PAPER 198 – DEVELOPMENT AND PERFORMANCE EVALUATION OF A FACULTATIVE STABILISATION POND FOR FISH WASTEWATER TREATMENT

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ABSTRACT

Wastewater is characterized by high concentration of nutrients and solid materials which are usually discharged into water Streams, Environment and Rivers without any form of treatment. This practice causes pollution and changes in river hydrology and other environmental issues such as eutrophication of receiving water and environment. Thus, the search for effective method for the control or removing pollutant from wastewater. To this end waste treatment using stabilisation pond has become a preferred alternative waste stabilisation pond is a relatively shallow body of wastewater contained in an earthen man-made basin into which wastewater flows and from which after a certain retention time, a well-treated effluent is discharged. The study aimed at developing and evaluating the performance of a facultative wastewater stabilisation pond for the fish wastewater treatment. The objectives of the study are to: Design a facultative wastewater pond, construct the designed facultative stabilisation pond, and carry out performance evaluation on some physicochemical parameters using the efficiency removal formula % removal = $\frac{c1-cf}{cf}$ x 100. The aerial loading rate formula was used for the design of facultative pond. The result of experimental analysis reveals BOD_5 in all instances in terms of whether the pond was screened or covered that there was significant reduction in concentration. The entire configuration allowed for average reduction in concentration by 53%, PH in the other hand in all instances had slight increases, for TDS, TSS, EC with exemption of TSS there was reduction in concentration of 50% irrespective of whether the pond is covered, screened or covered plus screened.

KEYWORDS: Wastewater, BOD_5, retention time.

1. INTRODUCTION

Aquaculture has witnessed tremendous growth during the past decades (FAO, 2004); this has culminated to the increasing trend and interests over time in fish farming for both commercial and domestic purposes. Fish produced by farming activities currently accounts for over one third of all fish directly consumed by Human (FAO ;2004). This large growth resulted in competition for natural water (Piedratha, 2003); this has consequently led to intensification of aquaculture system and environmental problems

Aquaculture, similar to other animal production system, generates waste; the amount and quantity of these wastes depend on the production system and feed quality (Keramat, 2008). Such wastewaters are characterized by high concentrations of nutrients and solid materials which are usually discharged into water streams, environment and rivers without any form of treatment (Sandra *et al.;*2018). The discharge of such wastewater forms a major environmental concern because they cause eutrophication of receiving water and environment; thus, the search for effective method for the control or removing pollutants from wastewater has attracted a lot of research concern. Fish farmers have used different kinds of chemicals, mechanical means with differing degrees of limitations or success, adverse effect, and cost implications. In the face of all this, hence the recourse to the idea of employing natural methods that might be more appropriate in varying measures; for instance, treatment that will produce an effluent which may meet the recommended effluent discharge limit. To this end, waste treatment through the use of stabilisation ponds has become the preferred alternative. Waste stabilisation pond is a relatively shallow body of wastewater contained in an earthen man-made basin into which wastewater flows and from which after a certain retention time (time which takes the effluent to flow from the inlet to the outlet), a well-treated effluent is discharged (Ukpong, 2012).

2 METHODOLOGY

The Aerial loading rate formula was used for the design of facultative pond proposed by (Mara, 1997) and adopted by (Raji et al., 2017). According to Mara the equation uses the mean temperature of the air in the coldest month.

2.1 Design consideration for the pond

The basic design criteria for the development of the facultative pond were adopted from Metcalf and Eddy (1993). They are; optimal depth (m) of 1.2 -2.5, surface loading (kg/ha) 60 -200, detention time (days) 5 -30, BOD (%) 80 -95, optimal temperature 20^{0}C, TSS (%) 70 – 80.

2.2 Design Preliminaries

Influent flow rate (Q) = 2mg/l, BOD_5 Organic Loading (BOD_5) = 55mg/L, Average air Temperature = 23^{0}C, Organic Loading rate = 80kg/ha/day, Sludge depth = 0.7 ,Assume seepage rate and evaporation = 2.0mm, Pond depth = 1.1m

2.3. Design Equations

$$A = \frac{Q\,(BOD)}{(LR)(1000)} \quad (2.1)$$

$$\text{Detention Time} = \frac{V}{Q} \quad (2.2)$$

$$HRT = \frac{V}{Q-V'} \quad (2.3)$$

Storage Volume = (Water Depth-Sludge Depth) x Pond Area (2.4)

Water Loss = Assumed Seepage rate x volume (2.5)

2.4 Design Calculations

Pond size determination from Equation. 2.1

$$A = \frac{Q\,(BOD)}{(LR)(1000)}$$

$$A= \frac{2(55)}{80\,X\,1000} = 1.375\text{ X }10^{-2}\ (3.39 \text{ x } 10^{-3}) = 13.7m^2$$

Applying the length to breadth ratio 2:1, Length is twice width, if width = w then length = 2w, Area is therefore

A= L x W = 2W x W = 2W^2

If Area = 13.7m^2

$= \sqrt{6.85}$

W = 2.6 But length is 2xW

L = 5.2m^2

Using ratio 1.1

Surface Length = 5.2 +1x1.1= 6.3m

Surface width = 2.6 + 1 x 1.1 = 3.7m

Bottom Length = 5.2 - 1 x 1.1 = 4.1

Bottom Width = 2.6 – 1 x 1.1 = 1.5

Calculate Storage Volume from Equation. 2.4

V = (Pond depth – Average Sludge depth) x Pond Area

V = (1.1 – 0.7) x 13.7m^2

V = 5.48m^3

Water Loss from Equation. 2.5

V' = (Assumed Seepage – Average Sludge depth) x Area

V' = (0.02 - 0.7) x 13.7

V' = -9.316

Hydraulic retention time from equation 2.3

$$\text{HRT} = \frac{5.2}{2-(-9.316)} = 0.48$$

Detention time from Equation. 2.2

$$\textbf{Detention time} = \frac{\boldsymbol{Area\ of\ pond\ x\ operating\ depth}}{\boldsymbol{flow\ rate}}$$

$$\text{Detention time} = \frac{13.7\ x\ 1.1}{2} = 7.5\ day$$

3. RESULTS AND DISCUSSION

3.1 Performance of the designed Wastewater stabilisation pond (WSP)

The performance of a facultative waste stabilisation pond WSP) depends on a host of factors and by extension, on the intended purpose. Generally, facultative WSP could be either be an oxidation or anaerobic pond; they are intended merely as waste-holding devices. The objective is to produce suitable effluent for discharge to surface waters or the environment. Based on its structure, ample dissolved oxygen may exist and aerobic metabolism may take place in the upper portion of the pond whereas there may be little or no dissolved oxygen in the lower depths. Thus, its performance can be hampered by temperature, light, organic loading, size and shape, and hydraulic considerations. The interplay of these factors can affect the process from attaining natural purification. Despite all this, the overall performance of WSP can be tied to two basic factors; in this regard, the assumed seepage and water loss regime which derive directly from the hydraulic considerations. In specific terms, the design considerations which took into cognisance the effect of optimal depth, detention time, ambient temperature fluctuation, surface loading and BOD concentration impacted positively on the WSP performance. The concrete flooring of the WSP mitigated against the possibility of soil erosion while the trapezoidal shape allowed for maximum surface loading condition as well depth. The design allows for 80-95 % BOD removal efficiency with a concentration of 55mg/l; though, BOD concentration of 20-40 mg/l is considered adequate. On the other hand, the large surface area with the corresponding depth allowed for high rate of energy conversion for optimal temperature regime. Since the efficiency of a WSP cannot be discussed in isolation of overhead cost, it suffices to note that the WSP design allowed for non-prohibitive (minimum) operational and maintenance costs, relatively.

3.2 Physico-chemical parameter analysis and removal efficiency

(a) Physico-chemical parameter behavioural pattern

Table 3.1 below shows the behavioural pattern of the parameters under different pond configurations. For BOD_5, it is seemingly clear in all instances, in terms of whether the pond is screened or covered that there was significant reduction in concentration. In the overall, the entire configuration allowed for an overall average reduction in BOD concentration by 53 %. This result is in agreement with the findings of Mahsssen *et al*. (2008) though lower than that of Oke *et al*. (2006) who obtained 95 % removal efficiency. Despite this, the concentration is below the allowable threshold as prescribed by FEPA (2012) for fresh water fish farming; this implies that it can safely be discharged to the environment. However, the marginal difference in performance brings to the fore that if BOD reduction is the primary objective of the WSP, pond configuration in terms of whether it is covered, screened or both, has no serious impact on the outcome. Similarly, the concentration of DO is within the allowable range and also attest to the marginal relative importance of the nature of the pond with respect to overall effectiveness. It suffices to be cognisant of the fact that decreases in BOD_5 regime provide no tangible information of the changes in specific organic compounds. Despite this though, it measures the effect of a waste under conditions approximating natural stream conditions. In respect of the results here as in **Table 3.1**, it is glaring that the 5-day BOD cannot be considered a quantitative result without an approximation of the rate of oxidation and the BOD_5 to the ultimate oxygen demand. This is relevant considering that in facultative ponds or WSP, particulate matter is the main source of BOD in the effluent since the influent wastes may have been converted to bacteria or algal protoplasm. On the other hand, there was slight increases in pH, the overall pH in all instances connotes that the water may not portend any deleterious hazard and thus could be discharged into the environment and safe for fish farming. The pH regime for a time period of experiment has to do with carbon dioxide removal; the removal of carbon dioxide from the pond waters may invariably result in an increase in the pH of the waters. The trend is repeated for TDS, TSS and EC with exemption of increases in TDS as in when the pond is screened; though, the average 10 % reduction is almost in accord with the findings of Gopolang and Letshwenyo (2018) who obtained 8.5 %. However, reduction in TDS is not effective as the overall water quality is heavily impacted; this is evident by comparatively juxtaposing it with the recommended water quality standard for fish farming.

Table 3.1: Reduction pattern of the Physico-chemical parameters on the basis of nature of pond

Parameters	Initial concentration (mg/l)	Final effluent concentration (mg/l)	Percentage Increase/Reduction (%)	FEPA (2012) mg/l	Fish farming quality standard (mg/l)
BOD_5	7.45				
A		3.4	54.0		
B		3.6	51.0	30	5.0
C		3.4	54.0		

DO	7.41				
A B C		4.3 4.5 4.5	41.9 39.0 39.0	Not < 2	5.0
pH	7.18				
A B C		8.74 8.76 8.77	21.7 -22.0 -22.0	6-9	6-9
TDS	114.13				
A B C		101.80 173.84 101.65	10.8 -52.0 10.0	< 2000	0.13
TSS	0.57				
A B C		0.31 0.28 0.26	45.0 50.0 54.0	30	10-20
EC	178				
A B C		158 160 158	11.0 10.0 11.0	2000 (µs/cm)	NA

a, b, and c represents screened, pond covered and screened + pond covered, respectively; NA: Not applicable

4. CONCLUSIONS

Difficulties in obtaining precise relationships between agricultural practices and environmental problems occur because of the diffuse source of residuals from agriculture and the many factors that are involved. Some of which are not controllable by man, in this regard, the variability of waste discharges complicates assessment of the environmental impact of agricultural production; for instance, excessive amounts of nutrients and the conditions they can cause; as superfluity of amounts in surface waters can result in over fertilisation and can accelerate the process of eutrophication. Against the backdrop of these facts and the findings in this study, the following specific and general conclusions were drawn; viz: Optimal residence time varies across the pond configuration with respect to the parameters. For both BOD and DO, the best resident time is seven (7) days for effective load reduction if the pond is screened; also for TDS and EC but at fourteen (14) days. For both pH and TSS, the optimal reduction time is twenty-one (21) days by applying a combination of screened with the pond covered currently. For screened, covered, screened and covered pond configurations, the optimal removal efficiency can be obtained in seven (7) days followed by twenty-one (21) days.

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