

Highly Polluted Wastewaters Treatment by Improved Dissolved Air Flotation Technology

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Abstract. Numerous investigations are oriented towards the development of new wastewater treatment technologies, having high efficiencies for removing even low concentrations of pollutants found in water. These efforts were determined by the destroyer impact of the pollutants to the environment and human's health. For this reason this paper presents our study concerning an improved dissolved air flotation technology for wastewater treatment. There is described a dissolved air flotation (DAF) installation composed by two equipments: pressurized capsule and lamellar settling. Also, there are presented some advantages of using nanoparticles as flotation collectors.

1. Introduction

Flotation represents a separation process (physical and chemical) of pollutant (solid matter and/or fats) by establishing a contact in different phases: the floating pollutant, the liquid phase and air. Nowadays, this is an important separation technique, frequently used around world, and its applications varies from selective separation of minerals to ions and even microorganisms ^[1,2].

Artificial flotation represents a process in which air is forced introduced into the wastewater. The air bubbles rising to the surface adhere to the suspended particles or emulsified fats presented in the liquid and lead pollutants to the wastewater surface. The large interface contact surface produced by the formation of air bubbles in the water mass requires the necessity of an energy input proportional to their superficial energy - "potential energy". This process is based on the adhesion capacity of the dispersed particles, solid or liquid at the gas/air bubbles, forming conglomerates that using the ascending force of the bubble rise to the water surface.

Dissolved air flotation (DAF) was also worldwide used during the last fifty years for the removal of oils, greases and suspended solids. Nowadays, DAF systems are frequently applied in wastewater treatment field, product recovery, and thickening of biological solids in industries such as textile and leather, paper and cellulose, food processing etc. Even though the technology advances and the range of applications for DAF is expanded, the engineers and process designers frequently use outdated and insufficient design data for DAF systems for industrial pretreatment.

The DAF technology is generally applied in industrial wastewater treatment plants (WWTPs), where the amount of pollutants is above the average (municipal wastewaters). The research team



members introduced a modified DAF unit in a laboratory leachate wastewater treatment plant. The efficiency of wastewater treatment depends on pollutant types and concentrations.

2. Experimental procedures

The dissolved air flotation unit consists of two main equipment: a pressurized capsule and a lamellar settler. One of the most important element of DAF is the pressurized capsule in which the water comes into contact with the compressed air. Air consumption in the transfer process is $(20 - 100) \text{ Ndm}^3/\text{m}^2$ water, that is $(1.5 - 5.0)\%$ of the water volume. Inside the pressurized capsule which is a cylindrical chamber having at the ends 2 caps are introduced water and air under pressure. Under pressure conditions (6 bar) the air is dissolved into the water mass. The detention time and the contact surface area are important in order to increase the amount of dissolved air, with benefit to the flotation process (an increase of the specific flow rate and of the saturation coefficient). Achieving a very fine dispersion of the water may increase the contact area.

At the top of the capsule is located the circuit for water feeding with the help of 4 sprinklers as fine dispersed droplets and not as jet. At the bottom of the capsule is positioned the air supply figure 1. The researchers found that introducing moving plastic elements inside the capsule will lead to obtaining a longer time contact between air bubbles introduced through the circular pipe and the water.



Figure 1. The pressurized capsule for a DAF unit and an example of a plastic element.

The longitudinal settler consists in two compartments placed in series: a lamellar zone and a technical room (figure 2). At the usual lamellar clarifiers the clogging phenomenon can appear between the settling plates. The flotation process inside the clarifier can overcome the clogging. The air-water mixture enters into the clarifier with the help of a transport system that consists of pipes and three funnels. Funnels are diffusers. So, the air bubbles - water mixture does not "wash" the slab foundation. As the air is depressurized, small air bubbles are formed and the bubbles rise to the water surface. On their way up the air bubbles gather suspended particles, leading them to the surface, from where are targeted, as foam, to skimmer and discharged outside the system.

At the bottom of settler the sludge is deposited and the treated water is discharged through a pipe into the emissary. An efficient settling for the entire clarifier length is obtained by using well designed plates systems, mounted obliquely (52°). The stability of the liquid and sludge retention is given by the rectangular cross section of the settling and the interior construction. Through a system of connected suction pipes is collected the settled sludge from the bottom of lamellar clarifier. Through a hydrocyclone this sludge is pumped by the sludge pump placed in the technical chamber. Periodically,

dense mineralized sludge is discharged into dewatering textile bags from where it is dehydrated and manually removed.

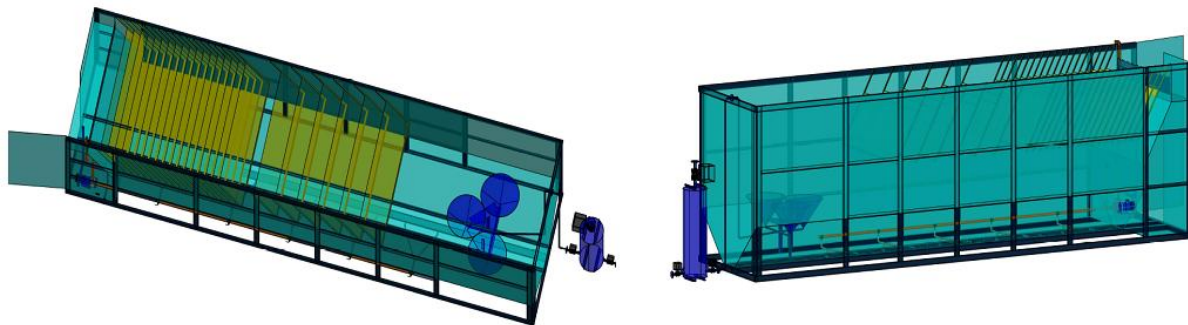


Figure 2. The final settler for the improved DAF unit.

3. Results and discussions

Figure 3 presents the laboratory scheme and installation for the DAF unit. The water recirculation inside the DAF system was considered, as shown in figure 3. The laboratory DAF facility consist of a lamellar clarifier, a pressurized capsule, a pressure clean/treated water pump, a valve and a foam removal equipment. The air is introduced inside the pressure capsule with the help of a compressor.

By treated water recirculation a clear advantage appears - air saturation of part of the treated water returns into DAF. The laboratory facility was tested in an industrial (food processing) wastewater treatment plant. The DAF unit was installed to remove the very fine chopped poultry feathers, which have passed the grills and all the previous wastewater treatment stages.

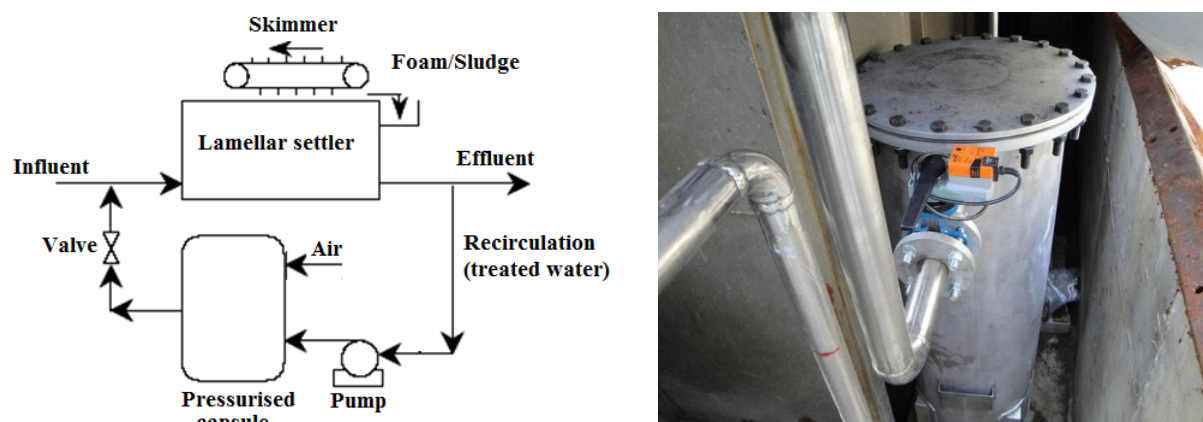


Figure 3. Experimental laboratory DAF unit installed in an industrial wastewater treatment plant.

For a correct designing of the lamellar settler, mathematical modelling and numerical simulations were realized by the researchers. The role of the numerical simulations was to determine the profiles of pollutants inside the settler. In order to build the mathematical model for the determination of the pollutant profile inside the lamellar settler, the general equation of dispersion was considered and the obtained results are shown in Figure 4. As it can be observed, in the front part of the settler, where the air-water mixture is introduced, is the highest concentration of pollutants. In the flotation zone, the most part of pollutants is removed. In the second part of the lamellar clarifier the water treatment process is completed and the pollutant concentration (suspended solids mostly represented by fine chopped feathers) decreases from 300 mg/l to 25 mg/l.

During the experimental measurement bubbles were formed; the bubbles were produced by supersaturating the water with air introduced under pressure (6 bars), followed by a depression (using a valve and 3 diffusers) to normal atmospheric values. The formed bubbles had a small diameter and the chopped feathers adhered to the bubbles and formed a foam layer at the water surface.

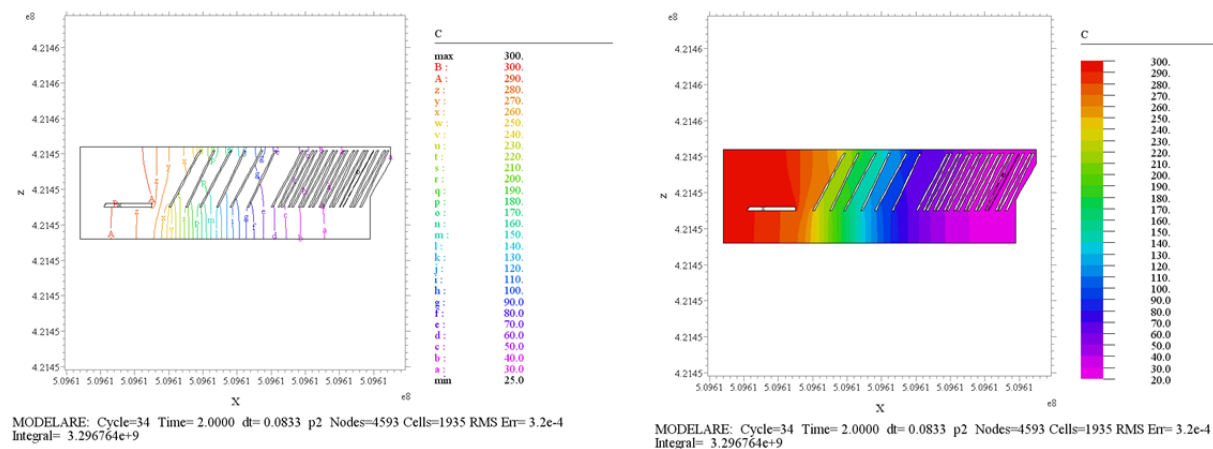


Figure 4. Pollutant (suspended solids) profile inside the lamellar settler – numerical simulations.

The installation was designed for a capsule pressure of 6-8 bars and a retention time of (1 - 3) min in the pressured capsule, where the water contacts the compressed air in the presence of the plastic elements. The depressure valve together with the 3 diffusers, placed inside the clarifier, plays an important role in the appearance of air bubbles in the wastewater mass.

Foaming is a process of surface separation of the impurities present in the foam generated by the diffusion of air into the body of water.

Formation of the bubble – suspended solid flocs depends on the depth of the flotation tank, and in the experimental laboratory installation a depth of 2.5 m was realized. The water retention time in the flotation tank was 1.5 hours.

The improved DAF unit removed 82% of the suspended solids.

Some of the innovative aspects and the advantages of the dissolved air flotation unit are:

- higher efficiency of the process obtained through the plastic moving elements inside the capsule that "tease" trail of bubbles to the surface;
- existing a large air-water surface contact offered by the using of sprinklers for water dispersion in very fine droplets within the capsule;
- facile installation of the pressurised capsule even in existing clarifiers;
- providing higher treatment efficiency without using any bio-products or consumables for enhancing the biological degradation processes - completely organic process;
- smaller footprint required as compared to conventional longitudinal settlers and flocculation;
- shorter flocculation times, as compared to gravity separation, because a smaller floc particle size is required;
- modular construction.

Recently, flotation reagents have an essential role in the pollutant removal both as sludge or foam. During the developing of industrial applications for flotation, the major advantage resulted from acquiring very effective flotation reagents. Depending on their role the flotation reagents are divided into collectors, frothers, modifiers, depressants and flocculants.

The purpose of the collector is to selectively form a hydrophobic layer on a given pollutant surface without binding to the pollutant particles in flotation slurry; thus allowing the hydrophobized particles to attach to air bubbles, which can be recovered in the froth product.

In the scientific literature is described a new technology where as collectors can be hydrophobic nanoparticles adsorb onto much larger, hydrophilic particle surfaces to facilitate the attachment to air bubbles in flotation, Figure 5. Also, it is showed that the role of nanoparticles is to facilitate particle-bubble attachment and/or to minimize detachment. The goal of the researchers is to consider the

influence of nanoparticle parameters on the various stages of particle flotation for identifying the important role of nanoparticles and to optimize nanoparticle properties for this application.

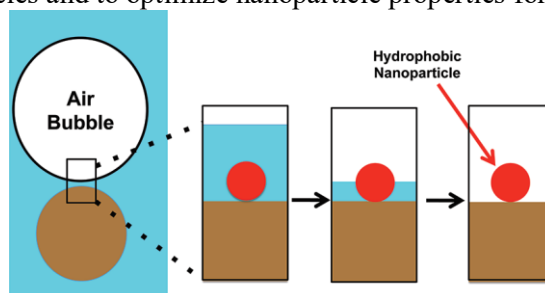


Figure 5. Thinning and rupture of the liquid film between a mineral particle with adsorbed nanoparticles and an air bubble [4].

Moreover it was found that smaller and more hydrophobic nanoparticles are the most efficient flotation collectors. The forces required to pull a nanoparticle-coated sphere from the air/water interface of a bubble into the water was determined via micromechanical measurements. The maximum pull-off force ranged from 0.0086 μN for a clean 55 μm glass bead to 1.9 μN for a bead bearing adsorbed 46 nm diameter polystyrene spheres [3].

4. Conclusions

Some of the advantages of the dissolved air flotation unit such as high efficiency of the wastewater process, facile installation sustain the further research in this field. Applying nanoparticles in DAF process could represent an efficient and innovative way to increase the DAF efficiency.

The research team, during the implementation of project no. PN-III-P2-2.1-PTE-2016-0183 will develop and test a pilot DAF installation. A nanomaterial dosing systems will be included in the treatment stage to obtain a more stable foam and a better pollutant removal efficiency. In order to validate the new proposed technology will be designed and realised wastewater treatment stage with a capacity of 24 m^3/day .

References

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