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Performance Evaluation of a Tropical Modern Brewery Waste Stabilization Pond: A Case Study of Ama Breweries, Enugu State, Nigeria

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Abstract: *The concern for a sustainable environment informed the construction of a waste stabilization pond (biologically based wastewater treatment facility) by Ama Brewery, Nigeria, for the brewery effluent treatment and fish pond for the natives. The water quality and the efficiency of the pond in terms of pollutant and microbial removal were assessed and the treated effluent compared with environmental standards for discharge into receiving surface water and fisheries. Physico-chemical parameters, coliform and Escherichia coli at the WSP inlet and outflow were assessed monthly for twelve months, using standard methods. Suspended solids, total dissolved solids and phyto-nutrients (ammonia and phosphate) increased at the outlet (5.9%, 17.4%, 60% and 24.14% respectively). Decrease in biochemical oxygen demand and increase in chemical oxygen demand were 8.11% and 25.17% respectively. Despite the prevailing favourable environmental conditions for optimal performance, the pond was inefficient due to poor maintenance.*

Keywords: *coliform, fish pond, pollutants, wastewater, water quality*

I. Introduction

` The concern for a sustainable environment has necessitated the development of environmentally friendly industries that operate on environmentally sound technologies that take care of their wastes. Ama Brewery, Enugu State, Nigeria (a tropical brewery) was established with this in mind hence the construction of the waste stabilization pond (WSP). Also, there is a wastewater treatment plant (WWTP) and piping of the treated effluent from the WWTP, as well as storm water run offs from the brewery to the waste stabilization pond/fish pond built for the community [1].

II. Waste Stabilization Ponds

Waste stabilization pond (WSP) technology is a highly sustainable technology for wastewater treatment [2], designed to function efficiently and effectively in the tropics due to favourable environmental factors [3, 4]. They are natural, have low operating and maintenance costs [4] and can be used for fisheries and irrigation purposes [5]. They use direct solar energy and do not need any electromechanical equipment, saving expenditure on electricity and more skilled operation; hence appropriate for developing countries. The efficiency of WSPs will impact on their uses for beneficial purposes. However, they require much more land than conventional electromechanical treatment processes such as activated sludge.

Within WSPs aerobic bacteria oxidize organic matter and about 30% of the influent biochemical oxygen demand (BOD) escapes in the form of methane gas [6]. Also, duration of retention, high temperature, pH (> 9) and light intensity together with high dissolved oxygen concentration is some of the principal mechanism that remove faecal bacteria in WSPs [7]. In addition, nitrates, phosphates, sulphates and silicates that are the limiting nutrients for plant growth are reduced by algal activity [7, 8].

For a waste stabilization pond to be utilized for fisheries it has to meet acceptable standards. Svobodova*et al.*[9]listed the toxic concentrations of some parameters for fish in culture:at dissolved oxygen content of below 3.0 mg/l suffocation may occur; pH below 5.0 may be lethal; and non-dissociated ammonia is highly toxic (as low as 0.0125 mg/l for salmonids and 0.05 mg/l for cyprinids); above 0.4 mg/l hydrogen sulphide is lethal to salmonids; iron as low as 0.1 mg/l may be toxic to salmonids; lethal levels of lead are 1 to 10 mg/l for salmonids and 10 to 100 mg/l for cyprinids; hatchability of larvae is adversely affected by as low as 0.002 mg/l cadmium whereas 2 to 20 mg/l is lethal to most species of fish; as low as 0.025 mg/l mercury may be lethal; while zinc above 0.1 and 0.5 mg/l is toxic to salmonids and cyprinids respectively; copper above 0.01 mg/l is toxic; and COD below 10 mg O_2 per litre and BOD_5 below 5 mg O_2 per litre are both lethal.

This work was undertaken to assess the water quality and the efficiency of Ama Brewery Waste Stabilization Pond (WSP) in terms of pollutant and microbial removal and compare its treated effluent at the outflow with environmental standards for fisheries and discharge into Ajali River surface water, which has been earmarked by the government for municipal water supply.

III. Materials and Methods

3.1. Study area. Ama Brewery, owned by Nigerian Breweries Plc, is located on longitude 07°23' E and latitude 06°26' N. It is situated in AmaekeNgwovillage; along Eke Road in Enugu State, Nigeria (Fig. 1) [1]. Ama Brewery is the biggest brewery in Nigeria and one of the most modern in the world. Ama Brewery waste stabilization pond is located along Eke Road and one kilometre away from the nearest town settlement - Eke. The effluent was piped down to the WSP site from the waste water treatment plant (WWTP).The WSP measured 150 m X 50 m X 2 m in length, width and depth respectively. The pond embankment is stone pitched and the in-let and out-let pipes are diagonally located at the upper part of the pond to ensure the desired retention time of the effluent for biodegradation before its discharge. The construction pattern was in line with the descriptions of [7, 10, and 11].

3.2. Water quality (physico-chemical and bacteriological parameters) assessment. Physico-chemical parameters of Ama facultative waste stabilization pond (WSP) were assessed in a monthly interval for one year between 10.00 and 12.00 hr. Wastewater samples were taken from two locations – influent area, Location 1 (L1) and outflow, Location 2 (L2), using a two-litre capacity plastic can. Depth, temperature and pH were measured *in situ* with a calibrated pole, mercury thermometer (0 - 100°C) and a Hanna field pH meter respectively. Other parameters such as colour, dissolved oxygen, alkalinity, ammonia, silica, phosphate, hydrogen sulphide, sulphate, nitrate, suspended solids, total dissolved solids (TDS), total hardness, chloride, chemical oxygen demand (COD), biochemical oxygen demand (BOD), potassium, calcium, magnesium, iron, lead, cadmium, mercury, zinc, copper, coliform and *E. coli* were analyzed following [12] methods.

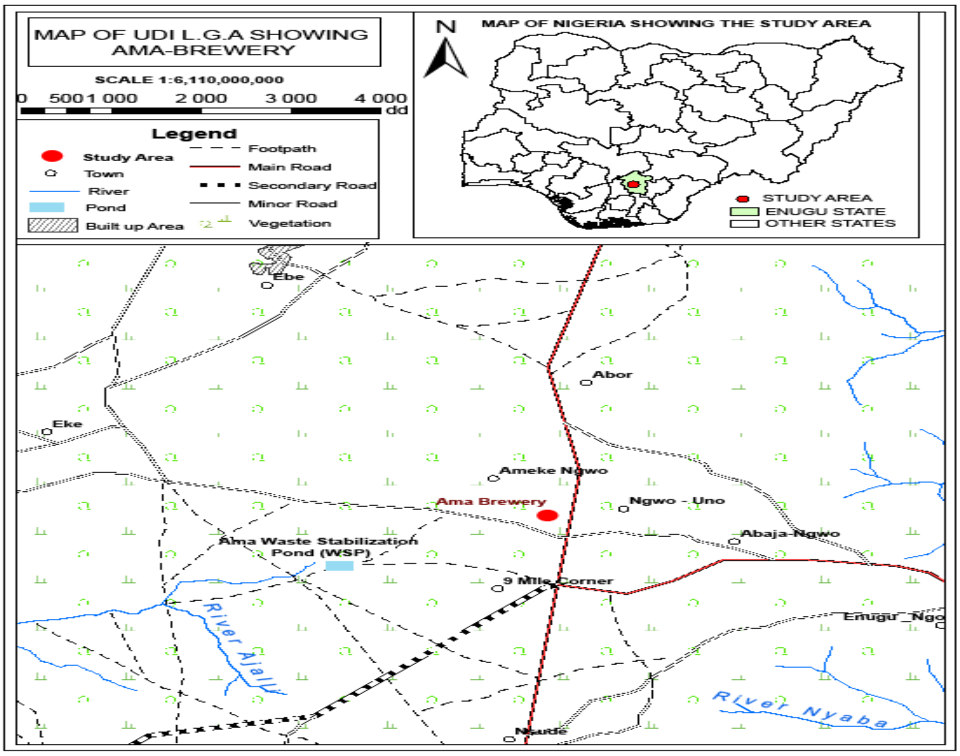

Fig 1 Map of Udi L.G.A. Showing Study Area

3.3. Data analysis*.* Percentage reduction/increase between observed values at inflow and outflow for various parameters investigated were calculated as follows:

Per cent (%) Increase = {(Location 2 minus Location 1) / Location 1)} X 100;

Percent (%) Reduction = {(Location 1 minus Location 2) / Location 2)} X 100.

IV. Results and Discussion

4.1. Assessment of pond performance. No variations were observed in depth, nitrate, potassium and iron at the inflow and outflow, indicating that essential nutrients were not reduced. Water temperature, colour, pH, alkalinity, ammonia, silica, phosphate, hydrogen sulphide, suspended solids, TDS, COD, magnesium, lead, zinc and copper increased in the outflow but more than 50% increase was observed for ammonia (60%), hydrogen sulphide (59.52%), lead (200%) and copper (400% (Table 1). High levels of lead and copper are toxic to living organisms. Irreversible neurological damage, renal disease, cardiovascular effects and reproductive toxicity have been associated with lead poisoning especially in children [13]. Also, decreases were observed in dissolved oxygen, sulphate, total hardness, chloride, BOD, calcium, cadmium, mercury coliform and *E. coli* and more than 50% decrease was observed for total hardness (240.58%), cadmium (76.19%), mercury (200%) and *E. coli* (83.3%) but the levels were still high for fisheries.

Assessment of the performance of the pond was based on BOD, COD, suspended solids (SS), nutrient removal (ammonia and phosphate) and microbial removal. The percentage BOD and coliform removal were very low (8.11% and 36.30% respectively) when compared with the observations of [14] for Akuse, Ghana (65% and 99.9%); [15] for Zaria (95% and 99.6%) and [16] for Egypt (50.6% for BOD). The observed increases in COD, SS, ammonia and phosphate rather than decreases were contrary to expectations, indicating inefficiency. This was due to short circuiting and high rate of flushing out caused by poor pond maintenance culture. The outflow was dug down about three meters from the original diagonal position to the outlet pipe, thereby reducing the retention time of the organic matter and water in the pond. Moreover, the pond environment was badly maintained hence macrophytes took over the pond. Macrophytes affect insolation by their shading effect; reduce wind overturn and increase evapo-transpiration in the pond thereby causing the sludge to build up. These agree with the works of [17, 7 and 5] and [8].

The ratio of BOD: COD for the inflow was 40:151 (approximately 1:4) and the outlet was 37: 189 (approximately 1:5). These values (1:4 and 1:5) according to the wastewater classification by [18] indicate that the BOD was medium while COD was strong.

The coliform in the inlet was high and it decreased by 36.30% as it left the outflow due to rise in pH as a result of algal activities. Although the WSP is not designed for microbial removal, it could achieve that by algal productivity raising the hydroxyl ion content of the pond [17, 14, 7, 10, 8, 15, 16]. To ensure the conformation to coliform standards, there is need to construct a maturation pond that will ensure diverse algal population and further increase in pH, to kill off the coliform so as to ensure the health of communities living downstream of the receiving water body, Ajali River. The same holds for *E.coli* whose removal range was 83.3%.

Due to pre-treatment of the organic matters in the WWTP, the suspended solid (SS) was of very weak category of [18]. The percentage increase in SS and dissolved solids from inflow to outflow was 5.9% and 17.4% respectively. This informs the increase in the sludge formation in the pond that was aggravated by poor pond maintenance. Therefore, there is urgent need for de-silting (sludge removal) to ensure efficient performance of the pond.

It has been documented that wastewater effluents with concentrations of phyto-nutrients (ammonia, nitrates, phosphate) can cause undesirable phytoplankton growth (eutrophication) in the receiving water body [19]. The ammonia concentration in the outflow was 1.68 mg L^{-1} (60% increase over inflow values). Although this is of weak composition according to [18] it is above 0.2 mg L^{-1} specified in Nigerian Federal Ministry of Environment guidelines [20]. This was as a result of accumulated nutrients and degradation of organic matter in the pond. Phosphate concentration at the outflow was 3.6 mg L^{-1} (24.14% increase over inflow values). This observation indicates inefficiency and contradicts lower levels observed by [15,16] for Ghana and Egypt respectively. As suggested by [21,7] in order to avoid eutrophication of the receiving water body, Ajali River, the evaluation of the pond performance becomes imperative. A recent visit shows that this has been done.

4.2. Suitability for fisheries. Observed concentrations (mg/L) of parameters investigated at the outflow such as of ammonia (1.68), hydrogen sulphide (6.7), iron (1) cadmium (2.1), mercury (2.1), zinc (13.6) and copper (0.5) are injurious to fish in culture following the standards by [9]; hence the WSP was not suitable for fish farming (Table 2).

Table 1 Observed values, percentage reduction of physico-chemical and bacteriological parameters from WSP inflow to outflow (2008) and comparison with [20] standards for discharge into surface water

Parameter	Inflow	Outflow	Reduction/ increase (%)	FME standards
Water temperature (^{O}C)	27	27.67	2.48+	40
Depth (m)	0.18	0.18	0	NA
Colour (Hazen units)	80	90.42*	13.03+	7
pH	6.63	6.75	1.81+	6 - 9
Dissolved Oxygen (mg/l)	7.79	5.42	43.73-	NA
Alkalinity (mg/l)	10.6	14.92	40.75+	15
Ammonia (mg/l)	1.05	1.68	60+	0.2
Silca (mg/l)	1.9	2	5.26+	NA
Phosphate (mg/l)	2.9	3.6	24.14+	5
Sulphide (mg/l)	4.2	6.7*	59.52+	0.2
Sulphate (mg/l)	5	4	25-	4.25
Nitrate (mg/l)	1.3	1.3	0	20
Suspended solids (mg/l)	0.51	0.54	5.9+	30
Total Dissolved Solids (TDS) (mg/l)	0.23	0.27	17.4+	2000
Total Hardness (mg/l)	235	69	240.58 -	NA
Chloride (mg/l)	24	16	50-	600
Chemical Oxygen Demand (COD) (mg/l)	151	189*	25.17+	80
Biochemical Oxygen Demand (BOD) (mg/l)	40	37	8.11-	50
Potassium (mg/l)	6.6	6,6	0	NA
Calcium (mg/l)	16.9	11.6*	45.69-	3
Magnesium (mg/l)	23.4	23.9	2.14+	200
Iron (mg/l)	1	1	0	20
Lead (mg/l)	0.01	0.03	200+	<1
Cadmium (mg/l)	3.7	2.1*	76.19	<1
Mercury (mg/l)	6.3	2.1*	200-	0.05
Zinc (mg/l)	13.3	13.6*	2.26+	<1
Copper (mg/l)	0.1	0.5	400+	<1
Coliform (MPN/100 ml)	1254	920*	36.30-	400
E. coli (MPN/100 ml)	108	18	83.3-	NA

- Represents reduction;+ represents increase; * represents above FME standards.

Table 2 Comparisons of some water quality parameters of Ama brewery WSP outflow (2008) with 'fish in culture' standards [9]

Water quality parameter (mg/l)	WSP outflow	[9] standard
Non-dissociated ammonia	1.68	As low as 0.0125 mg/L is highly toxic for salmonids; 0.05 for cyprinids
Hydrogen sulphide	6.7	0.4 Lethal to salmonids
Iron	1	0.1 is toxic to salmonids
Cadmium	2.1	As low as 0.002 affects hatchability of larva adversely; 2 – 20 lethal to most species of fish
Mercury	2.1	0.025 may be lethal
Zinc	13.6	0.1 and 0.5 are toxic to salmonids and cyprinids respectively
Copper	0.5	Above 0.01 is toxic

V. Conclusions and Recommendations

5.1. Conclusions. Water quality attributes such as colour, sulphide, calcium, COD, heavy metals (cadmium, mecury and zinc) and coliform at the pond outflow did not meet WHO and national standards for discharge of wastewaters into surface waters, which in this case is Ajali River, which has been earmarked by the government for municipal water supply. Observed ammonia, hydrogen sulphide, cadmium, mercury, zinc and copper levels may be injurious to fish; consequently the pond should not serve as a fish pond.Suspended solids, total dissolved solids and phyto-nutrients (ammonia and phosphate) increased at the outflow (5.9%, 17.4%, 60% and 24.14% respectively), consequently the receiving river is at risk of eutrophication.
The study revealed that the waste stabilization pond (WSP) was constructed according to acceptable standards but its inefficiency in removing organic matter was as a result of poor pond maintenance.

5.2. Recommendations. Urgent removal of the sludge is advocated to improve pond efficiency.It is recommended that the dug up area should be closed to avoid short circuiting and increase retention time. Also, macrophytes should be removed to increase transparency and reduce evapo-transpiration (which reduce the volume of water) and shading, which affect algal photosynthesis negatively. There is also the need to construct a maturation pond that will ensure more diverse algal population and increase in pH to reduce coliform and *E. coli* levels thereby securing the health of communities that utilize water from Ajali River. Regulatory bodies should monitor and ensure strict compliance on effluent discharge standards.

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References

[1] Nigerian Breweries (NB) Plc.,*Environmental and Social Report* (Lagos, Nigeria: Corporate Communication Department, 2006).
[2] D. Mara, *Design manual for waste stabilization ponds in India* (United Kingdom: Leeds Lagoon Technology International, 1997).
[3] S. Kayombo, T.S.A. Mbwette, and J.H.Y. Katima, *Waste stabilization Ponds and Constructed Wetlands Design Manual* (Tanzania: University of Dar es Salaam, 1998).
[4] M.R. Pena and O.O. Mara, *Waste Stabilization Ponds*, 2004, *http://www.irc.nl*Accessed August 3, 2009.
[5] B.I. Lloyd, A.R. Leaner, C.A. Vorkas and R.K. Gugnesharajah, Underperformance evaluation and rehabilitation strategy for waste stabilization ponds in Mexico, *Water Science and Technology 48(2)*, 2003, 35-43.
[6] G.V.R. Marais, Dynamic behaviour of oxidation ponds, in R.E. Mckinney (Ed.), *proceedings of the second international symposium on waste treatment lagoon* (Laurence, Kansas: University of Kansas, 1970).
[7] J.C. Agunwamba, *Waste engineering and management tools* (Enugu, Nigeria: Immaculate Publications Ltd, 2001).
[8] N.O. Nweze and G.F. Chumboh, Physical and chemical characteristics, algal flora and coliform content of the University of Nigeria, Nsukka sewage treatment plant oxidation pond, *Nigerian Journal of Botany, 19(1)*, 2006, 103-116.
[9] Z. Svabodova, R. Lloyd, and M. Jana, *Water Quality and Fish Health* (European Inland Fisheries Advisory Commission (EIFAC) (United Nations: Food and Agricultural Organization, 1993).
[10] D. Mara, Low-cost, high performance waste water treatment and reuse for public health and environmental protection in the 21st century, *10th Annual CWWA Conference on Innovation Technologies in the Water and Waste Water Industries for the 21stCentury*,Grand Cayman, October 2001.
[11] M.R. Pena, *Advanced primary treatment of domestic wastewater in tropical countries: development of high rate anaerobic ponds*, doctoral thesis, University of Leeds, UK, 2002.
[12] American Public Health Association, *Standard methods for the examination of water and wastewater, 20th edition* (Washington DC: American Water Works Association and Water Pollution Control Federation, 1998).
[13] Agency for Toxic Substances and Disease Registration (ATSDR), *Lead toxicity*, 2007, www.atsdr.cdc.gov/csem/lead/docs/lead.pdfAccessed March 12, 2013.
[14] O.A. Hodgson, Treatment of domestic sewage at Akuse (Ghana), *Water SA, 26*, 2000, 413-416.
[15] I.A. Oke, J.A. Otun, C.A. Okuofu, and N.O. Olarinoye, Efficiency of a biological treatment plant at Ahamadu Bello University, Zaria, *Research Journal of Agricultureand Biological Sciences, 2(6)*, 2006, 452-459.
[16] M.E.G. Mahassen, M.S. Waled, M.A. Azza, and K. Mohammed, Performance evaluation of a waste stabilization pond in a rural area in Eygpt, *American Journal of Environmental Sciences.4(4)*, 2008, 316-326.
[17] D.O. Mara, and H.W. Pearson, *Design manual for waste stabilization ponds in Mediterranean countries* (Leeds, U.K.: Lagoon Technology International, 1998).
[18] Metcalf and Eddy Inc., *Wastewater engineering treatment disposal and reuse, 3rd edition* (New York: McGraw-Hill Book Company, 1991).
[19] E.G. Bellinger and D.C. Sigee, *Freshwater algae: identification and use as bioindicators* (West Sussex: Wiley Blackwell, 2010).
[20] Federal Ministry of Environment, National environmental protection (effluent limitation) regulations,section 1.8, in*Federal Environmental Protection Act*(Nigeria: Federal Republic of Nigeria, 1991), 21 – 26.
[21] H.W. Pearson, O.O. Mara, and C.R. Bartone, Guidelines for the minimum evaluation of the performance of full-scale waste stabilization ponds, *Water Research, 21 (9)*, 1987, 1067-1075.