FS-PRI-003

TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
ON TEXTILE INDUSTRY

DISSOLVED AIR FLOTATION

SERIES: PRIMARY TREATMENTS

TTITLE	**DISSOLVED AIR FLOTATION (FS-PRI-003)**
Last update	December 2014
Last review	

UNIVERSIDADE DA CORUÑA

INDITEX

DISSOLVED AIR FLOTATION (FS-PRI-003)

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Reviewed by			
Last update	Date	Done by:	Update main topics

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1.- INTRODUCTION

The main objective of primary treatment is to reduce the concentration of suspended solids from wastewater. The basis of this reduction is to calm water in a tank (reducing water flow velocity) so that solids with a density significantly greater than water settle down; additionally, materials less dense than water (oil and grease, etc.) can float.

A less turbid effluent is produced in a primary treatment (due to the reduction in suspended solids) and also sludge ("primary" sludge) is generated. This sludge normally contains biodegradable organic fraction, so that a primary treatment means to reduce BOD as well. The magnitude of this reduction depends on the process used and the characteristics of the raw wastewater.

Although there are several processes that can be considered within primary treatment (filtration, sieving, lagoons, septic tanks, Imhoff tanks, etc.) main processes used in sewage treatment plants of medium and large size can be classified as follows:

- Solid-liquid separation process (no addition of chemical reagents):
  - Primary Sedimentation.
- Process of solid-liquid separation (with pre-addition of chemical reagents) implies that previously, the characteristics of suspended solids have been improved by the addition of coagulants and / or flocculants. This is known as physical-chemical process. The following possible process steps would be taken:
  - Improved primary sedimentation.
  - Dissolved Air Flotation (DAF process).
  - Joint process (sedimentation - flotation).

Elementary flotation of wastewater has always been used for the removal of floatable materials, i.e. solids and/or liquids of density significantly lower than water.

The difference between particles, or flocs, density and liquid intervenes in flotation process. However, contrary to what happens in the settling process, this solid-liquid separation is applied to particles having true density (natural flotation) or apparent density (induced flotation) lower than the liquid that contains them.

There are different ways of carrying out the flotation process. The differences between them lie in the way of generating or introducing air bubbles within water.

- Introduction of air into the wastewater at atmospheric pressure.
- Dissolved air flotation (DAF).
- Induced air flotation (IAF).

Although it is more complex, the flotation system producing the best separation efficiency, and therefore the most used, is the dissolved air flotation.

2.-DISSOLVED AIR FLOTATION: FUNCTION AND OBJECTIVES

The dissolved air flotation (DAF) is a kind of “induced flotation” applying the capacity of certain solid or liquid particles to join with air bubbles forming particle-gas clusters less dense than liquid phase.

The resultant of forces (gravity, thrust, friction) leads to an upward movement of the gas-particle cluster that finally concentrates on the liquid surface.

DAF process consists on creating air microbubbles (30 to 120 microns in diameter) inside wastewater, which get attached to the particles to remove. In this way, floatable aggregates (with joint density lower than water) are formed.

In order to achieve microbubble formation, a first pressurization of a volume or a water flow (treated or untreated) is carried out, leading to the dissolution of air until oversaturation, and then this flow is depressurized in the flotation tank to atmospheric pressure, where dissolved air excess is released in the form of numerous microbubbles.

Microbubble generation tends to be formed in the solid-liquid interface, resulting in the fixation of the air on the particles and thereby facilitating its floatation.

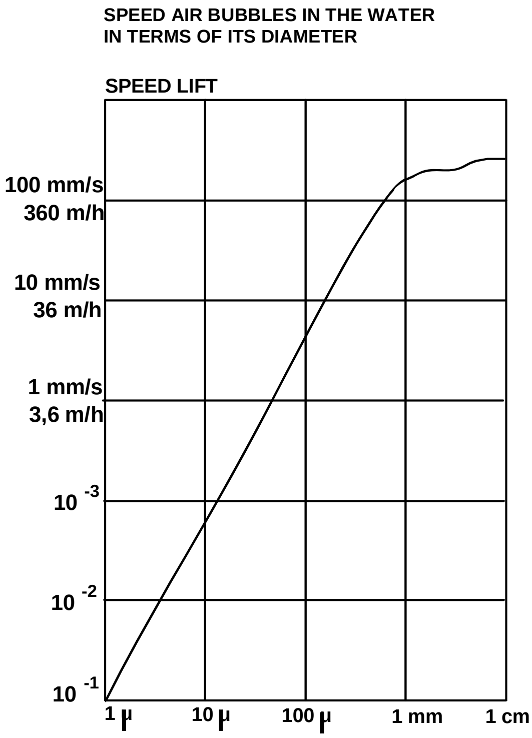

Figure 1.- Vertical speed of air bubbles as a function of diameter.

2.1.- Typologies

The pressurisable water flow can be the entire inflow of wastewater, part of this water flow or water already treated by the process (effluent). This results in DAF three types of usable process, called full flow, partial flow of recirculated flow (R-DAF), respectively (see diagrams of figures 2 to 4).

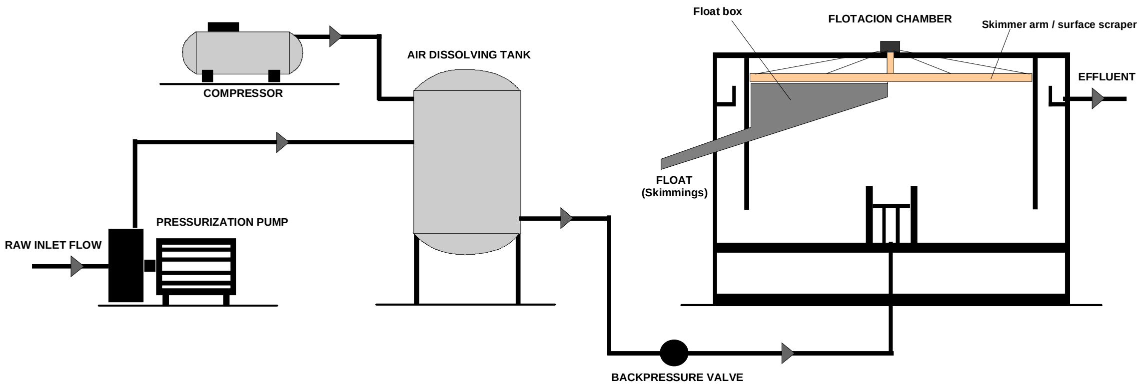

Figure 2.- DAF with total inflow pressurization (CEPIS, 1992).

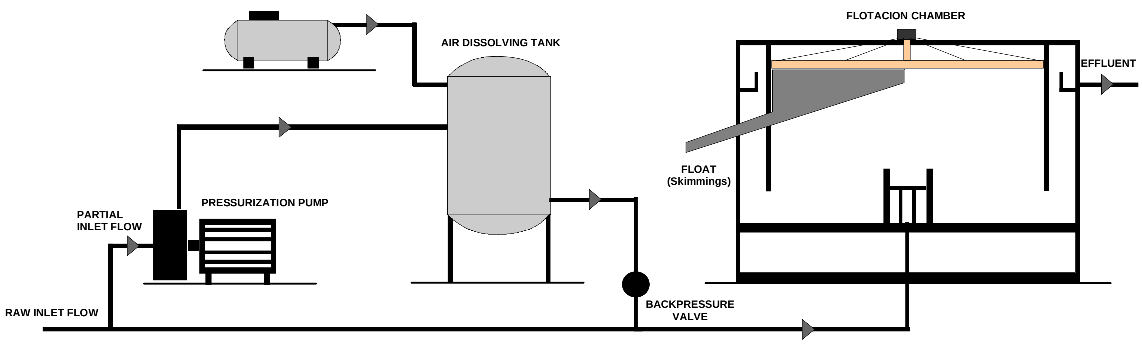

Figure 3.- DAF with partial inflow pressurization (CEPIS, 1992.

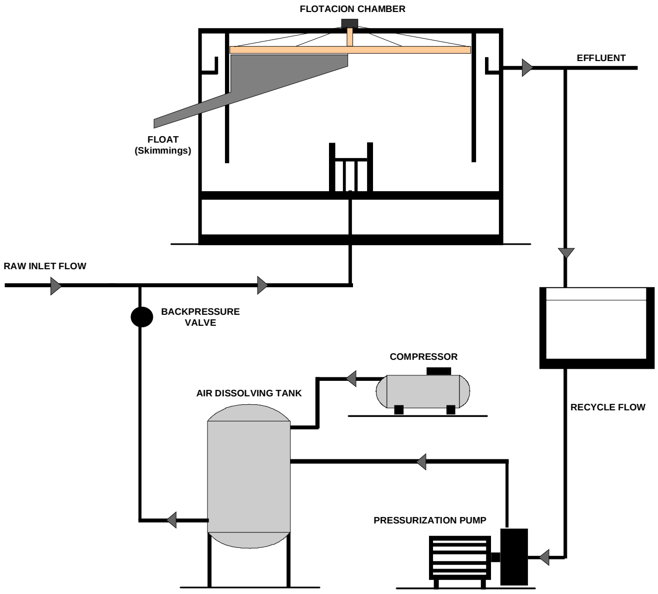

Figure 4.- DAF with recirculated flow pressurization (CEPIS, 1992)

a) Inflow pressurization (total or partial):

In this system, all or part of the wastewater flows through the pressurization cylinder. The most important characteristics of this variant are (Sainz-Sastre, 2007):

Benefits:

- Produces a maximum dissolution of air and generates a larger amount of bubbles, with an optimal distribution over the entire water body.
- Produces the best conditions for the formation of micro-bubbles in the solid-liquid interface.

Disadvantages:

- Energy consumption is very high.
- Passing raw wastewater through the pumping system can lead to colloid and/or emulsions formation.
- Equipment (pumps, valves, etc.) may suffer from abrasion.
- In the case that a coagulation-flocculation process is used before, passing through the pump to the pressure tank produces already formed flocs breakage.

a) Outflow recirculation pressurization:

This is, by far, the most used type in wastewater treatment. In this variant, part of the effluent is recirculated and introduced into the pressurizing system. The most important features of this operating system are (Sainz-Sastre, 2007):

- Pressurization requires less equipment, and thus lower energy consumption, as the recirculation flow rate is lower than the input to the system.
- Easily assimilated flow changes and/or composition.
- Prevents the formation of colloids and emulsions considering that the water to be treated does not pass through the pumping system, optimizing the floc formation in those plants with coagulation-flocculation processes prior to flotation system.
- When pressurizing, the use of treated water avoids pump abrasion problems
- The quantity of water recirculated is in direct relation with the suspended solids and oil and grease removed.

In the market there is equipment that does not use pressure tank; in this case the necessary air pressure is injected into the recirculating loop. Drive line of the recirculating pump is mounted in a zig-zag pattern, thereby increasing turbulence and residence time, so that the dissolution of air is improved.

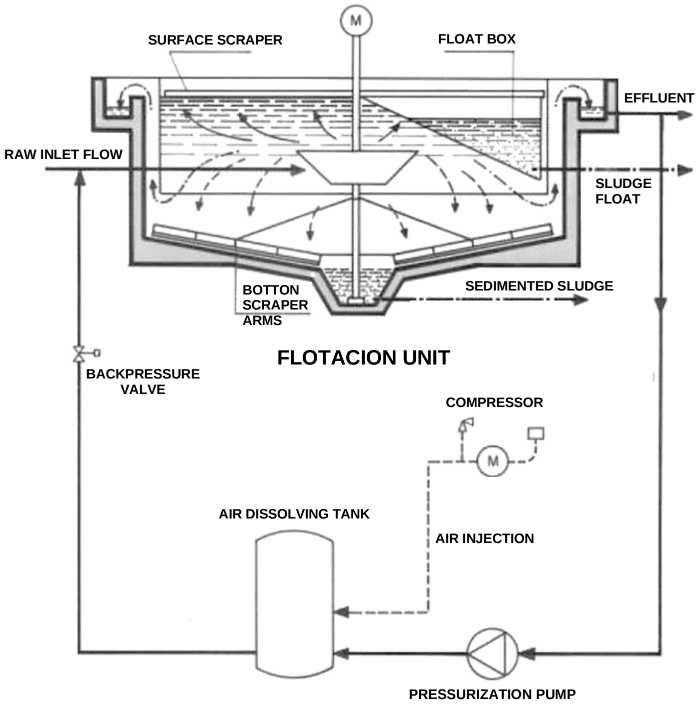

Figure 5.- Functional diagram of a circular DAF system.

2.2 Applicability

Among the possible applications and advantages which the DAF process may have as wastewater primary treatment, the following ones should be noted:

- In the event of a major incidence of untreated industrial effluent, from certain industries such as refineries, paper, paints, canned meats, lamination, etc., its use may be inevitable.
- When the effluent does not need very stringent discharge limits in dissolved substances.
- Given its operating flexibility, it can be very useful in cases of large seasonal variations in flow.

3.- NEEDS AND/OR REQUIREMENTS

As an industrial wastewater primary treatment, DAF process typically requires the pre-addition of chemical reagents. In general, it will be necessary to coagulate and flocculate previously. Thus, in practice, the DAF unit will result as a part of a physical-chemical process.

4.- DESIGN

4.1.- Sizing

The effectiveness of a dissolved air flotation system is based on the ratio of kilograms of air used per kilograms of removed solids. This ratio varies between 0.005 and 0.09 kg air/kg solids removed. The exact value to use depends among other factors, on:

- The pressure of the system, typically ranging between 4 and 7 atmospheres
- The concentration and nature of the suspended solids, oil and grease to be separated.
- Other wastewater characteristics, such as pH.

The amount of air required is:

$$A = p \cdot k$$

Where:

A = air needs (kg/h)
p = specific needs of air (kg air/solids separating kg)
k = solids flow to be removed (kg/h)

Recirculation DAF systems are dimensioned considering that flow recirculation depends on:

- The amount of suspended solids, oil and grease present in the wastewater.
- Water flow to be treated.
- Conditions of pressure and temperature.

The recirculation flow is estimated by:

$$F_r = \frac{A}{\alpha \cdot X_S^P}$$

Where:

F_r = recirculation flow rate (m^3/h)
X_S^P = air solubility in pure water at work temperature and pressure (kg/m^3)
α = coefficient that takes into account the content of impurities in wastewater (0.60 to 0.80)

The solubility of air at atmospheric pressure depends on the water temperature indicated by the following table:

Table 1.**- Solubility of air at atmospheric pressure depending on water temperature.**

Temperature (ºC)	Solubility in pure water of air (ppm)
0	29.2
5	25.7
10	22.8
15	20.6
20	18.7
25	17.1
30	15.6

In the case of wastewater with high salinity, the real solubility at those conditions should be searched in the literature.
Thus the design flow for the flotation tank or chamber will be:

$$F = F_{WW} + F_r$$

Where Q is the design flow (m^3/h) and Q_{WW} is the treatment wastewater flow rate (m^3/h).

The surface of the float is given by:

$$S = \frac{F}{H}$$

Where S is the horizontal surface (m^2) and H is the hydraulic load (m/h).

The volume and depth of the flotation tank is:

$$V = TRH \cdot F\,; \qquad h = \frac{V}{S}$$

Where:

V = volume of the flotation tank (m^3)
HRT = hydraulic retention time (h)
h = depth (m)

The depth varies between 1 and 3 meters, depending on the type of device for distributing pressurized water inside the flotation chamber.

The volume of the pressure chamber is determined from its own retention time, HRT:

$$V_{p\,tank} = F_r \cdot TRH$$

The pressure chamber HRT will have a retention time of 2-3 minutes.

The pumping equipment for pressurizing is defined by the recirculation flow rate and the required work pressure.

4.2.- Additional processes

DAF process applied to the primary sewage treatment usually requires pre-addition of chemical reagents. It generally requires coagulation-flocculation.
Coagulation step destabilizes colloids, while flocculation produces suspended solids and destabilized colloids aggregates. On these aggregates or flocs, depressurized air bubbles are able to act.

Coagulation is a quick process that requires very low retention, from 0.5 to 3 minutes. It is a process that requires great energy mix (FS-PRIM-001).

Flocculation is a process of slow mixing with retention times of 10 to 30 minutes. It is a process that requires less energy mixing or agitation.

Inorganic salts are typically used in coagulation, such as aluminum polychloride, aluminum sulfate or ferric chloride.

In flocculation the most common reagents are poly-electrolytes or polymers of high molecular weight.
Coagulant and flocculant doses depend on the characteristics of the wastewater. If for project development there is not a budget for the testing of coagulation and flocculation (jar-test) in order to identify the proper chemicals and their optimal doses, the following minimum doses are commonly considered for design purposes:

- Coagulant > 50 mg/L
- Flocculant > 5 mg/L

Figure 6.- Physical-chemical process based on coagulation-flocculation + FAD (WWTP Cee - Coruña).

4.3.- Flotation chamber

The float chamber may be rectangular or circular. In the case of rectangular chambers is advisable to install a screen with an inclination angle of 60° respect to horizontal and 30 to 50 cm in length, as shown in the following figure. The width of the chamber depends on the type of equipment used for scraping the floating material and rarely exceeds 8 meters.

The length can vary between 4 and 12 meters whenever A or C scenarios do not occur (see figure). In case A, the length is insufficient, and in case C, there is sedimentation of floatable material due to an excess in tank length.

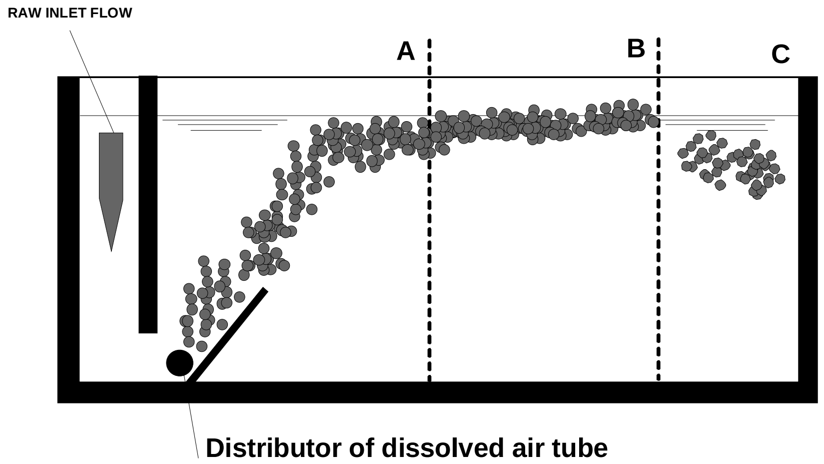

Figure 7.- Rectangular flotation chamber (CEPIS, 1992).

Rectangular flotation tanks are provided with surface endless chain sweepers so as to extract foams. In the circular tanks case, the *skimmer arms* are radial. In order to adjust the speed of rotation or displacement of the trawl, a variable speed drive mechanism should be available.

The depressurization-flotation tanks, must be provided with sludge scrapers and purge line, for removing solids with higher density than water that have not been captured by the microbubbles formed, resulting that the amounts of sludge to purge depend on the characteristics of the suspended solids

The following figure shows the outline of a circular flotation chamber sample. The mixture between pressurized water and water to be treated occurs near to the flotation chamber inlet point, which in the center has a circular conduct, which conveys water to the top and avoids short-circuiting. The supernatant is continuously swept away to one or more collection gutters. While the water makes a downward movement, goes through the bottom of the intermediate cylinder and is collected in the trough located at the periphery of the outer cylinder.

The clarified liquid is removed from the surface, protected by weir baffles that prevent floating materials to flow downstream.

The characteristics of raw water and pretreatment conditions influence both the retention time and the hydraulic load. For this reason it is advisable to conduct a field study before preparing the final draft.

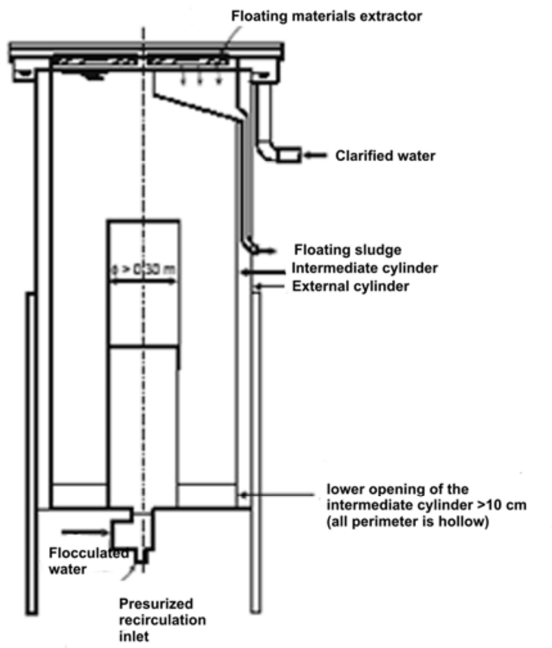

Figure 8.- Circular flotation chamber.

Other general design criteria:

- Maximum diameter of the flotation tank: 20 m.
- Flotation tanks must have bottom scrapers.
- The scrapers drive system must have a variable speed drive mechanism. A slow drift velocity can cause breakage of the foam formed and the return of solids to water, with a corresponding loss of performance.
- The normal concentration of foams is in an order of magnitude between 3-3.5% in suspended solids. This concentration may increase through the use of polyelectrolyte.
- Maintaining a constant level of water inside the pressurizing tank is essential in order to ensure the contact time, for such a purpose a float valve or any other system is used.
- The pressurization chamber must have at least: safety valve, level control, purge and pressure gauge.
- It is important that this equipment works continuously, since at the startup process air conditions have to be set up.
- In the depressurization system, very fine size bubbles have to be achieved, so that for the same amount of air more quantity of bubbles are formed and therefore, more solids are captured. Moreover, larger bubbles break easier. This mode of operation carries buoyancy low speeds, as reflected in the recommended hydraulic loads.

Ranges of design parameters for DAF process applied to wastewater with prior coagulation-flocculation process are shown in Table 2.

Table 2.- Design parameters values for DAF process.

Parameters	Value
Air/Solids ratio(kg/kg)	0.03 - 0.09
Working pressure (atm.)	2.5 (4 to 6)
Pressurization rate (*) (%)	10 – 40
Hydraulic load (m/h)	2.5 - 10 (3.5 to 3)
Hydraulic retention time (HRT) (min)	20 – 40 (40 – 60)
Solids load (mass load) kg/m^2/h	4.5 – 5 Non limiting

*) Pressurization rate = percentage of pressurized flow relative to the flow of raw water to be treated.

In the above parameters, water recirculation rate must be taken into account

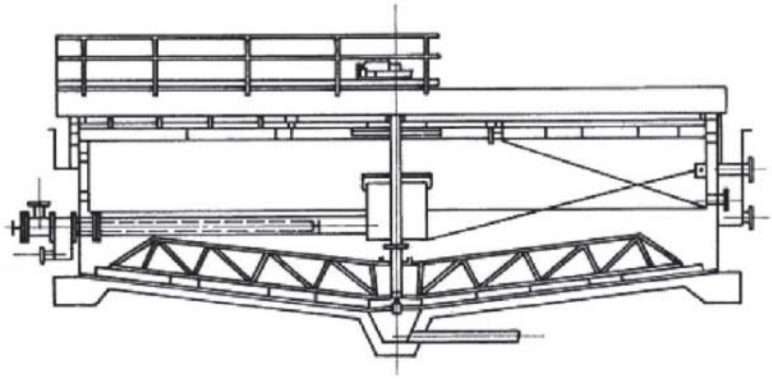

Figure 9.- Circular flotation tank floor scheme

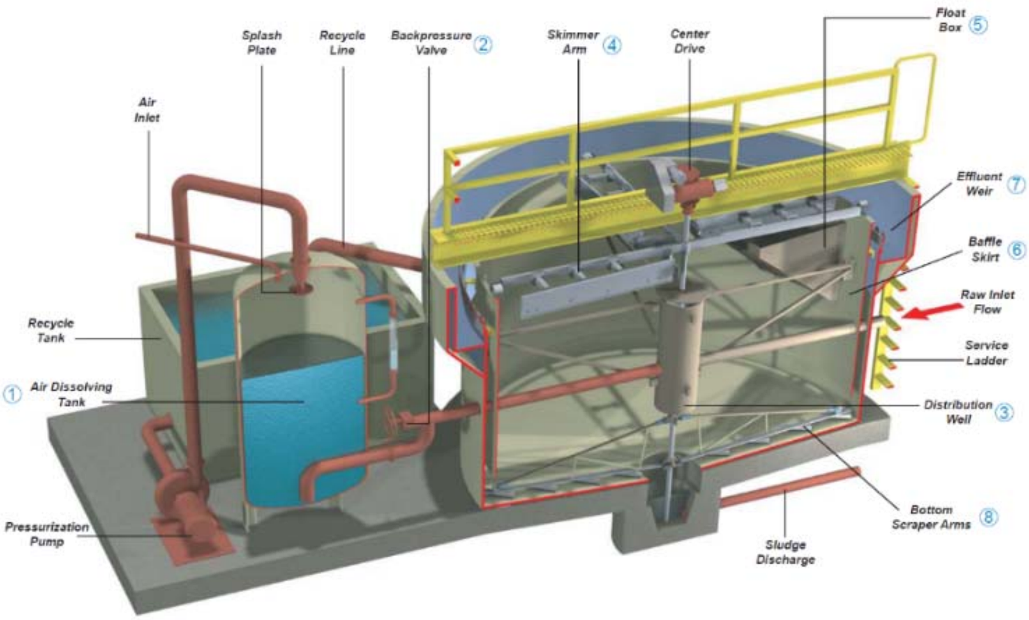

Figure 10.- Elements of a DAF system with a circular flotation chamber (ADVANCED ENERGY SOLUTIONS SAE LTDA.).

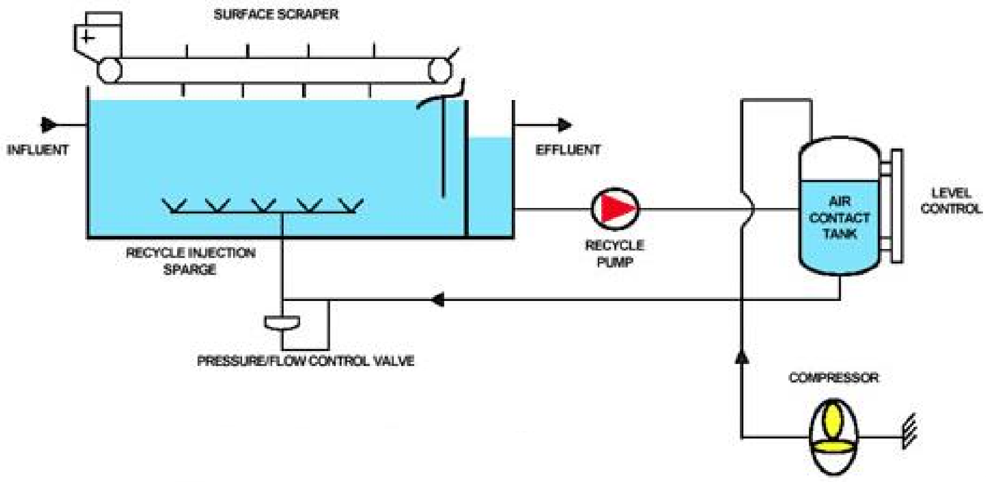

Figure 11.- Rectangular flotation tank scheme.

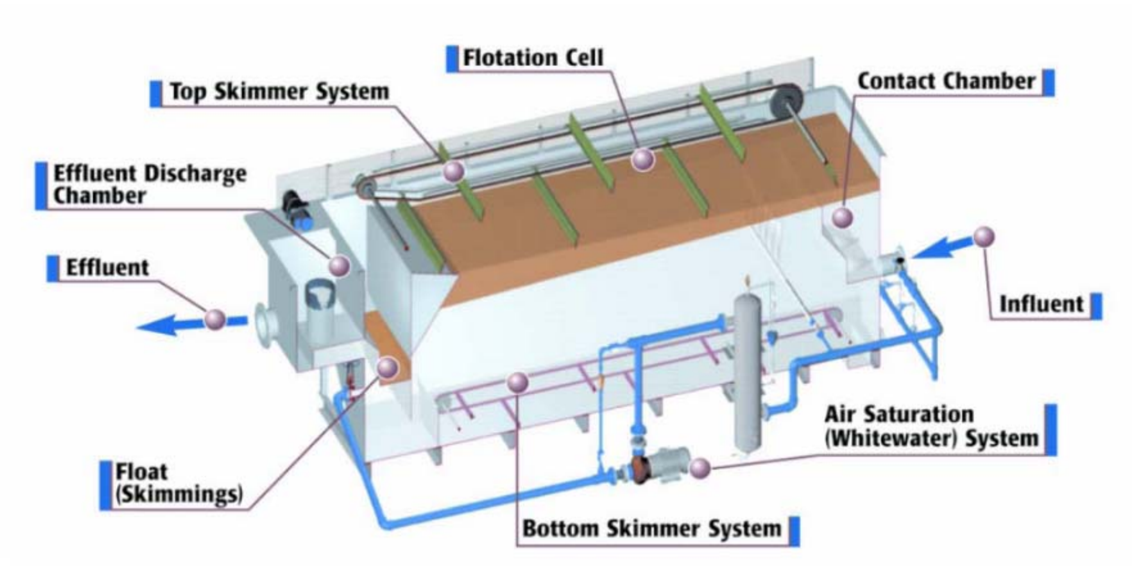

Figure 12.- Elements of a DAF system with rectangular flotation chamber (Ross, C., Valentine, GE et al .; 2013).

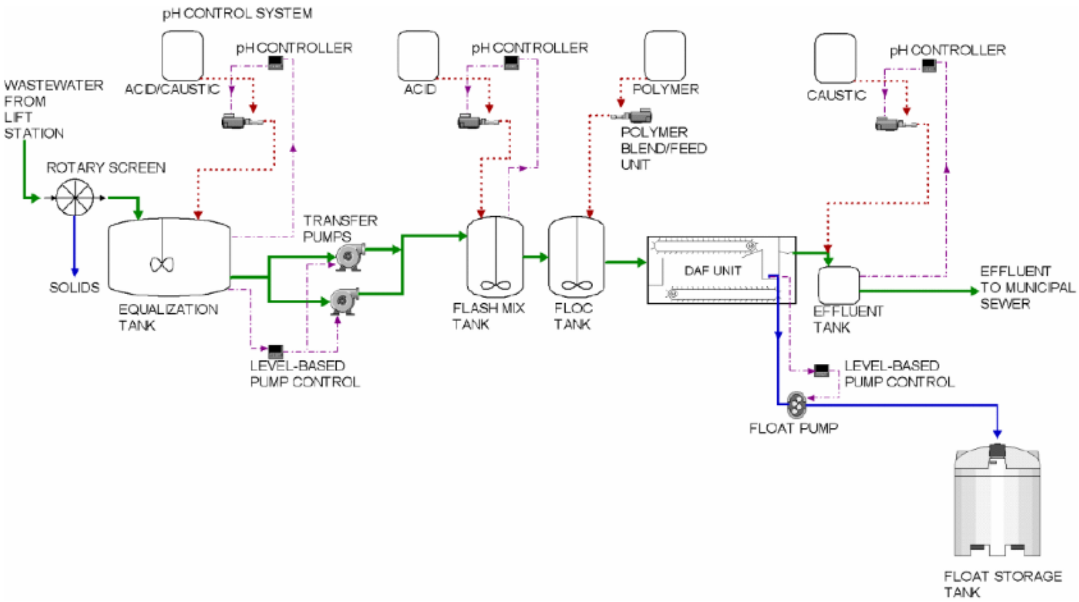

Figure 13.- Integration of a DAF system in a WWTP pretreatment (Ross, C., Valentine, GE et al .; 2013).

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Figure 14.- DAF system with prior flocculator tube (Float Anaconda® FRC-20; 20 m3 / h; TORO).

5. SLUDGE PRODUCTION

The amount of sludge to purge from a FLOATING SYSTEM is given by the following expression:

$$P_{f1^o} = Q \times SS \times R \times 10^{-5}$$

Where:

Pf1° = average daily sludge production (SS kg/day)
Q = average flow (m^3/d)
SS = average concentration of SS in the influent wastewater (mg/L)
R = SS reduction in flotation (%)

If the sludge density is assumed to be the same as that of water, primary sludge volume can be estimated by:

$$V_{f,1^o} = \frac{P_{f1^o}}{10C}$$

Where:
V_{1s} = average sludge flow (m^3/day)
C = sludge concentration (%)

Sludge concentration is typically between 3 and 5%, but should always be characterized.

6. YIELD

DAF units with prior coagulation-flocculation improve yields in comparison with simple flotation or primary settling units.

Regarding suspended solids, BOD_5 and oils and grease, the following yields can be achieved:

Table 3.- DAF achievable yields with coagulation + flocculation.

SS Reduction (%)	65 - 80
BOD_5 reduction (%)	45 - 50
Oil & grease reduction (%)	70 - 90

7.- SPECIFICATIONS IN THE TREATMENT OF WASTEWATER OF TEXTILE INDUSTRY

- Attention to air solubility with high salinity conditions, since it is lower.
- Attention to air solubility with high temperature, which also decreases.

8.- PARAMETERS AND CONTROL STRATEGIES

Parameters for controlling the process efficiency:

- Solids concentration in influent and effluent.
- Effluent turbidity.
- Bubble type observation
- Concentration of sludge removed by the scrapers.
- Skimmers advance velocity.
- Check pressure and flow pressurization equipment.

Maintenance and control activities (García-Martínez, et al, 2012.):

- Verification of bridge through start, stop and safety switch operation
- Inspection of central electromechanical gear motor operation (if circular tank).
- Lubrication levels.
- Noise, vibration and compressors overheating assessment,.
- Check the operation of pressurization pumps.
- Check pressure and flow on pressurization equipment.
- Review thickened sludge homogenization tank agitator and check the pumping of thickened sludge.
- Check overflows and sludge thickening.

9.- OPERATING PROBLEMS

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SOLUCIONES AVANZADAS DE ENERGÍA SAE LTDA. Calle 102A No. 70B -13 Bogotá, Colombia - E-mail: info@saeltda.com. FLOTACION DE AIRE DISUELTO - DISSOLVED AIR FLOTATION - Hi-Tech - SYSTEMA (DAF)

TORO WASTEWATER EQUIPMENT INDUSTRIES - Equipos para el tratamiento de aguas. C/ Sauce, s/n - Polígono Industrial La Mora. La Cistérniga, 47193, Valladolid, Spain.

ANNEX 1
AREA REQUIREMENTS ESTIMATION

NECESSARY AREA ESTIMATION FOR DAF PROCESS

OVERLOADFLOW RATE ($m^3/m^2.h$)		
Rank	2,5 a 10	
Adopted value	**2,5**	**10**
FLOW (m^3/h)	**AREA NEEDED (m^2)**	
1	2	0,5
10	4	1
20	8	2
30	12	3
40	16	4
50	20	5
60	24	6
70	28	7
80	32	8
90	36	9
100	40	10

Capacities and Sizes*

Model	m³/hr	L	B	H
1200	4	2750	980	1050
2600	10	3300	1350	1050
3800	15	3650	1680	1050
4800	20	4350	1680	1050
7100LD	25	4900	2180	1050
7100HD	35	4900	2180	1350
11000	50	6750	2750	1350
15000	70	7400	2750	1350
19000	100	9300	2750	1350
24000	150	10500	3600	1650
38000	200	10100	4000	1650
45000	250	12100	4000	1650
60000	300	14000	5000	1650

*Dimensions and capacities are only a guide and are subject to change. Please confirm with your local Ovivo representative prior to using the above.

Geometries of 4 units "EnviroDAF6000" to 14000 m^3/day.

ANNEX 2
GRAPHIC DESCRIPTION OF PROCESS UNITS

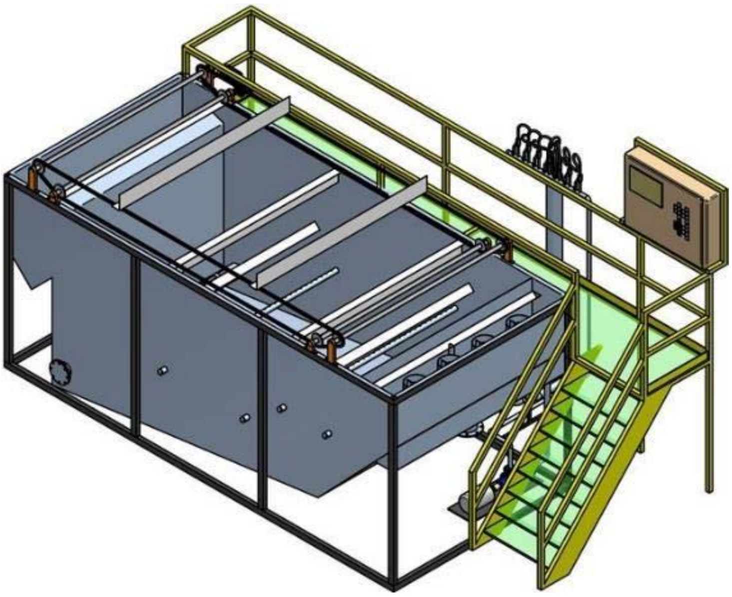

Figure 1
General sketch of square flotation chamber with a system of surface skimmers.

Figure 2
Detail of skimmers removing the floating sludge.

Figure 3
Detail of skimmers removing the floating sludge.

Figure 4
Overview of a WWTP sludge flotation system circular concrete building.

Figure 5
Overview of a WWTP circular sludge flotation system made of sheet metal.

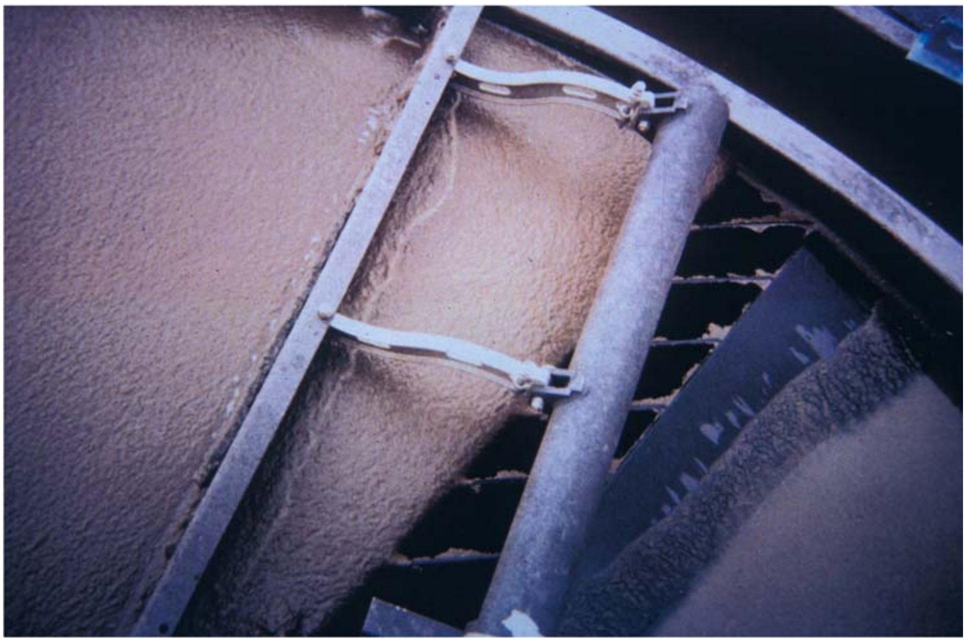

Figure 6
Detail of skimmers removing the floating sludge in a circular flotation tank.

Figure 7
General view of a DAF system with circular flotation chamber.

Figure 8
Detail of skimmers removing floating sludge.