# STUDY ON ABSORPTION OF OZONE IN WATER USING PERFORATED SIEVE TRAY COLUMN

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## ABSTRACT

The aim of this work is concerned with detailed study of transfer of ozone into water.. 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). The process will carried out with two important assumptions; first that ozone is the only active species that physically dissolves in water. And second that there is no chemical reaction .the process carried out in a perforated sieve tray column with 1 m long and 33 cm diameter. The effects of process variables such as (Water flow rate, pH and air flow rate which is refer to the concentration of free ozone in the gas phase in the absorption column). The result show that the absorption rate increases with increasing the water flow rate and decreasing the air flow rate in a pH range (7-8).

# دراسة امتصاص الاوزون بالماء في برج امتصاص ذو صواني مثقبة

**الخلاصة**

الهدف من هذا البحث كان اجراء دراسة تفصيلية لعملية امتصاص الاوزون من قبل الماء. وحيث ان الاوزون لايمكن خزنه او نقله فان البحث تطلب انتاجه موقعيا بشكل مباشر مصاحب لعملية الامتصاص (الاوزون ينتج اينما وحيثما يتم استخدامه). والبحث اجري بشكل كامل على اساس فرضيتين، الاولى هي ان الاوزون هو الجزيئة الفعالة الوحيدة التي تذوب في الماء خلال الدراسة والثانية هو عدم وجود تفاعل كمياوي. وتم دراسة عدة متغيرات هي الدالة الحامضية، معدل جريان ماء الامتصاص ومعدل الجريان للهواء الداخل الى برج الامتصاص والذي يحدد نسبة الاوزون في الطور الغازي داخل برج الامتصاص. وقد استخدم برج امتصاص ذو صينية مثقبة وصينية منخل لتوفير وسط التماس بين الاوزون والطور السائل بطول متر واحد وعرض 33 سم.

وقد دلت النتائج المستحصلة على ان معدل الامتصاص يزداد بزيادة معدل جريان الماء وخفض معدل جريان الهواء في مدى للدالة الحامضية يتراوح بين (7-8).

## INTRODUCTION

Today it is possible to produce ozone in high concentration from the feed gas oxygen under economical conditions and introduce it to water. Producing ozone from air you will have a solution of ozone, oxygen and nitrogen in to water. Producing ozone from oxygen you will only have solution of ozone and oxygen in to water. [1]

Ozone has greater disinfection effectiveness against bacteria and viruses compared to chlorination. In addition, the oxidizing properties can also reduce the concentration of iron, manganese, sulfur and reduce or eliminate taste and odor problems. Ozone is a colorless gas that has an odor similar to smell of the air after a major thunderstorm. Solubility in Water by weight at 20°C: 0.003 g/l (3 ppm) [2]

In 1785, Van Marum noticed that air near his electrostatic machine acquired a characteristic odor when electric sparks were passed. In 1801, Cruickshank observed the same odor at the anode during the electrolysis of water. In 1840 Shonbein named the substance, which gave off this odor, "ozone", from the Greek word "ozein" - to smell. In 1857 Siemens designed an ozone generator that has since evolved into the present day, cylindrical dielectric type that makes up most of the commercially available ozone generators in use, and which has sometimes been called the "Siemens Type" ozone generator. The first drinking water plant to use ozone was built at Oudshoom, Holland in 1893. Another, drinking water plant began operations at Nice, France, in 1906. Since Nice has been using ozone since that time, it is generally referred to as the "birthplace of ozonation for drinking water treatment."[3]

Abbas H. Sulaymon carried out an absorption process for ozone with water in a packed bed column and give a good results for the rate of absorption and show that the optimum absorption rate for ozone with water could be obtained in the pH (7-8) and also show that the temperature of the ozone generator will increase and that will accelerate the decomposition of ozone after approximately 20 minutes. [4]

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. Excessive dose of ozone will lead to the formation of per manganate, which gives water a pinkish color. This soluble form of manganese (Mn) correspond to a theoretical stoichiometry 2.20 $mgO_3$/mg Mn. Stoichiometry is the determination of the proportions in which chemical elements combineor are produced and the weight relation in a chemical reaction.[5]

Ozone exists as a gas at room temperature. The gas has 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 [6]

Perforated sieve trays are cheapest and satisfactory for most applications. This kind of trays has been used for many years for liquid gas contacting in commercial absorption columns. The perforated sieve tray have lower coast in comparison with bubble cup trays. The relative cost will depend on the material of construction used. [10]

This kind of trays may be divided according to their operating principles in to two categories, first one are trays with downcomer, in which the gas rises through holes in the tray floor, bubbles through the liquid in fairly uniform manner and liquid flows across the tray floor over an outlet wire through a downcomer to the tray below. These tray are also classified according to the number of liquid passes on the tray: a single pass tray for normal liquid flow rates (11 – 110 $m^3$/hr); reverses flow tray(inlet and outlet downcomers are on the same side of the tray) for low liquid rates (up to 11$m^3$/hr); multiple pass tray(the liquid stream is sub-divided by using several downcomers) for high liquid rates( exceeding 110$m^3$/hr) and large diameter columns [11.14].

The other kind of this trays are that trays without downcomer, in which gas rises through holes in the tray floor and at the same time liquid counter currently through these holes onto the tray below. Liquid flow forms random patterens in draining and does not form continuous streamlets from each hole. These trays have a narrower range of efficient operable loadings, but they are used when a low pressure drop is required. [12, 13]

The aim of this study was to discover the suitability of the perforated sieve tray as a contact media between water and ozone and finding the optimum hydrodynamics for the absorption process of ozone in water

## Experimental work

### Experimental Apparatus

The experimental laboratory apparatus used consist of the following:
Glass column, Liquid storage tank, Blower, Centrifugal pump, Connecting pipes, Measuring instruments and Ozone generator as shown in figure 1.
The column employed was a cylindrical glass pipe, 1m long, 0.3m diameter. The inside of the column was fitted with one perforated tray and one chimney tray. The perforated tray made of aluminum. 5 mm thick and 0.3 m diameter. The chimney tray (some times called weepage collection tray) was made of aluminum, 5mm thick and 0.3m diameter. This tray is located below the perforated tray, in order to collect liquid weeping from the perforated tray, on the one hand, as well as ensuring uniform gas flow distribution at the region beneath the perforated tray, on the other hand, in order to prevent possible localized preferential weeping from the test tray caused by gas flow misdistribution.
A spherical glass tank was used with 50 liters volume was used to collect liquid overflowing the outlet serrated weir on the one hand as well as acting as reservoir for all the liquid employed in the rig on the other hand. This tank connected to the supply recirculation pump which fed the liquid to the rig.
A suitable centrifugal blower was used to introduce air at ambient conditions to the rig below the chimney tray via suitable piping arrangements.
A locally fabricated orifice plate was employed as air flow measuring device, following insertion in a suitably located position to ensure absence of flow disturbance. Also a suitable proprietary area flow meter was used to measure the liquid flow rate. Although the meter was originally calibrated for water flow.

The pH value of water before and after treating was measured by means of digital pH-held with range from 0-14.
The duration time for all experiment will be 20 minutes. Because after that time its known from previous work that the temperature of the ozone generator will increase and that will accelerate the decomposition of ozone and in the final results mean decreasing the amount of ozone that being absorbed.

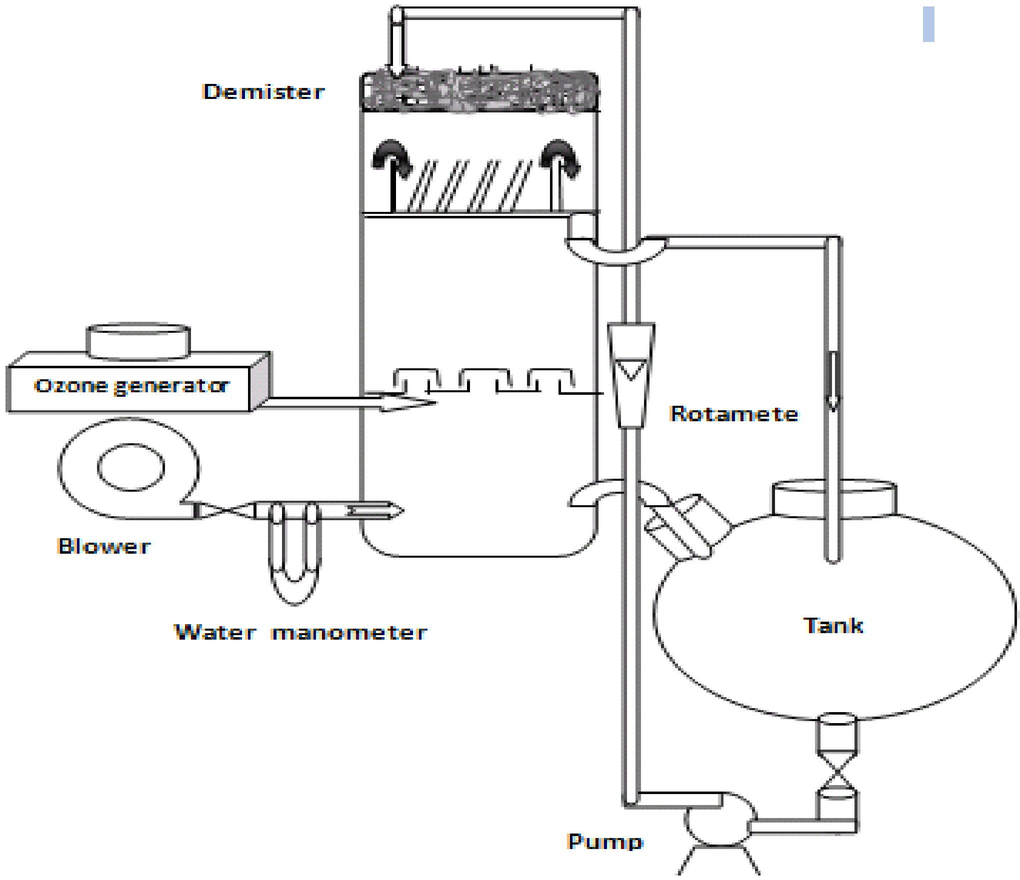


**Fig. 1 Schematic flow diagram of the absorption unit**

## Experimental procedure

The raw water was bringing up from Tigris River at Aljaderiah town in the middle of Baghdad to the laboratory and left for ten days to settling.

- Initially, a sufficient quantity of the water to be used was prepared and introduce to the liquid tank. This liquid quantity amount to be about 50 liters.
- The air blower was operated and the air flow was adjusted to a value of 200 $m^3$/hr by a manual gate value utilizing the installed calibrated orifice meter for this purpose. This value of air flow corresponded to the minimum required to avoid dumping of the liquid from the perforated test tray at its minimum adopted inlet flow rate of 250 lit/hr.
- The supply recirculation liquid pump was then operated and the liquid flow was adjusted at 250 lit/hr by the globe valve upstream of the area flow meter which is utilized for this purpose. This value of liquid flow was practically the minimum

stable rate of flow achievable in the rig due to the variation in the reservoir tank liquid level over the duration of an experimental run.

- The glass column was then observed to ensure that some liquid overflowed the outlet serrated weir. If that was not the case, the air flow rate was very gradually increased to achieve this overflow and subsequently fixed and recorded at this over flow occurrence. This procedure was necessary to keep away from the dump point.
- Ozonized oxygen gas produced from the ozone generator passes in countercurrent to water at the bottom of the column, at the end of the duration time for the experiment, the ozone concentration in water was determined using pH meter.
- The next step was to increase the air flow by increments to value corresponding approximately to 215, 277, 310, 340, 393 and 412 $m^3$/hr while maintaining the liquid flow rate at 250 lit/hr; and again after the end of the operation duration time was determined the concentration of the ozone in water.
- The procedure pointed out in points (2) to (6) above was repeated for increments in the liquid flow rate to the perforated tray; namely 300, 350, 400, 450 and 500 lit/hr.

## RESULTS AND DISCUSSION

At the time that ozone species and water molecules come in to contact, the absorption process will take place. Where the gases come in to contact with water, and all the theories of mass transfer between liquid and gas can explain this process with two important assumptions, first is that ozone is the only species that physically dissolved in water, and second that there is no chemical reactions.[4]

Figure 2 shows the relations between ozone concentrations (which are referring to the amount of ozone being absorbed) with the air flow rate at different water flow rates. It's clear that the amount of ozone absorbed with water decreases with increasing air flow rate at low water flow rates. But at high water flow rate such as 450 and 500 lit./hr the absorption rate will increase especially in the air flow rate range between 275 and 350 $m^3$/hr. decreasing the flow rate of air that which carry the ozone gas species in the perforated sieve tray column will increase the contact time of ozone species with water molecules and give this species more chance to meet with water molecules. Also at high water flow rate the amount of ozone being absorbed increase even with increasing air flow rate because the huge amount of water that will be available at that high rates will increase the chance even for high velocity ozone species to come in to contact with water molecules but not for air flow more that 350 m3/hr because this will again decrease the chance for the ozone species to come in to contact with water molecules even at high water flow rates and that is relates to the increasing the velocity of air which carry the ozone gas and as a result decreasing the contact time for the ozone and water. it’s clear from the figure that the for high liquid flow rates (400 lit/hr) and above, the optimum air flow rate will be between (300 to 350) $m^3$/hr.

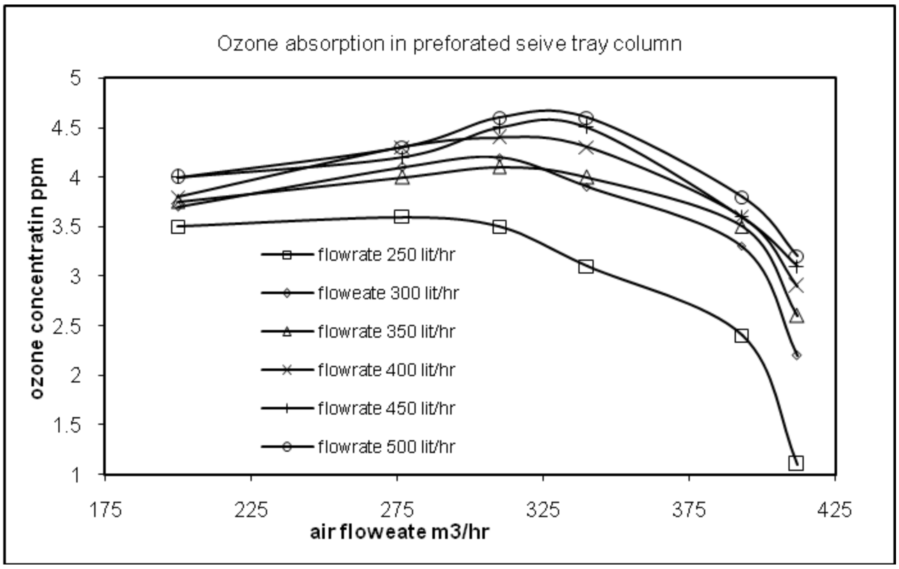


**Fig.2 Ozone concentration vs. air flow rate at different water flow rate**

Figure 3 shows the relation between ozone concentration and air flow rate at different Hydrogen number (pH) and similarly to figure 2 the ozone concentration decrease with increasing air flow rate for all range of pH being studies and of course for the same reasons of the above figure.

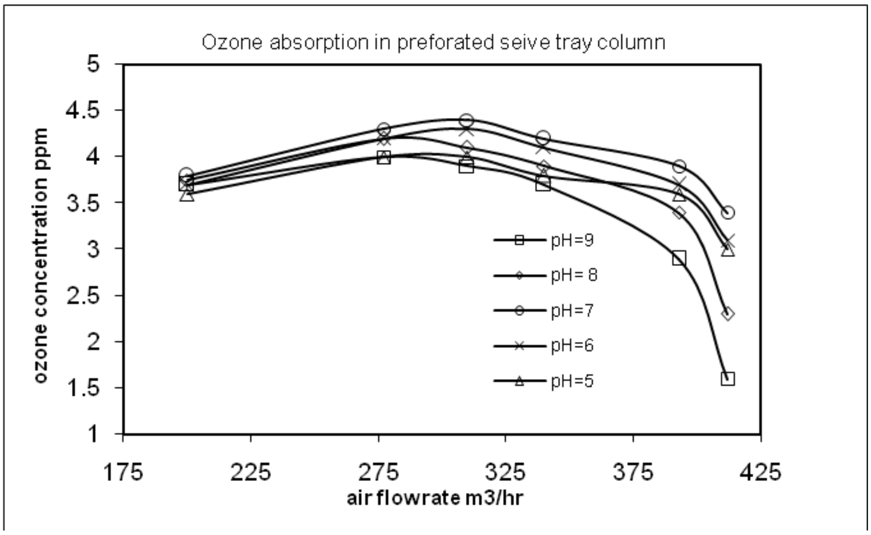


**Fig. 3 Ozone concentration vs. air flow rate at different pH**

Also figure 3 shows that the maximum absorption rate obtained in the pH range from (7-8) and this clearly observed in the figure 4.

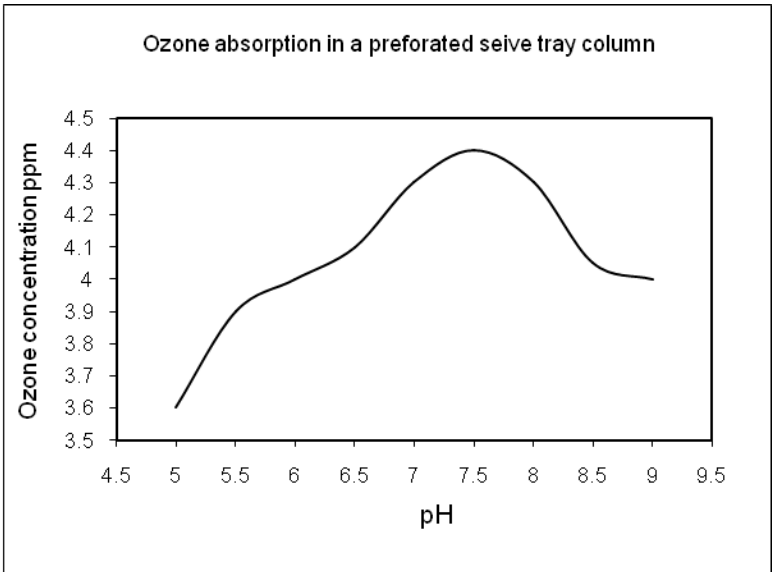


**Fig 4 Ozone concentration vs. pH**

It's clear that increasing pH will increase the concentration of ozone in water until pH reaches the range between approximately (7-8) then the concentration will decrease again. The hydrogen number of water is an important factor affecting the absorption of ozone in water and this is related to the hydroxide ions initiate ozone decomposition, which involves the following reactions

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

$$O_3 + 2HO_2 \longrightarrow H_2O + 3O_2$$

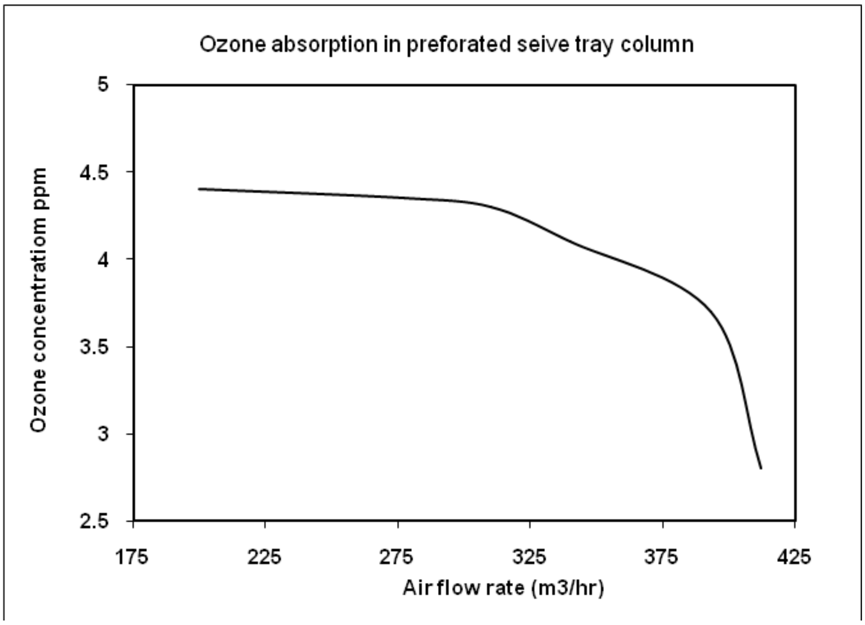


**Fig. 5 Ozone concentration vs. air flow rate**

Figure 5 shows that the absorption rate of ozone decreasing with increasing air flow rate and this related to the decreasing of contact time between ozone species and water molecules.

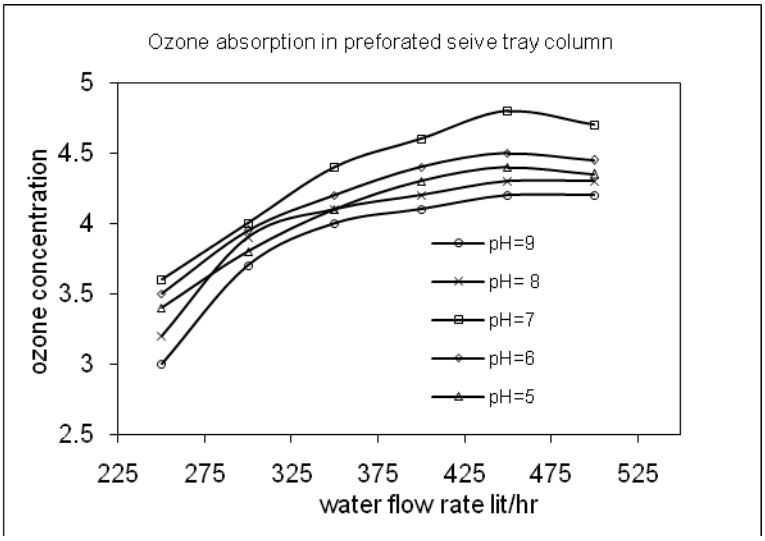


**Fig.6 Ozone concentration vs. water flow rate at different pH**

Figure 6 shows that the absorption rate of ozone increases with increasing water flow rate for all hydrogen numbers range tested in this work, and this related to the increasing of water molecules that might come in to contact with ozone. also this figure shows that at high water flow rate range between 400 – 500 lit/hr the absorption rate does not increase as much that happened in the lower range because most of ozone species already be recovered for the same limited amount of ozone supplied to the absorption unit.

## CONCLUSIONS

- The amount of ozone absorbed in the sieve perforated tray column increase with increasing water flow rate and decreasing air flow rate and keeping the pH range between (7-8).

- Increasing the air flow rate in this kind of absorbers is an important factor for increasing the performance of absorption, but that will effect negatively on the ability for ozone to dissolve in water , and that lead to think twice before choosing this kind of absorber as a contact medium between ozone and water.

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