Journal of Molecular Liquids 173 (2012) 113–118

Contents lists available at SciVerse ScienceDirect

Journal of Molecular Liquids

journal homepage: www.elsevier.com/locate/molliq

Influence of acetaminophen on gas hold-up, liquid circulation velocity and mass transfer coefficient in a split-cylinder airlift bioreactor

Elmira Mohsenzadeh, Mostafa Keshavarz Moraveji *, Reza Davarnejad

Department of Chemical Engineering, Faculty of Engineering, Arak University, Arak 38156-8-8349, Iran

ARTICLE INFO

Article history:
Received 14 June 2012
Received in revised form 1 July 2012
Accepted 2 July 2012
Available online 11 July 2012

Keywords:
Airlift reactor
Acetaminophen
Gas hold-up
Oxygen transfer

ABSTRACT

In this study, hydrodynamic parameters and mass transfer characteristics were measured at four acetaminophen concentrations (1000–4000 mg/l) in water over the range of superficial gas velocity of 0.2–1 cm/s at 25 °C in a split-cylinder airlift bioreactor. The gas hold-up and overall oxygen transfer coefficient for all the fluids increased with increasing the gas velocity. The specific interfacial area increased and liquid-side oxygen transfer coefficient decreased with increasing gas velocity. Furthermore, the gas hold-up increased and bubble diameters decreased with acetaminophen addition. The overall oxygen transfer coefficient and gas hold-up increased and bubble diameter decreased with increasing acetaminophen concentration. The overall oxygen transfer coefficient increased due to increasing the specific interfacial area (with surface tension and bubble size reduction). Two correlations based on the dimensionless numbers were developed to find Sherwood number and gas hold-up.

1. Introduction

Environmental contamination by pharmaceuticals and personal care products (PPCPs) has recently gained widespread public attention as a pervasive problem. These effluents are loaded with pathogenic microorganisms, pharmaceutical partially metabolized, radioactive elements and other toxic chemical substances [1,2]. Airlift reactors are widely used in the biotechnology processes such as biochemical fermentation, chemical reactions and biological wastewater treatment [3]. The airlift reactors are a promising reactor for two- and three-phase reactions due to its advantages of their simple construction, high fluid circulation, mass and heat transfer, short mixing time, low shear stress and energy consumption [4–6].

The gas hold-up can be an indicator for the mean residence time of the gas phase and the gas–liquid mass transfer coefficient. It also affects the liquid circulation velocity. Moreover, the liquid circulation velocity affects the mixing behavior in the airlift reactors [3].

The effect of aeration rate on the performance of water-based systems in ALRs has widely been studied [6–12]. Pajoum Shariati et al. studied pharmaceutical wastewater treatment in an external loop airlift membrane bioreactor [13]. They removed 100% of acetaminophen by 2 days. Moraveji et al. used some alcoholic solutions in an internal airlift reactor to reduce the average bubble size, increase the gas hold-up, the interfacial area for mass transfer, and the gas–liquid mass transfer coefficient [14]. Kalekar and Bhagwat considered the various surfactants adsorption at gas–liquid interface [15]. Moraveji et al. investigated that surfactant existence increased gas hold-up and mixing time, although it decreased the liquid circulation velocity and the rate of oxygen mass transfer [16].

The purpose of the present work was to investigate the effect of acetaminophen at various concentrations on hydrodynamic parameters and mass transfer characteristics in a split-cylinder airlift reactor. Our data were then compared with pure water system. According to our data, two correlations based on the dimensionless numbers were also obtained and examined.

2. Experimental

2.1. Materials

Acetaminophen was obtained from Temad Company (Iran). Its characteristics were illustrated in Table 1. The various concentrations (1000 4000 mg/l) were locally prepared.

2.2. Methods

2.2.1. Apparatus and measurement methods

The experimental set-up is shown in Fig. 1. All parts of it have been explained in detail in the literature [14].

In this study, volume expansion method was applied to measure the overall gas hold-up during the steady-state condition in the airlift bioreactor. The local gas hold-up, liquid circulating velocity, mixing time and oxygen mass transfer coefficient measurement methods were proposed and reviewed elsewhere [14]. All experiments were carried out at ambient conditions (atmospheric pressure and 25(± 0.5) °C).

* Corresponding author. Tel.: +98 9363098063; fax: +98 861 4173450.

0167-7322/$ – see front matter
doi:10.1016/j.molliq.2012.07.002

Table 1
Acetaminophen physical properties.

Acetaminophen	Paracetamol
Systematic name	N(4-hydroxyphenyl)ethanamide N(4-hydroxyphenyl)acetamide
Formula	$C_8H_9NO_2$
Mol. mass	151.17 g/mol
Description	White and crystalline powder
Density	1.263 g/cm^3
Solubility in water	12.78 mg/cm^3 (20 °C)

2.2.2. Bubble diameter measurement

The steady-state bubble diameter size was determined with photographic technique by a digital camera (Panasonic, model: DMC-FS20 with resolution of 10M pixels). It was placed at the middle of reactor (0.6 m above the bottom of the ALR). Fig. 2 shows two slides regarding acetaminophen and pure water bubbles. The moving average method was used to account number of bubbles which were more than 300 bubbles that were randomly chosen in 10 pictures. Then, bubble diameters were measured by WINDIG software (version 2.5).

In spherical bubbles d_1 is equal to d_2 (so $d_v = d_1 = d_2$), while elliptical bubbles were measured according to the maximum and minimum diameters of bubbles as follows:

$$d_v = \sqrt[3]{d_1^2 d_2} \tag{1}$$

where d_1, d_2 and d_v are the maximum, minimum and equivalent diameters, respectively.

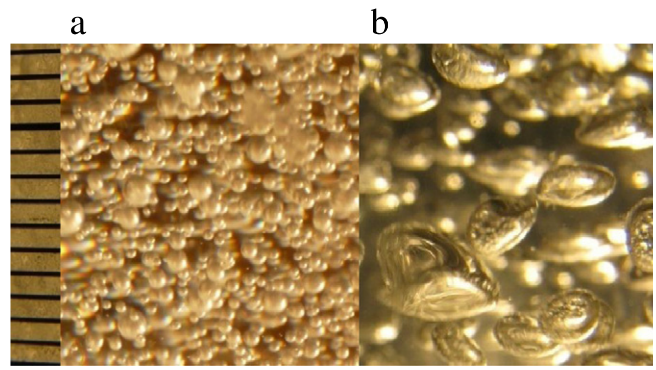

Fig. 2. Bubble photographs in $U_G = 0.2$ cm/s. (a) Acetaminophen concentration 4000 mg/lit, (b) pure water.

The average of bubble diameter (d_{ave}) is calculated as follows:

$$d_{ave} = \frac{\sum_{i=1}^{i=N} d_i^3}{\sum_{i=1}^{i=N} d_i^2} \tag{2}$$

d_i is bubble diameter and i is the number of bubbles.

The bubble diameter average using the moving average method is shown in Fig. 3. Fig. 4 shows the percentages of bubbles with the same diameter in a liquid bulk versus their diameters.

The surface tensions of the various fluids were measured by the Ring method using a tensiometer (model K10ST, KRUSS GmbH, Hamburg, Germany). The densities were calculated using the Buoyancy method [17]. The obtained data are summarized in Table 2.

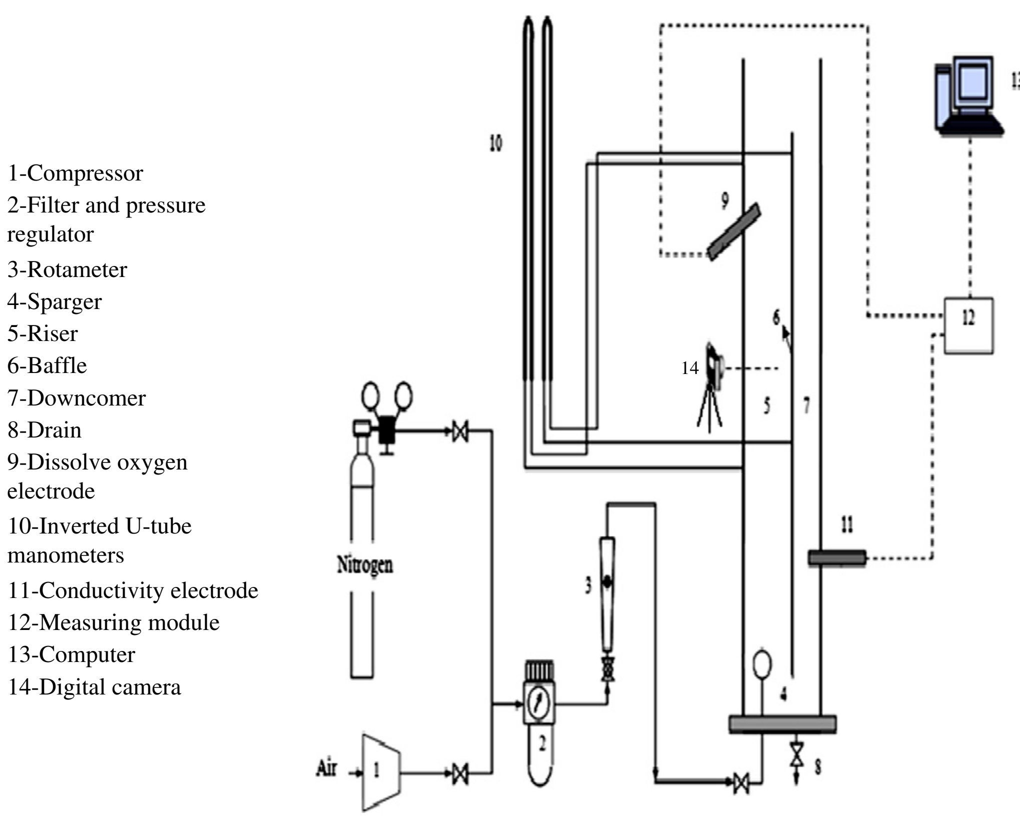

Fig. 1. Schematic presentation of the split-cylinder airlift reactor.