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# Bubble hydrodynamic influence on oxygen transfer rate at presence of cationic and anionic surfactants in electroflotation process*

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**Abstract:** In this work, the effects of the presence of surfactants in the liquid phase and the hydrodynamic regime of the bubble flow on the oxygen transfer rate were investigated in an electroflotation process in batch mode. The volumetric mass transfer coefficient $K_La$ and the oxygenation capacity were evaluated to improve the performances of the electroflotation process in terms of oxygenation. In order to evaluate the liquid-side mass transfer coefficient $K_L$, the volumetric mass transfer coefficient $K_La$ was dissociated into $K_L$ and the specific interfacial area $(a)$ since the last one was obtained from the gas hold-up and the bubble diameter. The effect of Reynolds number which define the hydrodynamic of the bubble flow has been also studied. Models of $K_La$ and $K_L$ have been established to show the effects of the hydrodynamic parameters and liquid phase characteristics on the oxygen transfer rate.

**Key words:** electroflotation, mass transfer coefficient, hydrodynamic parameters, surfactant

## Introduction

The effects of surfactants in wastewater on the oxygen transfer rate have been studied because of their industrial relevance. In fact these surfactants are present in the wastewater issued from diverse applications ranging from paint technology, lubrication, paper making, oil recovery and biochemistry of proteins[1].

It is generally recognized that small amounts of surfactant additives as contaminants affect markedly mass transfer rate from the gas to the liquid phase[2-5]. Mass transfer effectiveness is most frequently assessed in gas-liquid contactors by measuring the volumetric mass transfer coefficient $K_La$ [6]. This coefficient is a key parameter in electroflotation process which can be used as aeration system.

Electroflotation (EF) is a simple process that floats pollutants (or other substances) by their adhesion onto tiny bubbles of hydrogen and oxygen generated from electrolysis of aqueous solutions[7-9]. The chemical reactions taking place at the cathode and the anode are given as follows:

Anodic oxidation

$$2H_2O \rightarrow O_2^{\uparrow} + 4H^+ + 4e^- \quad (1)$$

Cathodic reduction

$$4H_2O + 4e^- \rightarrow 2H_2^{\uparrow} + 4OH^- \quad (2)$$

Chen[9] has shown that EF is more competitive than other flotation technologies such as dissolved air flotation and dispersed air flotation. In fact, the electroflotation process gives the highest oxygenation efficiency[10].

The $K_La$ values are often global and thus insufficient to understand the gas-liquid mass transfer mechanisms[11]. For this purpose, it becomes essential to separate the parameters, especially the liquid-side mass transfer coefficient $K_L$ and the interfacial area $a$ [12-14].

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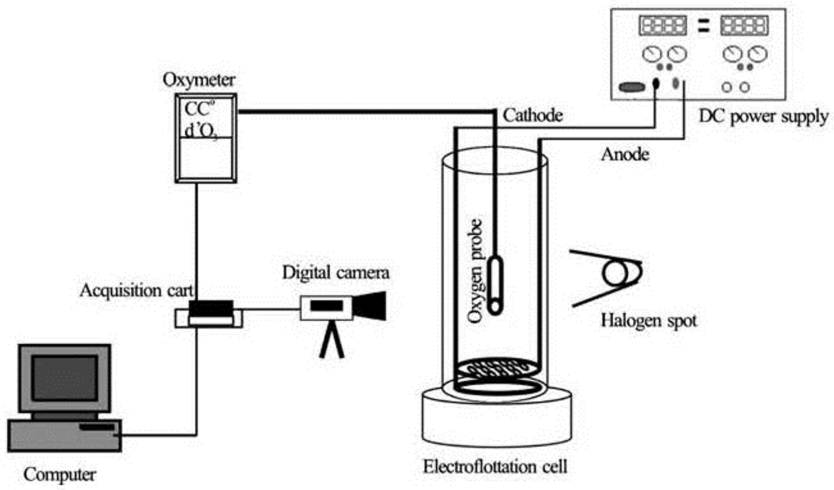


Fig.1 Experimental set-up

## 1. Theory

The volumetric mass transfer coefficient of dissolved oxygen can be derived from the two-film theory. Assume that the diffusion rate of oxygen through gas film is much higher than the diffusion rate through liquid film, then the resistance of gas film can be neglected. For a complete mixed system, Eq.(3) is obtained[15]

$$\frac{dC}{dt} = K_L a(C^* - C) \tag{3}$$

where $dC/dt$ is the rate of change of oxygen concentration with time.

Equation (3) can be readily integrated to yield the following expression for $C$ as a function of time

$$C = C^* - (C^* - C_0)\exp(-K_L at) \tag{4}$$

where $C_0$ is the initial dissolved oxygen concentration at $t = 0$ and $C^*$ is the equilibrium oxygen concentration in liquid phase.

A nonlinear regression analysis based on the Gauss-Newton method was recommended by American Society of Civil Engineers (ASCE) to fit Eq.(4) to experimental data using $K_L a$, $C^*$ and $C_0$ as three adjustable model parameters[16].

The volumetric mass transfer coefficient must be corrected to a standard reference temperature $(T)$ of 20°C by using the Arrhenius relationship[6]

$$K_L a_{(20^\circ \mathrm{C})} = K_L a_{(T)} \theta^{(20-T)} \tag{5}$$

A generally-accepted value of the temperature correction factor, $\theta$ is 1.024.

The Oxygenation Capacity (OC) presents the mass of oxygen that can be transferred by the aeration system per $m^3$ and per hour to evaluate the dissolved oxygen concentration in water.

$$\mathrm{OC} = K_L a(C^* - C_0) \tag{6}$$

## 2. Experimental set-up and mesuring techniques

### 2.1 *Electroflotation cell*

The electroflotation cell, shown in Fig.1, is used for batch mode. It is a cylindrical plexiglas vessel and is 0.092 m in diameter and 0.71.5 m in height. It is provided with two electrodes: titanium coated with ruthenium oxide anode and a stainless steel cathode. These two electrodes are supplied by a generator of DC current which enables the variation of current density. It is also noticed that the gap between anode and cathode is maintained at 0.005 m to minimize the ohmic loss. The cathode compared to the anode is perforated and occupies the top position .This perforation allows the evacuation of bubbles produced at the anode.

### 2.2 *Image acquisition and treatment method*

The equipments used for the determination of the bubble size distributions by image analysis are a microscopic zoom digital video camera (model NV-A3E from Panasonic, Japan), an acquisition card (model Pinnacle PCTV PRO version 4.02 from Pinnacle systems), a PC (model Pentium 4, from Fujitsu Siemens) with a digital image analysis programs namely: Photofiltre (Version 6.2.6), Photoshop (CS2), Ulead Photo Impact (Version 11 Pro) and 700 watt power halogen spot.