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Study, Analysis and Design of a Waste Stabilization Pond (WSP) for Institute of Management and Technology (IMT) Enugu Community.

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Abstract*: Waste stabilization pond (wsp) were designed to treat 1043500m^3 day^{-1} of wastewater generated from hostels, classrooms, staff offices and quarters.*
Construction of pilot scaled ponds for the experiment were done following existing models by mara D.D (1975b) to size the different kinds of ponds. Design temperature of 20^{o}C were adopted for the operation of the the three ponds; anaerobic, facultative and maturation ponds.
The design population is about 42000 people of which include staff and students of institute of management and technology (IMT) enugu.
The design project has 3 pond ; anaerobic, facultative and maturation pond. The design equation used were according pond to Mara and Pearson (1986). The anaerobic pond design was based on volumetric loading and the pond depth is 3.5m, pond area is 577.43m^2 pond volume is 2021m^3 and a retention time is 2day.
The facultative pond was designed based on surface loading which is dependent on temperature (20^{o}c) and the pond depth is 2m, pond volume is 13860m^3 and retention time of 13days was adopted.
The analysis and design of maturation pond followed Marais (1974) for faecal coliform removal. The pond depth is 1.5m, pond area is 1400m^2 Pond volume is 20880m^3 and retention time is 20days. The physiochemical analysis on selected parameters : BOD, COD, E-COLI showed a significant percentage reduction upto 80% in the effluent content.

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I. Introduction

Waste management can never be under emphasized for any growing community like Institute of Management and Technology (IMT) Enugu. Waste stabilization pond(WSP) is an open basin dug on earth for removal of pathogenic organisms and other pollutants in waste waters from residential areas. Wsp's can be applied whenever a central sewage system is adopted. Over the years, IMT has witnessed increase in population. It is narrative to say that among the challenges it has faced, waste management has not been left out. This study, seeks to address and recommend a central sewage collection system and a waste stabilization to address challenges faced in managing soluble waste around the community. If adopted it will reduce the cost due to frequent desluging of septic tanks, reduce pollution of underground waters through contaminant transport, save the environment from dirt due to leakages and spills from septic tanks. These spills causes foul odors most often and cholera outbreak can occur if not managed properly. When a central sewage system is adopted, the effluents from the waste stabilization pond can serve as irrigation waters for farmers around the community to increase their crop yield, overall output and the center can serve as a research center for allied departments. Effluents from wsp's has been reported to be rich in potassium and phosphorus

Application of waste stabilization ponds has been on the increase due to its natural purifying process capabilities(Long Ho et.al , 2017)

Due to the increase in population in developing counties, major cities are now facing urbanization which has given rise to high level of waste water and pollution. These waste pose a serious threat to public health when they are not treated or not readily dispose off (Adetavo A.T 2005)

Waste stabilization ponds (WSPs) are popular wastewater treatment system used for the removal of organics and pathogenic organisms. It consists of a large, shallow earthen basin in which wastewater is retained long enough for natural purification processes to provide the necessary degree of treatment. High efficiencies of WSP have been reported with respect to removal of intestinal nematode (Lakshminarayama and Abdulappa, 1972; Feachem et al., 1983; Saqqar and Pescode, 1992); organic compounds and faecal bacteria (Mara, 1976). In addition, it is also economical (Arthur, 1983). It is simple to construct, operate and maintain and it does not require any input of external energy.

The screened raw sewage is treated in the waste stabilization pond by natural processes based on the activities of both algae and bacteria. Although some oxygen is provided by diffusion from the air, the bulk of the oxygen in the ponds is provided by photosynthesis (Howard et al., 1985). WSP system usually requires large land area because of its long detention time which is still suitable in several African communities where land acquisition is not a problem. Besides, its efficiency depends on the availability of sunlight and high ambient temperature which are the prevailing climate conditions in most of these communities.

In addition to being useful in the treatment of sewage, waste stabilization pond is being applied in the treatment of industrial and agricultural wastes. Its long detention time; its relatively slow-rates of sludge accumulation; and its physicochemical conditions such as neutrality to alkaline pH, make it attractive in treating industrial wastewaters. Besides, in maturation ponds, aerobic conditions promote precipitation of heavy metals. Ponds have been successfully used to treat industrial wastes high in copper and group II metals, waste from palm oil and natural rubber industries and polishing waste water from activated sludge plants and trickling filter (Agunwamba, 2001).

However, the main constraint against selecting this technology is not land cost but land availability. WSPs are limited in application by their large area requirement (Mara et al., 1983). In the past, researches have been conducted to improve pond efficiency, thereby maximizing land use by solar enhanced wastewater treatment in waste stabilization ponds (Agunwamba et al., 2009.

The institute of management of technology (IMT) is a state government aided polytechnic with a population of about 42,000 people of which include staff and student. The main camps is located at Enugu municipality. The camp consist of campus 1 which is the administration unit, campus 3, campus 4, the hostels and the rectors village

This project deals with the design of sewage ponds in IMT Enugu for waste water treatment. The treatment facilities will be for waste water that comes from toilet, kitchens, bathrooms, most of which contain faecal matter

In construction of WSP's, certain factors are to be considered such as climate, soil nature, availability of land and ground water level (AGUNWAMBA, 2000). It is advisable that such WSP's should be situated at 300m to 500m away for residential area to avoid hazardous effect from such pounds and away from areas with high prospect of future expansion development (Mara et al 1998)

Most improvements have been done to increase the performance of WSPs. Ugwuanyi S.E et. Al (2013) observed that the cost of wastewater treatment is about one third lower than the conventional WSPs when he introduced solar reflector and hydraulic jump to increase the efficiency of WSPs.

This project is mainly restricted to the design of the anaerobic, facultative and maturation ponds.

Indeed conventional treatment schemes were developed due to climate and area constraints. These constraints are often not the case in developing countries, moreover the use of energy intensive mechanism is not desirable in less developed counties where energy supply is not reliable. Further conventional treatment facility require regular large scale maintenance, a thing that is either too expensive or impossible to fund in developing countries. Stabilization ponds offer many advantage over conventional treatment schemes one of their most important advantages is their ability to remove pathogens (WHO EMR Technical publications)

In addition, several review articles about aspect of pond design principles based on pathogen inactivation model Ho et al 2017 and die off mechanisms of bacterial indicated (Verbyla and Mihelcic 2015) suggested that an update on the efficiency of WSP treatment from the hydrodynamic perspective was needed. It is primary aim of the present review to update refine and protection of water resources against pollution is the development of sound economy for both the maintenance of public health and the conservation of water resources, it is the essential that water pollution be controlled (S.O. 2005)

WSPs are usually the most appropriate method of domestic and municipal water treatment in developing countries, where the climate is most favorable for their operation (Varon 2004) WSP system comprise one or more series of different types of pond, usually the first pond in the series is an anaerobic pond and the second is a facultative pond. These may be followed by maturation ponds but this depends on the required final effluent quality which in turn depends on what is to be done with effluent: If to be used for restricted or unrestricted irrigation used for fish or aquatic vegetable culture or discharged into surface ground water.

ANAEROBIC PONDS

Anaerobic ponds (APs) are the smallest units in the series and are size according to their volumetric loading which is the quantity of organic matter expressed in grams of BODs applied to each cubic meter of ponds (2m to 5m) devoid of dissolved oxygen sludge is deposited on the bottom and the anaerobic digestion biogas is produced which could be collected by covering the anaerobic pond with a floating plastic membrane (Varon 2004, Wafler 2008). They should not be operated below 10^oc, and the load, which can be treated increase linearly with temperature rise (eg $100g/m^3/day$ at 10^oc and $300g/m^3$ at 20^oc) the design temperature should be the mean of the coldest month of the year (Varon 2004). A retention time of one day should be sufficient for a BOD_5 lower than $300mg/m^3$ day @ 20^0c but the recommended retention time range varies from 2 to 5 days (WSP 2007). For high strength industrial wastes, up to three anaerobic ponds in series might be necessary

FACULTATIVE PONDS

Facultative treatment ponds (FPs) are the simple of all WSPs they consist of large shallow ponds (depth of 1 to 2m) with an aerobic zone to the surface and a deeper anaerobic zone. There are two types of facultative ponds: primary facultative ponds that receive raw waste water (after grit removal) and secondary facultative pond receiving settled wastewater usually from the anaerobic pond. Facultative ponds are designed for BOD removal on the basis of low surface loading

WSPs are covered by algae, the algae grow using the sunlight and they produce oxygen in excess to their own requirement, which they transfer to water. It is this excess of oxygen that is used by bacteria to further break down the organic matter via aerobic digestion (oxidation) transforming the organic pollutants into co_2. Additionally to aerobic and anaerobic digestion of BOD in the facultative ponds “sewage BOD” is converted into “algal BOD”

The algal production of oxygen occurs near the surface of aerobic ponds to the depth to which height can penetrate (i.e. typically up to 500mm) Additional oxygen can be introduced by wind due to vertical mixing of the water.

FPs can result in the removal of 80% to 95% of the BODs (WSP 2007) which means an overall removal in the order 95% over the two ponds (AP& FP) total nitrogen removal in WSP systems can reach 80% or more, and ammonia removal can be as high as 95%. The retention time for a facultative pond less between 5 to 30 days (WSP 2008). Sometimes two or more consecutively smaller FPs are construction instead of a very large one, because it is more practical for dislodging

MATURATION PONDS

Maturation ponds (low-cost polishing pond which succeed primary or secondary facultative ponds are primary designed for tertiary treatment, i.e. the removal of pathogens, nutrients and possibly algae, whereas anaerobic and facultative ponds are designed for BOD removal. Maturation or polishing ponds are essentially designed for pathogen removal and retaining suspended stabilized solids (Tilley et al 2008) the size and number of maturation ponds depends on the required bacteriological quality of the final effluent. The principal mechanism for faecal bacterial removal in facultative and maturation

ponds are retention time, temperature, high PH or radiation of the sun leading to solar disinfection (Curtis et al 1992). Maturation ponds are shallower (1 to 1.5m) with 1m being optimal the recommended

hydraulic retention time is 15 to 20 days (WSP 2007) if used in combination with algae and for fish harvesting, this type of pond is also effective at removing the majority of nitrogen and phosphorous from the effluent (Tilley al 2008)

Project Description

The project involved the design of a wastewater stabilization pond system to treat the sewage from the institute to a level that it can be safely join the natural filtration system. This project aimed at addressing the sanitary concern of the locality for which it was designed. (Lugali Yvonne 2012)

Project Site

The project site is located in institute of management and technology (IMT) Enugu.

II. Material and Method

The quality and quantity of wastewater varies with season during the year and the data collected was considered over a period of various months in the year but the main emphasis was on the month when institute was in operation.

The site for the pond was visited with the aim of roughly establishing the nature of the terrain, wind direction and proximity to the residential areas. The ponds were sited away from residential areas and the wind blow away from the residential home (Lugali Yvonne 2012)

Thorough literature search was conducted using the library and internet resources to acquire information relevant to this design
(Yvonne Lugal 2012)

DESIGN ESTIMATION FOR THE POND SYSTEM

The following equation were used for the design of each pond. The equation are used based on Mara and Reach (1986) for the sizing of each of the ponds. They include: total volume of water generated= population x average human waste water contribution is 100 liters per day (1001l day).

ANAEROBIC POND SYSTEM

The anaerobic ponds are designed on the basic of volumetric BOD loading, B_v

$B_v= L_1 Q/V_1$

Where l_1 is influent BOD (mg/L), Q is flow rate (m^3/day) and v_1 is anaerobic pond volume (m^3). The first step is to select b_y (Mara and Mara et al 1986) and Mara et al (1998) according to (Lugali 2012) recommend the safety design values as shown in the table below

Design values for anaerobic ponds (Lugali 2012)

Temperature ^oC	Volumetric g/m^3.d)	BOD removal (%)
<10	100	40
10-20	20T-100	2T+20
20-25	10T+100	2T+20
>25	350	70

the hydraulic retention time is calculated from below equation (Yvonne 2012)

$T_i = V_i /Q$ days)

The mid- depth area $A_i= V_i d_i$

Where d_i is the assumed pond depth

Design of facultative pond according to (Lugali Yvonne 2012)

Facultative ponds are designed on the basis of surface loading B_s

$$B_s= 10L_i Q/A_2$$

However according to the Mara (1957) equation the surface loading is based on temperature and it according to equation below.

B_s = 20T- 120(kg/ ha-day)

The total BOD

L_1Q_2= BOD removal (%) x L_1 Q(kg/day)

The mid area

$$A2 = l1\ Q2/B2\ (M2)$$

Ponds volume

$$V_2 = A_2 \times d_2$$

Where d_2 is the assumed pond depth (m)

Hydraulic Retention time.

$$T_2 = V_2/ Q \text{ (days)}$$

FOR THE DESIGN OF MATURATION POND

We have the following equation (Yvonne Lugali) for focal coliform

$Ne= N_1 (1+k_2 t_3) f_c/100ml$

$Ne = N_1 l\ (1+k_1t_1)\ (1+k_1 t_2)\ (1+k_1t_1)\ _n)$

DATA USED FOR CALULATION

parameter	Raw wastewater	Standard recommended
Bacteriology coli forms (CFC/100ml)	12,039,333	500
BODs 20^oc (mg/l)	580.784	50

System design

The four most important parameter for WSP design used in this design were.

- Temperature: the design temperature was 20^oc, which was the mean air temperature of the coolest month(Gulu meteorological station)
- Net Evaporation: the net evaporation rates in the months used for selection for the design was 1500mm/year. (Gulu meteorological station).
- Flow: A flow design value of 25 liters of wastewater generated per person per day.
- BOD: This value was calculated from average over a period of selected months for the wastewater. A value of 580.78mg/l was used.

Determination of the design flow

This was done based on the current population of institute of management and technology (IMT) Enugu which is 41740 people

Flow value of 25 percent of the total wastewater is used because the maximum time spent by the population is 8 hour and most wastewater come from toilet and may be some for washing band and extra activities

Therefore if an estimate is 8 liters for each flushing and an average of 3 flushes per person per day.

Total amount flushed = 8x3=25liters

Plus 1 liter extra for each person

Loading and retention time design approach

Total volume of waste generate= population x average human wastewater contribution where 100 liters per day

Population=41740 people

Vol of waste generated= 0.25x 41740 x100

Volume =1043500/day

DESIGN FOR ANAEROBIC POND

Br $=l_1Q/r_1$, but Br 20T-100@ 20^oc=Bv-(20x20)-100+ 300mg/m^3-day

Br $=l_1Q/r_1$ 300= (580.784x1044): r_1 (where L_1= influence BOD @ 20^oc =580.784)

300= 606300.912/ r_1= 606300/300

V1 =2021m3+

$T_1 = v_1/\pm Q$=2021/1044= 1.94=2days

But $A_1= v_1/d_1$ where d_1 = assumed depth =3.5m

$$A = \frac{20121}{3.5} = 577.23$$

But Area = L x B for a rectangular section with ratio of 2:1

$$\frac{L}{W} = 2; A = 2w^2\ therefore\ width\ of\ the\ basin\ w = \sqrt{\frac{577.3}{2}}, w = 16.99m\ aprox. 17m$$

Since $L = 2w, lenght = 2x\ 17m = 34m$

FACULTATIVE POND

Bs = $10L_1$ Q/ A_2

But Bs (20T- 120) = 360 (1.107- 0.0027) T.20

Bs = 350kg/ha.day

V_2= $10L_1Q$/ 135 A_2 = (10 x 232.336 x 1044) ÷ 350

V_2= 6930 x 2 = 13860m^3

V_2 = A_2x depth where d_2 = 13860m^3

$T_2 = V_2/Q_m$ = 13860/1044 = 13.28 approximately 13days

Area = length x breath for a rectangular section

$$\frac{L}{W} = 2; A = 2w^2\ therefore\ width\ of\ the\ basin\ w = \sqrt{\frac{693}{2}}, w = 8m, L =\ aprox. 16m$$

Maturation Pounds

The method used is that of (national water and sewage corporation laboratory Gulu office) 2012 for design of a pond series for faecal coli form in removal

This assumed that faecal coliform removal can be reasonably well represented by a first order kinetic model in a completely-mixed reactor. The resulting equation for a single pond is given by

Ne =(N_1 ÷ (1+ $k_T t_3$) fc) ÷ 100ml

Where Ne and $N_{1=}$ are the number of feacal coliform/ 100ml in the effluent and influent, K_T is the first order rate constant for faecal coli removal (day-^{1}) and t_3 is a retention time (day) for a series of anaerobic, facultative and maturation ponds, the above equation becomes

Ne =N_1 ÷ $_($1+ kft_1) (1+ $k_t t_2)_n$)

K_T= 2.6 (1.19) $^{T-20}$ = 2.6

Ni = 12039333 +c ÷100ml

Nc = 12039333÷ (1+2.6 x2) (1+ 2.6 x13) (1+ 2.6 x 20)

Nc= 1057 Fc/ 100mc

Pond volume

V_3 = Q x T_3 (m^3)

V_3 = 1044 x 20 = 20880m^3

Mid depth Area = V_3 d_3 where d_3 = 1.5m.
Area= 20880/ 1.5 = 13920m$^{2=}$

$$\frac{L}{W} = 2; A = 2w^2\ therefore\ width\ of\ the\ basin\ w = \sqrt{\frac{13920}{2}}, w = 53m, L = \ aprox.106m$$

Summary of result Anaerobic pond

Influence BOD	580.784mglL
Pond Area	3.5m
Pond Area	577.43m^2
Retention time	2. Days
Length	34m
Breadth	17m
Volume	2021m^3

Facultative pond

Influence BOD	232.313mg/l
Pond depth	2m
Pond Area	6930m^2
Retention time	13days
Length	16m
Breadth	8m
Volume	**13860m^3**

Maturation pond

Influent faecal coliform	1203933fc/ 100m^2
Pond depth	1.5m
Retention time	1400m^2
Length	265m
Breadth	53m
Effluent fecal coilform	1052fc/100ml
Volume	20880m^3

III. Discussion

The anaerobic pond is designed for BOD removal according to volumetric loading to reduce the BOD loading of the waste water generated. The sludge is deposited at the bottom of the pond and broken down by the anaerobic bacteria. The pond is trapezoidal in shape so as to avoid erosion of the pond banks with a side slope of 1:1.

A length, breadth ratio of 2:1 is used and this is to ensure that sludge banks do not from around the inlet

The pond has retention time of 2days which reduce the BOD loading from 580.784mg/l in the influent to 232.3136mg/l

The facultative pond is also used for BOD removal but is designed according to surface loading. The surface loading of the pond is based on temperature and called the empirical method, (mean coldest temperature in the year 20^{o}c. the sludge is also deposited at the bottom of the pond and the pond is trapezoidal in shape for the same reason as the anaerobic pond. A length: breadth ratio of 2:1 is used to ensure that sludge bank do not from around the inlet of the pond.

The pond has retention of 13 days during which the influent BOD which is 232.3136mg/l reduces to 474.4mg/l in the effluent thus meet the standard value set by NEMA which is 50mg/l according to the kinetic model of design by kayombo (1998) which assumes completely mixed reactor time of 12days and an area of 630m^2 was obtained and therefore results from this design can be depended on. Maturation pound is design according to Marias method (1974) for feacal removal it is also trapezoidal in shape to avoid erosion of 1:1. The length breadth ratio is 5:1 to better approximate plug flow conditions. The pond has a retention time of 20days for complete decomposition and this time is enough to reduce the faecal coliform 12039333fc/ 100mc to 1052fc/100mc which falls within the acceptable standard of national water and Sewage Corporation of 5000fc/100 ml.

IV. Conclusion

The anaerobic pond has area of 577.43m^2 and a retention time of 2days with the influent BOD at 580.784mg/l

The facultative pond has an area of 6930m^2 and a retention time of 13days. The effluent BOD is 4704mg/l which less than the standard of 50mg/l so the pond is effective

The maturation pond has an area of 1400m^2 and a retention period of 20days. The number of faecal E.coli in the influent is 1203933fc/100mc and the number in the effluent is 1052fc/100mc.

This meets the standard value which is less than 10000fc/100mc . The research was able to reveal that ponds has the capacity to reduce most of the organic pollutant to an appreciable percent.

V. Recommendation

Primary data was collected over a short period of time so there is need for more time to improve on accuracy of result.

The ponds depth is average depending on the range of values given in the literature (kayombo et al 1998). Therefore there is need for further research to give the optimal (depth of each pond in order to ensure effective treatment of sewage

Maturation ponds retention time is also an average so need for research to determine optimal time for complete decomposition

A diversion channel should be built around the pond (the topside) to divert storm water runoff coming from adjacent areas and all the ponds should be surrounded by a fence for public safety and health protection

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