CALCULATION OF THE VOLUMETRIC MASS TRANSFER COEFFICENT IN A CLOSED SYSTEM WITH THREE COLUMNS IN SERIES

Erinda Piluri
General Directorate of Metrology, Tirana, **ALBANIA**
E-mail
erinda.piluri@dpm.gov.al

Dhurata Koraj
Department of Industrial Chemistry, Faculty of Natural Sciences/University of Tirana
ALBANIA
E-mail
dhurata.koraj@fshn.edu.al

Ilirjan Malollari
Department of Industrial Chemistry, Faculty of Natural Sciences/University of Tirana
ALBANIA
E-mail
ilirjan.malollari@fshn.edu.al

ABSTRACT

In this paper it is presented an analysis of a closed system that measures ethanol vapor concentration, in order to have a proper representation of the human body lungs. In addition to the theoretical evaluation by predicting the mass transfer coefficient, continuous measurements were made in the system to reach the experimental determination of the mass transfer coefficient. From the comparison of the predicted values with the measured values, it was concluded that our system of three bubble columns set in series, is able to efficiently perform a natural process that takes place in the human body.

Keywords: Mass transfer coefficent, bubble column, ethanol concetration.

INTRODUCTION

Experimental evaluation of ethanol vapors is performed through a non-invasive technique using a continuous system. The analogy of this system with our lungs is the main motivation behind the experiments conducted. While experimental data are important in achieving specific result, it is also valuable to perform several calculations based on bubble columns applications in chemical engineering. In this study we present comparisons of calculated models with experimental values of a three column system, that are used to measure vapor ethanol concentration.

METHODOLOGY

We use three continuous closed columns in series (figure 1), with equal amount of solution water-ethanol, with ethanol concentration 0.476 mg/l. The connectors used between columns, for each set of experiments, are of specific diameter as it influences the pressure drop in our system. Air passes through each vessels solution with a fine-gas sparger and carries with it a certain amount of ethanol vapor which, when it evaporates, lives in the upper part of the solution. This process is repeated in the second column where the air from the first reactor is passed to the second column and again absorbs an amount of ethanol vapor and passed to the third column where, unlike the first two, we try to achieve equilibrium between the concentration alcohol content and concentration of alcohol in the air. The air stream after leaving the third column is passed to the analyzer for mass concentration of alcohol. Gas flow was kept 12 l/min and temperature ranged from 32^{0}C to 38^{0}C.

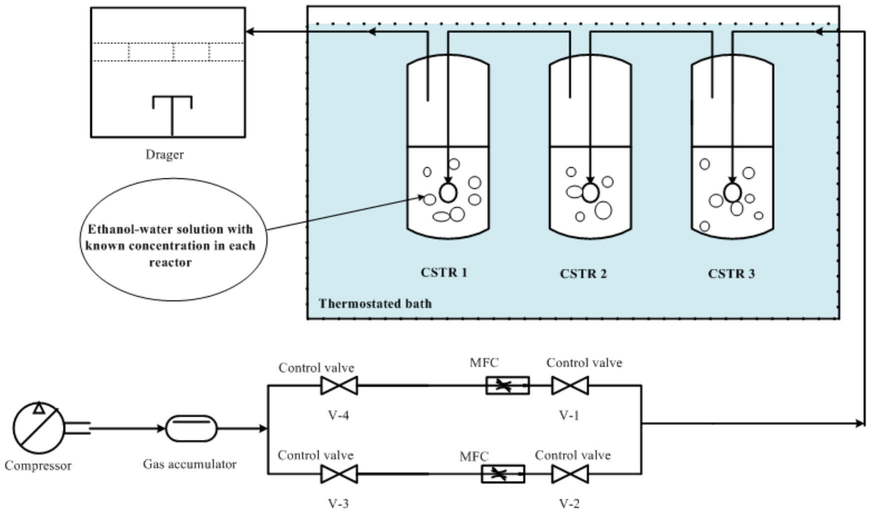


Figure. 1 Experimental flowsheet of the system used to measure ethanol vapour concetration.

In table 1 are described base operational parametres in our system, which are valuble also for model calculations

Table 1. Columns operational parameters

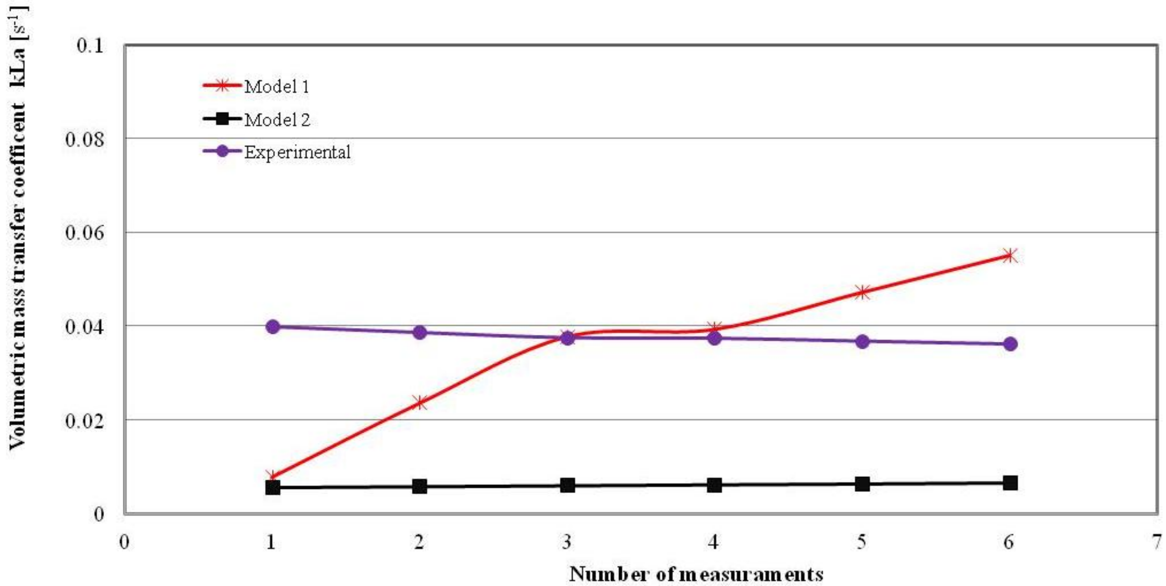
Ql (l/min)	8-22
ρ_{tret} (kg/m^3)	995.68-993
ρ_g (kg/m^3)	(1.165-1.135)
μ_L (kg/m^3)	(0.801-0.685)·10^{-3}
μ_g (kg/m^3)	(1.87-1.91)·10^{-5}
d_{sp} (μm)	100
d_{vs} (μm)	120
g (m/s^2)	9.81
R (J/kmolK)	8314
V_L (ml)	100-700
M (kg/kmol)	29
Pt (Pa)	101632
D^0_{o2} (m^2/s)	2.33·10^{-9}
α (s^{-1})	0.5
T_0 (K)	0
P_0 (Pa)	101325
T(K)	303-313
P(Pa)	101632
d_{sh}(mm)	90
Ω	1

RESULTS AND DISCUSION

In table 2, we have presented main models that have bee studied in similiar enviroment. We used their data and compered them with our experimental results. Model II is based on equations used for a babble column, with characteristics similar to our column system, developed by Fadavi et al (2015).

Table 2. Mathematical models used to compare with our experimental system.

Model I	**Reference**
$D = D_0 \left(\frac{P_0}{P}\right)\left(\frac{T}{T_0}\right)^{3/2}$	Chemical Engineering manual. (2014)
$k_L = \frac{0.15 D_i}{d_{vs}}\left(\frac{\nu_L}{D_i}\right)^{1/2}\left(\frac{d_{vs} U_G \rho_L}{\mu_L}\right)^{3/4}$	Schügerl et al. (1978)
$(k_L a) = 0.467 U_G^{0.82}$	Shah et al. (1982)
$k_L a = 0.5 \varepsilon_G$	Letzel et al., (1999)
Model II	**Reference**
$kLa = 19.91 \cdot 10^{-3} e_T^{0.361} \varepsilon_G^{0.667}$	Fadavi et al. (2005)



Graph 1. Description of volumetric mass transfer cofficent calculated from Model 1and Model II and experimental evaluation of our system.

It is very important to quantitavly express the amount of one component, passing form one phase to another, that is why calculation of mass transfer coefficient has always been focus of modeling in bubble columns. We studied several models and selected the ones that used systems similar to our set up.

We observed that based on Model II, mass transfer coefficient was almost constant during each set of measurements. Values calculated with Model I increased at the beginning then stabilized predicting the values reached from the experiment 0.039 s^{-1}. Form our experimental results we could see that after some time the ability of the solution to desorbed ethanol decreased slowly.

CONCLUSIONS

Bubble columns are the most widespread units used in separation processes as absorbers, desorbers, due to their operation simplicity, low cost and flexibility working in liquid phase. This study was based on the application of an experimental set up which achieved good approximation with theoretical models used. We evaluated the volumetric mass transfer coefficient and observed that it strongly depended on many factors as, gas velocity, sparger, gas hold up etc.

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