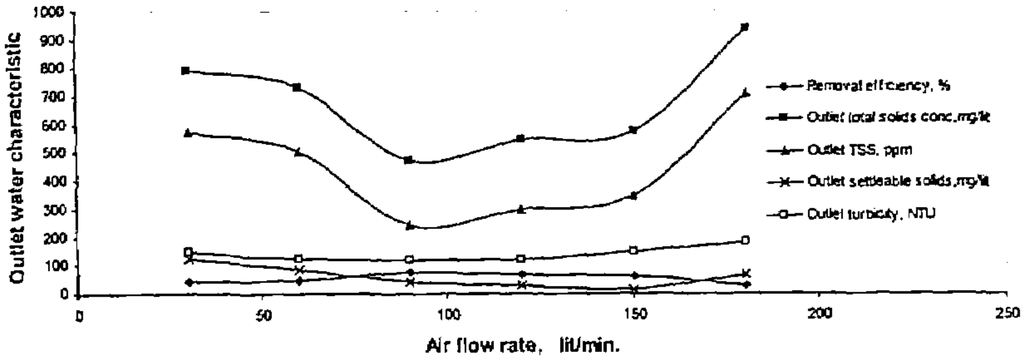
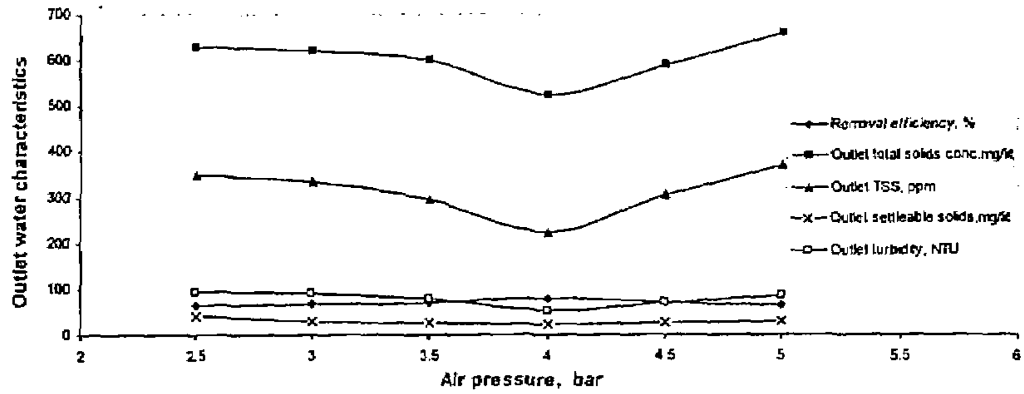


Figure (2):Effect of the air flow rate on the different characteristics of the outlet water



Figure(3): Effect of air pressure on the different outlet water characteristics

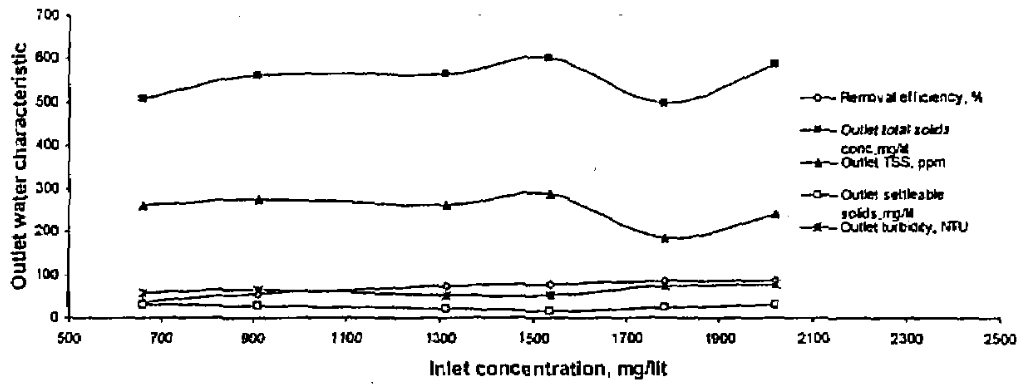


Figure (4): Effect of the inlet concentration on the oulet water characteristics

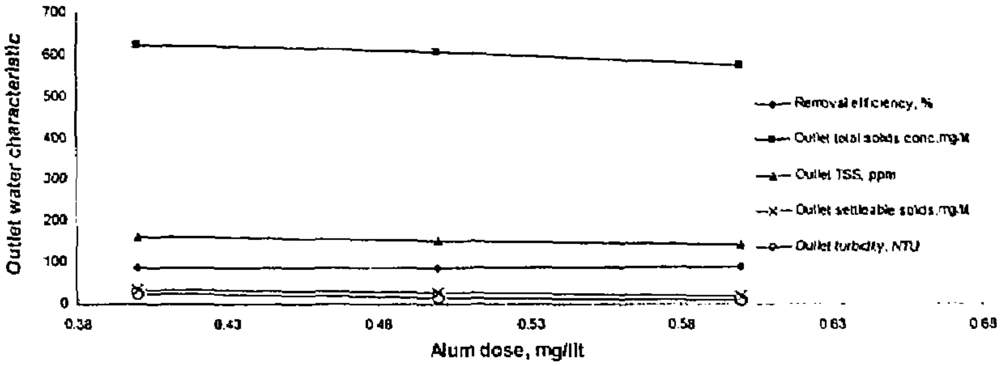


Figure (5): Relation between the alum dosage and the characteristics of the outlet water

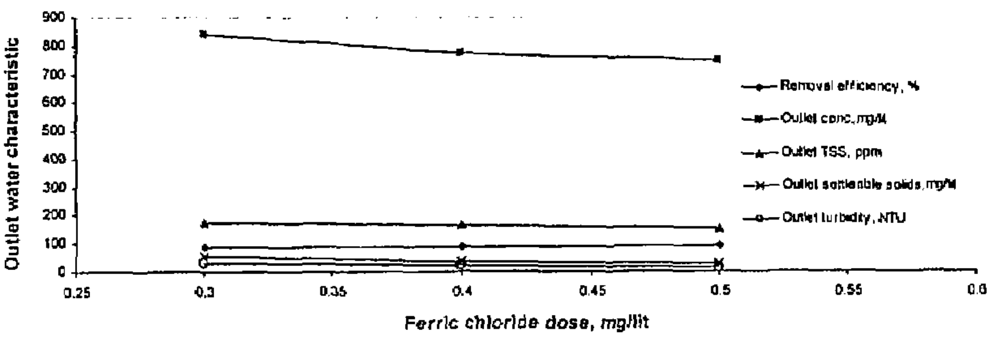


Figure (6): Relation between ferric chloride dosage and the outlet water characteristics

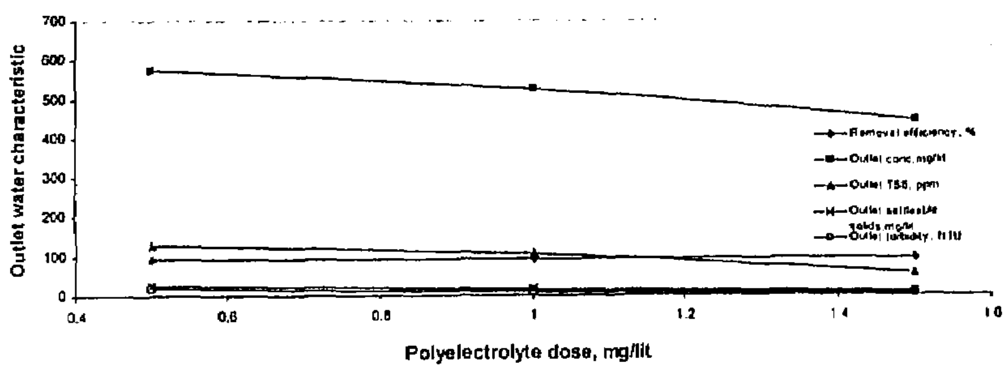


Figure (7): Relation between the polyelectrolyte dosage and the outlet water characteristics

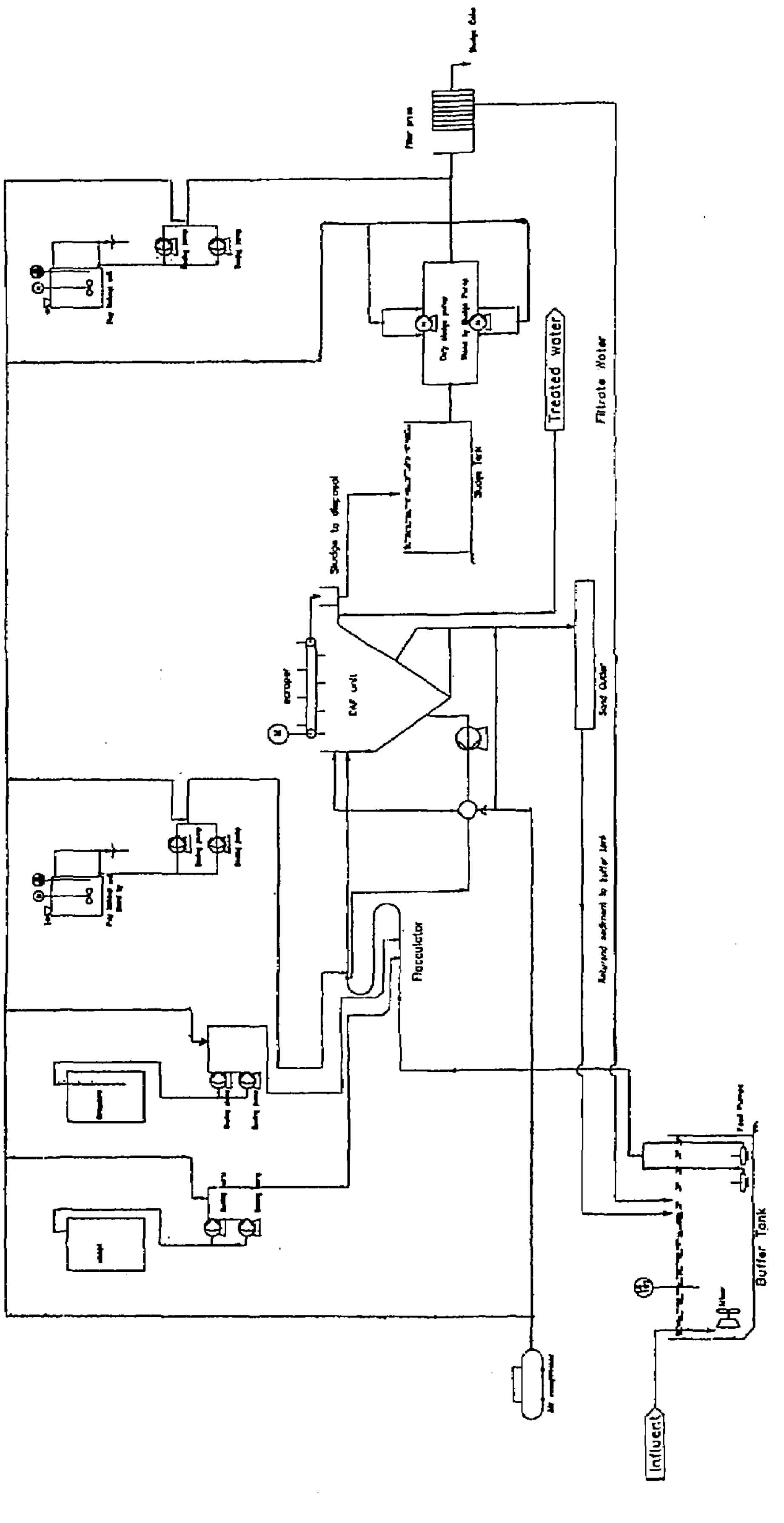


Figure (8) : Flow Diagram For DAF Unit