DOI: http://dx.doi.org/10.4314/gjer.v11i2.5

GLOBAL JOURNAL OF ENGINEERING RESEARCH VOL 11, NO. 2, 2012: 107-121
 ISSN 1596-292x
www.globaljournalseries.com; Info@globaljournalseries.com

VARIATION OF SOME WASTE STABILIZATION POND PARAMETERS WITH SHAPE

E. C. UKPONG

ABSTRACT

Waste Stabilization Pond (WSP) are designed to provide control environment for wastewater treatment. The primary purpose of wastewater treatment is the reduction of pathogenic contamination, suspended solids, oxygen demand and nutrient environment. The geometry of the pond could be structured in order to give the desired dispersion condition. However, the variation of pond shape and parameters such as coliform bacteria, suspended solids (ss), BOD_5, dispersion number and detention time (θ) have been studied, analysed and compared between rectangular and trapezoidal pond in order to determine their performance efficiency. The results of the experimental analysis reveal that the performance of the rectangular pond was better than that of the trapezoidal pond in term of bacteria reduction, BOD_5 and dispersion number, respectively.

KEYWORDS: Geometry, coliform bacteria, dispersion number, trapezoidal pond, rectangular pond.

1 INTRODUCTION

A few Waste Stabilization Ponds (WSPs) have been in use for the treatment of municipal wastewater since early 1940 in Israel. However, it can be safely said that this form of treatment was actively discouraged in the United States, prior to 1950. Since that time there has been a tremendous increase in the number of these installations. By 1968 a total of 3,457 municipal installations were serving some 6.1 million people. Most of the communities using WSP as at 1940 have populations of less than 5,000 persons. When properly designed, WSPs provide a reliable method for achieving treatment at minimum cost to small community.

In recent years, however, a rising chorus of concern has developed regarding the quality of the effluent discharged from WSPs. The basis for this concern is the algae and coliform organisms, which may be present in the effluent. WSPs are now regarded as the method of first choice for the treatment of wastewater in many parts of the world. The most appropriate wastewater treatment to be applied before effluent are used in agriculture or discharged to a water course is that which will produce an effluent meeting the recommended micro-biological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirement (Arar, 1988).

A WSP is a relatively shallow body of wastewater contained in an earthen man-made basin into which wastewater flows and from which after certain retention time (time which takes the effluent to flow from the inlet to the outlet) a well-treated effluent is discharged. Many characteristics make WSP substantially distinguished from other wastewater treatment methods. This includes design construction and operation simplicity, cost effectiveness, low maintenance requirements, low energy requirements, easily adaptive for upgrading and high efficiency. Not only has it been found to be one thousand times better in destroying pathogenic bacteria and intestinal parasites than the conventional treatment plants as reported by Mara and others (1983), it is also more economical as reported by Arthur (1983).

Conventional treatments of liquid wastes

E. C Ukpong, Department of Civil Engineering, Faculty of Engineering, University of Uyo, Uyo, Akwa Ibom State, Nigeria

involve mechanical treatment systems, and are the norms in developed countries. However, they are not the best option for less developed countries. Indeed, conventional treatment schemes were developed due to climatic and area constraints. These constraints are often not the case in developed countries. Moreover, the use of energy intensive mechanisms is not desirable in less developed countries, where energy supply is not reliable. Further, conventional treatment facilities require regular high-skilled maintenance, a thing that is either too expensive or impossible to find in developing countries.

The primary purpose of wastewater treatment is the reduction of pathogenic contamination, suspended solids, oxygen demand and nutrient enrichment. WSP are therefore designed to provide a controlled environment for wastewater treatment in developing countries. Their sizes are established from theoretical and empirical relationship that give, directly or indirectly, an estimate of the hydraulic retention time needed to achieve a given effluent quality as reported by Kellner and Pires (2002). In hot climates, ponds should always be considered the first method of choice for sewage treatment; indeed, a very good case must be made for not using them. Stabilization ponds offer many advantages over conventional treatment schemes. One of their most important advantages is their ability to remove pathogens. For conventional systems, pathogen removal is only attained with tertiary treatment such as the use of maturation ponds or chlorination. In addition, stabilization pond systems are much less costly, for both capital costs and maintenance costs as stated in a World Bank report by Arthur (1983). Pond systems are a viable option for both large and small populations.

Modern WSP design procedures are able to ensure compliance with the effluent quality requirements of the EU directive on urban wastewater treatment (Council of the European Communities, 1991). Besides, biochemical oxygen demand (BOD_5) removals are greater than 90 per cent and are readily obtained in a series of well-designed ponds. Total nitrogen removal in 70 ï 90 per cent while total phosphorus removal ranges between 30 ï 45 per cent as reported by Lloren.

Waste Stabilization Pond (WSP) are particularly efficient in removing excreted pathogen whereas in contrast all other treatment processes are very inefficient in this and require a tertiary treatment process such as chlorination (with all its inherent operational and environmental problems) to achieve the destruction of faecal bacteria.

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. In terms of biological activities, ponds are classified as anaerobic, facultative and maturation ponds.

The importance of WSP is well documented in the literature (Marais, 1974; Mara and Others, 1983; and Polprasert and Others, 1983). Its cheapness over the conventional technologies and the abundance of sunlight and prevalent high ambient temperature in the tropical and subtropical regions, have made it so popular.

The parameters used in judging the performance of WSP are bacteria rate of degradation, biochemical oxidation, dispersion, bacteria die-off rate and thermal stratification, which are influenced by temperature gradient. Many models by Polprasert and Others, 1983; Marais and Shaw, 1961. Bowles and Others, 1979; Klock, 1971; Thirumurthi, 1969; Prats and Others, 1994) have been proposed to describe the process of bacterial degradation. But none has been found acceptable. Finney and Middlebrooks (1980) and Marecos do Monte and Mara (1987) in terms of predicting the practical performance of the WSPs. Hence, the call in recent times has been to develop more appropriate models that will describe the process accurately (Polprasert and Others, 1983; Bowles and Others, 1979; and Finney and Middlebrooks, 1980; Pescud and Others, 1988).

A lot of attention has been given to the development of models for WSP performance since early 1960. Models have been developed to cover bacteria reduction, bacterial Kinetics, design, Kinetics of organic degradation, coliform decays, completely mixed-flow, plug-flow, steady and non-steady dispersion, predicting effluent quality, design and dynamic, temperature profile, dispersion and multiple depth layer model. But none have yet been developed on thermal stratification and the effect of wind on pond performance.

Also the development of models for high quality effluent have been the subjects of much research since early 1980 when wastewater treatment by WSPs became more popular. This study therefore presents the review of literature under the following headings: thermal stratification processes and their occurrence in WSP, temperature gradient in WSP, models for WSP, dispersion and wind effect on WSP performance. Apart from the multiple depth layer models developed by Agunwamba (1997), no other models exist for thermal stratification in WSP. However, no such models will be found until the nature of the factors that influence thermal stratification in WSP are taken into consideration. Apart from being too complex to follow, Kellner and Pires (2002), these factors are subjected to some random environmental and climatic conditions, which render them random in nature. Hence, WSP should be treated as a random process (Bronk, 1980). In this connection, Agunwamba, (1997) had stressed the importance of incorporating these random factors in design and management of WSP.

Although WSP system is economical compared with the conventional treatment, no model has yet been found to describe it accurately (Bowless and Others, 1979; Finney and Middlebrooks, 1980; Polprasert and Others, 1983). WSP are becoming popular for treating wastewater, particularly in tropical and sub-tropical regions where there is an abundance of sunlight, and the ambient temperature is normally high. The ability of WSP systems to reduce the biochemical oxygen demand (BOD_5) of wastewater is well established in the literature. Mathematical models have been developed to describe the Kinetics of organic degradation in these ponds. However, equally important in the effectiveness of WSP systems in reducing pathogenic micro-organisms. Because of lack of sound design criteria, there are still some doubts as to whether WSP can meet the present effluent standards set by many authorities without disinfections.

1.1 Waste Stabilization Pond Systems and their Application

A World Bank report by Shuval and Others, (1986) came out strongly in favour of stabilization ponds as the most suitable wastewater treatment system for effluent use in agriculture. Stabilization ponds are the preferred wastewater treatment process in developing countries, where land is often available at reasonable opportunity cost, and skilled labour is in short supply.

Waste Stabilization Pond (WSP) are now regarded as the method of first choice for the treatment of wastewater in many parts of the world. In the United States, one third of all wastewater treatment plants are WSP usually serving populations up to 5,000 as reported by EPA (1983), while Boutin and Others (1987), Mara (2001) and Bucksteeg (1987) have also reported that WSP are very widely used for small rural communities in Europe with population closed to 2,000, and further reported that larger systems exist in Mediterranean France and also in Spain and Portugal. However in warmer climate (the Middle East, Africa, Asia and Latin America), Marecos do Monte and Mara (1987); and Soares and Others, (1996) reported that ponds are commonly used for large populations up to around one 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 effluent.

Several researchers (El-Gohary and Others, 1993; Shereif and Others, 1995; Oswald, 1995 and 1990; Onazzani and Others, 1995; Shereif and Mancy, 1995; Fasa and Others, 1995; Mcktite, 1986; Shelef, 1975; Zohar, 1986, Etan, 1995; Al-salem and Lumbers, 1987; Saggar and Pescod, 1991; 1995a, 1996; Olsen and Others, 1998; Olsen and Others, 1998; Saggar, 1996; Shatanawi and Fayyad, 1996; Tsagarakis and Others, 1996, TSagarakis, 1997. Tehobanoglous and Angelakis, 1996; Tsagarakis, 1997; Onep, 1994; Nicdrum and Others, 1991. Lchtiher, 1997; Al-salem and Lumbers, 1987; Saggari, 1996; Shatanawi and Fayyad, 1996; Zhao and Others, 1996 and Zohal (1986 and Gambrill and Others, 2002) have studied the application of WSPs in different countries of the world such as Israel, Egypt, Turkey, Tunisia, Jordan, France, Greece, Morocco, USA, Middle East, Africa, Latin America, Spain, Portugal and so many other places.

In Israel it was reported that WSP have been regarded as the wastewater treatment technology of first choice given the need for the use of treated wastewater for irrigation.

In several countries, wastewater is generally too valuable to waste and the re-use of pond effluents for crop irrigation or for fish culture is very important in the provision of high quality food.

2 METHODOLOGY (EXPERIMENTAL)

This research work on the variation of waste stabilization pond (WSP) parameters with shape was carried out by laboratory investigation at the Civil Engineering laboratory of the University of Nigeria, Nsukka, in order to determine the quality parameters for rectangular and trapezoidal ponds for the purposes of comparison.

2.1 Laboratory Scale WSP (LSWSP)

Two rectangular and trapezoidal units made of thick flat sheet all with the same dimensions measuring 2.0m, 0.5m and 0.4m for Length, width and depth, respectively were used in the experimental work. The LSWSP arrangement is represented in Figure 1 showing the vertical profile of the laboratory ponds.

The LSWSP inlets were connected in series to a flow inducer to obtain a constant and continuous influent flow. Feedlines of 19mm diameter (pvc) pipes with 19mm diameter gate valves to regulate the influent flow were connected from the ponds to the 500 litre polyethylene vessel capacity feed tank with a tee joint to enhance even distribution between all the ponds.

Two 500l polyethylene vessel was used as the feed tank to which feedlines were connected to facilitate continuous operation of the system. The feed tanks were placed at different elevations of 2.5m and 1.8m, respectively with the ponds to enable the wastewater enter the pond through gravity and also to allow the influent drop freely into the two ponds to facilitate dispersion with the ponds. The effluent discharges through a 19mm diameter pvc pipes separately with the 19mm diameter gate values to minimize backflows. The experiments were conducted inside the sanitary laboratory in a controlled room temperature and pond illumination was accomplished by providing a set of fluorescent bulbs fitted to a wooden stand. A few weeks allowed for the system to attain steady state conditions. The samples for the LSWSP were then collected following a particular procedure for the studies.

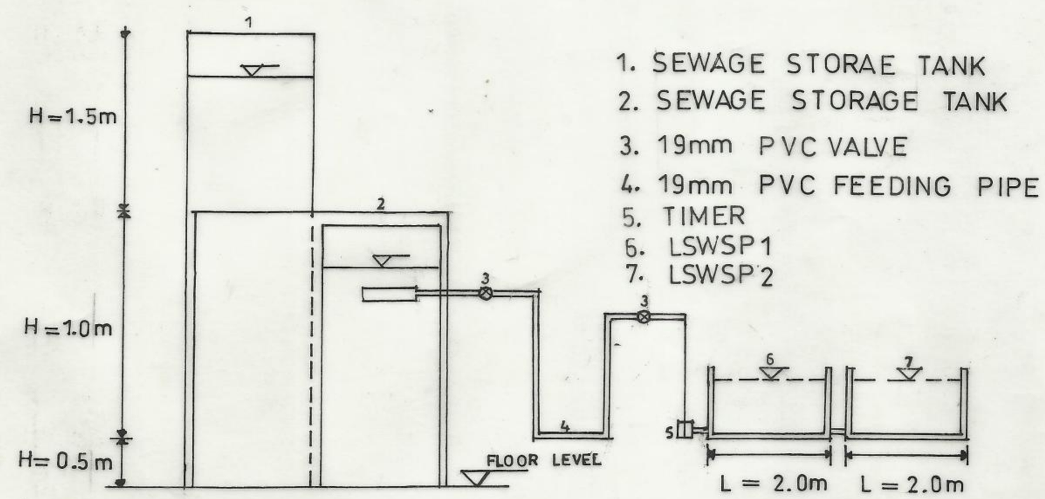

Fig. 1: Vertical profile of LSWSP

2.2 Tracer Studies

The test results obtained in Table 1 shows that the rectangular pond suffered more short ï circuiting than trapezoidal pond. Also it is observed that the smaller the flow velocity the higher the value of the dispersion number (d), the detention time (đ) was calculated by dividing the length of the pond by the flow velocity per day (L/U) as it gave a closer fit to the existing conditions of the ponds.

The variation in the dispersion number (d) ranges from 0.00189 to 0.0831 with changes in the magnitude of detention time (đ) and flow velocity. The highest value of dispersion number (d) corresponded to the least flow velocity of 6.4 x 10^{-3} m/s. While the greatest velocity of flow of 7.68 x 10^{-3} m/s does not exactly correspond to the least dispersion number, but still it gives the suggestion that the greatest velocity results in the least dispersion number. Both ponds had quite close ranges of dispersion number greater than zero but do not approach infinity.

2.3 Methodology for Tracer Studies

Tracer studies were carried out to determine dispersion characteristics of WSP for different values of detention time (đ).

Sodium chloride (NaCl) was used as the impulse tracer material in all the experiments (Thirumurthi, 1969), and the response tracer concentration was monitored at the exit stream at fixed time intervals. The amount of input impulse tracer concentration varied from 20 ï 80g for both ponds.

The base amount of NaCl present in the wastewater was taken into consideration when the exit responses were monitored (blank). The calculation is given by:

$$\text{mg/L CL} = \frac{(A + B) \times N \times 35{,}450}{\text{Milititre Sample}} \quad \text{- -} \quad (1)$$

Where

A = titration for sample (ml)
B = titration for blank (ml) which may be positive or negative
N = normality of $AgNO_3$ (usually N = 0.0141).

But mg/l NaCl = mg/l Cl x 1.65 - (2)

The calculation of the dispersion number (d) was made with the method proposed by Levelspiel and Smith (1957) which is described below:

Mean detention time (actual),

$$đ = \frac{\sum \theta_i C_i}{\sum C_i} \quad \text{- -} \quad (3)$$

Standard deviation,

$$ů^2 = \frac{\sum \theta_i C_i}{\sum C_i} - (\theta)^2 \quad \text{- -} \quad (4)$$

$$\text{if } \Phi = \frac{\theta_i}{\theta}$$

$$\text{then } ů^2 = 2d ï 2d^2 (1 ï e^{-1/d}) \quad \text{- -} \quad (5)$$

the term, d, can be calculated by trial and error where

$đ_i$ = time after impulse injection, days; and
C_i = tracer response concentration at the exist stream, mg/l.

Levespiel and Smith (1957) also proposed a model in which the dispersion index is calculated from the variance of the concentration curves. The variance determination represents and includes all points in the curve.

$$(ůɗ)^2 = \frac{×ɗ^2C}{×C} - \left(\frac{×ɗC}{×C}\right)^2 \quad \text{-------------------------} \quad (6)$$

ɗ = Time measured from the time of injection of tracer i into the flowing fluid.
C = Concentration of tracer in the fluid
$(ůɗ)^2$ = Variance of the time concentration curve.

The procedure is to get $(\sigma ɗ)^2$ from the time ï concentration data and then determine the dispersion index from:

$$d = \frac{1}{8}\left(\sqrt{8\sigma^2+1}-1\right) \quad \text{-----------------------} \quad (7)$$

where

$$ů^2 = \frac{(ůɗ)^2}{ɗ}$$

ɗ = Theoretical detention time (L / U).

Agunwamba *et al.* (1990) improved on the equation proposed by Polprasert and Bhattaria (1985) by making the coefficient of correction $ů^3$ dependent on (h/w), the aspect ratio and arrived at the equation:

$$d = 0.10201 \left(\frac{Ux}{U}\right)^{-0.81963} x \left(\frac{h}{L}\right)^{h} \left(\frac{h}{w}\right)^{ï\ (0.980741 + 1.38485)\left(\frac{h}{w}\right)} \quad \text{-------------} \quad (8)$$

Where:
d = dispersion index
Ux = shear velocity (m day^{-1})
U = pond flow velocity (m day^{-1})
h = pond depth (m)
w = pond width (m)
L = pond length (m)

3 RESULTS AND DISCUSSION

The results of relevant tests carried out during this study produced the following values of MPN, SS, BOD, dispersion number and detention time for both trapezoidal and rectangular shapes as shown in Tables 1, 2, 3, 4 and 5 respectively.

Table 1: Result for Dispersion Number (d), Temperature, T°C, and Detention Time (d)

TRAPEZOIDAL SHAPE				RECTANGULAR SHAPE		
Days	**d**	**T°C**	**θ (days)**	**d**	**T°C**	**θ (days)**
1	0.0675	32.49	0.0022	0.0852	32.49	0.0022
5	0.0675	32.49	0.0022	0.0852	32.49	0.0022
7	0.0675	32.49	0.0022	0.0852	32.49	0.0022
9	0.0675	32.49	0.0022	0.0852	32.49	0.0022
12	0.0675	32.49	0.0022	0.0852	32.49	0.0022
16	0.0675	32.49	0.0022	0.0852	32.49	0.0022

Table 2: Results for Total Coliform Test

Date & Time	Pond	Influent (Coliform bacteria)	Effluent (Coliform bacteria)	Eff. Coli bacteria Inf. Coli. Bacteria
18th Sept.	Rectangular	93 x 10^2	0 x 10^2	0.00
	Trapezoidal	93 x 10^2	23 x 10^2	0.25
22nd Sept.	Rectangular	2400 x 10^2	1400 x 10^2	0.58
	Trapezoidal	2400 x 10^2	460 x 10^2	0.19
24th Sept.	Rectangular	75 x 10^2	23 x 10^2	0.31
	Trapezoidal	1100 x 10^2	135 x 10^2	0.12
26th Sept.	Rectangular	75 x 10^2	18 x 10^2	0.24
	Trapezoidal	75 x 10^2	60 x 10^2	0.80
29th Sept.	Rectangular	13 x 10^2	3 x 10^2	0.23
	Trapezoidal	14 x 10^2	9 x 10^2	0.65
3rd Oct.	Rectangular	14 x 10^2	4 x 10^2	0.29
	Trapezoidal	9 x 10^2	1 x 10^2	0.11
7th Oct	Rectangular	23 x 10^2	8 x 10^2	0.35
	Trapezoidal	23 x 10^2	8 x 10^2	0.35
9th Oct.	Rectangular	3 x 10^2	3 x 10^2	1.00
	Trapezoidal	3 x 10^2	3 x 10^2	1.00

Table 3: Results for S.S Test

Date & Time	Pond	Influent		Effluent		Eff. of SS/Inf. of SS
		Wt. of SS (mg)	**mg/L SS**	**Wt. of SS**	**mg/L SS**	
18th Sept.	Rectangular	1.0 x 10^{-3}	20	2. x 10^{-3}	40	2.0
	Rectangular	1.0 x 10^{-3}	20	1.0 x 10^{-3}	20	1.0
	Trapezoidal	1.0 x 10^{-3}	20	2.5 x 10^{-3}	20	1.0
	Trapezoidal	1.0 x 10^{-3}	20	1.0 x 10^{-3}	20	1.0
22nd Sept.	Rectangular	1.0 x 10^{-3}	20	3.0 x 10^{-3}	60	3.0
	Rectangular	3.0 x 10^{-3}	60	2.0 x 10^{-3}	40	0.67
	Trapezoidal	1.0 x 10^{-3}	20	1.5 x 10^{-3}	30	1.5
	Trapezoidal	1.0 x 10^{-3}	20	1.0 x 10^{-3}	20	1.0
24th Sept.	Rectangular	9. x 10^{-3}	180	8.0 x 10^{-3}	160	0.89
	Rectangular	4.0 x 10^{-3}	80	3.0 x 10^{-3}	60	0.75
	Trapezoidal	1.0 x 10^{-3}	20	1.0 x 10^{-3}	20	0.1
	Trapezoidal	7.0 x 10^{-3}	140	3.0 x 10^{-3}	60	0.43
26th Sept.	Rectangular	3.0 x 10^{-3}	60	1.0 x 10^{-3}	20	0.33

	Rectangular Trapezoidal Trapezoidal	2.0×10^{-3} 3.0×10^{-3} 1.0×10^{-3}	40 60 20	2.0×10^{-3} 1.0×10^{-3} 1.0×10^{-3}	40 20 20	1.0 0.33 1.0
29th Sept.	Rectangular Rectangular Trapezoidal Trapezoidal	1.0×10^{-3} 3.0×10^{-3} 3.0×10^{-3} 3.0×10^{-3}	20 60 60 60	2.0×10^{-3} 3.0×10^{-3} 2.0×10^{-3} 3.0×10^{-3}	40 60 40 60	2.0 1.0 0.67 1.0
3rd Oct.	Rectangular Rectangular Trapezoidal Trapezoidal	4.0×10^{-3} 3.0×10^{-3} 6.0×10^{-3} 6.0×10^{-3}	80 60 120 120	4.0×10^{-3} 4.0×10^{-3} 3.0×10^{-3} 2.0×10^{-3}	80 60 60 40	1.0 1.0 0.50 0.33

Table 4: BOD Test Result (Mg/L)

TRAPEZOIDAL SHAPE				**RECTANGULAR SHAPE**		
Days	**Influent**	**Effluent**	**Eff. BOD/Inf. BOD**	**Influent**	**Effluent**	**Eff. BOD/Inf. BOD**
1	354.00	332.00	0.94	250.50	180.00	0.72
5	214.00	178.00	0.83	220.00	100.00	0.45
7	192.00	150.00	0.78	321.00	174.00	0.55
9	182.00	143.60	0.79	219.00	112.00	0.51
12	234.00	140.80	1.09	235.00	180.00	0.76
16	204.10	106.80	0.52	340.00	102.00	0.30

3.1 Coliform Test

From the test results obtained in Table 2 and Fig. 2, it is observed that the Coliform bacteria per 100ml tend to diminish with time (in days or weeks) in each dilution examined. For Trapezoidal shape, the values range from 3×10^2 to 2400×10^2 for influent coliform and from 3×10^2 to 460×10^2 for the effluents. While for Rectangular shape, they vary from 3×10^2 to 2400×10^2 for influent coliform and from 3×10^2 to 1400×10^2 for the effluents. The numerical value estimates the bacterial content, coliform density of water as well as establishes its sanitary quality through accurate data interpretation. In most countries of the world, standard tests have been set for a maximum permissible number of faecal coliform in sewage effluent. A chronological analysis reveals that a pond with greater number of coliform bacteria is a measure of pollution. Hence, the number of coliform bacteria is higher in Rectangular Shape than in Trapezoidal Shape. Therefore, the performance of trapezoidal shape is more efficient than the rectangular pond. Short-circuiting and long time stagnation of most samples collected, gave results that seem to be unrealistic. For instance, bacterial concentration value was zero for effluent of a rectangular pond. For the same detention time (d), the smaller velocity gave a better performance in the reduction of coliform bacteria.

3.2 Suspended Solids Test

The results obtained in Table 3 shows the concentrations of suspended solids for both Rectangular and Trapezoidal ponds. The performance of the pond follows a general trend of being better with smaller velocity. This shows that the greater the detention time, the more solids that would be settled between the influent and effluent points. The ranges of concentration of suspended solids for influent are between 20mg/l and 180mg/l, and for effluent between 20mg/l and 160mg/l.

It is concluded that a newly constructed ponds had a mean suspended solids removal efficiency of above 50%.

3.3 Comparison between Performance of Rectangular and Trapezoidal Ponds in Terms of BOD_5

Table 5 below summarizes the performance results between rectangular and trapezoidal ponds as listed in the table.

Table 5: Performance Results between rectangular and trapezoidal ponds

S/N	Rectangular Ponds	Trapezoidal Pond
1	It suffered more short ï circuiting and recorded a larger dispersion number (d) on the average.	It suffered less short ï circuiting, and recorded the least dispersion number (d).
2	The mean coliform removal efficiency of 62.0% recorded was higher than that of the Trapezoidal ponds, though both ponds recorded similar highest and least efficiencies separately.	The mean coliform removal efficiency of 54.0% recorded was lesser than that of the rectangular pond.
3	The rectangular pond recorded the least ratio of effluent to influent concentration of suspended solids of itôs least ratio of effluent to influent of 0.20 corresponding to 80% of suspended solids removed; and a Solid removal rate of 64%	The trapezoidal pond had a lower mean solid removal rate of 82%. Solids concentration of 0.19 corresponding to 81% of solids removed.

CONCLUSION AND RECOMMENDATION

From the experimental results and analysis obtained and evaluated, it is observed that the parameters are decreasing toward the effluent. The various irregularities in the variation of these parameters can be attributed to short ï circuiting within the ponds, wrong sampling and weighting; this is mostly experienced with the suspended solids test.

The higher dispersion number recorded in the rectangular pond corresponds to the higher rate of stabilization. But this assertion does not quite agree with the higher rate of suspended solids removal in the rectangular pond. It is also observed that there is a decrease in the BOD and Coliform bacteria at the influent and effluent as the number of days increases or progresses.

This can be attributed to the higher pH value which has definitely limited bacterial oxidation and resulted in the decrease in BOD and Coliform bacteria. It can then be concluded that waste stabilization ponds constructed for the treatment of raw sewage are given an approval performance with good reduction of all the pollutants.

The experiment so far performed reveals that rectangular shape has percentage reduction of 60% while trapezoidal shape has 52%. The overall performance of the rectangular pond was better than that of the trapezoidal pond as indicated by the results obtained and graphs plotted in Figure 2.

Based on these results, a rectangular stabilization pond is recommended in favour of the trapezoidal pond as a result of higher dispersion number recorded. Also, due to the discrepancy of the result of the suspended solids tests, it is recommended that more studies should be undertaken to determine the performance of the ponds with circular shape in order to find the efficiency and stabilization of these ponds.

Secondly, the performance of the trapezoidal pond as against the rectangular pond especially as in the sedimentation tanks should be investigated also.

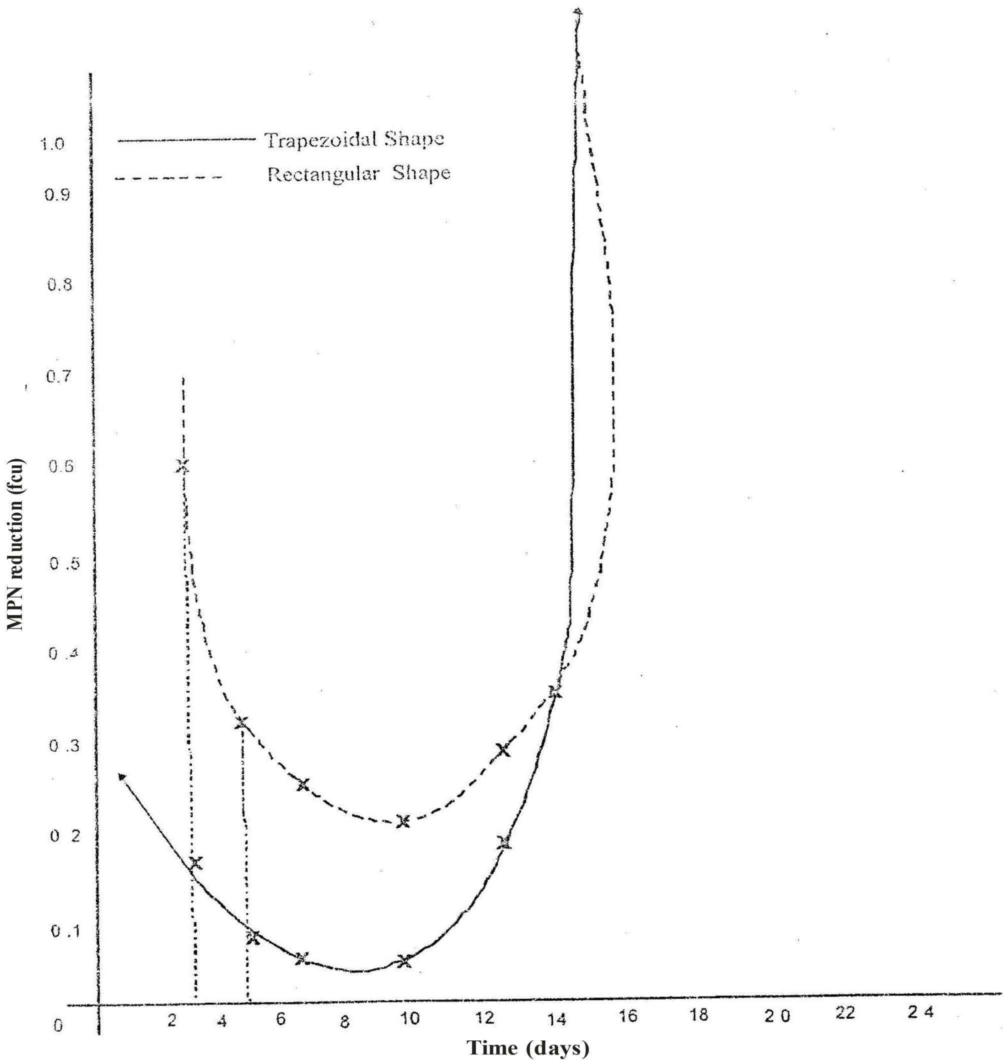

Fig. 2: Variation of MPN Reduction with Time (in Days)

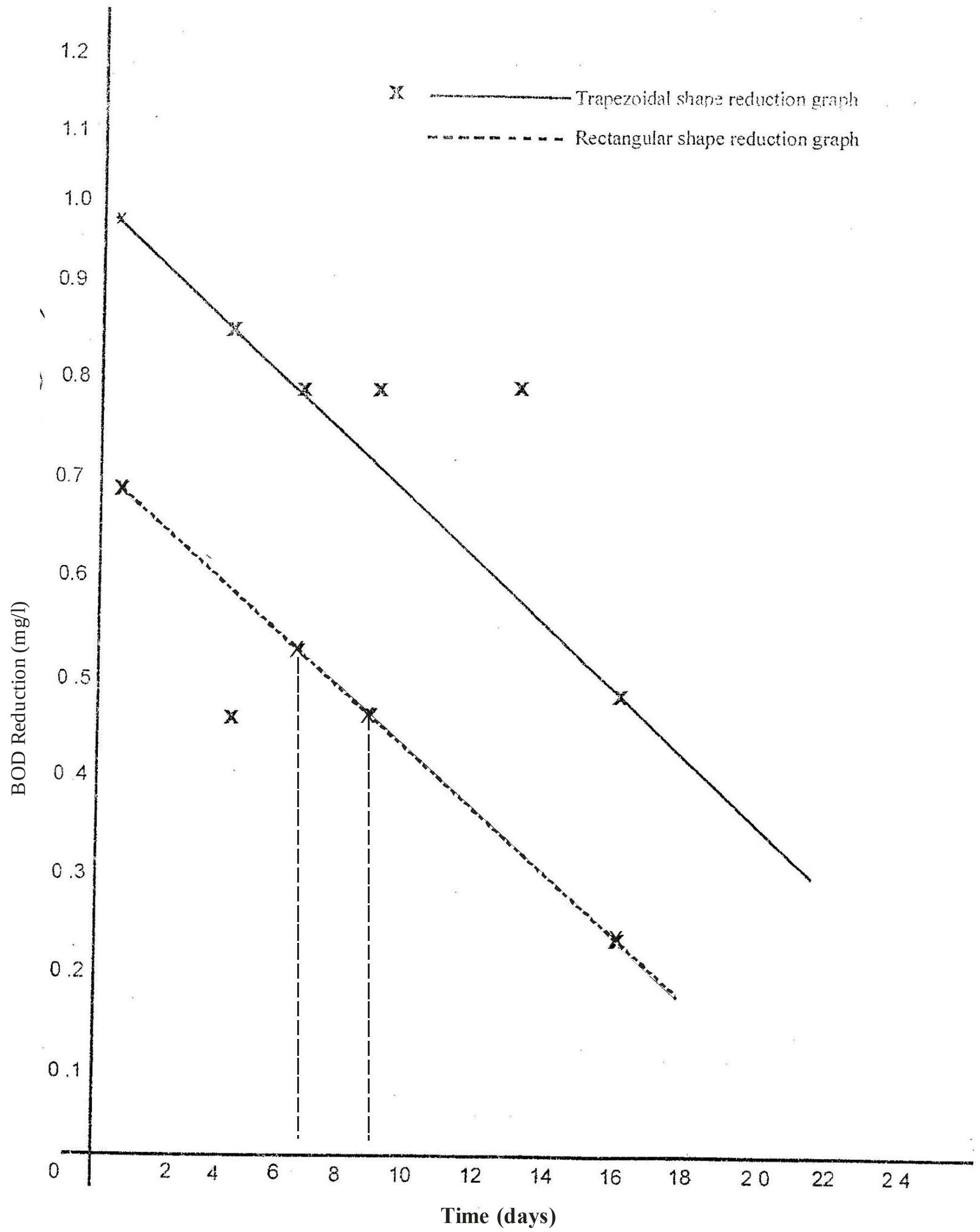

Fig. 3: Variation of BOD Reduction with Time (in Days)

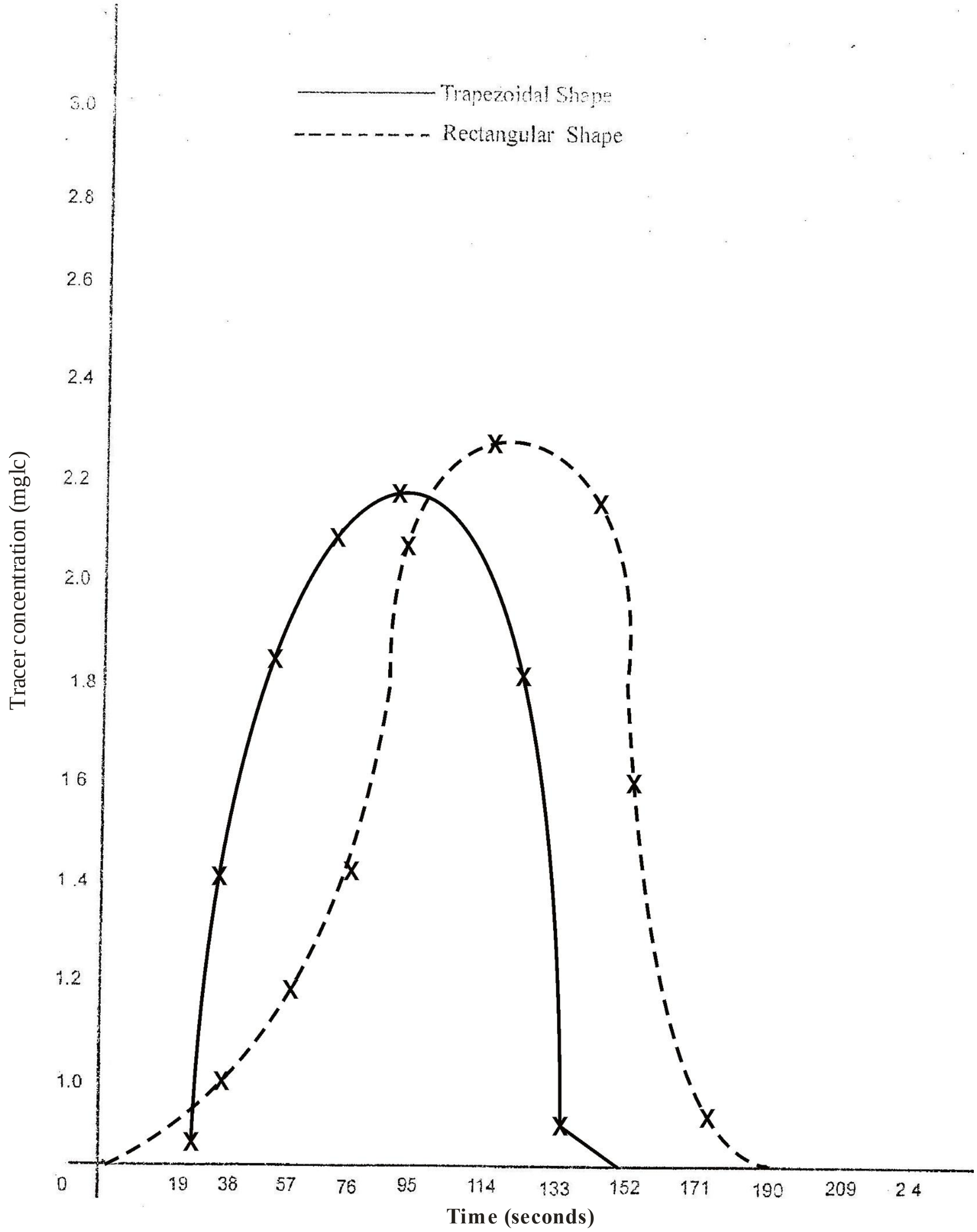

Fig. 4: Variation of Tracer Concentration with Time (in Seconds)

REFERENCES

Agunwamba, J. C., 1990. Simplified optimal design of the waste stabilization pond. Water, Air and Soil Pollution, 59, 299-309.

Agunwamba, J. C., 1997. Prediction of bacterial population in waste stabilization ponds using multiple depth layer Model, I. E. (1). Journal – EN, 77, 42-48.

Al-Salem, S. S and Lumbers, J. P., 1987. An initial evaluation of Al Sumra: Waste stabilization Ponds. Water Science and Technology, 19, (12): 33-37.

Arthur, J. P., 1983. Notes on the design and operation of waste stabilization ponds in warm climates of developing countries. Technical Paper No. 6, World Bank, Washington DC, 211-221.

Boutin, P. Vachon, A and Racault, Y., 1987. Waste stabilization ponds in France, an overall view. Water Science and Technology, 19, (12): 25-31.

Bowles, D. S., 1979. "Coliform Decay rates in waste stabilization ponds". Journal Water Pollution Control Federation, 51, 87-99.

Bucksteeg, K., 1987. German experiences with sewage treatment ponds. Water Science and Technology, 19, (2): 17-23.

Council of the European Communities., 1991. Council Directive of 21 May, 1991 Concerning Urban Wastewater Treatment (91/271/EEC), Official Journal of the European Communities, L135/40 (30 May).

El-Gohary, F. Abdel, Wahaab, R., El-Hawary, S. Shehata, S., Badr, S and Shalaby, S., 1993. Assessment of the performance of an oxidation pond system for wastewater reuse. Water Science and Technology, 27, (9): 115-123.

EPA., 1983. Design Manual: Municipal wastewater stabilization ponds. Report No. EPA-625/1-83-015. Cincinnati: Environmental Protection Agency, Center for Environmental Research Information.

Etan, G., 1995. Survey of Collection, Treatment and Utilization of Wastewater in Israel, Jerusalem, Israel: Ministry of Agriculture, Office of the Water Commissioner.

Ferrara, R. A and Harleman, D. R. F., 1980. Dynamic nutrient cycle model for waste stabilization ponds. ASCE 106, Eel, 37-42.

Finney, B. A and Middlebrooks, E. J., 1980. Facultative wastewater stabilization pond design. Journal Water Pollution Control Fed., 52, 134-147.

Kellner, E and Pires, E. C., 2002. The influence of thermal stratification on the hydraulic behaviour of waste stabilization ponds. School of Engineering of Sao Carlos, Hydraulics and Sanitary Eng. Dept. (EESC/USP), Av. Dr. Carlos Botelho, 1465, Sao Carlos SP13560-250, Brazil, Water Science and Technology, 45, (1): 41-48.

Klock, J. W., 1971. Survival of coliform bacteria in wastewater treatment Lagoons. Journal of Water Pollution Control, Fed, 43, 2071.

Levenspiel, O., 1957. Notes on the diffusion-type model for the longitudinal mixing of fluid inflow. Chemical Eng. Sci., 6, 227.

Mara, D. D., 2001. Low-cost high performance wastewater treatment and reuse for public health and environmental protection in the 21st century, 10th Annual CWWA Conference on Innovation Technologies in the water and wastewater industries for the 21st Century, Grand Cayman, October, 2001.

Marais, G. V. R., 1974. Faecal bacterial kinetics in stabilization ponds. Journal of Environmental Engineering diversion, ASCE, (1): 119-129.

Marais, G. V. R and Shaw, V. A., 1961. A rational theory for the design of sewage stabilization ponds in Central and South Africa. Trans S. Afr. Inst. Civil Eng. 13, 20.

Marecos do Monte, H. M., 1985. Hydraulic dispersion in waste stabilization ponds in Portugal. M.Sc. (Eng.) Dissertation Leeds: Lagoon Technology International Ltd.

Marecos do Monte, M. H. F and Mara, D. D., 1987. The hydraulic performance of waste stabilization ponds in Portugal. Water Science and Technology, 19, (12): 219-227.

Metcalf, L and Eddy, H. P., 1991. Wastewater Engineering treatment, disposal, reuse, third edition, McGraw-Hill Book Company, New York, 506-511.

Olsen, N. R. B., Hedger, R., George, D. G and Heslop, S., 1998. 3D CFD Modeling of spatial distribution of algae in Loch Leven, Scotland. 3rd International Conference on hydroscience and engineering. August 31 - September 3, 1998, Cottbus, Germany.

Oswald, W. J., 1990. Advanced integrated wastewater pond systems. Proceedings of the ASCE Convention: Supplying water and saving the environment for six billion people. San Francisco, C. A., 5-8 Nov. 1990, 73-80.

Oswald, W. J., 1995. Ponds in the twenty-first century. Water Science and Technology, 31, (12): 1-8.

Polprasert, C., Dissanayake, M. C. and Thank, N. C. (1983). Bacterial die-off kinetics in waste stabilization ponds. Journal of Water Pollution Control Fed., 55, (3): 285-296.

Prats, D and Liavador, F., 1994. Stability of kinetic models from waste stabilization ponds. Water resources, 28, (10): 2125-2132.

Saggar, M. M and Pescod, M. B., 1991. Microbiological performance of multi-stage stabilization ponds for effluent reuse in agriculture. Water Science and Technology 23, (7-9): 1517-1524.

Saggar, M. M and Pescod, M. B., 1995a. Modeling the performance of anaerobic wastewater stabilization ponds. Water Science and Technology, 31, (12): 171-183.

Saggar, M. M and Pescod, M. B., 1996. Performance evaluation of anoxic and facultative wastewater stabilization ponds. Water Science and Technology, 33, (7): 141-145.

Sheriff, M. M. and Mancy, K. H. (1995). Organochlilorine pesticides and heavy metals in fish reared in treated sewage effluents and fish grown in farm using polluted surface waters in Egypt, Science and Technology 32, (11): 153-161.

Shuval, H. I., Adin, A., Fattal, B., Rawitz, E and Yekutiel, P., 1986. Wastewater irrigation in developing countries: Health effects and technical solutions. Technical Paper No. 51, World Bank, Washington DC.

Soares, J., Silva, S. A., De Oliveira, R., Araujo, A. L. C., Mara, D. D and Pearson, H. W., 1996. Ammonia removal in a pilot-scale waste stabilization pond complex in Northeast Brazil. Water Science and Technology, 33, (7): 165-171.

Thirumurthi, D., 1969. Design principle of waste stabilization ponds. Journal Sanit. Eng. Div. Proc. Amer. Soc. of Civ. Eng., 95, No. SAZ, Proc. Paper, 6515, 311.

Tsagarakis, K., 1997. Evaluation of municipal wastewater treatment plants in the Mediterranean region. Interim Ph.D. Report. Leads, England: University of Leeds, School of Civil Engineering.

Tsagarakis, K., Papadaki, E., Kotsovinos, N and Angelakis, A. N., 1996. Evaluation of wastewater treatment plants in Greece. In: Proceeding of the International Scientific Symposium on water resources management 2, pp. 233-240. Larissa, Greece: Technical Chamber of Greece (Thesalia Branch).

Ukpong, E. C., 2004. ñModeling stratification and mixing in waste stabilization pondsò Ph.D. Thesis, University of Nigeria, Nsukka.

Zhao, Q and Wang, B., 1996. Evaluation on a pilot-scale attached-growth pond system treating domestic wastewater. Water Resources, 30, 242-245.

Zohar, Y., 1986. Wastewater treatment by stabilization ponds in Israel. Progress Report 1, Jerusalem, Israel: Ministry of Health.