# Effective Positioning of Solar Reflections in Solar Enhanced Waste Stabilization Ponds.

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## ABSTRACT

The essence of this research is to determine the performances of different positioning of solar reflectors in solar enhanced waste stabilization pond in order to obtain an optimum position that would give the best treatment efficiency. In this study, four sets of six SEWSPs of varying sizes made of metallic tank with inlet and outlet valves, and solar reflectors were constructed to increase the incident sunlight intensity.

Wastewater samples collected from the inlet and outlet of the SEWSPs were examined for physio-chemical and biological characteristics for a period of twelve months. The parameters examined were temperature, pH, detention time, total suspended solids, dissolved oxygen, biochemical oxygen demand ($BOD_5$), chemical oxygen demand (COD), algae count, fecal coliform and *E. coli*. The distribution and variation of both the physiochemical and biological characteristics inside the water body were found to be influenced as maximum temperature, DO, pH, algae count, as well as minimum $BOD_5$, COD, fecal coliform and *E. coli* was observed when the solar reflectors were placed at the outlet position.

(Key words: waste stabilization pong, effective positioning, efficiency, solar radiation, wastewater)

## INTRODUCTION

Wastewater stabilization pond (WSP) technology is one of the most important natural methods for waste water treatment. Waste stabilization ponds are mainly shallow man-made basins comprising a single or several series of anaerobic, facultative or maturation ponds. It is a basin dug on the ground for removal of organic and pathogenic organisms (Agunwamba, 2000). Not only has it been found to be one thousand times better in destroying pathogenic bacteria and intestinal parasites than the conventional treatment plants (Mara et al., 1983), it is also more economical, (Arthur, 1983). It is simple to construct, operate, and maintain and it does not require any input of external energy. Although a waste stabilization pond system usually requires large land area because of its long detention time which is attributable to its complete dependence on natural treatment process, it is very suitable in several African communities where land acquisition is not a problem. Besides, its efficiency depends on availability of sunlight and high ambient temperature which are the prevailing climatic conditions in most of these communities.

In addition to being useful in the treatment of sewage, WSP is being applied in the treatment of industrial and agricultural wastes. Its long detention times; its relatively slow-rates of sludge accumulation; and its physicochemical conditions, such as neutrality to alkaline, pH, make it attractive in treating industrial wastewaters.

WSPs are usually classified according to the nature of the biological activities taking place. Other criteria for classification include the type of influent (untreated, screened, settled or activated sludge influent); pond overflow condition, and method of oxygenation, which is influenced by the degree of mixing and dispersion within the pond system. In terms of biological activities, ponds are classified as anaerobic, facultative and maturation ponds.

The primary treatment takes place in the anaerobic pond, which is mainly designed for removal of suspended solids, and some of the soluble element of organic matter. During the secondary state in the facultative pond, most of the remaining removed through the coordinated activity of algae and heterotrophic bacteria. The main function of the tertiary treatment in the maturation pond is the removal of pathogens and nutrients (especially nitrogen). WSP technology is the most cost effective wastewater treatment technology for the removal of pathogenic micro-organisms. The treatment is achieved through natural disinfection mechanisms. It is particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes (Mara et al., 1992).

## Factors That Limit Pathogen Survival

The survival of most pathogens is highly variable depending upon the receiving water, particularly turbidity, temperature, oxygen levels, presence of nutrients and pesticides, pH, organic matter, and solar radiation (Barcina et al., 1990). Most bacterial pathogens are sensitive to temperatures exceeding 140 degrees Fahrenheit. Higher temperatures also kill protozoa cysts. The normal pH range for most water bodies is close to 7 (neutral) and would not affect bacteria survival. Only at extreme pH (< 4.5 or > 8.2) can cell die-off be expected. The effect of ultraviolet radiation on bacterial and protozoan mortality has long been known. *E. coli* and *Enterococcus faecalis* were significantly reduced when exposed to visible light in both freshwater and marine systems (Barcina et al., 1990).

In the construction of WSPs, land availability is the major militating factor. As earlier stated, WSPs require sunlight and temperature to enhance the efficiency of the removal processes. Most regions of the world do not have access to large land surface areas to enable them construct WSPs that can meet the standard dimensions specified. Therefore, this research seeks to assess the performances of different positioning of solar reflectors in solar enhanced waste stabilization pond in order to obtain an optimum position that would not only reduce the large land area requirement but will also give the best treatment efficiency.

## MATERIALS AND METHODS

### Physical Pond Design

The study was conducted using a 1:20 scale model of a conceptualized prototype waste stabilization pond. Geometrical similarity was applied for the design of the scale model pond. The design was performed first using Froude number similarity and compared with Reynold’s number. The ratios that must exist between the model and prototype pond as well as the corresponding flow characteristics are given in Table 2.

### Experimental facilities

The University of Nigeria, Nsukka, Nigeria treatment plant that supplied the influent to the solar enhanced waste stabilization ponds consists of a screen (6 mm bar racks set at 12 mm centre) followed by two imhoff tanks, each measuring about 6.700 m x 4.700 m x 10 m, and then by two facultative ponds in series.

Four sets of six solar ponds with one sewage storage tank (1.2m x 0.5m x 0.5m) that receives its influent from an overhead storage tank (1.2m x 1.5m x 1.5m) were constructed for the experiment.

Five (5) out of the six ponds were fixed with solar reflectors each of size 0.2 m by 1.0m at the inlet, right side, left side and outlet respectively for set 1, 2, 3 and 4. All the ponds were operated at a detention time of 7days. The detailed experimental characteristics of the various ponds are explained in the Table 1.

The six solar ponds were filled with sewage from the second facultative pond through a sewage storage tank. Storage tanks were fed continuously by an overhead storage tank which in turn was filled with sewage from a facultative pond through an underground pipe, with the aid of a water pump being powered by a generator. The pictorial and schematic diagrams of the experimental setup is shown in Figures 1, 2, 3, 4, and 5.

**Table 1:** Detailed Experimental Characteristics of the Various Ponds.

| Experimental Set-ups | No. of Solar Ponds | Characteristics | Purpose |
|---|---|---|---|
| Set 1 | 6 | Inlet Position | Effect of Solar Position ermiControl |
| Set 2 | 6 | Right Position reflector | Effect of Solar Position |
| Set 3 | 6 | Left Position | Effect of Solar Position |
| Set 4 | 6 | Outlet Position reflector | Effect of Solar Position |

**Table 2:** Prototype to Model Relationships on Kinematics Similarity (Reynolds Model) Law.

| Parameter | Unit | Equation | Relationship | Prototype | Model |
|---|---|---|---|---|---|
| Length, L | M | $\alpha$ | 1/20 | 20 | 1 |
| Width, W | M | $\alpha$ | 1/20 | 8 | 0.4 |
| Depth, D | M | $\alpha$ | 1/20 | 4 | 0.2 |
| Surface Area, A | $M^2$ | $\alpha^2$ | 1/400 | 160 | 0.4 |
| Volume, V | $M^3$ | $\alpha^3$ | 1/8000 | 640 | 0.08 |
| Ideal detention time, T (=V/Q) | hrs | $\alpha^2$ | 1/400 | 160 | 0.4 |
| Influent rate, Q | $M^3/d$ | $\alpha$ | 1/20 | 264 | 13.2 |
| Average theoretical Velocity (U=QD/V) | M/d | $\alpha^{-1}$ | 20 | $4.125\times10^{-2}$ | $8.25\times10^{-1}$ |
| Average Pond Reynold's No. Re ($Re=UR_h/\ $) | _ | $\alpha^0$ | 1 | 116 | 116 |
| Average Froude No. $Fr=u/(gR_h)^{0.5}$ | _ | $\alpha^{-2}$ | 40 | $1.54\times10^{-5}$ | $6.21\times10^{-4}$ |

**Figure 1:** Inlet Position of Reflectors.

**Figure 2:** Right Position of Reflectors.

**Figure 3:** Left Position of Reflectors.

**Figure 4:** Outlet Position of Reflectors.

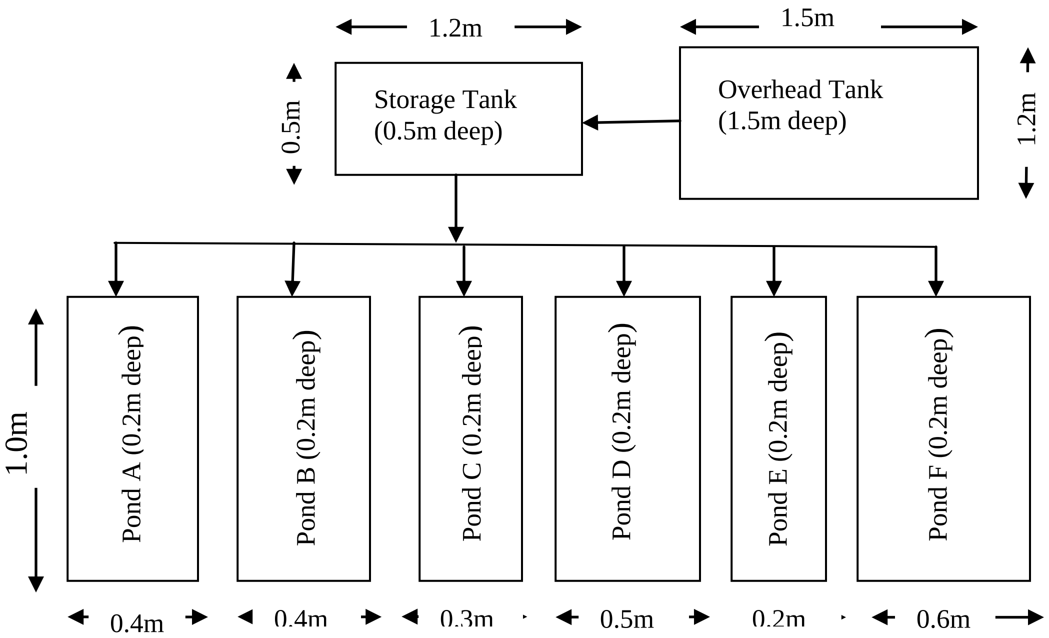

**Figure 5:** Schematic Diagram of Experimental Setup

## Experimental Procedures

Collection of water samples was carried out weekly during the period from four sets of six different solar ponds and one from the outlet of the storage tank for laboratory analysis to determine the concentrations of $BOD_5$, COD, DO, algae count, fecal coliform, *E. coli*, suspended solids, temperature and pH. Solar reflectors were fixed at the inlet, right side, left side and outlet positions for the four sets respectively in order to determine the optimum position that would give the best treatment efficiency.

Physicochemical analysis was carried out using the procedures described in standard methods (APHA, 1998) for the determination of parameters. Samples were collected once a week and analyzed for pH, dissolved oxygen (DO), $BOD_5$, COD, suspended solids and water temperature. DO and pH were measured by DO meter (HI 9142 water multi-parameter testing meter) and pH meter, respectively. Pond temperatures were obtained with a thermometer.

In bacteriological analysis, fecal coliform removal efficiency was obtained by the most probable number (MPN). While, algae concentration and *E. coli* were also determined using the procedures described in standard methods (APHA, 1998).

## RESULTS AND DISCUSSIONS

### Data Variability

The results of the variability in efficiency of parameter removal for the different solar positioning are presented in Figures 6 to 19. Figures 6 to 14 depict the temporal removal efficiencies for the four different solar positioning of the SEWSP with respect to coliform, *E. coli*, BOD, COD, suspended solids, algal concentration, pH, DO and temperature respectively. While, Figures 15 to 19 illustrates the effect of solar reflectors positions on removal efficiencies in the SEWSPs with solar radiation. The various graphs are discussed below.

### Effects of Solar Positions

Pond E with the least geometry of (1 x 0.2 x 0.2) had the highest level of treatment efficiency for all the four cases. Comparing pond E which had the same dimensions for all the cases, results showed that the removal of coliform bacteria was higher in Set 4, followed by Set 2, Set 3 and Set 1 for outlet position, right-side position, left-side position and inlet position respectively (Figure 6).

The average concentrations of coliform bacteria in Sets 1, 2, 3 and 4 were 210/100ml, 106/100ml, 150/100ml, 92/100ml, respectively. Similar result was obtained for *E. coli* (Figure 7) where the average values were 18/100ml, 11/100ml, 14/100ml, 9/100ml for Sets 1, 2, 3 and 4 respectively. This results were corroborated by the higher average temperature (27.9$^o$C, 28.7$^o$C, 28.2$^o$C, and 29.9$^o$C) observed in Sets 1, 2, 3, and 4, respectively (Sinton et al., 2002).

Also, the average $BOD_5$ removal efficiency was higher in Set 4 as compare to Sets 1, 2 and 3 (Figure 8). The minimum and maximum concentrations were 100mg/l and 286mg/l, 98mg/l, and 251mg/l, 111mg/l, and 281mg/l, 90mg/l and 246mg/l for Sets 1, 2, 3, and 4, respectively. For COD, average values ranges from 182mg/l to 498mg/l, 170mg/l to 446mg/l, 186mg/l to 526mg/l and 156mg/l to 322mg/l for Sets 1, 2, 3, and 4, respectively (Figure 9). The average suspended solids removal efficiency was higher in Set 4 as compare to Sets 1, 2, and 3 (Figure 10). The minimum values of suspended solids were 7mg/l, 6mg/l, 9mg/l and 3mg/l for Sets 1, 2, 3, and 4 where as the maximum values were 24mg/l, 21mg/l, 26mg/l, and 10mg/l for Sets 1, 2, 3, and 4, respectively. The average removal efficiencies for all the parameters are given in Table 3. The difference in removal efficiencies for Sets 1, 2, 3, and 4 were found to be significant for all the parameters at 5% degree of significance.

### Solar Effect Consideration

Solar effect was observed as Pond E with the smallest width of 0.2m had the highest efficiency among ponds B, C, D, E, and F for all positions with respect to all the parameters investigated. Application of the same reflector in all the ponds produces the highest intensity per unit volume in pond E. This increases the temperature in pond E by 1.9$^o$C above all the other ponds. The average temperatures of ponds A, B, C, D, E, and F were 26.1$^o$C, 27.5$^o$C, 28.2$^o$C, 27.2$^o$C, 30.1$^o$C, and 26.3$^o$C, respectively. The temperature values agreed with variation of dissolved oxygen in these ponds. Pond E had the least value while pond A had the highest since the solubility of oxygen decreases with increase in temperature. Figure 15 to 19 show the variations of removal efficiency with solar intensity. Generally, efficiency increases with the amount of solar radiation for each of the parameters investigated for all the different solar reflector positions.

## CONCLUSION

In the integration of solar reflectors in waste stabilization ponds, sewage effluent from a facultative pond in the University of Nigeria, Nsukka was used. Four sets of solar ponds with different solar positions were constructed, each set comprises of six ponds (B, C, D, E and F) with pond A, without a reflector, as control experiment. Laboratory analysis was carried out in order to understand the effect of solar positioning on wastewater treatment efficiency from SEWSPs.

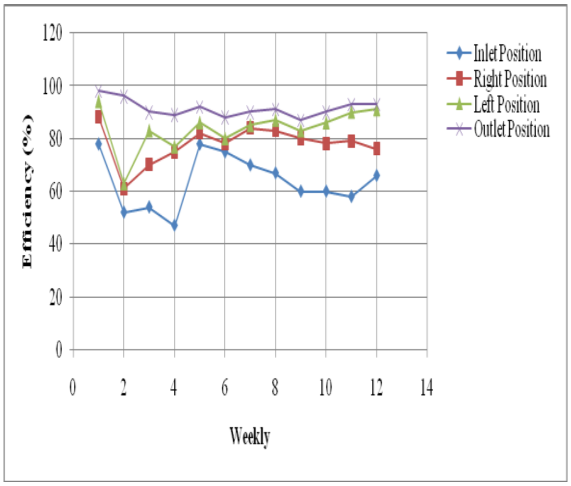

**Figure 6:** Efficiency of Coliform Removal with Time.

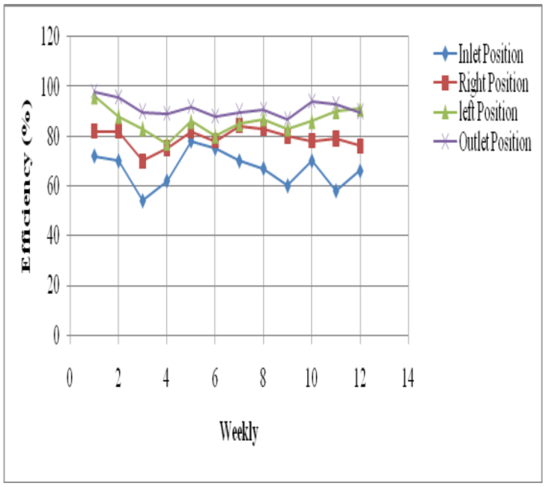

**Figure 7:** Efficiency of *E. coli* Removal with Time.

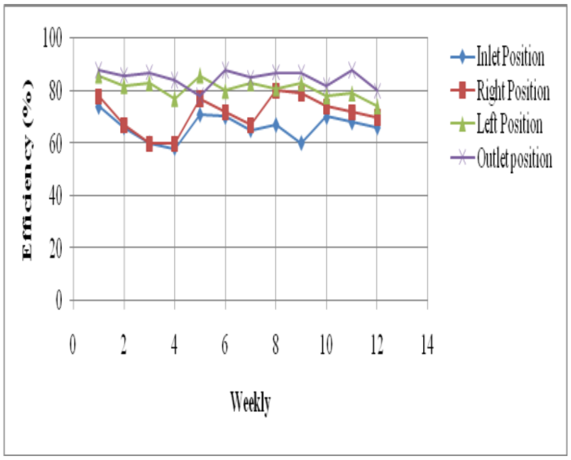

**Figure 8:** Efficiency of BOD Removal with Time.

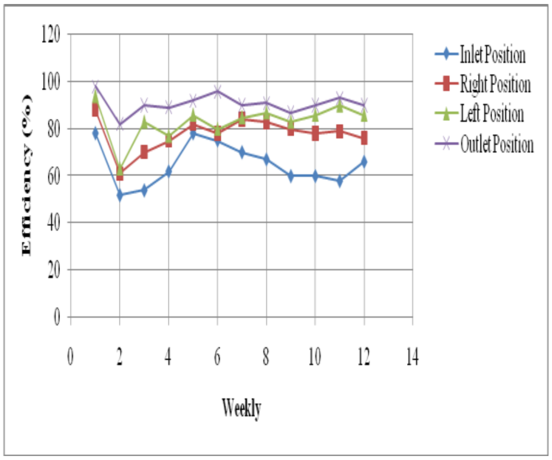

**Figure 9:** Efficiency of COD Removal with Time.

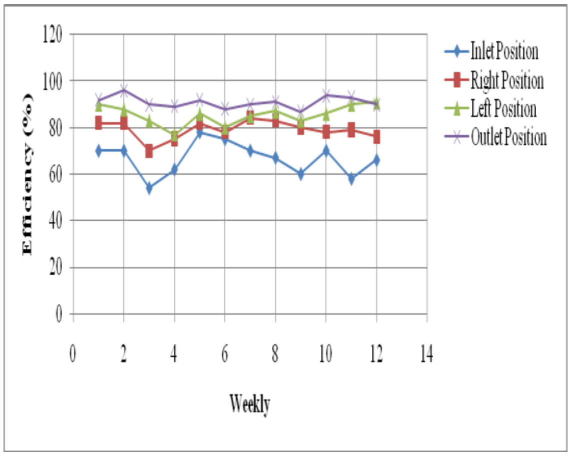

**Figure 10:** Efficiency of Suspended Solids Removal with time.

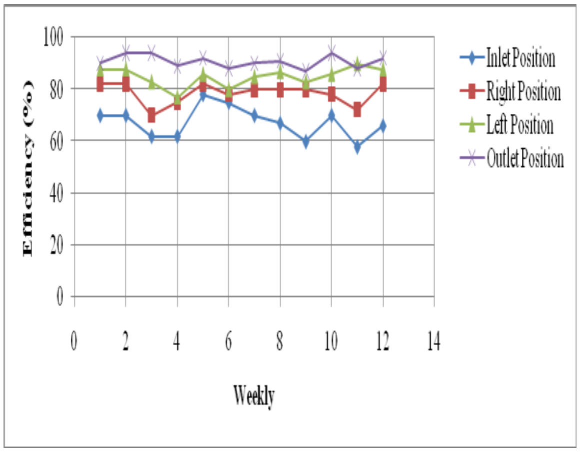

**Figure 11:** Efficiency of Algal Conc. Variation with time.

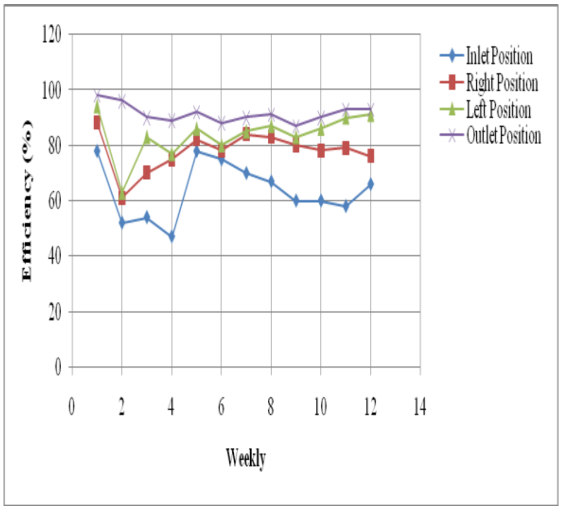

**Figure 12:** Efficiency of pH Variation with Time.

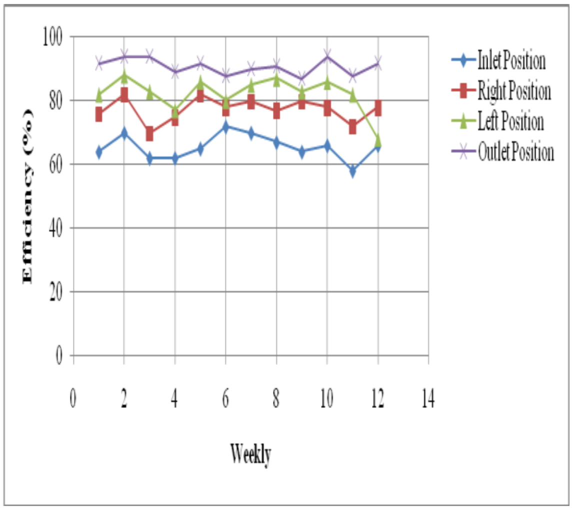

**Figure 13:** Efficiency of DO Variation with Time.

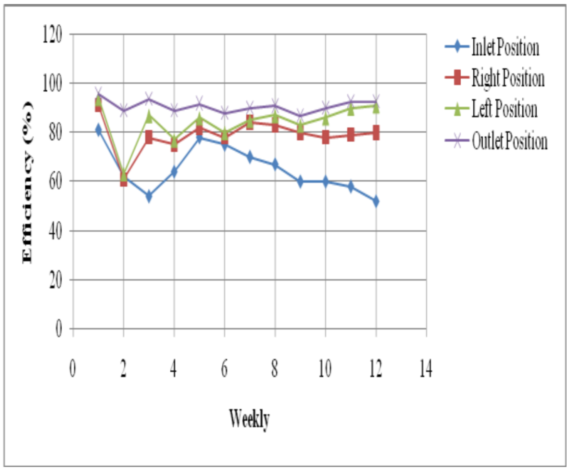

**Figure 14:** Efficiency of Temp. Variation with Time.

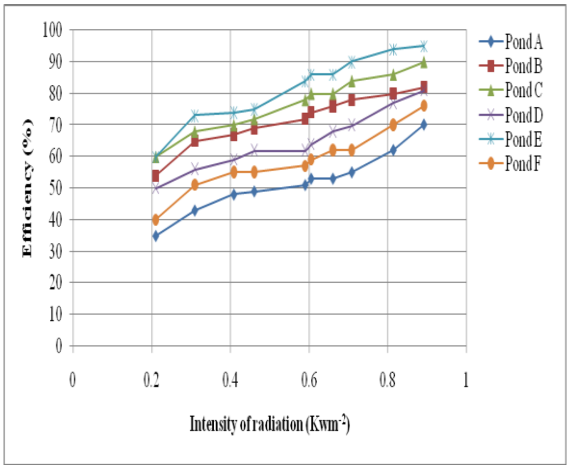

**Figure15:** Efficiency of Coliform Removal vs. Solar Intensity.

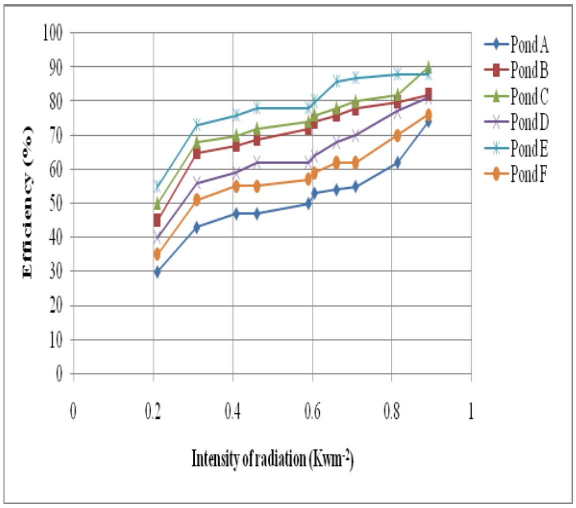

**Figure 16:** Efficiency of *E. coli* Removal vs. solar intensity.

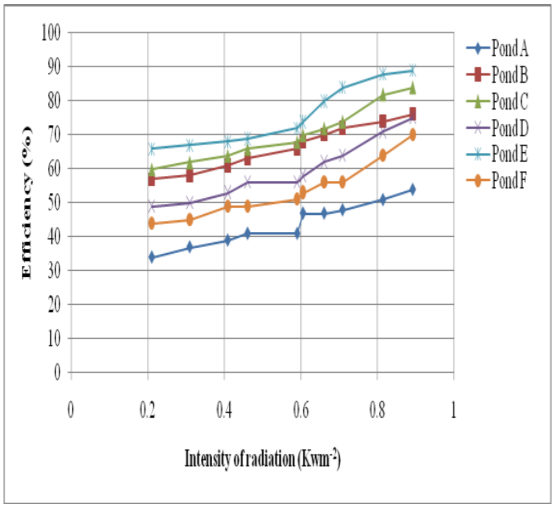

**Figure 17:** Efficiency of BOD Removal vs. solar intensity.

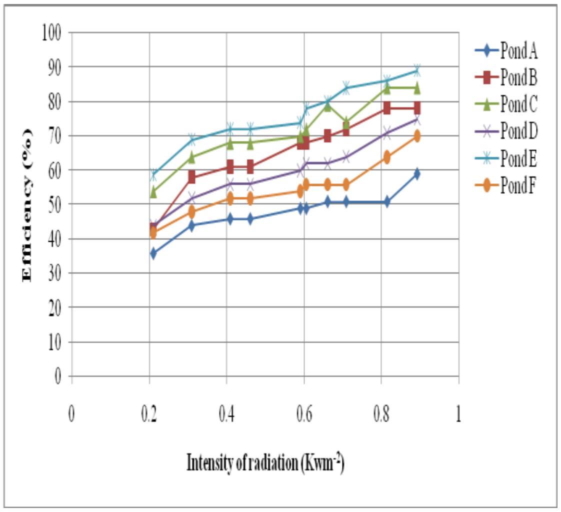

**Figure 18:** Efficiency of COD Removal vs. Solar Intensity.

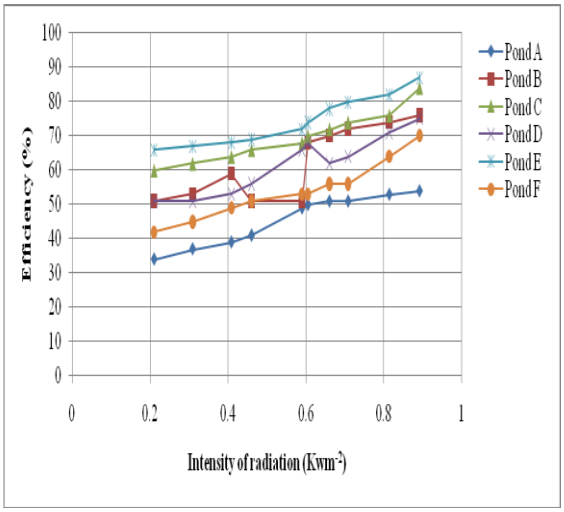

**Figure 19:** Efficiency of Algal conc. Variation vs. Solar Intensity.

**Table 3:** Average Removal Efficiencies of the Ponds as it affects the Parameters Investigated with Respect to Reflectors Positions.

| Position of Reflectors | Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Coliform | *E. coli* | $BOD_5$ | COD | SS | DO | Algal conc. | pH |
| Inlet (Pond E) | 64.2±10.9 | 61.2±12.6 | 59.5±8.4 | 55.7±9.6 | 54.9±11.9 | 7.4±1.9 | 19±9.8 | 7.7±1.6 |
| Right (Pond E) | 83.2±12.3 | 77.6±13.1 | 78.1±13.3 | 77.9±12.4 | 78.4±10.9 | 7.1±1.2 | 13.2±10.2 | 7.4±1.9 |
| Left (Pond E) | 86.1±13.4 | 80.9±12.7 | 80.7±9.2 | 79.4±6.7 | 79.9±9.9 | 5.9±1.4 | 11.1±14.1 | 6.5±1.4 |
| Outlet (Pond E) | 87.3±12.5 | 83.3±9.1 | 82.2±11.2 | 80.8±12.2 | 81.6±14.1 | 4.9±1.7 | 10.3±12.3 | 6.4±1.7 |

Samples in two replicates and n = 35.

From the experimental results comparative analysis revealed that, the efficiencies of the SEWSPs with respect to these parameters fluctuated with the different positions of the solar reflectors, with the position of reflectors at the outlet giving the highest treatment efficiency.

## RECOMMENDATION

It is recommended that, in the design of solar enhanced waste stabilization ponds, solar reflectors be fitted at the outlet position as it gives more room for increase microbial activities in SEWSPs for maximum treatment efficiency.

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