Chemical Engineering Science 62 (2007) 2545–2555

Chemical Engineering Science

www.elsevier.com/locate/ces

Impact of agitation and aeration on hydraulics and oxygen transfer in an aeration ditch: Local and global measurements

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Received 17 November 2004; received in revised form 23 September 2005; accepted 23 September 2005

Abstract

In urban waste water treatment plants one of the most developed processes to treat pollutants is the activated sludge basin. The aim of this paper is to present results on the hydraulics and aeration performance of an aerated basin at pilot plant scale. Local gas retention, gas velocity and bubble size have been measured and linked to the classical global measurements of oxygen transfer coefficient and of horizontal liquid velocity. Different operating conditions have been tested to show the impact of each parameter on hydraulics and aeration performance.

The increase of *air flow rate* induces an increase of the local gas retention, of the gas velocity as well as of the Sauter diameter. Changes in these local parameters do exhibit a strong impact on the oxygen transfer coefficient. Hence these local measurements are used to discuss and gain a deeper understanding of the oxygen transfer phenomena.

An augmentation of the *horizontal liquid velocity* results in higher values for the global oxygen transfer coefficient. This is confirmed by observation and local measurements, which show a stronger inclination of the air plume with increasing velocity. This translates to a larger course for the bubbles to cover before reaching the surface.

With respect to global oxygen transfer measurements, the optimal *position of the agitator* was found to be near the bottom of the reactor for the type of pilot plant studied. In addition it can be stated that the horizontal position of the impeller has a large impact on the liquid horizontal velocity. Improved understanding is gained through local investigations, which reveal the increased inclination of the air plume as one major cause.

Keywords: Aeration; Hydrodynamics; Mass transfer; Optimisation; Activated sludge basin; Optical probe

1. Introduction

The aeration ditch (AD) is a classical biological treatment in urban wastewater treatment plants. ADs are used to reduce pollutants from wastewater under agitated and non-aerated/aerated conditions. Since a couple of years independent agitation and aeration systems are developed to improve the overall performance: horizontal submerged impellers and fine bubble diffusers at the bottom of the tank. Their impacts on the hydraulics and aeration performances have been the subject of several investigations (e.g. Capela, 1999). However, at this time there are no commonly accepted rules with respect to the location of the impeller. Recommendations differ with respect to its vertical position (halfway to one third up from the bottom) and with regard to the distance between the turn and the position of the agitator. Hence questions still remain with respect to: (a) The preferred vertical and horizontal position of the impeller to ensure a sufficient velocity in order to avoid settling at a minimum energy input; (b) the optimum combination of agitation-aeration to increase oxygen transfer.

Recent studies published in literature show an increase in application of computational fluids dynamics (CFD) in order to gain deeper insight into AD systems (Cockx et al., 2001; Littleton et al., 2001; Hunze and Schumacher, 2003; Vermande et al., 2003; Tanguy et al., 2004). Common measurements used in AD system are the so called global measurements, such as

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0009-2509/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ces.2005.09.016

the mean horizontal liquid velocity and the oxygen transfer efficiency under clean water and process conditions (Gillot et al., 1997). However, they are insufficient to implement correctly and validate the CFD.

As any modeling technique it relies on the type and precision of the experimental data used. As underlined by Boyer et al. (2002) extra measurements are regarded as necessary to perform correct simulations.

Possible types could be local measurements such as: 3D velocity for the liquid phase, gas retention, gas velocity and the bubble size distribution. In their literature review, Boyer et al. (2002) detailed available non-invasive and invasive techniques to characterize locally gas–liquid flow, such as photography and image analysis, PIV, ultrasonic tomography, needle and ultrasound probes. The choice of the technique must be in agreement with the precision level: from the global steady state characteristics of the reactor (global gas hold up, flow regime, etc.) to the local and transient characteristics of the flow.

In our study, the invasive optical technique with a double optical probe was selected. This technique characterizes well the gas phase and can still be used when others are inefficient; e.g. the visualization technique is limited to a zone near to the transparent wall.

Kiambi (2003) did a comparison study between a double optical probe and imaging in a bubble column. The author highlights the intrusive nature of the double optical probe: (i) some bubbles are flattened by the probe, (ii) some are deviated by the first impact and do not reach the second sensitive probe, (iii) the impact can cause sudden change in direction. With respect to the reliability for bubble characteristics measurements, he stated a deviation of less than 5% between the two techniques for bubble size of 2.15 and 4.5 mm. Hence this double optical probe can be used with sufficient confidence in two phase flow.

The aim of this paper is to determine characteristics of the air plume in a pilot activated sludge basin under different agitation and aeration conditions. These local measurements are discussed in conjunction with measurements obtained on the global scale.

2. Materials and methods

2.1. Pilot and equipment

The pilot basin is a stainless steel aeration basin of 7.5 m^3 with a water depth (h) of 1.2 m (Fig. 1). All dimensions are depicted in the Fig. 2.

It is equipped with an impeller and with 8 independent aeration racks. The impeller position is chosen by the operator: 2 horizontal and vertical positions are selected for this study. Each aeration rack is made of 2 fine bubbles disc diffusers. The equipment characteristics are detailed in the Table 1.

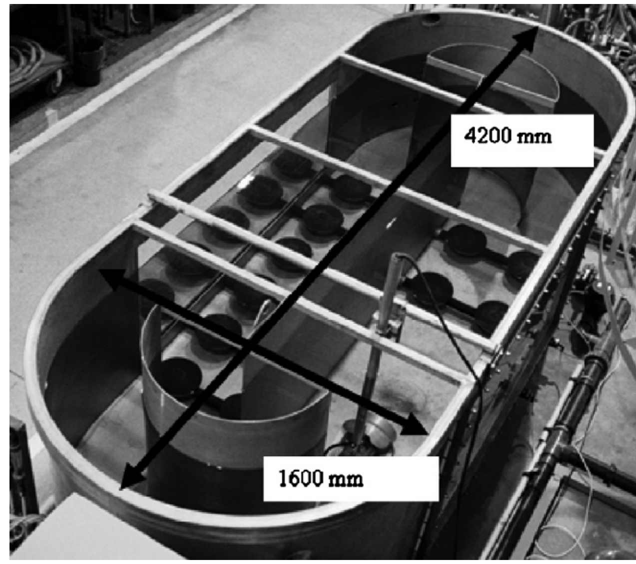

Fig. 1. Overview of the aeration ditch.

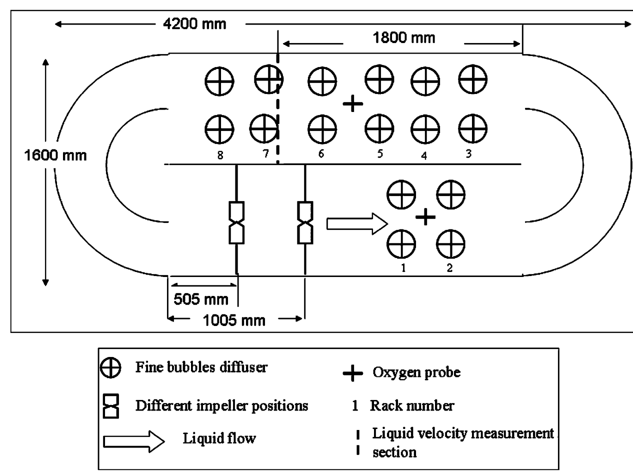

Fig. 2. Schematic view of the aeration ditch.

Table 1
Characteristics of the agitator and diffusers

Agitator		Diffusers	
Position	Chosen by the operator	Position	0.10 m from the bottom
Model	Flygt SR 4610	Model	Europelec aquadisc
Diameter	0.21 m	Material	EPDM (ethylene propylene diene monomer)
Blades	2	Diameter	0.25 m
Rotation speed	0–1390 rpm	Air flow rate	0.5–5 Nm^3h^{-1} (peak flow of 8 Nm^3h^{-1})

2.2. Measurements

2.2.1. Measurements of the liquid velocity (U_L)

Experimental tests were carried out in order to evaluate the horizontal water velocity under different agitation conditions (Table 2). They were performed under clean water conditions using a flow meter Flo-Mate (Marsh-Mc Birney). The apparatus used for estimating the velocity, is based on Faraday' principle. This gives the velocity's component in the main axis of the probe at a precision estimated at ±5%.