IJCPE
Iraqi Journal of Chemical and Petroleum Engineering

Iraqi Journal of Chemical and Petroleum Engineering
Vol.10 No.1 (March2009) 29-34
ISSN: 1997-4884

University of Baghdad
College of Engineering

The Factors Affecting the Absorption of Ozone in Water

Abbas H. Sulaymon*, Abdul Razzak H. Al.Karaghouli and Mustafa Hassan Flayeh

**Environmental Engineering Department - College of Engineering - University of Baghdad – Iraq*

Abstract

This study was concerned with using ozone gas in drinking water treatment plant at Ibn-Sina Company. The main purpose of this research is to find the best contactor for ozone unit proposed. An investigation was conducted to study the absorption of ozone by water in two type of absorber. The effects of the process variables (such as height of water column, contact time, and pH) on the amount of ozone absorbed were investigated. Box-Wilson central composite rotatable design is used to design the experimental work for the mentioned variables. It was found that the optimum value of the variables studied was:

i) Height of water column (90 cm)
ii) Contact time (17-18 min)
iii) PH (7 - 7.5)

Introduction

The degradation of raw source water has become a worldwide problem, and more serious in developing countries. Safe and healthy drinking water are paid more and more attention. The rapid economic development and increasing polluted sources water put forward the need for advanced purification of drinking water in order to remove the trace pollutants in the water after conventional treatment. Along with the pollution of sours water, more and more importance has been attached to the technologies on advanced purification of drinking water, of which ozonation process has got yearly investigation and found wide use in the world [1].

Ozone (O_3) or trioxygen is a molecule composed of three oxygen atoms, temporarily existing in a very unstable and reactive state. Ozone is so reactive that a suitable container for storage probably does not exist. Unlike the O_2 molecule, this triatomic oxygen defies man's attempts to store or liquefy it.

Compared to O_2, O_3 is an extremely active molecule, probably by a factor of 1,000 times and is sometimes referred to as activated oxygen [2].

Ozone exists as a gas at room temperature. The gas is colorless with a pungent odor readily detectable at concentration as low as 0.02 to 0.05 ppm (by volume), which is below concentration of health toxic concern. Ozone gas is highly corrosive and toxic [3,4].

Since ozone cannot be stored or conveniently purchased by the gram, pound, gallon or ton, it must be produced on site as needed, (where needed and when needed) [3,5].

There is many way to produce ozone, all of the following can be used [2].

1. Electrical Discharge – Corona Discharge.
2. Electrolytically – Electrolysis of an Acid.
3. Photo chemically – Ultraviolet radiation.
4. Radio chemically.

Some application of ozone to potable – water treatment is sterilization of all forms of bacteria and viruses; increased settling; removal of tastes, odors, and colors; oxidation of sulfides, cyanides, and algae; removal of trihalomethan precursors; and oxidation of organic materials. Ozone oxidation followed by filtration also can be employed for the removal of iron and manganese [8].

A unit for treatment of water by ozonation including, on the one hand at least one apparatus for the production of ozonized white water and, on the other hand, at least one contactor in a way that the mixing of the water to be treated and the white water occurs in said contactor. The installation for the production of ozonized white water includes a device for dissolution of ozone in a carrier liquid [9].

The aim of the present work is concerned with detailed study of transfer of ozone into water.

Several variables have been investigated including, height of water column, contact time, and pH on the two types of absorbers packed and bubble column.

Experimental and Materials

Experimental Apparatus:
Ozone was transferred to water by using an absorption apparatus. The absorption unit consists of an absorption apparatus and ozone generator unit Fig. (1).

Absorption Apparatus:

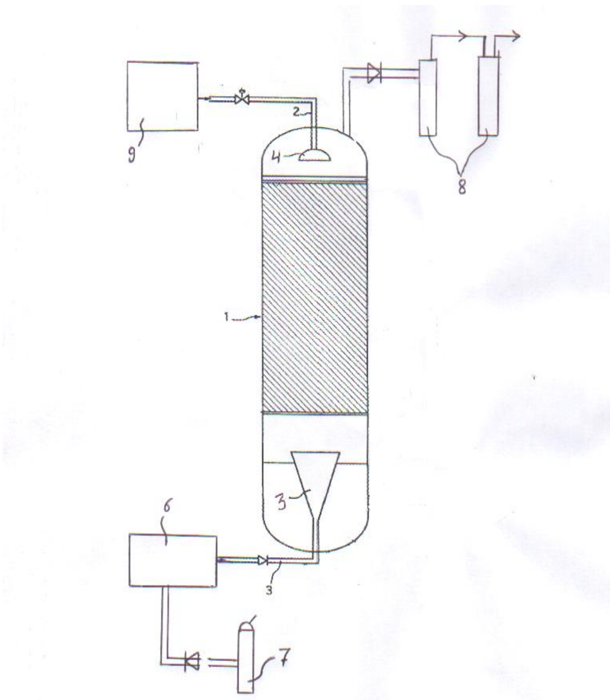
1- The packed column:- The experiments in the present work were carried out using a (5 cm) I.D glass(Q.V.F) column filled with one of three types of packing used in experiment, (10 mm in size) glass rashig rings, (18 mm in size) intalox saddles, and (15 mm in size) spherical packing.

2- Bubble Diffuser:- The bubble diffuser plays a basic and indispensable role in the present work. The bubble diffuser used was sintered glassware disk with diameter of 30 mm and pore size 100-160 micron.

Ozone Generator:
Ozone generator used to generate the ozone has the following specification: Type: Fisher, Model: 502, Max Dos: 10 g/hr at 500 Liter O_2/ hr

pH-Meter:
The pH value of water before and after treating was measured by means of a digital pH-held with specifications as following:
Type: Schott Gerate, Model: 820, Range: 0-14

The Experimental Procedure:
The raw water was transferred from Tigris River at Al-tarmyya city in the north of Baghdad to the laboratory and left for one week to settling. The raw water was pumped by dosing pump from the top of column and distributed over the packing of column by buechnner funnels.
Ozonized oxygen gas produced from ozone generator, which calibrate first before starting the experiments at constant flow rate of oxygen gas and at different time (stripping the ozone gas by iodide solution), passes in counter current to water at the bottom of column and diffused through water by sintered glass disk. The diffuser at the first time, hot hydrochloric acid followed by several rinses of distilled water sucked through it under a good vacuum, this removes dust particles and powdered glass. The sintered glassware should remain in the oven at a temperature of (110 –150) C°.
Excess of ozone which was not absorbed by water passes through the contact column to the two gas washing bottles contain potassium iodide solution to captured the escaped ozone.
With reference to (Fig.1), an installation for the ozonation of water was essentially constructed from Q.V.F column of 5 cm inside diameter and 200 cm height that permits the supply of a fluid.
Q.V.F column forms an absorption column, so as to obtain maximum dissolution of the ozone in the water with the help of the gas-liquid contactor with a minimum of loss, a packed column has been chosen. The column was filled with a packing material, in bulk, which in context of this research comprises of one of three types used, raschig ring, intalox saddle, and spherical packing.
The column was fitted with an inlet for the water destined to be saturated with ozone. So as to allow a good distribution to the carrier liquid inside the column, a distribution device having the form of a sprinkler unit is installed at the inlet.
The column has, in addition, to its lower part, a gaseous inlet. Furthermore, the homogeneous distribution of the ozone over the whole cross-section of the column is achieved by a porous sintered device.



(1) Q.V.F Column, (6) Ozone Generator,

(2) Inlet Liquid Device, (7) Oxygen bottle,

(3) Inlet Gas Device, (8) Washing bottle,

(4) Sprinkler, (9) Water tank.

(5) Porous Sintered Device,

Fig.1 Absorption Unit

Results and Discussion

Effect of Height of Water Column:

The effect of height of water on the amount of ozone absorbed was studied in order to determine the height at which absorption process is best performed.

Figure (2) shows that for all contact time studied the amount of ozone absorbed by water increase as the height of water increases.

Similarly the relation between ozone concentration and the height of water was plotted for given pH values as shown in (fig. 3). The highest value of ozone concentration was obtained approximately at pH=7.

Referring to this figures it can be seen that the concentration of ozone increases with increases of height of water until height value of (90 cm) after which the concentration of ozone is decreased with height of water column because the rise velocity of the bubbles decreased as well as the diameter of the bubble decreased.

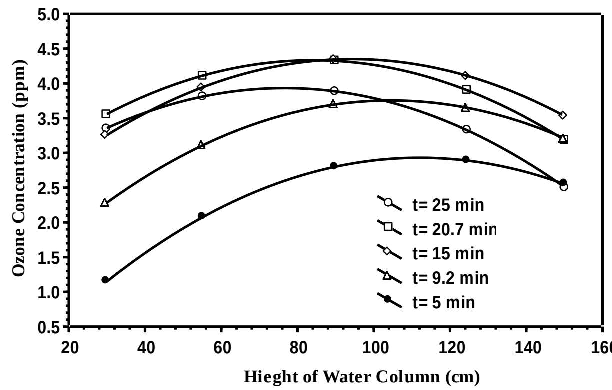


Fig. 2 Ozone Concentration Vs Height of Water Column at Various Contact Times.

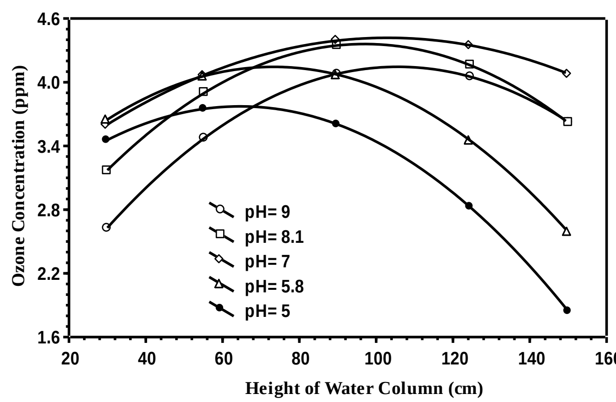


Fig. 3 Ozone Concentration Vs Height of Water Column at Various pH.

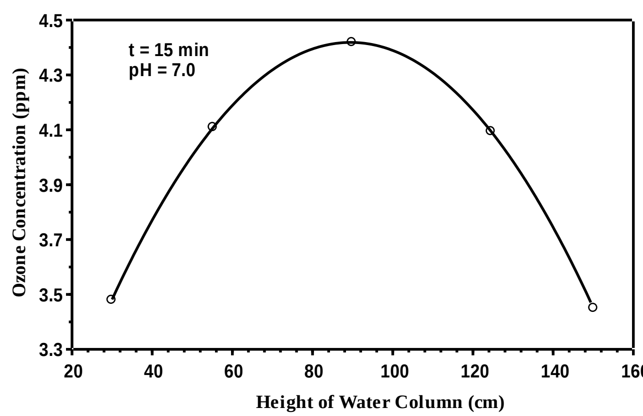


Fig. 4 Ozone Concentration Vs Height of Water Column

Effect of Contact Time:

The significant interaction effect between contact time and height of water column and between contact time and pH was shown in figs. (5) and (6).

The best time of absorption of ozone by raw water is an important factor in water treatment affecting the concentration of ozone.

Examining these figures, it can be seen that the amount of ozone absorbed increases with increasing the time of absorption. It is clear that when the contact time is less than 18 minute, the ozone concentration is highest. While increase the contact above this value will decrease the ozone absorbed because the temperature of ozone generator increased and this will accelerate decomposition of ozone.

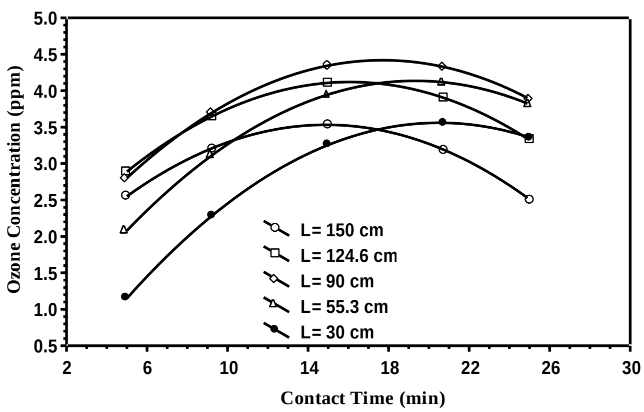


Fig. 5 Ozone Concentration Vs Contact Time at Various Height of Water Column.

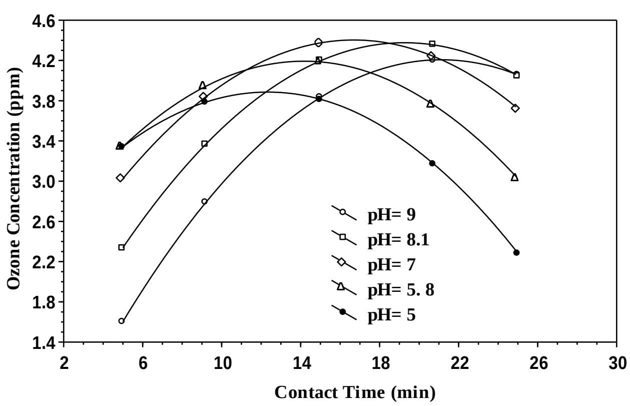


Fig. 6 Ozone Concentration Vs Contact Time at Various pH.

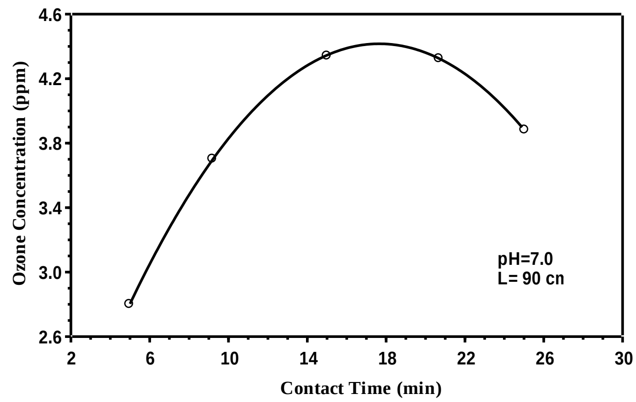


Fig.7 Ozone Concentration Vs Contact Time

Effect of Acidity Function:

The effect of pH is clearly observed by the concentration of ozone in water.

Figures (8) and (9) show that increasing the pH will increase the concentration of ozone in water. It is clear from these figures that when pH is equal to 7-7.5 the ozone concentration is highest.

The pH of the water is important because hydroxide ions initiate ozone decomposition, which involves the following reaction [18]:

$$O_3 + OH \longrightarrow HO_2 + O_2$$

$$O_3 + HO_2 \longrightarrow O_2 + O_2$$

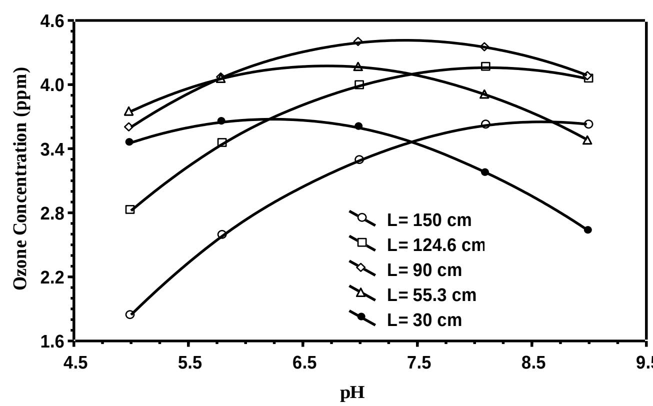


Figure (8) Ozone Concentration Vs pH at Various Height of Water Column.

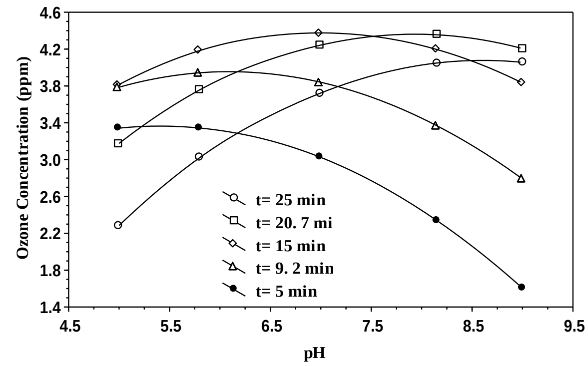


Figure (9) Ozone Concentration Vs pH At Various Contact Time.

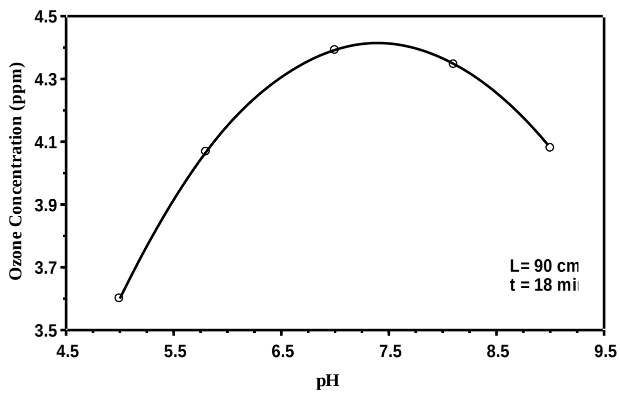


Figure (10) Ozone Concentration Vs pH

Analysis of Experimental Results:

The absorption processes that take place between ozone gas and raw water start immediately when the gases come into contact with water. The two-film theory, the penetration theory, the surface renewal theory or others can describe this mass transport. In this work, however, two-film theory was considered as a basis of description of the transport characteristic for the absorption of ozone into water in bubble and packed bed absorber.

The following assumption will be considered to treat the experimental result:

1- ozone is the only active species that physically dissolves in water.

2- there is no chemical reaction.

Comparison In Results Between Two Types of Absorber Used:

Comparison between types of absorber used in our experiments was represented in tables (1) and (2) these tables' shows that the maximum amount of ozone absorbed achieved by using glass packing of rachig ring type and when the effective area increased the mass transfer coefficient decreased.

Table (1) Amount of Ozone Absorbed by Different Type of Absorber.

Height of Water Column	**Ozone Absorbed (ppm)**			
	Bubble Column	**Packed Column**		
(cm)		**Rachig Ring**	**Spherical**	**Saddle**
30	3.2	3.5	2.05	3.3
55.3	3.7	3.93	2.92	3.74
90	4.28	4.93	3.1	3.76
124.6	3.48	4.94	3.2	3.98
150	3.2	4.0	3.1	3.5

Table (2) Values of Mass Transfer Coefficient

Type of Absorber		Effective Area m^2/m^3	K_L Experimental m/s	KL Theoretical m/s
Packing	Rachig Ring	163.39	$1 * 10^{-5}$	$3.5 * 10^{-5}$
	Intalox Saddle	99.6	$1.6 * 10^{-5}$	$4.7 * 10^{-5}$
	Spherical	76.97	$2.1 * 10^{-5}$	$4.5 * 10^{-5}$
Bubbl	Swarms Bubble	133	$1.2 * 10^{-5}$	$9 * 10^{-5}$

Conclusions

The following conclusions could be drawn from this investigation:

1. The second order polynomial regression analysis of the objective function i.e.; the amount of ozone absorbed by water and three variables (i.e.; height of water column, contact time, and pH) for bubble column contactor.

2- The amount of ozone absorbed increase with:
  a- increasing the height of water column.
  b- increasing contact time.
  c- increasing pH.

The best operating conditions are:
  d- height of water(90 cm).
  e- contact time(18 min).
  f- pH (7).

3- The use of packed contactor (raschig ring) is better than bubble contactor, because the contact area is larger.

References

1- Jinsong Zhang, "Studies and Application on Advanced Purification of Drinking Water", "By Internet".

2- Jim Eaglton, "Ozone In Drinking Water Treatment" , Feb. (1999) "By Internet".

3- Rip G.Rice & Paul K.Overbeck, "Ozone and The Safe Drinking Water Act", GDT Corporation, (1998), "By Internet".

4- Dee Smell & Leslie S.Ettre, "Encyclopedia of Industrial Analysis", Vol.16, Pg. 538-551, (1972).

5- Ozone, National Drinking Water Clearinghouse Fact Sheet, "By Internet."

6- Kirk Othmer, "Encyclopedia of Chemical Technology", 3rd ed. Vol.16, P.683-713, Wiley, New York, (1981).

7- US. Patent, No. 5 843 307, Des. (1998).

8- Rip G.Rice & M.E.Browning, "Ozone Treatment of Industrial Waste Water", Pollution Technology Review, No.84, (1981).

9- United States Protection Agency (EPA), Office of Water, "Alternative Disinfectants and Oxidants Guidance Manual", April (1999), "By Internet".

10- Rip G.Rice, Paul K.Overbeck & Ken Larson, "Ozone Treatment of Small Water System", GDT Corporation, Oct. (1998), "By Internet".

11- Colson J.M. & Richardson J.E., "Chemical Engineering", Vol.6, 2nd. Ed., Pergamon Press. (1968).

12- Treybal R.E, "Mass – Transfer Operation", Mc Graw- Hill, 3rd ed., (1980).

العوامل المؤثرة على أمتصاص الاوزون في الماء

*عباس حميد سليمون, عبد الرزاق القره غولي و مصطفى حسن فليح

*قسم هندسة البيئة -كلية الهندسة- جامعة بغداد- بغداد- العراق

الخلاصه:

لقد اهتم هذا البحث بدراسة استخدام الاوزون في مجال معالجة مياه الشرب لصالح شركة ابن سينا العامه/ وزارة الصناعه والمعادن العراقيه. الهدف الرئيسي من هذا البحث هو ايجاد افضل الطرق لانتقال الاوزون للماء باستخدام نوعين من ابراج الامتصاص، البرج الفقاعي وبرج ذو حشوه. تم دراسة عدة متغيرات هي ارتفاع عمود الماء في البرج, زمن التماس, والداله الحامضيه للماء المستخدم (pH).

تم تحديد التجارب حسب طريقة (Box-Wilson Central Composite Rotatable Design) للمتغيرات المبينه أعلاه وقد وجد بأن افضل امتصاص للاوزون يكون عند القيم التاليه:

1 - طول عمود الماء في البرج(90 سم)

2 - زمن التماس(17- 18 دقيقه)

3 - الداله الحامضيه(7 - 7.5)