Asian Review of Environmental and Earth Sciences
Vol. 7, No. 1, 55-60, 2020
ISSN(E) 2313-8173 / ISSN(P) 2518-0134
DOI:10.20448/journal.506.2020.71.55.60

Design of a Wastewater Treatment Oxidation Pond

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Abstract

The proposed site of the wastewater treatment pond is located in a terrain inside the Polytechnic Campus and the New Staff Quarters where the storm-runoff flow has on effect. The site possesses good soil characteristics which include a particle size distribution of sandy soil with little fine particles of gravel, a specific gravity of 2.77 and a soil moisture content of 7.26% indicating a high degree of permeability. The output of geotechnical analysis indicated that the proposed site has soil particle density (ρs) and dry bulk density (ρb) of 1.76 g/cm^3 and 1.64g/cm3 respectively. Void ratio (e), porosity (ƞ) values of 0.87 and 0.46 (46%) were determined. The atterbergs limits of 19.0%, 14.96% and 19.6% for shrinkage limit (SL), plastic limit (PL) and liquid limit (LL) were estimated with a computed plastic index (PI) of 3.04. The soil profile formation is highly sandy with a good lateritic layer to support the pond foundation. The proposed pond design volume (V) is 898.5 m3 and land areas of 718.8 m2 were estimated for the project.

Keywords: Soil, Density, Limit, Pond, Permeability, Wastewater, Gravel, Atterbergs limit.

Citation | Oyati E. N; Olotu Yahaya; Gimba I.N; Ibrahim Rasheed (2020). Design of a Wastewater Treatment Oxidation Pond. Asian Review of Environmental and Earth Sciences, 7(1): 55-60.
History:
Received: 10 February 2020
Revised: 12 March 2020
Accepted: 14 April 2020
Published: 4 May 2020

Publisher: Asian Online Journal Publishing Group

Acknowledgement: All authors contributed to the conception and design of the study.
Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no conflict of interests.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.
Ethical: This study follows all ethical practices during writing.

Contents

Contribution of this paper to the literature
The proposed site of the wastewater treatment pond is located in a terrain inside the Polytechnic Campus and the New Staff Quarters where the storm-runoff flow has on effect.

1. Introduction

The treatment of wastewater using the interaction of bacteria, algae, and sunlight inside shallow confinement known as oxidation pond is one of the techniques of wastewater treatment. The essence of treating wastewater and effluent using the oxidation pond is basically structured to reduce and remove the pathogens and organic matters contained in wastewater. The wastewater stabilization pond has numerous advantages such as adequate treatment compartments, accurate balancing of temperature and other parameters as dissolved oxygen (DO), nutrient and organic matters [1-3]. Oxidation pond is made of a set of organisms associated together such as algae, fungi, viruses, and fungi. The biodegradable organic matter (BOD) is decomposed by the bacteria and carbon dioxide, nitrates and ammonia are released [4].

The oxidation pond could be designed to treat different categories of effluent ranges from industrial wastewater to municipal wastewater [5]. The naturally-based wastewater stabilization pond requires a large surface area for its construction. Oxidation pond is less scientifically-based with the design of 0.6 m to 1.6 m depth [2]. Effluents from oxidation are usually applied for irrigation and aquaculture agriculture. Also, stabilization ponds are commonly used in regions with warm to mild climate throughout the year [6].

The removal of suspended solids (SS) and organic matter is the initial stage of treatment in the anaerobic, the secondary stage takes place in a facultative pond where the remaining organic matter is removed using the simulated heterotrophic and activated algae Mara and Pearson [4]. Erick, et al. [1] reported that aerobic ponds are suitable for high biochemical oxygen demand (BOD) removal and ideal for areas where the cost of land is not expensive.

The new staff quarters of Auchi Polytechnic, Auchi could adopt this mechanism for its wastewater treatment. It has been observed that most of the septic tanks and soak-away pits in the new staff quarters are no longer effective due to an increase in wastewater generation. Hence, the objective of the present study was to design a wastewater oxidation pond at Auchi Polytechnic, New Staff Quarters that will be useful to treat wastewater effluent; having considered the suitability factors such as the intensity of temperature and sunlight for removal processes. Oxidation ponds are also productive because it generates effluent that can be used for other applications such as fertilizer and pilet for arable and fish farming.

2. Materials and Methods

2.1. Design Considerations

Four significant mechanisms (interception, gravity, advection and diffusion) are included in oxidation pond. The pond is designed to be at least 150 m from residential houses and the treated effluent would be constantly diluted of discharge. Soils and parent materials at site must be impermeable to pond waters as the waste solution can contaminate ground water if seepage occurs. The following considerations were made as follows: the aerobic pond should be sited in an open area for interception of solar radiation and wind; the storm water catchment needs to be kept to a minimum to increase the retention time of ponds; rainwater run-off from the roof building would be channeled away from the effluent system; technical pipeline laying system; and creation of accessibility for earth moving equipment. The designed ratio of width to length is 1:2. This process ensures that the effluent remains within the system for a required period of time. The oxidation stabilization width is designed for effective workability of excavators and desludging machinery, the design of 0.5 m for the freeboard is allowed for slurry and sedimentation. Figure 1 and Figure 2 show the dimensional views of the designed oxidation pond, while Figure 3 shows the oxidation operational system of wastewater treatment pond. Figure 4 and Figure 5 show the oxidation pond system and application of its by-product (Sludge) for cropland farming.

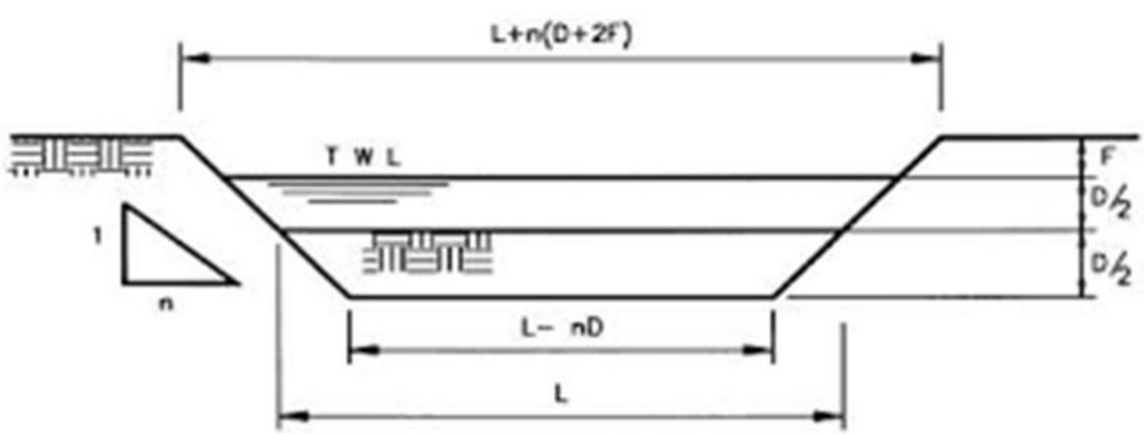

Figure-1. Front view of proposed oxidation pond.

Source: Mara and Pearson [4].

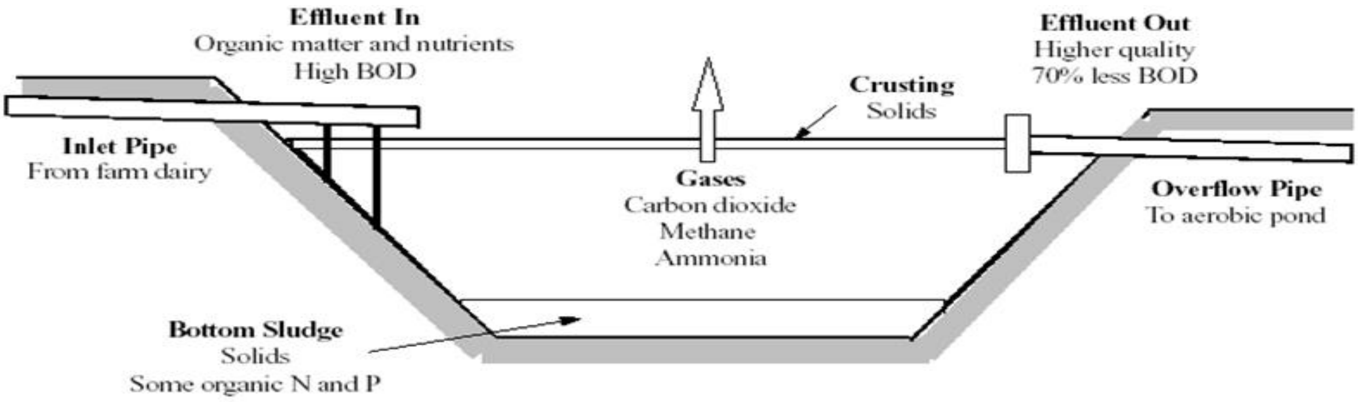

Figure-2. Oxidation pond and processes.

Source: Ramandan and Ponce [7].

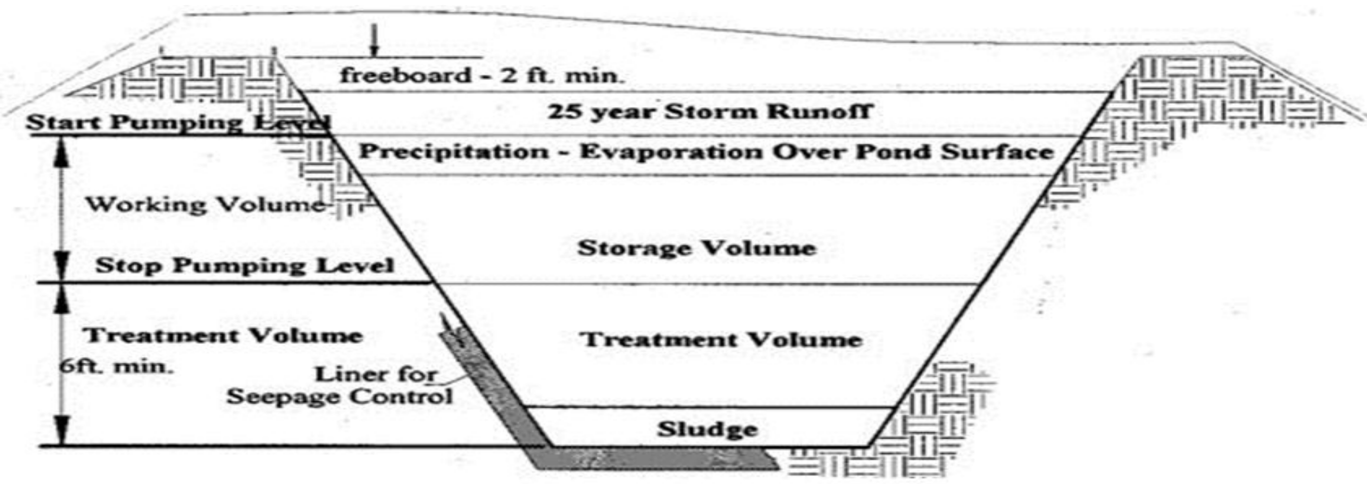

Figure-3. Wastewater treatment arrangement in oxidation pond.

Source: Ramandan and Ponce [7].

Figure-4. Oxidation pond treatment system.

Source: Alexiou and Mara [8].

Figure-5. Application of fertilizer value of oxidation pond treatment system for cropland.

Source: Alexiou and Mara [8].

2.2. Design Calculations

The proposed oxidation pond was designed to achieve 65% removal of biodegradable organic matter at about 20°C structured at 300 mg/l; temperature below 15°C causes the digestion processes to slow down with large sedimentation [4]. The chemical processes taking place in the anaerobic pond is represented in Equations 1-3:

$$5(CH_2O)_2 \rightarrow (CH_2O)_x + 2CH_3COOH + Energy \quad (1)$$

$$2CH_3COOH + 2NH_4HCO_3 \rightarrow 2CH_3COONH_4 + 2H_2O + 2CO_2 \quad (2)$$

$$2CH_3COONH_4 + 2CH_2 + 2NH_4HCO_3 \quad (3)$$

There is strong relationship between wastewater generation and population growth; therefore, population growth-projection and oxidation pond volume were calculated using Equation 4.

$$V = 3.5 * 10^{-5} Q L_a (\theta^{(35-T)}) ff^1 \quad (4)$$

Where:

V is the volume of the oxidation pond in cubic meter, the effluent flow rate is Q in m3/s, the biodegradable organic matter (BOD) is La, the pond temperature and temperature coefficient in T and Ө; the sulfide oxygen, algal toxicity factor are represented as ff^1 [9].

Equation 5 was applied to project the population of the New Staff Quarters in Auchi Polytechnic, Auchi for the next 20-year

$$P_t = P_o[1 + r(\%)]^t \quad (5)$$

Where,

P_O = Present Population = 250 people.

r = Growth rate = 2.8 %.

t = design period = 20 years.

P_t = Projected population.

$P_t = 250\ (1 + 0.028)^{20.}$

P_t = 434.3 = 435 people.

The initial treatment stage in stabilization pond is by introducing high volumetric organic matter of biodegradable (BOD) higher than 100g of BOD_5/m^3. However, the volumetric loading is equated using Equation 6. as follows:

$$\lambda_v = \frac{L_i Q}{V} \quad (6)$$

Where:

Influent of biodegradable organic matter (BOD), influent flow rate (Q) m^3/d and the volume of oxidation pond (m^3). Using the retention time, volumetric loading is computed from Equations 7-8.

$$\lambda_v = \frac{L_i}{t_{an}} \quad (7)$$

Where:

$$t_{an} = \frac{V}{Q} \quad (8)$$

Maximum surface organic loading (MSOR) and ambient air temperature of the coldest period is equated using the expression in Equation 9:

$$\lambda_{s(max)} = 60.3\ (1.099)^T \quad (9)$$

Where:

λ_s = surface organic loading, kg BOD_5/ha.d

T = mean ambient air temperature of coldest month, °C.

Archer [10] showed that the formula was designed for surface loading rate due to its suggestion of the agreement with available operating data, including a factor of safety of about 1.5, as represented in Equation 10.

$$\lambda_s = 20T - 60 \quad (10)$$

In the facultative pond, the hydraulic retention time (t_f) is estimated using Equation 11

$$t_f = \frac{A_f D_f}{Q} \quad (11)$$

A_f is the area of the stabilization pond; and D_f is the pond diameter.

The following assumptions were considered in the design:

i. BOD_5 Conversion = 905.
ii. BOD_5 removal rate = 0.36/day at 20°C.
iii. Temperature Coefficient = 1.06 at 20°C.
iv. Pond Temperature; (a).Warmth 35°C (b). Cold 25°C.
v. Maximum Pond Depth = 1.25 m
vi. Dispersion factor of ponds = 1.0

2.2.1. Sewer Design

The average generated sewage from the community is 87.0 m^3/day estimated using the Equation 12.

$$Q_d = P_t * P_{cd} * S_w \quad (12)$$

Where, Q_d is generated sewage; P_t is the projected population; P_{cd} is water consumed and S_w is spent. When the sewer is flowing at $^1/_6$ full-flow capacity, the velocity of flow (V) is estimated to be 0.3 m/s using manning formula as shown in Equation 13. Figure 6 indicates a partially filled section of a flow flowing in a circular pipe. D is the diameter of the pipe, while (h) depth of water in the pipe.

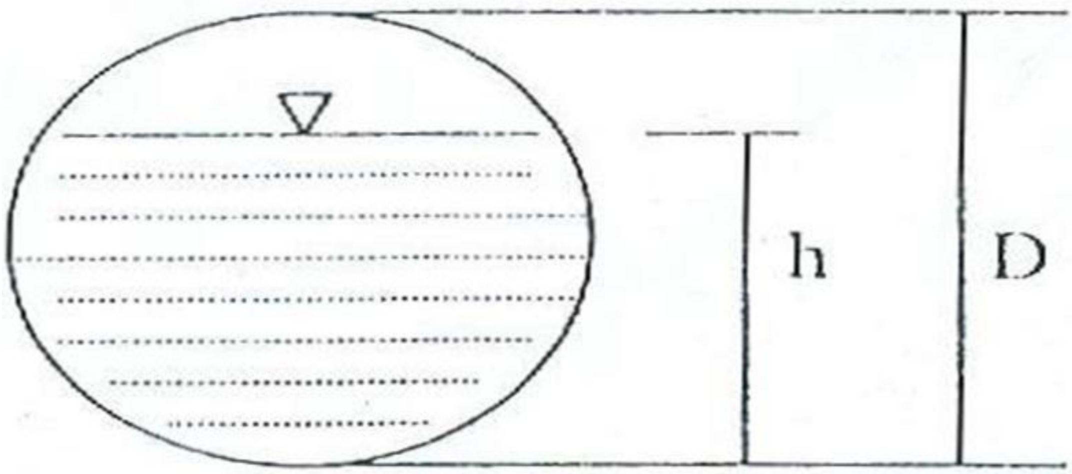

Figure-6. Partially filled section of a flow flowing in a circular pipe.
Source: Ramandan and Ponce [7].

$$V = \frac{1}{n} R^{2/3} S^{1/2} \tag{13}$$

Where, n ranges from 0.013-0.015. Therefore, the depth of flow from the circular channel was calculated using the expression in Equation 14.

$$Q = \frac{k}{n} D^{8/3} S^{1/2} \tag{14}$$

Q is the effluent flowrate; n is the manning coefficient of friction; h is depth of flow; S is the slope and D is diameter of conduit. The area of the pipe was determined using continuity equation as shown in Equation 15. Where V = 0.3m/s for a sewer flowing $^1/_6$ full

$$A = \frac{Q}{V} \tag{15}$$

Diameter of the effluent conveying PVC pipe was calculated using Equation 16.

$$D = \sqrt{\frac{4A}{\pi}} \tag{16}$$

3. Results and Discussion

New Staff Quarters of Auchi Polytechnic is a residential compound in the Polytechnic within the Auchi community with an estimated population equal to 250 people and a projected population of 485 people. The detailed results of the designed oxidation pond variables, geotechnical parameters, and wastewater analysis were well-validated. The projected population for New Staff Quarters for the next 20-year is 435 people. The soil is sandy with little fine particles of gravel. It has a bulk density (ρbulk) and particle dry density (ρdry) of 1.76g/cm^3 and 1.64 g/cm^3. The degree of saturation (ƞ), void ratio (e), moisture content (M.C) and a specific gravity of 91.4%, 0.87, 0.46 and 2.77 respectively. Oxidation surface pond area and volume of 723.8m^3 and 898.5m^3 were designed. Detention times (tan) at 25^{o}C and 35^{o}C were estimated to 6-day and 10.4 days respectively. Using the standard method, design load of less and not more than 350 BOD/m^{3}d for the dry season. However, the design consideration of 120 BOD/m^{3}d and temperature range of 10^{o}C-13^{o}C was applied to maintain odour challenges. The volumetric loading and sulfate concentration were applied using the procedure of Alexiou and Mara [8]. The effluent from municipal oxidation pond is designed to have BOD_5 between 60 and 75 mg/l and this is in line with World Health Organization (WHO) standard. It is deduced from the study that COD design variables for stabilization pond could be applied to replaced BOD. The dilution would be in the order of 7:1, and the living algae continues contains in the effluent becomes very useful due to its photosynthetic processes.

4. Conclusion

The design apparatus has indicated that the oxidation pond would be very suitable for wastewater treatment at the New Staff Quarters at Auchi Polytechnic, Auchi due to its inexpensiveness in design and construction. Also, the climatic conditions in Auchi highly favored the development of the wastewater stabilization pond. The reuse of the treated effluent will subsequently reduce the water pressure. Conversely, temperature, retention time and volumetric loading greatly affect organic loading and efficiency in the oxidation pond.

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