# WASTEWATER TREATMENT BY OXIDATION POND

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**ABSTRACT**
Wastewater oxidation ponds offer a significant financial advantage in wastewater treatment due to their simple operation and maintenance, as well as, their low energy requirements if the land is available. The retention time is an essential factor in designing the pond that evokes the large surface area needed for the pond system compared with conventional treatment systems. A tracer analysis has been conducted in this study in order to examine the actual time for the waste to be hosted in both a baffled and an unbaffled pond. The tracer analysis of pond systems showed that the retention time was 63% of the theoretical retention time for unbaffled pond and increased to 71% after adding baffles to the pond.

**KEYWORDS**
Wastewater, Oxidation, Pond, Biochemical Oxygen Demand, Trace, Baffles, Flow pattern, Retention time.

## INTRODUCTION

Wastewater *oxidation pond* model reactors are described by either ideal or non-ideal flow patterns. However, not all reactors are perfectly mixed nor do all tubular reactors exhibit plug flow behavior. The deviation from the idealized model can be caused by channeling, recycling or by creation of stagnant region in the pond. Although the wastewater stabilization pond system is economical compared with conventional treatment processes and efficient in reducing organic matter and pathogenic microorganisms, no model has yet been found to describe its hydraulic, biochemical and microbiological performances accurately ( Brown, 1979, Finney 1980, Metcalf & Eddy 1982, and Posprasert 1983 ). Lumbers et al., 1978 stated that the complete mix formula, which is often used in

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the design of the *oxidation pond*, is not correct and most of the pond systems are far from this condition. Maria, 1990 studied some facultative ponds in Spain and concluded that complete mix models can be used to present the hydraulic of the pond system at 99 % confidence level.

The hydraulic flow regime assumed by past workers for the pond are either complete mixing, plug or dispersed flows. Whereas the first two describe ideal flow conditions, the last describes non-ideal flow condition. Several authors ( Thirumurthi, 1972; Uhlmann, 1983; Polprasert,1985 and Marecos, 1987 ) have the opinion that the dispersed flow model is a better approach of describing the hydraulic regime in the wastewater stabilization pond.

The objective of the present study is to examine the flow regime of the pond system in two cases; 1) Pond without baffles; 2) Pond with baffles. Tracer studies were made to determine the retention time, and the diffusion in both baffled and unbaffled pond. These design parameters are used to select the proper model for the pond design, which is presented in a second paper.

**Experimental Work**

The experimental work included the construction of a prototype model for the pond. Figure 1 shows a sketch of the model illustrating the inlet, outlet and baffle system used. The model was installed inside wastewater treatment plant located at West Chester wastewater treatment plant, Pennsylvania, USA .

The dye used for the study was bromophenol blue sodium salt. This dye was chosen due to of its low price compared with the radio active dye, the ease of detection and its accurate results. The color densities of the dye were scanned by using spectrophotometer started at wave length 650 nm and ended at wave length 500 nm. Different dye concentrations ranging from 8.8 mg to 0.55 mg/l were all calibrated, figure 2 & figure 3

The dye solutions were prepared to make an average concentration of the bromophenol of 5 mg/l when added to the model and totally mixed with the model content ( 10 g of the salt per 2 $m^3$ model ) . The dye solutions were pored carefully in the model within few minute close to the inlet side wall of the model and the output concentrations were detected for a period of more than 50 days.

Two tracer studies were made, the first one on the model without baffles and the second on the model with baffles in up and down formation. The first run was performed in the treatment plant using the primary treated sewage (West Chester plant) to feed the model. The second run was made inside the laboratory using tab water for the model feeding, as the experiment started in winter time and the temperature in the treatment plant dropped below the freezing temperature inside the model causing problems in the feeding tubes and forming a frozen layer at the top of the model. For both models ( with and without baffles ) a feeding pump (Masterflex easy load model 17518-60 with tygon tube ) was used to feed the model with 100 liters per day (20 days theoretical retention time ) during the tracer study period.

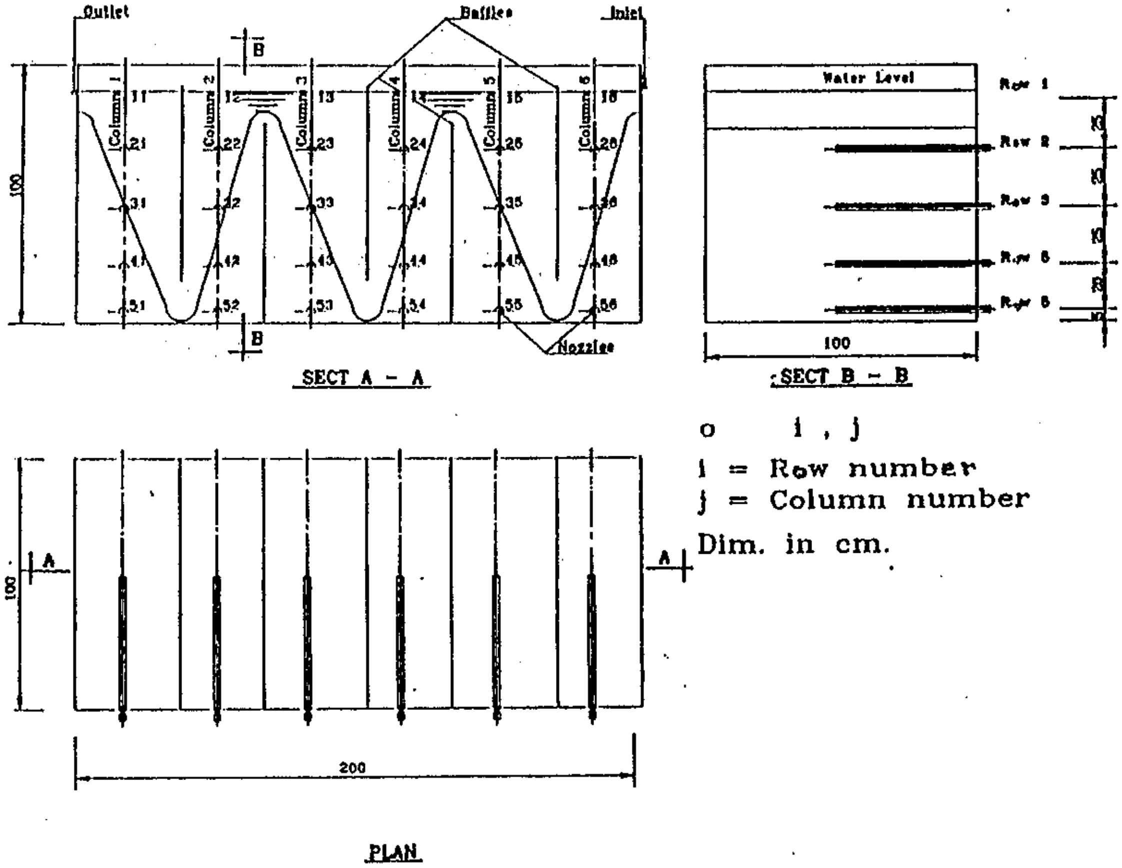


**Figure 1 Schematic diagram for the pond model.**

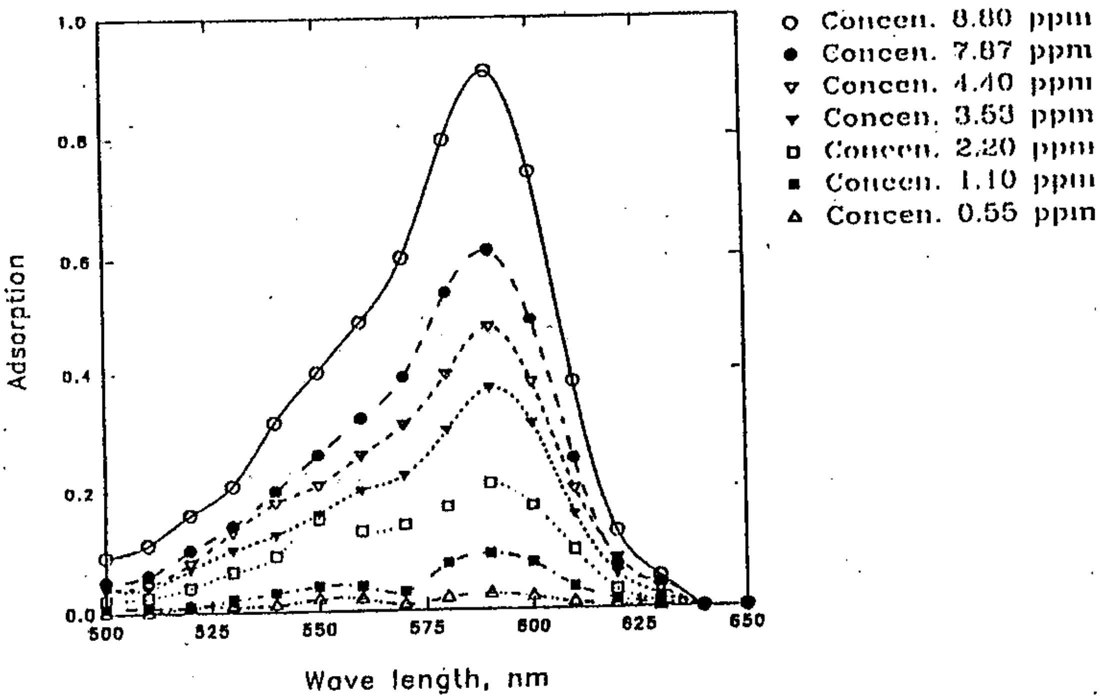


**Figure 2 Bromophenol absorption/concentration for different wave length**

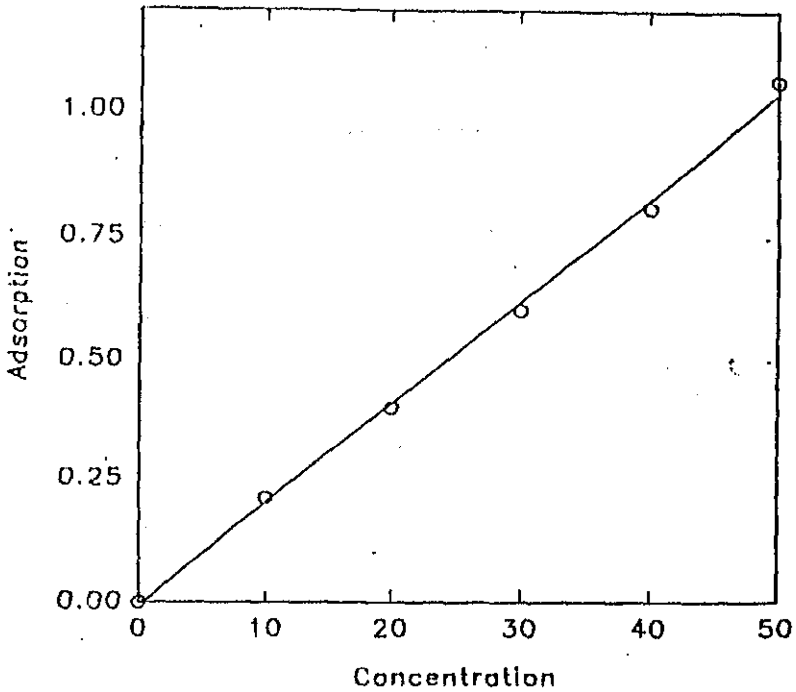


**Figure 3 Bromophenol calibration curve**

**Results and discussion:**

The output tracer concentrations of the two runs (unbaffled reactor and baffled reactor ) were measured using spectrophotometer at wave length 590 nm after injection as shown in figure 4 for unbaffled run, the dye concentration at the output nozzles start with zero value and reaches the peak concentration after 1.83 days and decline to zero again after 55 days for unbaffled reactor. The decrease of the dye concentration was sharp at the beginning then after 30 days (1.5 the theoretical retention time ) the slope of curve decreased.

In the baffled reactor run, the peak dye concentration was delayed to five days after dye injection with slightly less concentration value (4.14mg/1 ) than that for the unbaffled reactor (figure 4). In addition, there was slightly prolonged period of detecting the dye in the output, where zero concentration has been recorded after 58 days.

The statistical results, mean residence time, standard deviation and the dispersion numbers were calculated according to equations 1 to 3 (Levenspiel, 1972 ). A good designed and operated reactor has a mean residence time equal or close to the theoretical retention time (i.e. no dead volume ). The standard deviation shows the spreadness of the measurements ( dye concentration ) around the mean residence time. The dispersion number, d, describe the mixing regime in the reactor and in extreme d=α for the completely mixed reactor and d=0 for the plugged flow reactor.

$$\bar{t} = \frac{\sum t_i C_i \Delta t_i}{\sum C_i \Delta t_i}$$

$$\sigma^2 = \frac{\sum t_i C_i \Delta t_i}{\sum C_i \Delta t_i} - \bar{t}^{2}$$

$$\sigma_\theta^2 = \frac{\sigma^2}{\bar{t}^{2}} = 2(\frac{D}{uL}) - 2(\frac{D}{uL})^2(1 - e^{-uL/D})$$

Where
t = time after dye injection
c = die output concentration
$\bar{t}$ = mean residence time
$\sigma^2$ = standard deviation
$\theta = t/\bar{t}$
D/ uL = dispersion number
D = dispersion coefficient, cm2/sec.
L = length or reactor, cm.
u = mean displacement velocity, cm/sec.

Levenspiel, 1972 classified the dispersion in reactors as follows;
Small amount of dispersion if D/uL $\leq$ 0.002, Intermediate amount of dispersion if 0.002 $\leq$ D/uL $\geq$ 0.025, Large amount of dispersion if D/uL $\geq$ 0.002,
The results of the retention time, standard deviation and dispersion numbers are summarized in table 1

**Table 1 is a summary for the tracer parameters:**

| Parameter | Unbaffled reactor | Baffled reactor |
|---|---|---|
| $\bar{t}$, days | 12.68 | 14.19 |
| $\sigma^2$, days | 88.82 | 98.16 |
| d | 0.473 | 0.374 |

Both baffled and unbaffled reactor showed large amount of dispersion and the dispersion increased for the unbaffled reactor. The mean residence time was about 63% of the theoretical retention time ( 20 days ) for the unbaffled reactor, while it was about 71% for the baffled reactor. In addition, the tracer results for the baffled reactor was more spread (longer tail ) than that of the unbaffled reactor. That is the unbaffled reactor had 37% of its volume dead, and installing baffles reduced the dead volume to 29% . Maria, 1990, found that the dead volume ranged from 10 - 40 % ( unbaffled reactor ) and recommended to use baffles and use multiple inlet and outlet, as well as using diffusers to reduce this large dead volume.

Figure 4 shows the tracer results for the two runs compared with a complete mix reactor. Both curves lie almost under the complete mix curve, that is, the area under the age distribution curve for both reactors were less than unit, in other

words, $\int_0^{\alpha} Edt < 1$. In addition, the area under the unbaffled reactor curve was less than that of the baffled reactor run. Unbaffled reactor runs, the reason that made the area under the age distribution curve less than unit most probably due to difficulty to scan the die on the spectrophotometer at low concentrations .
Data results for both baffled and unbaffled reactor runs were adjusted by multiplying the measured dye concentration by (1/ calculated area under the dye age curve), so that the area under the age time distribution equals to unit (distributing the difference over the curve) . The E curves of the corrected dye measurements for both baffled and unbaffled reactors are shown in figure 5 in conjunction with the complete mix reactor.
The deviation of the data for both baffled and unbaffled reactor from the complete mix took place at early stage after dye injection, that the dye concentrations start with zero value and started to increased to a peak value of 0.068 (E ) for the unbaffled reactor after 1.83 day and 0.06 (E) for the baffled reactor after five days. While for the complete mix reactor the E value started with peak value equal to 1/t. This difference is most probably due to difference in the mixing behavior inside the reactor than that of the complete mix.
The second deviation took place at a time slightly longer than the theoretical retention time, where the dye concentration reached zero value more quicker than in the complete mix reactor. The reason for this difference is most probably due to error in detecting the dye with the spectrophotometer at low concentrations. Increasing the dye concentration that entering the reactor would not solve the problem because the used dye concentration was the highest concentration that can be used, and if higher dye concentrations were used the spectrophotometer would not detect it ( absorption > 1 ) .

**Conclusion:**

The traced study showed that the dead volume was 37% for the unbaffled pond and 29% for the baffled pond. Although there was a reduction in the dead volume of the model by using baffles (only 8% reduction than that of the unbaffled pond), it is not recommended to construct baffle due to the increase in the cost of construction . In addition, the diffusion coefficients were found to be 0.473 and 0.374 for the unbaffled and baffled models respectively.

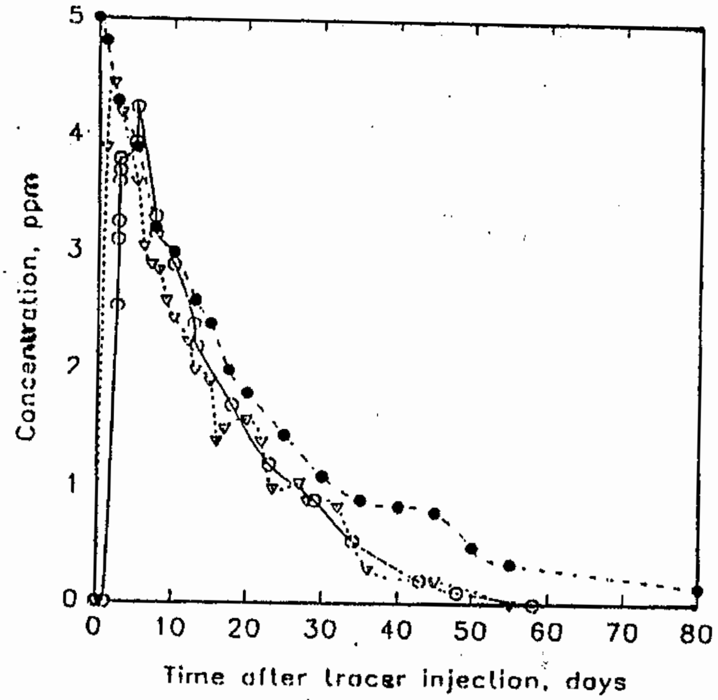


**Figure 4 Comparison of the complete mix reactor with baffled and unbafflled reactors tracer tests results.**

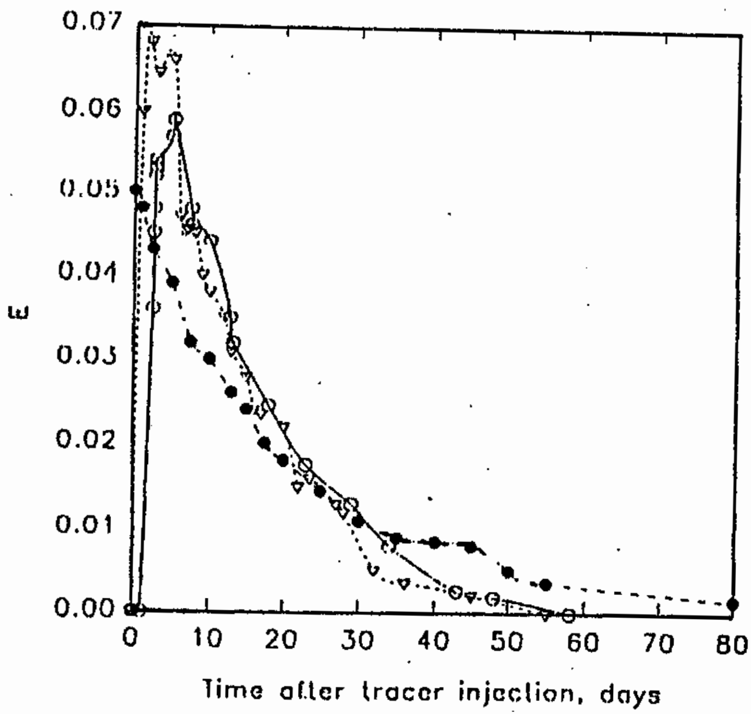


**Figure 5 corrected Tracer Results compared with complete mix reactor**

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# معالجة مياه الصرف الصحى بواسطة بحيرات الاكسدة

د٠ ضياء المنيرى – د٠ هشام القرمانى – د٠ صلاح بيومى

تقدم بحيرات الاكسدة ميزة اقتصادية واضحة فى معالجة مياه الصرف الصحى عندما تتاح الارض اللازمة ويرجع ذلك لسهولة تشغيلها وصيانتها بالاضافة الى قلة الطاقة اللازمة لها ٠ يعد زمن بقاء مياه الصرف الصحى فى بحيرات الاكسدة من أهم العوامل الداخلة فى تصميمها الأمر الذى يؤدى الى المساحات السطحية الكبيرة المطلوبة لهذه البحيرات اذا ماقورنت بأنظمة المعالجة التقليدية٠

فى هذا البحث تمت دراسة زمن البقاء الفعلى لمياه الصرف الصحى فى البحيرة وذلك فى حالة عدم وجود حواجز وحالة وجود حواجز ذلك عن طريق استخدام صبغة ملونة واقتفاء اثرها فى مخرج النموزج المعد للتجارب ٠

وتبين من الدراسة أن مدة البقاء الفعلية لاتزيد عن ٦٣٪ من مدة البقاء التصميمية وذلك فى حالة عدم وجود حواجز بينما ذادت الى ٧١٪ فى حالة وجود حواجز٠