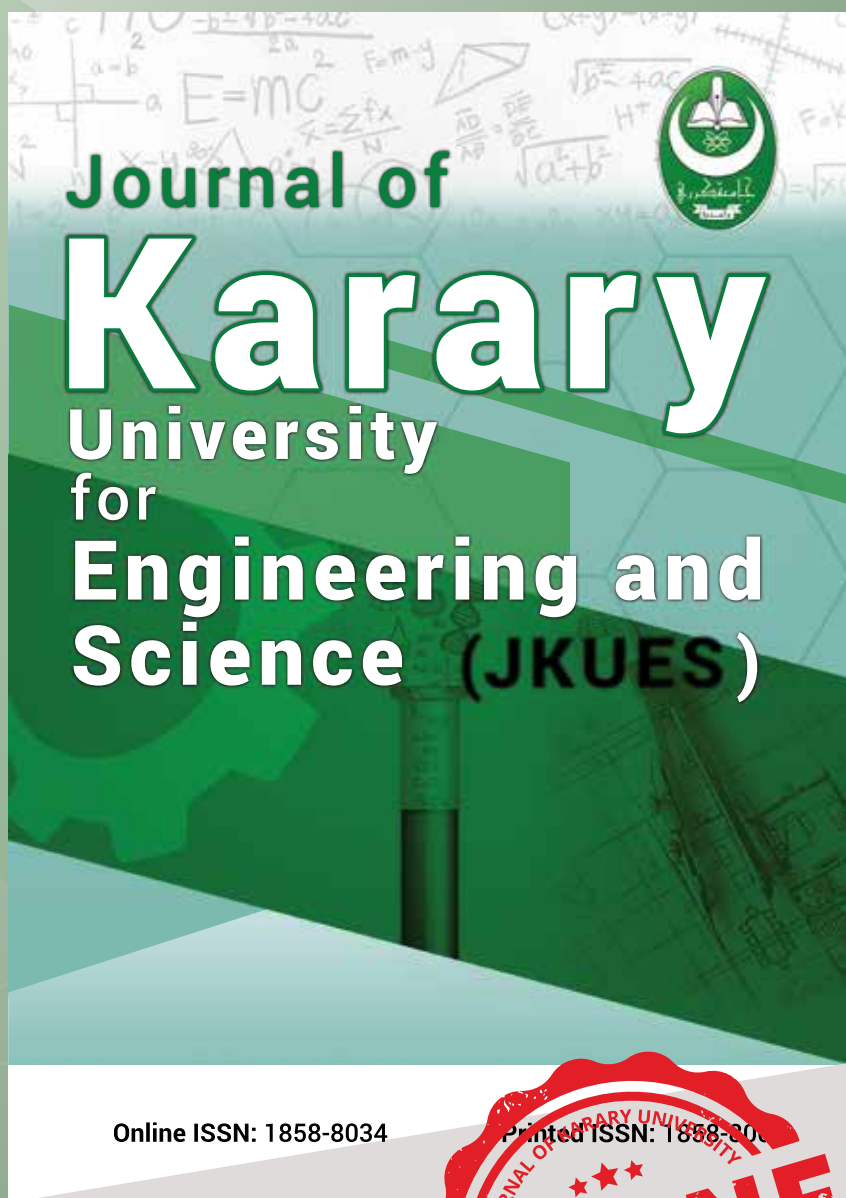


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Abstract

Gas absorption is the unit operation in which one or more soluble components of gas mixture are dissolved in a liquid. The absorption may be a purely physical phenomenon or may involve chemical reaction with one or more constituents in the liquid solution. In order to obtain the highest rate of absorption, gas and liquid streams flow in opposite directions in counter-current flow. The unit in this work has been designed to help grasp the basic principles of the chemical and physical aspects involved in absorption. This study unit is made of borosilicate transparent glass in order to show the water spread in the column and get the visual distribution of fluids behavior which helps to fully understand the phenomenon. In this work, the wetted wall column is used to determine gas/liquid mass transfer coefficients, which is essential to design absorption towers. This study investigates the absorption of oxygen from air into deoxygenated water (prepared by nitrogen sparing) in liquid film controlled absorption experiment. The liquid film mass transfer coefficients calculated at various mass flow rates of water and air. This work also studies the effect of water flow (expressed by Sherwood number) and air flow (expressed by Reynolds number) on oxygen concentration in the oxygenation and de-oxygenation process so affect on absorption process. From results, found that relation between Reynolds and Sherwood in wetted wall column been proportional this mean when we increase flow rate of water from 4 to 12 L/hr or air from 60 to 180 L/hr in wetted wall; concentration of oxygen in water out increase which mean absorption is better. Also, the final equation shows linear relation between Reynolds and Sherwood in wetted wall column. All these result help in understanding absorption process and factors influence in efficiency of towers used in real plant and helpful in design absorption tower.

Key words-Wetted wall column, absorption, Reynolds number, Sherwood number

I. INTRODUCTION

The removal of one or more selected components from a mixture of gases by absorption into a suitable liquid is the second major operation of chemical engineering that is based on interphase mass transfer controlled largely by rates of diffusion [1]. The gas-liquid absorption process may be treated as a physical process; the chemical reaction doesn't hold considerable effect. However when nitrogen oxides are absorbed in water to produce nitric acid, or when carbon dioxide is absorbed in a solution of sodium hydroxide, a chemical reaction occurs, which affects the actual rate of absorption. Absorption processes are therefore conveniently divided into two groups [2], those in which the process is solely physical and those where a chemical reaction is affecting the process. In considering the design of equipment to achieve gas absorption, the main requirement is that the gas should be brought into intimate contact with the liquid, and the effecting of the equipment will mainly be determined by the contact degree reached between the two phases [3]. In absorption, usually the gas is fed at the bottom of the column, and the solvent is fed at the top. The solvent and absorbed gas leave at the bottom, and the unabsorbed components leave as gas from the top. The essential difference between distillation and absorption is that in the former the vapor has to be produced in each stage by partial vaporization of the liquid at its boiling point, whereas in absorption the liquid is well below its boiling point [4]. In distillation there is a diffusion of molecules in both directions, so that for an ideal system equimolecular counter diffusion takes place [4], though in absorption gas molecules are diffusing into the liquid, with negligible transfer in the reverse direction, in general, the

ratio of the liquid to the gas flow rate is considerably greater in absorption than in distillation with the result that layout of the trays is different in the two cases [5]. Other typical absorption operations are carried out in spray columns, wetted wall columns, and stirred vessels. In general the gas and the liquid stream counter current to each other in order to obtain the greatest rate of absorption.

The main goal in this experimental work is to study of mass transfer coefficient in wetted wall columns, and to investigate the effects of water and air flow rates on the mass transfer coefficient. Then the affect of changing flow of air and deoxygenated water on absorption were studied by calculated the two dimensionless number Reynolds (which express the flow) and Sherwood (which indicate concentration of oxygen in water). Then Plotting Sh and Re for various air flow and water are done. Fitting the data allow to found the relation between them and determination of (n) [6].

II. EXPERIMENTAL WORK

A. Chemicals

- Nitrogen gas which is used to prepare deoxygenated water purity 97%.
- Air.
- Water.

B. Component of system

- The absorbing liquid is stored in (D1) tank. And pumped by (G1) to top of deoxygenating column (C2).
- From bottom of column C2, the deoxygenated water pumped by (G2) via flow meter (F12) to top of column (C1). the flow rate controlled using valve.



Fig. 1. Wetted wall column [7]

- Air pumped by compressor (P1) into the base of column C1.
- The air passes up the column C1 transferring oxygen to water.
- The concentration of dissolved oxygen and temperature of liquid entering and leaving the absorption column are measured by two probes (A11 and A12) at inlet and outlet.

C. Experimental Description

The operating principle of the unit is very simple. The feeding pump draws water from tank (1) to the oxygenation column, where it is sprayed by a special nozzle onto the internal wall of the cylinder in order to obtain a wetted wall. The air pump, pumps air in a counter-current at flow to the flowing water in the column. Oxygen is continuously absorbed from the flowing air by the seeping water on the wall. The water is drawn from the bottom of the column by the pump (P2). Afterwards, the oxygenated water is sent to the de-oxygenation column, where it is sprayed on the internal wall of the cylinder. Nitrogen is pumped inside the column in counter-current flow to extract the oxygen from the water.

III. CALCULATION

To calculate the two dimensionless numbers Sherwood and Reynolds for different air and water flow these steps are done.

A. Design information for these wetted wall columns:

- 1) Diameter of column=90cm.
- 2) Wetted perimeter=10.7cm.
- 3) Column pressure=700 mmHg.
- 4) Gas/liquid interface area $A = 960.84 \text{ cm}^2$.
- 5) Diffusivity of oxygen in water = $2.5 \times 10^{-2} \text{ cm}^2/\text{s}(\text{ref1})$.

B. Steps:

- 1) Calculating wetting rate (W)
 $W = \text{water flow rate} / \text{wetted perimeter}$. [8]
- 2) Calculate Reynolds
 $Re = W * 4 / \text{kinematic viscosity of water}$.
- 3) Calculate absorption rate N_a $N_a = \text{water flow} (C_{out} - C_{in})$, where:
 C_{ou} = concentration of oxygen in water out from column (this read from wetted wall column)
 C_{in} = concentration of oxygen in water inter the column (this read from wetted wall column) [9]
- 4) Calculate N_a/A , where:
 $A = \text{gas liquid interface area} = 960.84 \text{ cm}^2$
- 5) calculate the average driving force for mass transfer in column Once driving force is known as
 $\Delta C_{in} = C_{in} - C_{sat \text{ in}}$
 $\Delta C_{out} = C_{out} - C_{sat \text{ out}}$, where:
 $C_{sat \text{ in}}$ =saturated composition of oxygen in water at 700 mmHg and T_{in}
 $C_{sat \text{ out}}$ =saturated composition of oxygen in water at 700 mmHg and T_{out} [10]
Then calculate the long mean average =
 $\Delta C_{ln} = (\Delta C_{in} - \Delta C_{out}) / \ln(\Delta C_{in} / \Delta C_{out})$
- 6) Calculate the average mass transfer coefficient K_r
 $K_r = (N_a/A) / \Delta C_{ln}$
- 7) calculate $K_c = K_r / \rho$, where:
 ρ = density of water
- 8) Calculate $Sh = K_c * \text{diameter of column} / \text{Diffusivity of oxygen in water}$.
- 9) Repeat all step for different air flow and different water flow.
- 10) Plot $\ln(Sh)$ versus $\ln(Re)$

Note: TABLE I list value of oxygen solubility in water at various temperature and at 1 atm(760 mmHg) but the value of pressure in wetted wall column =700 mmHg so the oxygen solubility of oxygen in water (C_{sat}) must be calculate in this new pressure $C_{sat \text{ at } p} = C_{sat \text{ at } 1 \text{ atm}} * 700 \text{ mmHg} / 760 \text{ mmHg}$.

IV. RESULTS:

In this TABLE I temperature($T^\circ \text{C}$) and concentration (C Ppm) of oxygen in inter ant out de-deoxygenated water are obtained from wetted wall measuring devices for air flow (60,120,180 L/hr.) and water flow (4,8,12,16 L/hr.) then convert concentration from ppm to mg/l.

Calculation of Reynolds and Sherwood which obtained from equations above for air flow(60.120.180)and water flow(4.8.12.16)

$$Re = W * 4 / \text{kinematic viscosity of water}$$

$$Sh = K_c * \text{diameter of column} / \text{Diffusivity of oxygen in water}$$

TABLE I
THE WETTED WALL COLUMN RESULTS FOR DIFFERENT AIR AND WATER FLOW

Air flow rate L/h	Water flow l/h	T_{in} C°	T_{out} C°	C_{in} Ppm(g/g)	C_{out} Ppm(g/g)	C_{satin} At 1atm mg/l	C_{satout} At 1 atm mg/l	C_{satin} At p atm Ppm(g/g)	C_{satout} At p atm Ppm(g/g)	T_{ave} CO	γ viscosity at T_{ave} 100cm ² /s
60	4	17.1	16.3	0.45	8.61	9.54	9.86	8.77	9.07	16.7	1.0941
60	8	19.9	18.5	0.23	8.19	9.07	9.43	8.34	8.67	19.2	1.0268
60	12	20.4	19.4	0.12	7.88	8.98	9.26	8.25	8.51	19.9	1.0091
60	16	20.3	19.7	0.11	7.57	8.99	9.21	8.26	8.47	20.0	1.0066
120	4	23.0	20.7	0.03	7.97	8.64	9.03	7.94	8.30	21.9	0.9611
120	8	21.0	20.4	0.07	7.80	9.00	9.08	8.27	8.35	20.7	0.9895
120	12	20.5	19.9	0.11	7.76	9.06	9.17	8.33	8.43	20.2	1.0017
120	16	20.0	19.8	0.12	7.48	9.15	9.20	8.41	8.46	19.9	1.0091
180	4	23.5	21.0	0.03	7.85	8.56	8.98	7.864	8.253	22.3	0.9519
180	8	24.0	22.0	0.05	7.57	8.48	8.80	7.791	8.087	23.0	0.9362
180	12	23.0	22.0	0.05	7.41	8.64	8.80	7.938	8.087	22.5	0.9474
180	16	23.0	22.0	0.06	7.20	8.64	8.80	7.938	8.087	22.5	0.9474

TABLE II
REYNOLDS AND SHERWOOD FOR DIFFERENT AIR AND WATER FLOW

Air flow rate l/h	Water flow rate l/h	ρ At T_{av} g/cm ³	Re	Kc cm/s	Sh	Ln(Re)	Ln(Sh)
60	4	0.9988	38	0.00349	12548	3.64	9.44
60	8	0.9985	81	0.00684	24607	4.39	10.11
60	12	0.9982	123	0.00918	33061	4.82	10.41
60	16	0.9982	165	0.01052	37870	5.11	10.54
120	4	0.9978	43	0.00386	13891	3.77	9.54
120	8	0.9980	84	0.00634	22826	4.43	10.04
120	12	0.9982	124	0.00882	31804	4.82	10.37
120	16	0.9982	165	0.00997	35902	5.10	10.49
180	4	0.9978	44	0.00362	13026	3.78	9.47
180	8	0.9975	89	0.00653	23516	4.49	10.07
180	12	0.9982	132	0.00871	31360	4.88	10.35
180	16	0.9982	175	0.01034	37213	5.17	10.52

$$Kc = Kr/\rho$$

Where:

W=wetting rate, Kc= the average mass transfer coefficient
Kr , ρ = density of water.

Fig. 2 shows relation between Reynolds number and Sherwood number for air flow = 60L/hr. and water flow range (4-16 L/hr.) (data from TABLE (II))

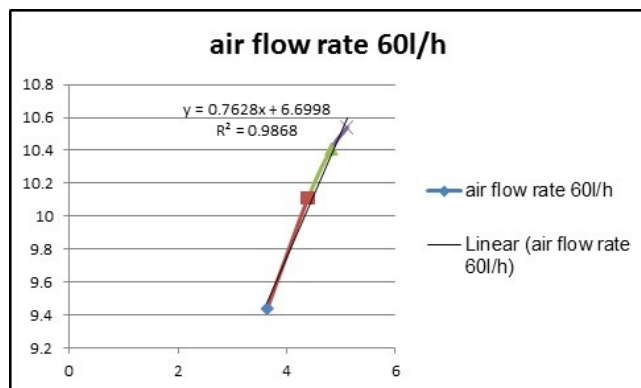


Fig. 2. Ln(Sh) versus Ln(Re)

The figures below show the relation between Reynolds number(which express flow rate) and Sherwood number (which expressed concentration of oxygen in water or absorption) for air flow 60, 120,180 L/hr.

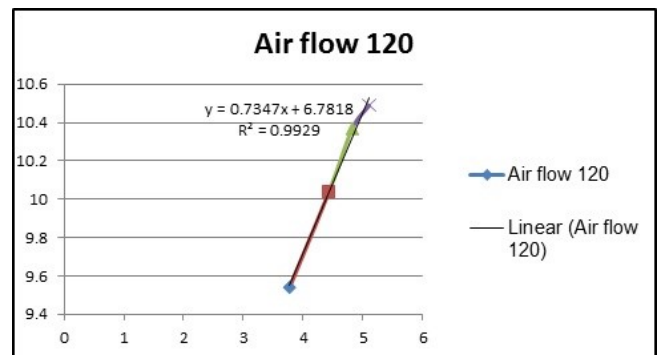


Fig. 3. show relation between Reynolds number and Sherwood number for air flow = 120L/hr. and water flow range (4-16 L/hr)

Numeric equation for linear relation between Reynolds (Re) and Sherwood (Sh):

$$Sh = aRe^n + b$$

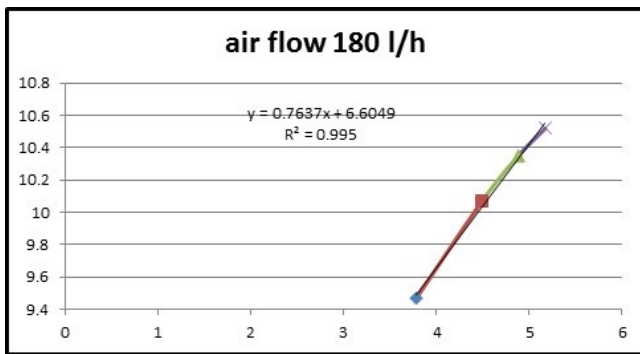


Fig. 4. show relation between Reynolds number and Sherwood number for air flow =180 L/hr and water flow range (4-16 L/hr)- data from TABLE II

$$\ln Sh = n \ln Re + C$$

after substitute the value of Re and Sh from above tables(1-3) the value of(n) be obtained in TABLE III.

TABLE III
THE VALUE OF(N) BE OBTAINED

Air flow rate l/h	60	120	180
n	0.762	0.734	0.763

V. DISCUSSION

From result obtained above found that relation between Reynolds and Sherwood in wetted wall column been proportional this mean when we increase flow rate of water from 4 to 12 L/hr or air from 60 until 180 L/hr in wetted wall; concentration of oxygen in water out increase which mean absorption is better. Also, final equation show linear relation between Reynolds and Sherwood in wetted wall column.

VI. CONCLUSION AND RECOMMENDATION

- There found that the proportional relation between Re(air and water flow) and Sh (absorption).
- Some of the plotted correlations indicate that the oxygen concentration increases slightly with the increase of air flow rate at constant water flow.
- The oxygen concentrations drop significantly with the increase of water flow rate at the beginning of the trend.
- linear relation between Reynolds and Sherwood in wetted wall column.
- For future studies, the temperature effect on oxygen concentration can be investigated in wetted wall gas absorption. In addition, graphical correlations of mass transfer coefficients of some other substances can be thoroughly studied, instead of O₂.

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