# LABORATORY STUDY OF THE EFFECT OF TEMPERATURE CHANGES ON MIXING AND PERFORMANCE OF PONDS

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**Abstract**

***This work is an investigation of the effect of temperature changes on the mixing and performance of ponds. The parameters tested for were: biochemical oxygen demand, dissolved oxygen, coliform, suspended solid, temperature and pH. Three metallic tanks were fed simultaneously by a plastic container under gravity. This was achieved by systems of hoses and pipelines with one plastic container supplying sewage to another. Each tank measured 2 × 0.5 × 0.4m while each plastic container measured 300litres. Aerobic conditions prevailed in both the plastic containers and the metallic tanks. There was a lighting system over each tank. Two tanks contained heating coils at the bottoms, thermostatically controlled. One tank was the control (without heating coils). Each tank also had control taps at both inlet and outlet. There was a sampling device for collecting sewage at every 0.1m depth of each tank. The results showed that mixing causes general fluctuations in dissolved oxygen, suspended solid, biochemical oxygen demand and coliform with respect to depth, as the temperature varies.***

**Keywords:** biochemical oxygen demand, dissolved oxygen, suspended solid, coliform, pH.

## 1. Introduction

Waste stabilization ponds (WSP), often referred to as oxidation ponds or lagoons, are holding basins used for secondary wastewater (sewage effluents) treatment where decomposition of organic matter is processed biologically. The activity in the WSP is a complex symbiosis of bacteria and algae, which stabilizes the waste and reduces pathogens. The result of this biological process is to convert the organic content of the effluent to more stable and less offensive forms. WSP are used to treat a variety of wastewater, from domestic wastewater to complex industrial water, and they function under a wide range of weather conditions, i.e. tropical to arctic. They can be used alone or in combination with treatment processes [1].

A WSP is a relatively shallow body of wastewater contained in an earthen manmade basin into which wastewater flows and from which, after certain retention time (time which it takes the effluent to flow from the inlet to the outlet) a well-treated effluent is discharged. Many characteristics make WSP substantially different from other wastewater treatment. They include design, construction and operation simplicity, cost effectiveness, low maintenance requirements, low energy requirements, easily adaptive for upgrading and high efficiency [1].

The most appropriate wastewater treatment is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements [2]. Adopting as low a level of treatment as possible is especially desirable in developing countries, not only from the point of view of cost but also in acknowledgement of the difficulty of operating complex systems reliably. In many locations it will be better to design the reuse systems to accept a low-grade of effluent rather than to rely on advanced treatment processes producing a reclaimed effluent which continuously meets a stringent quality standard.

Waste stabilization ponds (WSP) are now regarded as the method of first choice for the treatment of wastewater in many parts of the world. In Europe, for example, WSP are widely used for small rural communities (approximatedly up to 2000 population but larger systems exist in Mediterranean France and also in Spain and Portugal) [3, 4]. In the United States one third of all wastewater treatment plants are WSP, usually serving populations up to 5000 [5]. However in warmer climates (the Middle East, Africa, Asia and Latin America) ponds are commonly used for large populations (up to around 1 million). In developing countries and especially in the tropical and equatorial regions sewage treatment by WSPs has been considered an ideal way of using natural processes to improve sewage effluents.

The mixing of the pond contents is an important mechanism, which helps to convey oxygen produced at the pond surface to the lower layers. Wind and heat are the two factors of major importance, which influence the degree of mixing that occurs within a pond. Mixing contributes oxygen in its own way by the process of reaeration. It also helps to reduce thermal stratification, which aids in dispersing bacteria and algae throughout the pond thus producing an effluent of a more consistent quality.

The application of mixing is one of the first major advances in anaerobic treatment. Mixing is an important factor in pH control and maintenance of even environmental conditions. It distributes buffering agents throughout the reactor volume and prevents localized build-up of high concentrations of intermediate metabolic products, which may inhibit methanogenic activity. On the contrary, inadequate mixing propitiates the development of adverse microenvironments [1].

Temperature as a local environmental condition is significant because changes in the wastewater temperature can affect the biological reaction rate. For example, a decrease of 10℃will reduce the reaction rate by about half [6]. An environmental condition of temperature has an important effect on the survival and growth of bacteria. In general, optimum growth occurs within a fairly narrow range of temperature, although the bacteria may be able to survive within much broader limits. Temperatures below the optimum typically have a more significant effect on growth rate than temperatures above the optimum [6]. Optimum temperatures for bacterial activity are in the range from about 25℃to 35℃. Aerobic digestion and nitrification stop when the temperature rises to 50℃. When the temperature drops to about 15℃, methane producing bacteria become quite inactive, and at about 5℃, the autotrophic- nitrifying bacteria practically cease functioning. At 2℃, even the chemo-heterotrophic bacteria acting on carbonaceous material become essentially dormant.

As temperature rises, the rate of reaction also increases. In order to have a reasonable methane production rate, the temperature should be maintained above 20℃. Methane production rates are doubled for each 10℃temperature increase in the mesophilic range [6]. Increasing the temperature results in a more rapid bacteria kill. The temperature dependence of the biological reaction-rate constants is very important in assessing the overall efficiency of a biological treatment process. Temperature not only influences the metabolic activities of the microbial population but also has a profound effect on such factors as gas-transfer rates and the settling characteristics of the biological solids. The temperature at which the BOD of a wastewater sample is determined is usually 20℃.

Hence, this work focused on investigating the effect of variation of some pond parameters like DO, SS, Coliform, pH, BOD with depth. It investigated the effect of temperature on pond mixing and stratification. It also investigated the extent of stratification and mixing in ponds with respect to BOD, DO, SS, pH, temperature and coliform.

## 2. Experimental Procedure

### *2.1. Collection of Sample*

Influent sewage to the facultative ponds was collected from the University of Nigeria, Nsukka wastewater treatment plant.

### *2.2. Laboratory Set-Up*

Figure 1 shows the laboratory set-up of three metallic tanks A, B, C (containing sewage) fed simultaneously by plastic container II under gravity. This was achieved by systems of hoses and pipelines. Plastic container I supplied sewage to plastic container II under gravity too. Each tank measured 2 x 0.5 x 0.4m while the capacity of each plastic container was 300litres. Aerobic conditions prevailed in both the plastic containers and the metallic tanks.

There was a lighting system over each tank. Tanks B and C contained heating coils at the bottoms; thermostatically controlled. Tank A was the control (without heating coils). Each tank also had control taps at both inlet and outlet.

Plastic container I was constantly being supplied with sewage because the flow condition throughout the entire set-up was continuous. There was also a sampling device for collecting sewage at every 0.1m depth of each tank. It was numbered 1, 2, 3, and 4 to denote sewage samples collected from the surface to the bottom in that order. All samples were preserved in such a way as to avoid any significant change in quality between the times of sampling and actual testing. American standard methods were used throughout the analysis.

### *2.3. Sampling Technique*

In each of the seven different test days, tanks B and C were heated to different temperatures before sampling with the sampling device. The control, (tank A) was sampled without heating in each of the test days. Samples were taken from the middle of each tank.

After the heating, the temperature of the different layers (0.1m depth each) was tested. This was followed by dissolved oxygen test, pH test, BOD test, Coliform test and suspended solids test.

Table 1: Arithmetic average and standard deviationon of pond parameters *

| | T(°C) | pH (pH Units) | DO (mg/l) | SS (mg/l) | COLIFORM (x $10^4$ / 100ml) | BOD (mg/l) |
|---|---|---|---|---|---|---|
| B1 | $34 \pm 2.000$ | $8.0 \pm 0$ | $1.644 \pm 0.551$ | $455.714 \pm 2.000$ | $5.333 \pm 2.122$ | $135.667 \pm 2.223$ |
| B2 | $34 \pm 2.000$ | $6.4 \pm 0$ | $1.526 \pm 0.538$ | $21.429 \pm 2.006$ | $9.667 \pm 2.222$ | $101.333 \pm 1.004$ |
| B3 | $34 \pm 2.000$ | $6.8 \pm 0$ | $1.796 \pm 0.592$ | $20 \pm 2.000$ | $11 \pm 2.000$ | $117.667 \pm 2.000$ |
| B4 | $34 \pm 2.000$ | $7.5 \pm 0$ | $1.554 \pm 0.634$ | $17.143 \pm 2.000$ | $15.333 \pm 2.221$ | $85.667 \pm 1.740$ |
| C1 | $40 \pm 2.000$ | $8.0 \pm 0$ | $1.627 \pm 0.536$ | $514.286 \pm 2.002$ | $4.667 \pm 1.700$ | $163 \pm 1,811$ |
| C2 | $40 \pm 2.000$ | $7.5 \pm 0$ | $1.793 \pm 0.528$ | $29.714 \pm 2.000$ | $4.333 \pm 1.886$ | $131.667 \pm 1.222$ |
| C3 | $40 \pm 2.000$ | $6.8 \pm 0$ | $1.749 \pm 0.390$ | $26.857 \pm 2.221$ | $15.333 \pm 1.712$ | $89.333 \pm 1.921$ |
| C4 | $40 \pm 2.000$ | $6.4 \pm 0$ | $1.583 \pm 0.449$ | $23.857 \pm 2.000$ | $8.667 \pm 1.500$ | $103 \pm 2.411$ |

* Average values of 7 sets of observations in T, pH, DO, SS, Coliform and BOD were based on 3 sets of observations

Table 2: Parameters and statistical properties *

| Parameter | | | STATISTICAL PROPERTIES Mean (mg/l) | Standard deviation (mg/l) |
|---|---|---|---|---|
| DO | Pond | A | 2.122 | 0.569 |
| | | B | 1.630 | 0.590 |
| | | C | 1.688 | 0.487 |
| SS | Pond | A | 82.321 | 221.313 |
| | | B | 128.571 | 343.238 |
| | | C | 148.679 | 486.409 |
| BOD | Pond | A | 146.917 | 94.070 |
| | | B | 110.083 | 68.551 |
| | | C | 121.750 | 81.003 |
| Coliform | Pond | A | 20 x $10^4$ / 100ml | 40.694 x $10^4$ / 100ml |
| | | B | 10.33 x $10^4$ / 100ml | 11.198 x $10^4$ / 100ml |
| | | C | 8.25 x $10^4$/ 100ml | 10.361 x $10^4$/ 100ml |

* Notes same as in table 1

## 3. Analysis and Results

### *3.1. Characteristics of sewage control with respect to depth*

The variation of pH, dissolved oxygen, biochemical oxygen demand, suspended solid, coliform with depth are shown in figures 2 to 7. An average temperature of 27°Coccurred in tank A (sewage control without heaters). Dissolved oxygen increased towards the surface. Dissolved oxygen was observed at all depths. Maximum and minimum values of dissolved oxygen (for tank A) were 2.499mg/l and 1.79mg/l respectively.

The pH showed marked variation with depth. Photosynthesis controls the pH value. As one approaches the surface, $CO_2$ from respiration is no longer enough to satisfy the demand required by larger algae concentration. Assimilation of the $CO_2$ by algae causes the disequilibrium of the carbonate balance. Therefore, the pH of the whole water increases. Maximum and minimum pH were 8.0 and 6.4 respectively.

The vertical distribution of BOD was characterized by marked gradients of concentration. Maximum (237.667 mg/l) and minimum (51 mg/l) occurred at the bottom and surface respectively. The occurrence of increased BOD towards the bottom was due to the anaerobic redissolution and digestion of the matter previously sedimented. The maximum BOD reduction at the surface was associated with maximum DO, pH and temperature.

Coliform bacteria were higher at the bottom than on the surface. Due to higher photosynthetic activity at the surface, more bicarbonates available were utilized in the metabolic activity of algae, causing a reduction of bacteria. Coliform concentration ranged from less than 3 x $10^4$ to 53.333 x $10^4$ per 100 ml.

Suspended solids were found to be highest at the bottom (261mg/l) and least at the surface (12.857 mg/l). This was possibly because the sewage has been screened before entering the pond. In addition, stratification was suggested to have taken place, for stratification takes place in ponds as shallow as 0.2 m [7].

### *3.2. Effect of changes in temperature on parameters with respect to depth*

The variations of pH, SS, DO, BOD, Coliform with depth are shown in tables 1 and 2. For tank B, as the temperature varied in the different test days, the pH values for 0.1, 0.2, 0.3, and 0.4m depths were 8, 6.4, 6.8 and 7.5 respectively while for tank C, it was 8, 7.5, 6.8, and 6.4 respectively. This was because mixing affects photosynthetic activity. Photosynthesis controls the pH value.

In the dissolved oxygen test, as the temperature increased in the different test days, the DO levels fluctuated among the four depths. This was possibly because mixing has taken place and conveyed oxygen produced at the pond surface to the lower layers. In the suspended solid test, as the temperature changed, there was fluctuation in the trend because mixing helps to reduce thermal stratification of solids.

In the coliform test, fluctuation of coliform bacteria among the depths resulted possibly because mixing aids in dispersing bacteria and algae. In the BOD test, fluctuation of BOD values among the four depths resulted possibly due to the distribution of the digested, previously sedimented matter necessitated by mixing.

### *3.3. Level of stratification in ponds*

The data in figures 2 to 7 (for tank A) showed the occurrence of vertical stratification. Hence, stratification is not restricted to deep ponds only. However, the extent of stratification depends on the time of sampling. DO and pH decreased from the pond surface to the bottom. The reverse was the case for SS, BOD and coliform. Statistical Student T-Test

From table 2, pond A had the highest mean DO (2.122mg/l), followed by

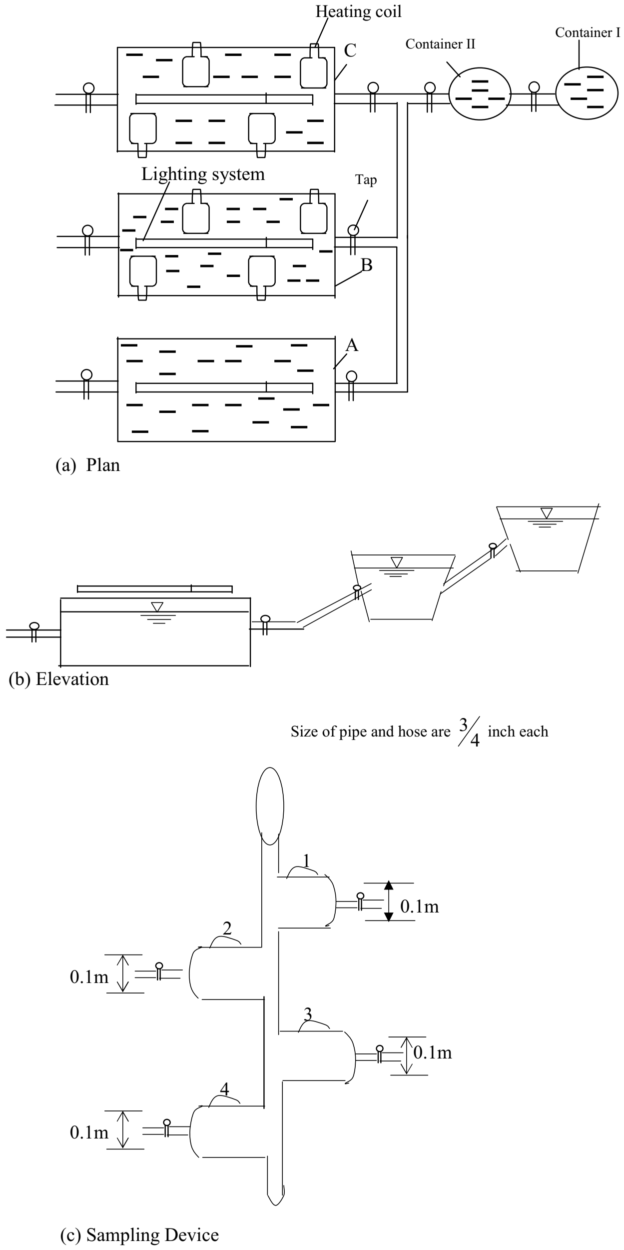


Figure 1: Laboratory Set-Up.

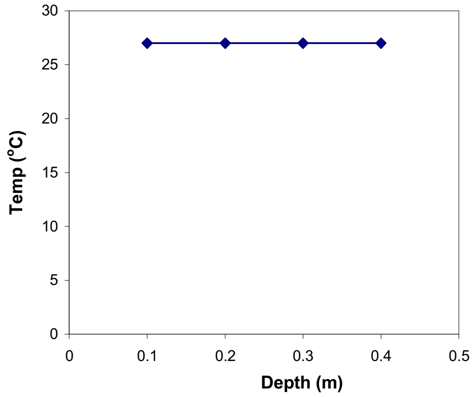


Figure 2: Relationship between average temperature and depth for tank A.

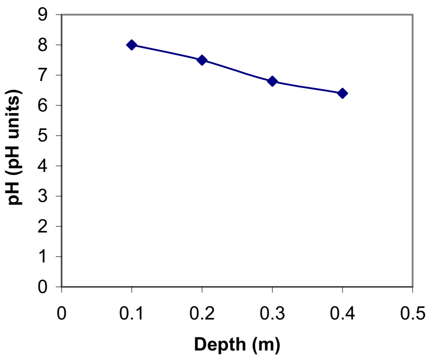


Figure 3: Relationship between pH and depth for tank A.

pond C (1.688 mg/l) and then pond B (1.63mg/l). The mean suspended solid was highest in pond C (148.679mg/l), followed by pond B (128.571mg/l) and then pond A (83.321mg/l). The mean BOD was highest in pond A (146.917mg/l), followed by pond C (121.750mg/l) and then pond B (110.083mg/l). The mean faecal coliform was highest in pond A (20 x $10^4$/ 100ml), followed by pond B (10.333 x $10^4$/ 100ml) and then pond C (8.25 x $10^4$/ 100ml).

### *3.4. Implication on the efficiency of waste stabilization pond*

The general trend showed marked reduction in suspended solid, coliform, dissolved oxygen,

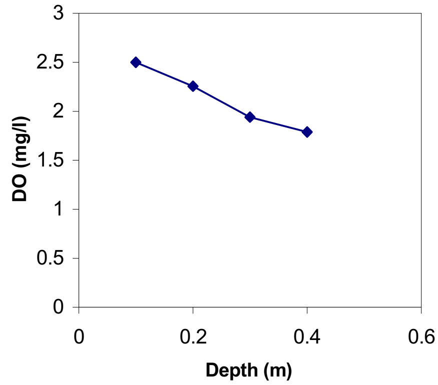


Figure 4: Relationship between DO and depth for tank A.

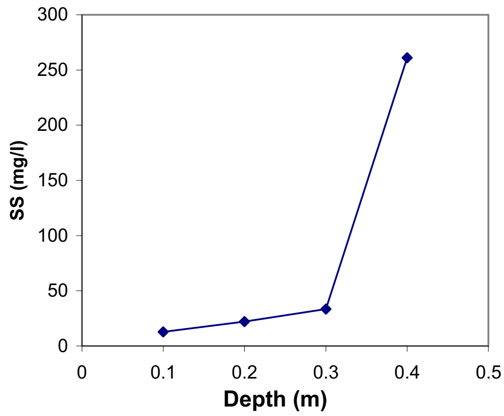


Figure 5: Relationship between SS and depth for tank A.

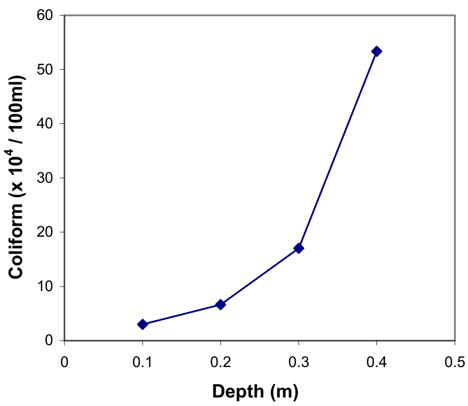


Figure 6: Relationship between Coliform and depth for tank A.

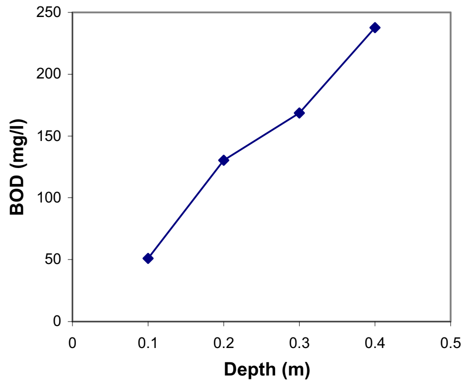


Figure 7: Relationship between BOD and depth for tank A.

biochemical oxygen demand as the temperature increased. This implied a high hydraulic efficiency. It also implied that the operating and environmental conditions were good.

## 4. Conclusions and Recommendations

From the results of investigations into the effect of temperature changes on pond mixing and performance, the following conclusions were drawn: Temperature changes affected mixing which invariably had significant effect on pond performance. The variability of pH value with respect to depth fell within the alkaline range, confirming that sewage is strictly alkaline in nature. The control (that is, tank A) at an average temperature of 27°Cshowed increase in biochemical oxygen demand, coliform, and suspended solid with depth. Dissolved oxygen was highest at the surface for tank A (sewage control, without heaters).

Tanks B and C showed general fluctuations in dissolved oxygen, biochemical oxygen demand, suspended solid, coliform and pH with changes in temperature. This was attributed to mixing caused by the heating coils being positioned at the bottom of the tanks. The shallow nature of the tanks depth could equally have caused it.

Since temperature has effects on several other parameters other than reaction constant, it is important to reflect this effect in future pond modeling in order to ensure more accurate results.

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