Carbon Dioxide Capture from flue gas Chlorella Vulgaris micro algae in an Air-Lift Column with External Liquid Circulation

Rabar Rahimi[1], Negar Azhand [2]

1,2 Department of Chemical Engineering, University of Sistan and Baluchestan, IRAN

1. Introduction

Today, population growth, industrial expansion, gaseous emissions from the thermal chimneys, energy supply processes and different Petrochemical operations has been increased concentrations of greenhouse gases in the atmosphere over the past decades. An increase in this gas causing global warming and the creation of environmental issues. The most damaging greenhouse gas is carbon dioxide. There are many ways to stabilize the gas, one of these methods which is completely environmentally compatible and economically affordable is to use microalgae to stabilize carbon dioxide. The use of microalgae due to its great supply, easy access, reasonable price and lack of pollution and airlift bioreactor due to the presence of low shear stress for microalgae growth is suggested. Cylindrical airlift bioreactors have the most suitable space for the growth and proliferation of microalgae [1]. This bioreactors consists of two concentric cylinders which are composed of three parts; the riser, downcomer and the gas Sparger [2]. To increase the mass transfer rate, gas Spurger should be used to supply carbon dioxide and to improve the oxygen existence from the culture medium [3]. Experimental researches in the field of biological removal of carbon dioxide in the airlift bioreactor have been conducted by Zhang [3], Merchuk and shitter [4], Drandf et al. [5] and Lstansky et al. [6]. In this researches an airlift bioreactor with internal cycle has been applied and the effect of the circulation velocity and light intensity on the carbon dioxide removal efficiency and the growth of microalgae were investigated. Merchuk et al. [7] compared the growth of the red microalga it Porphyridium sp in three bench-scale bioreactors of 13 dm3 volume: a bubble column, an airlift reactor and a modified airlift reactor with helical flow promoters in the top of the downcomer. The results showed that Algal growth in the airlift reactor with helical flow promoters had lower gas requirements than in the other reactor configurations. This implies lower costs in air compression and in air and CO2 requirements. It was concluded that the advantages found are related to the particular fluid dynamic characteristics of the reactor. Luo et al. [8] studied the effect of the Spurger structure on the hydrodynamics and mass transfer characteristics of an internal loop airlift reactor. Three spargers includes 4-orifice nozzle, O-ring distributor and the 2-orifice nozzle with different diameters were tested. The results showed that the 4-orifice nozzle improved the volumetric mass transfer efficiency for that it generated a smaller mean bubble diameter and therefore a larger specific interfacial area than other spargers. Hosseini et al. [9] conducted an experimental work to investigate microalgae growth in a top-lit open gas-lift bioreactor with a 4-inch diameter ceramic sparger. The results gave comparable volumetric biomass productivity, but around three-times higher areal productivity than reported for traditional raceways. they found that by being top lit only, the costs of installing, operating and maintaining supplementary lighting are avoided, as well as the tanks can be buried for cheaper construction costs. In this study, external gas sparger has been used in such a way that the space between the two cylinders is riser and the central cylinder acts as downcomer.

2. Methodology

The experiments was performed at two stages. First hydrodynamic experiments that includes gas Rota meter calibration, gas holdup measurement and calculation of the circulation velocity. Second, Chlorella Vulgaris microalgae cultivation in an external loop airlift bioreactor (Fig. 1) at three different inlet air flow rate with a fixed value of carbon dioxide percentage (2.3 %) which in each experiment, the residence time of microalgae lasted for 10 days. During this time, microalgae exposed to 12 hours light whit a light intensity of 1400 lux / m2 and spent 12 hours in the dark. The effect of inlet gas flow rate on the hydrodynamic parameters, growth of microalgae and carbon dioxide removal efficiency are presented below.

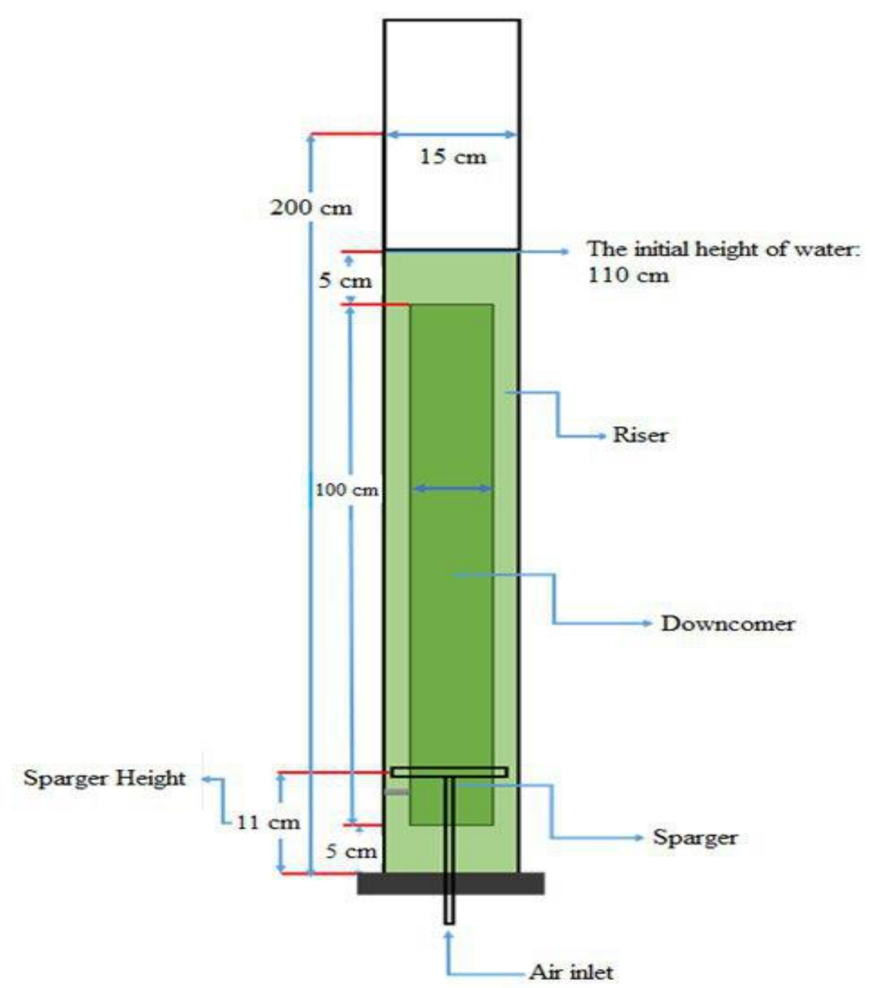

Fig. 1 Schematic diagram of the photo-bioreactor used in the study

3. Results

three tests at 25 ° C and atmospheric pressure

Artificial velocity m/s	Air inlet flow rate m^3/s	CO_2 inlet flow rate m^3/s	Experiment No
0.001564	1.5×10^{-5}	0.35×10^{-6}	Case 1
0.002193	2.1×10^{-5}	0.5×10^{-6}	Case 2
0.002606	2.5×10^{-5}	0.58×10^{-6}	Case 3

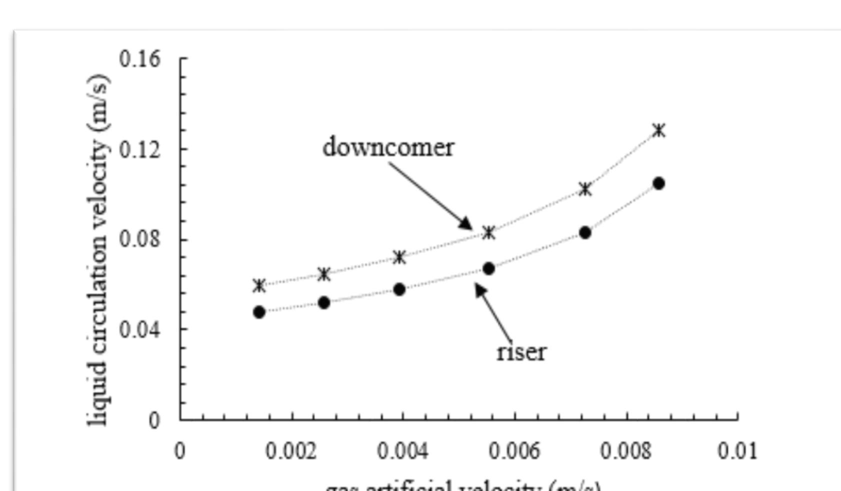

Fig. 2. Variation of the Liquid circulation velocity whit artificial velocity

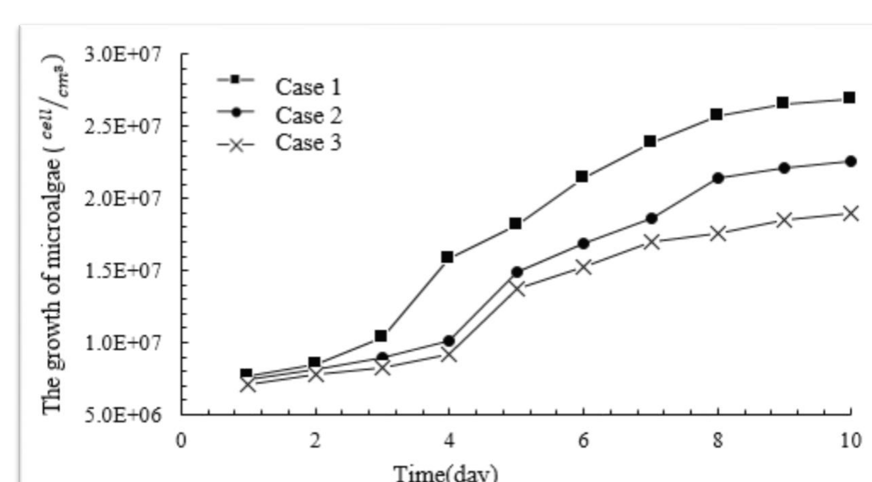

Fig. 3. Effect of circulation velocity on the microalgae growth.

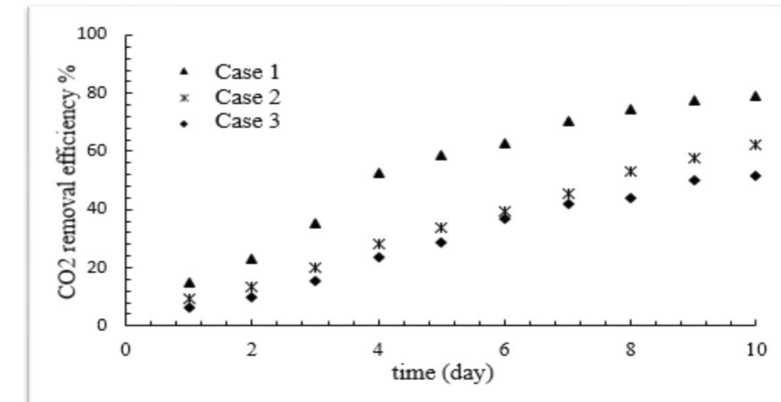

Fig. 4. Effect of circulation velocity on the CO_2 removal efficiency

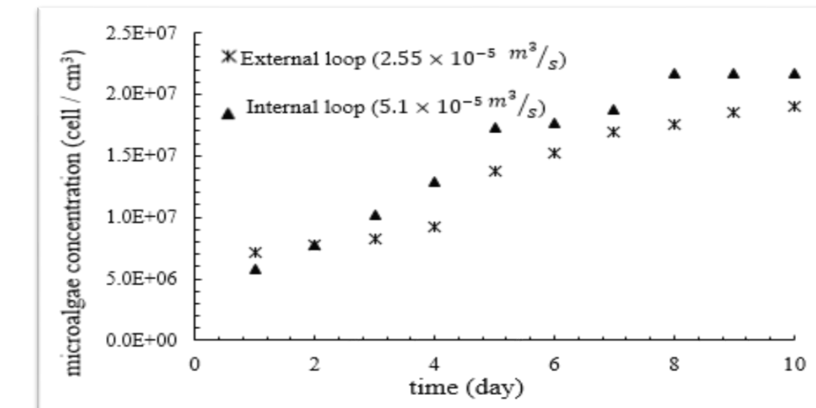

Fig. 5. Comparison between internal and external loop bioreactors.

4. Conclusions

The results shows that by increasing artificial velocity of inlet gas, the total gas holdup and circulation velocity is also increased. The initial concentration of the microalgae injected into the bioreactor in the first, second and third experiment, was 7710000, 7460000 and 7520000 cell / cm^3 which after 10 days and at the end of each test reached to 26.1 million, 23.91 million and 21100000 cell / cm^3 respectively. It is found that the carbon dioxide removal efficiency in the first, second and third experiment was 78.87 %, 62.18% and 51.41% at the artificial velocities of 0.00157 m/s, 0.00219 m/s and 0.00261 m/s respectively. As is evident, microalgae growth and carbon dioxide removal efficiency decreases whit an increase in the artificial velocity of inlet gas. A comparison between the results in both internal and external loops shows that although in both cases by increasing the inlet gas flow rates, the amount of microalgae growth and carbon dioxide removal efficiency is decreased but it was observed that the performance of airlift bioreactor in the internal loop is more favorable so that even by doubling the amount of inlet gas flow rate in the internal loop compared with external loop, the more microalgae growth and carbon dioxide removal efficiency is obtained.

5. References

[1] F. Acién, J. Fernández, J. Magán, and E. Molina, "Production cost of a real microalgae production plant and strategies to reduce it," *Biotechnology advances*, vol. 30, pp. 1344-1353, 2012.

[2] A. S. Mirón, M.-C. C. García, F. G. Camacho, E. M. Grima, and Y. Chisti, "Mixing in bubble column and airlift reactors," *Chemical Engineering Research and Design*, vol. 82, pp. 1367-1374, 2004.

[3] K. Zhang, N. Kurano, and S. Miyachi, "Optimized aeration by carbon dioxide gas for microalgal production and mass transfer characterization in a vertical flat-plate photobioreactor," *Bioprocess and biosystems engineering*, vol. 25, pp. 97-101, 2002.

[4] J. C. Merchuk and R. Shechter, "Modeling of an airlift reactor with floating solids for wastewater treatment," *The Canadian Journal of Chemical Engineering*, vol. 81, pp. 900-905, 2003.

[5] S. Drandev, K. I. Penev, and D. Karamanev, "Study of the hydrodynamics and mass transfer in a rectangular air-lift bioreactor," *Chemical Engineering Science*, vol. 146, pp. 180-188, 2016.

[6] P. Lestinsky, P. Vayrynen, M. Vecer, and K. Wichterle, "Hydrodynamics of airlift reactor with internal circulation loop: experiment vs. CFD simulation," *Procedia Engineering*, vol. 42, pp. 892-907, 2012.

[7] J. C. Merchuk, M. Gluz, and I. Mukmenev, "Comparison of photobioreactors for cultivation of the red microalga Porphyridium sp," *Journal of Chemical Technology and Biotechnology*, vol. 75, pp. 1119-1126, 2000.

[8] L. Luo, F. Liu, Y. Xu, and J. Yuan, "Hydrodynamics and mass transfer characteristics in an internal loop airlift reactor with different spargers," *Chemical engineering journal*, vol. 175, pp. 494-504, 2011.

[9] N. S. Hosseini, H. Shang, G. M. Ross, and J. A. Scott, "Microalgae cultivation in a novel top-lit gas-lift open bioreactor," *Bioresource technology*, vol. 192, pp. 432-440, 2015.

October 16-17, 2017 Dubai, UAE