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RESEARCHES REGARDING AIR SOLUBILITY IN PRESSURIZED CAPSULE DESIGNED FOR WASTEWATER TREATMENT BY FLOTATION

Mihai MATACHE[1], Augustina PRUTEANU[1], Corina MOGA[2], Cristina BUTNARIU[3]

[1] INMA Bucharest, gabimatache@yahoo.com

[2] SC DFR Systems SRL, corinamoga@yahoo.com

[3] University POLITEHNICA of Bucharest

Abstract: *DAF (dissolved air flotation) systems are usually used in the last stage of a wastewater treatment stations. The purpose of these systems is to obtain optimum purity degrees by separating and collecting the colloidal particles in suspension in treated water using air microbubbles. For achieving this purpose, we designed a pressurized capsule with a maximum operating pressure of 10 bar. The efficiency of such a DAF system is characterized by the quantity of dissolved air in water equivalent with the number of generated microbubbles which could adhere to the surface of colloidal particles and collect them in a foam on top of the water level. Within this paper we observed the air solubility within the pressurized capsule function of the air-water mixture pressure and the fluid temperature.*

Keywords*: Wastewater, flotation, air solubility*

1. Introduction

The industries all over the world generate large quantities of wastewater which usually becomes an important source of pollution. Thus, the need for better treatment technologies arises especially for the last stage of wastewater treatment plants in which small to microscopic particles have to be removed.

Dissolved air flotation (DAF) systems are known to be efficient for removal of colloidal particles in suspension. The process operating such a system presumes the existence of a pressurized capsule in which a mixture air-water is formed in which under pressure air is dissolved, conducting to apparition of microbubbles. Later on, that mixture is injected in the water treatment tank and the microbubbles adhere to the colloidal particles present in the wastewater and get them to the surface where they form a foam which can be removed by mechanical means [1,2].

The performance of treatment technology using dissolved air flotation systems is dependent by the quantity of dissolved air, the number and dimension of the air bubbles and by their movement and capacity to carry the small particles to the top of the wastewater [3,4].

The compressed air pressure and the water pressure are important parameters for controlling air solubility in water. The volume and size of air bubbles produced on depressurization depends on the output pressure, the flow rate and the fluids temperatures. Larger microbubbles are produced at lower pressures and higher temperatures. The particles removal is more efficient using smaller air bubbles which have a lower rising speed and more time to adhere to particles and produce a higher effective bubble surface area. Within a DAF system will be separated particles of similar densities and sizes, which cannot be removed by other methods based on gravity alone. The process is efficient especially for particles below 100 μm, which are too light for gravity separation by sedimentation. The lower size limit for flotation separation is approximately 35 μm, although particles as small as 1 μm can be separated.

Within this paper we observed the air solubility within the pressurized capsule function of the air-water mixture pressure and the fluid temperature. The air solubility in water is the key element in treatment process optimization, for the separation of solids from a liquid.

2. Material and method

The quantity of air (gas mixture) which will dissolve into water is proportional with the air partial pressure. For air (gas mixture), Henry’s law could be used to predict the percentage of each gas which will be soluble into the solution. But different gases have different solubilities. Solubility of air in water can be expressed as a solubility ratio:

$$S_{air} = \frac{m_{air}}{m_{water}}, \tag{1}$$

where
S_{air} = solubility ratio
m_{air} = mass of air (kg)
m_{water} = mass of water (kg)

Air solubility in water follows Henry's Law - "the amount of air dissolved in a fluid is proportional to the pressure in the system" - and can be expressed as:

$$c = \frac{P}{k}, \tag{2}$$

where
c = solubility of dissolved gas
k = proportionality constant depending on the nature of the gas and the solvent
P = partial pressure of gas (Pa)
Air is a mixture mainly formed from oxygen and nitrogen, from which oxygen has a higher solubility in water. Air dissolved in water contains approximately 35 – 36 % oxygen compared to 21% in air. We designed a pressurized capsule of 0.3 m^3 volume and a maximum operating pressure of 10 bar in order to produce air microbubbles with variable size proportional to the working pressures.

Fig. 1. 3D model of the pressurized capsule

The imposed flow rate of the air-water mixture at the capsule output was of 100 litres per hour. The capsule had at inputs tap water and compressed air, the air-water mixture being outputted through a system of nozzles in a buffer tank. The control unit of the capsule allowed the control of the pressure within the capsule. The temperature of water was controlled using and industrial cooler. The process automation of the pressurised capsule supposed to maintain a steady level of water at the middle level of the capsule, with a cushion of compressed air above.

The pressure for the experiments was chosen to be within 3-7 bar, suitable for the bubble size between 20-100 μm, which represent the optimum dimensions for flotation process. The input water temperature was 10, 15 and 20 ºC in order to observe the air solubility. We collected the output mixture in a buffer tank in which we measured the dissolved oxygen concentration using an Oxygen portable meter ProfiLine Oxi 3205 fitted with a galvanic oxygen sensor CellOx. The measurements were performed in laboratory conditions, within INMA Bucharest Testing Department.

3. Results and discussion

For each experiment we performed 3 repetitions and reported the mean value obtained. The water input temperature was set at 10, 15 and 20 degrees Celsius and we measured the concentration of dissolved oxygen within the air-water mixture present at the output of the pressurized capsule, after depressurization and collection of the fluid in the buffer tank. First, we experimented with water at 10 ºC which was fed to the pressurized capsule together with the compressed air. The mean values for the dissolved oxygen concentration are presented in table 1.

Table 1: Experiments performed at 10ºC

Crt No	Working pressure (bar)	Mixture temperature (ºC)	Dissolved oxygen mg/l
1	2.99	10	32.01
2	3.99	10	40.32
3	5.01	10	51.06
4	6.00	10	63.42
5	7.00	10	70.04

It can be observed that the concentration of dissolved oxygen in water rises as the pressure increases. In table 2 we have presented the mean values obtained for the mixture temperature of 15ºC, in the same conditions as the previous ones. We can see the same pattern for the dissolved oxygen concentration as seen for the first temperature, with a slight decrease of the mesured values.

Table 2: Experiments performed at 15ºC

Crt No	Working pressure (bar)	Mixture temperature (ºC)	Dissolved oxygen mg/l
1	2.99	15	28.89
2	4	15	37.98
3	4.98	15	49.78
4	6.1	15	57.91
5	7.04	15	67.49

In table 3 are presented the experimental values obtained for the mixture temperature of 20ºC. The dissolved oxygen decreased to lower values, validating the fact that air solubility in water decrease with the rise of temperature.

Table 3: Experiments performed at 20ºC

Crt No	Working pressure (bar)	Mixture temperature (ºC)	Dissolved oxygen mg/l
1	2.98	20	26.12
2	3.98	20	35.55
3	4.96	20	44.26
4	6.01	20	52.04
5	7.03	20	59.64

Processing the experimental data, we obtained a 3D diagram representing the pattern in which the input parameters, fluid temperature and working pressure, are affecting the air solubility in water.

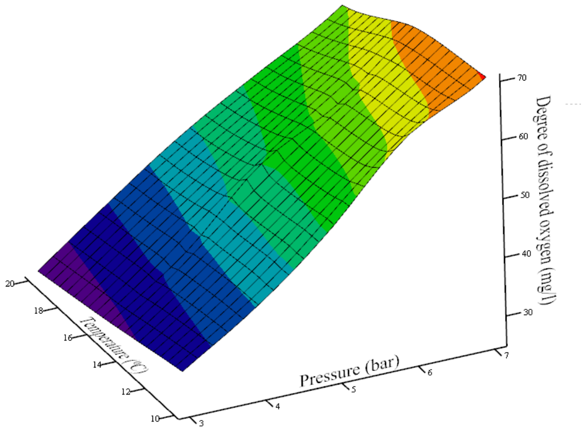

Fig. 2. 3D diagram of the dissolved oxygen concentration function of the working pressure and fluid temperature

Observing the diagram, we can see the linear characteristic of the experimental obtained results, fact that highlights the data consistency and validates the experiments.

4. Conclusions

The wastewater treatment by flotation represents a very important stage in the cleaning process of industrial and agricultural wastewater. Flotation could be achieved using dissolved air in a pressurized capsule. The most important parameter in flotation process is the quantity of dissolved air in water and this is influenced by the working pressure in the capsule and the fluid temperature. During our experiments, the best results were obtained for the minimum fluid temperature of 10 ºC and the maximum working pressure of 7 bar. These results could be used to optimize the wastewater treatment by flotation process in future applications.

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