Wetland System: A Cheaper and Efficient Treatment Option for Food Processing Waste in Africa

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Introduction

- Industry has been reckoned to contribute to environmental pollution in developed countries and much research has been done to proffer technological solutions.

- However, little is known appropriate adoption that are “Best Available Technology (BAT)” or “Best Practicable Technology (BPT)” and “Locally Adaptable and not Entailing Excessive Costs (NEEC)” to curb external diseconomies of production among industrial firms in developing countries, especially in Africa

Introduction

- In this regard, this research investigated the technology adopted (advanced wastewater treatment plant) for a brewery industry in West Africa.
- The cost and treatment efficiencies among other indicators were examined.
- In spite of the prohibitive investments costs, the effluent characteristics are far higher than the international threshold for wastewater discharged into river bodies.

Introduction

- The technology adopted by the brewery industry is an advanced wastewater treatment plant. The treatment process is made up of secondary treatment including both anaerobic and aerobic treatment.

- Hence, an alternative low-cost and efficient wastewater treatment technology (Subsurface Flow Constructed Wetland System) was recommended and designed for adoption by food processing industry in Africa.

Technology adopted by the brewery industry

- The influent is composed of the wastewater from the brewing house and the packaging unit.
- The raw wastewater is channeled into an influent pump pit where the raw water is pumped into an equalization tank.
- The equalization tank prevents shock and pH correction also takes place.
- Hydrochloric acid or caustic soda is added depending on the pH of the raw wastewater.

Technology adopted by the brewery industry

- After the PH correction in the equalization tank, the wastewater is piped to the Upflow anaerobic sludge blanket (UASB) reactor where anaerobic organisms digest the organic matter in the wastewater.
- Upflow anaerobic sludge blanket (UASB) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used in the treatment of wastewater.
- The UASB reactor is a methanogenic (methane-producing) digester that evolved from the anaerobic clarigester.

Technology adopted by the brewery industry

- UASB uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank.
- Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms.
- The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants.
- Biogas with a high concentration of methane is produced as a by-product, and this is captured and used as an energy source.
- The biogas is captured and used for factory heating purpose.

Technology adopted by the brewery industry

- The treated wastewater is piped to an aerobic reactor.
- With UASB, the aeration and the whole process of settlement and digestion occurs in one or more large tank(s).
- Only the post UASB liquids, with a much reduced BOD needs to be aerated.
- The aerobic reactor is made up of three channels. The capacity of the aerobic reactor is also about 3000 m^3.
- Chlorination subsequently takes place after treatment with calcium hypochlorite. The sludge is collected into a sludge tank for final disposal.

Technology adopted by the brewery industry

- The effluent is channeled to an open drain for discharge into river bodies that is about 2.5 km away from the treatment plant.

- However, the effluent mixed up with an existing oxidation pond at about 2.0 km before the discharge point.

- The industry monthly wastewater volume is 124,000 m^3 and that the cost of installation of the plant is USD 5 million.

Technology adopted by the brewery industry

- The emission surveillance data revealed that the efficiency of the treatment plant in BOD_5 removal, COD removal and TSS removal are 72.9%, 72.69% and 42.68% respectively.

- Despite the huge technology investment towards pollution control, the effluent at discharge point has BOD_5, COD and TSS values of 256.5 mg/l, 562.58 mg/l and 74.33 mg/l respectively which all exceed the Federal Ministry of Environment threshold of 30 mg/l, 80 mg/l and 30 mg/l for BOD_5, COD and TSS discharged into river bodies for food processing industry.

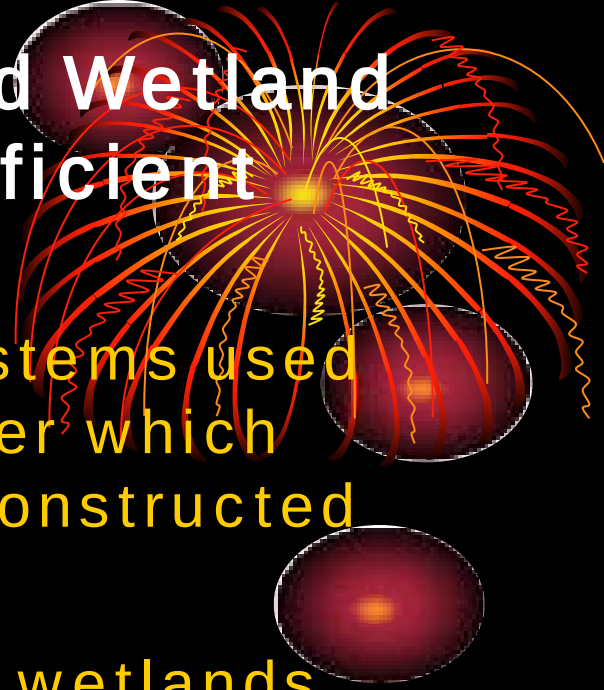
Subsurface flow Constructed Wetland as alternate low-cost and efficient technology

- The cost of bioreactor is prohibitive and a survey of wetland technology indicates an adaptable technology.

- Wetlands are defined as ecosystems where the water surface is at or near the ground surface for long enough each year to maintain saturated soil conditions and related vegetation (Crites, *et al,* 2006).

- The capacity of these ecosystems to improve water quality has been recognized for at least 30 years (USEPA, 2003).

Subsurface flow Constructed Wetland as alternate low-cost and efficient technology



- There are two basic wetland systems used in the treatment of polluted water which includes natural wetlands and constructed wetlands.
- There are three types of natural wetlands which have been known to treat urban wastewater and storm water. These include swamps, bogs and marshes.
- There are also three types of constructed wetlands which includes Free Water Surface (FWS) constructed wetland or Surface Flow (SF) wetlands, Sub Surface Flow (SSF) constructed wetlands and engineered wetlands.

Subsurface flow Constructed Wetland as alternate low-cost and efficient technology

- However, a Subsurface flow constructed wetland is recommended over Free Water Surface wetland for the brewery industry because subsurface flow wetlands are often used where the wastewater being treated in noxious or odorous and where the attraction of wildlife may be undesirable [Crites, *et al* (2006)].
- When the reduction of BOD is the controlling parameter, selection of SSF variety might be desirable, as the difference in cost is not that great and, on average, the table indicates that a SSF wetland will cost only 37% more than FWS, but the advantage in treatment efficiency is very large (a ratio of 5.29 times).

Controlling parameters for design

- For the brewery industry, the controlling parameter is the BOD, however the pathogens and suspended solid are also key parameters to be considered. Hence, the subsurface and vertical flow constructed wetland is considered to be more appropriate.
- All constructed wetland systems are considered to be an attached-growth biological reactors, and their performance can be estimated with first-order plug-flow model.
- The Federal Ministry of Environment effluent threshold for food processing industry effluent is shown in Table 1 below:

Table 1: Influent Concentration and FME Threshold for the brewery Industry

Parameters	Unit	Influent Concentration	FME Threshold
BOD	mg/L	946.8	30
COD	mg/L	2059.9	80
TOC	mg/L	0.036	N/S
TSS	mg/L	129.67	30
TDS	mg/L	834.32	2000
Total N	/L	3.61	N/S
SO_4	mg/L	14.6	500
PO_4	mg/L	114.06	5
Cl	mg/L	7.64	600
NO_3	mg/L	6.95	20
NH_3	mg/L	7.09	N/S
Total P	mg/L	36.74	N/S
Cu	mg/L	0.129	1
Fe	mg/L	0.441	20
Zn	mg/L	0.635	<1
Mn	mg/L	0.064	20
Faecal Coliform	mg/L	2.1×10^3	400
*** N/S = Threshold have not been set by the Federal Ministry of Environment**			

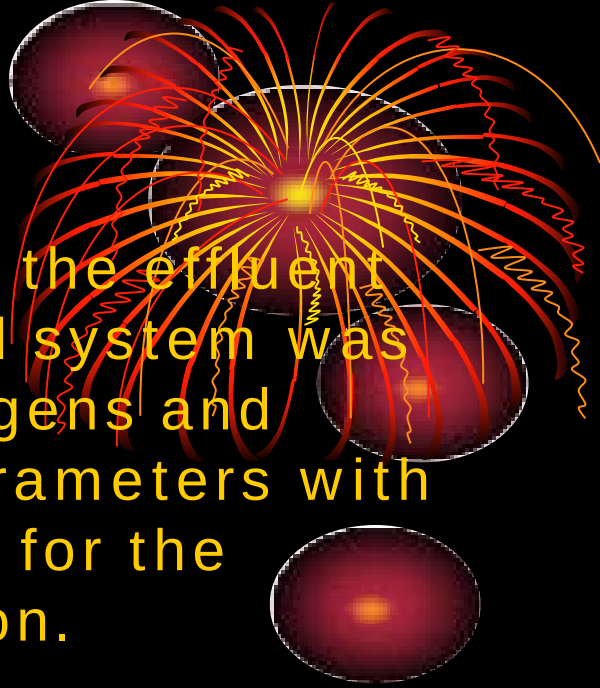
Wetland Sizing

- The parameter (BOD, etc) that requires the largest treatment are for removal is the limiting design factor, and that area should be selected for the intended project.
- The wetland should then provide acceptable treatment for all other parameters of concern.

$$A_s = \frac{Q \ln (C_0/C_e)}{K_T(y)(n)}$$ (Crites et al, 2006)

- The influent concentration is obtained from the waste characterization study for the brewery industry. The effluent concentration could be obtained from the Federal Ministry of Environment effluent threshold for food processing industry effluent shown in Table 1

Wetland Sizing



- From the waste characteristics and the effluent threshold, the design of the wetland system was carried out for the BOD, TSS, Pathogens and Phosphate because they are the parameters with characteristics above the threshold for the brewery industry under consideration.
- The COD and TOC are closely linked with the BOD. In addition, the design is also carried out for total nitrogen, total phosphorus and ammonia because the effluent threshold are not stipulated by the Federal Ministry of Environment.
- However, the BOD, TSS and the Pathogens are the controlling parameters for the food processing industry. All other parameters not designed for are within the Federal Ministry of Environment threshold for food processing industry.

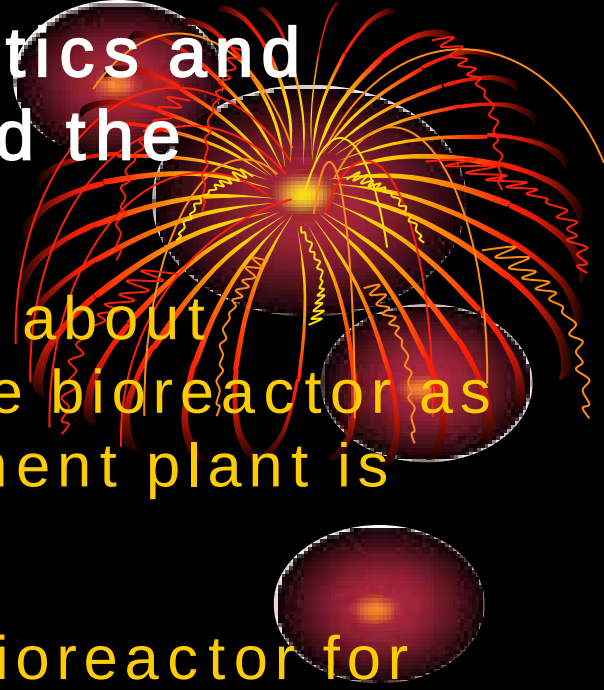
Wetland Sizing

Parameters	Q	C_o	C_e	T	K_{20}	K_T	y	n	As
BOD	4153	946.8	30	28	1.1	1.753	0.6	0.38	44828.6
TSS	4153	129.7	30	28	1.1	1.753	0.6	0.38	19010.4
FC	4153	2100	400	28	1.1	1.753	0.6	0.38	21534.7
COD	4153	2060	80	28	1.1	1.753	0.6	0.38	42185.6
PO_4	4153	114.1	5	28	1.1	1.753	0.6	0.38	40613.2

Treatment Media and Vegetation

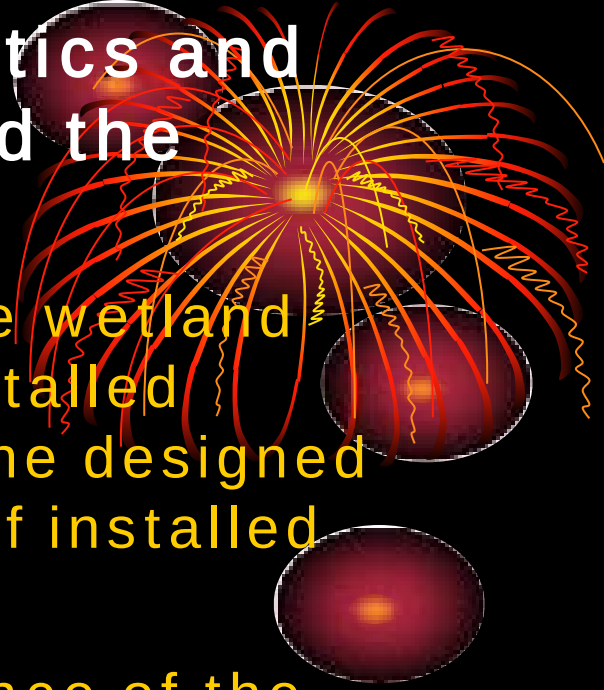
- The initial rooting medium for the vegetation would be fine gravel which would 150mm deep. However, the mail treatment layer would be a relatively small gravel(<20mm).
- The total SSF wetland depth would be 0.6m. Vegetation in SFF wetlands should be perennial emergent plants.
- The recommended vegetation for the SSF wetlands for the brewery industry is Reeds and a typical variety is *Phragmites Australis (common reed).*
- The distribution is worldwide and optimum PH is 2 to 8. Growth is very rapid via rhizomes and lateral spread is approximately 1m/year, providing very dense cover in 1 year with plants spaced at 0.6m.

Comparism of Waste Characteristics and Costs for the Wetland System and the Bioreactor



- The constructed wetland requires about 44,829m^2 while the land take of the bioreactor as measured from the brewery treatment plant is about 6,675$m^{2.}$
- The cost of the installed 3000m^3 bioreactor for the brewery industry is USD 5 million however the cost of the constructed subsurface flow wetland system with a capacity of 5,200m^3 is costing USD 1.65 million.
- The designed capacity of the wetland system is to accommodate a daily wastewater generation volume of 4,153 m^3 with an additional capacity of 25% as factor of safety to accommodate excess production.

Comparism of Waste Characteristics and Costs for the Wetland System and the Bioreactor



- Hence, the designed capacity of the wetland system is bigger than that of the installed bioreactor. In addition, the cost of the designed wetland system is 33% of the cost of installed bioreactor.
- The cost of operation and maintenance of the designed wetland system is much lower than that of the installed bioreactor .
- The comparative treatment efficiency of the designed wetland system and the installed bioreactor is shown in the Tables below.
- The waste characteristics for the designed subsurface flow constructed wetland falls within the Federal Ministry of Environment threshold for food processing industry

Comparism of Waste Characteristics and Costs for the Wetland System and the Bioreactor

- However, for the installed Bioreactor, most of the waste characteristics are above the stipulated threshold.
- In addition to the waste characteristics threshold, the treatment efficiency of the designed subsurface flow constructed wetland for the controlling parameters, BOD, TSS and Faecal Coliform are 96.83%, 88.42% and 96.29% respectively.
- For the installed UASB reactor, the treatment efficiency for the same controlling parameters, BOD, TSS and Faecal Coliform are 62.94%, 15.36% and 63.81% respectively. Hence, the designed subsurface flow constructed wetland is more efficient in the removal of BOD, TSS and Faecal Coliform.

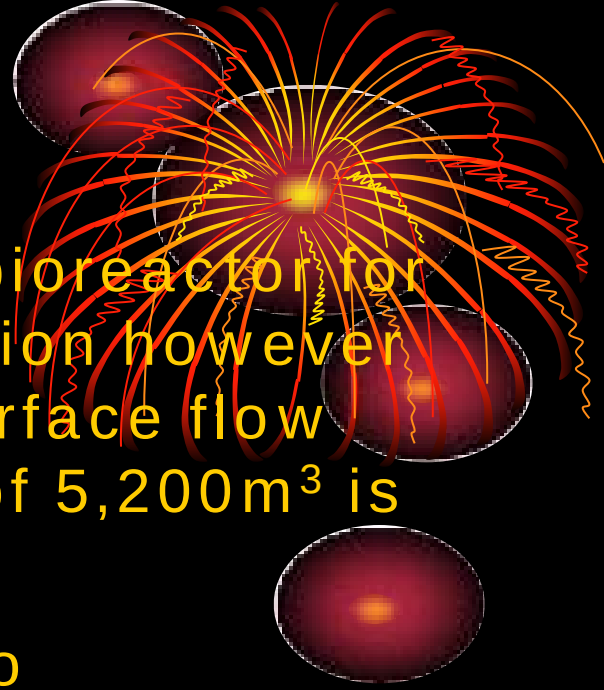
Table 3: Comparism of Waste Characteristics of Wetland System and the Installed Bioreactor

Parameters	Unit	Before Treatment	UASB Bioreactor After Treatment	SSF Constructed Wetland After Treatment	FME Threshold
BOD_5	(mg/L)	946.8	350.92	30	30
TSS	(mg/L)	129.67	109.75	15.01	30
Total N	(%)	3.61	2.98	0.58	N/S
PO_4	(mg/L)	114.06	39.41	16.9	N/S
NO_3	(mg/L)	6.95	2.55	5.1	20
NH_3	(mg/L)	7.09	3.43	3.98	N/S
Total P	(mg/L)	36.74	12.6	27.55	N/S
FC	MPN/100ml	2100	760	78	400

Table 4: Comparism of Treatment Efficiency of Wetland System and the Installed Bioreactor

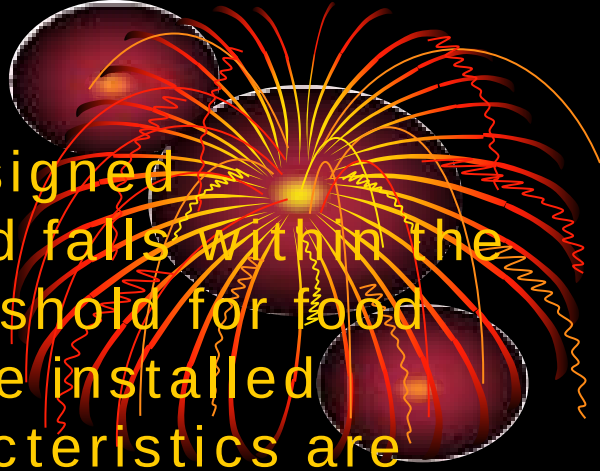
Parameters		Bioreactor After Treatment	SSF Construted Wetland After Treatment
BOD_5	(mg/L)	62.94%	96.83%
TSS	(mg/L)	15.36%	88.42%
Total N	(%)	17.45%	83.93%
PO_4	(mg/L)	65.45%	85.18%
NO_3	(mg/L)	63.31%	26.62%
NH_3	(mg/L)	51.62%	51.62%
Total P	(mg/L)	65.71%	25.01%
FC	MPN/100ml	63.81%	96.29%

Conclusion



- The cost of the installed 3000m^3 bioreactor for the brewery industry is USD 5 million however the cost of the constructed subsurface flow wetland system with a capacity of 5,200m^3 is costing USD 1.65 million.
- The wetland system is designed to accommodate a daily wastewater generation volume of 4,153 m^3 with an additional capacity of 25% as factor of safety to accommodate excess production.
- Hence, the designed capacity of the wetland system is bigger than that of the installed bioreactor. In addition, the cost of the designed wetland system is 33% of the cost of installed bioreactor.

Conclusion



- The waste characteristics of the designed subsurface flow constructed wetland falls within the Federal Ministry of Environment threshold for food processing industry. However, for the installed Bioreactor, most of the waste characteristics are above the stipulated threshold.
- In addition to the waste characteristics threshold, the treatment efficiency of the designed subsurface flow constructed wetland for the controlling parameters, BOD, TSS and Faecal Coliform are 96.83%, 88.42% and 96.29% respectively. For the installed UASB reactor, the treatment efficiency for the same controlling parameters, BOD, TSS and Faecal Coliform are 62.94%, 15.36% and 63.81% respectively.
- Hence, the designed subsurface flow constructed wetland is more efficient in the removal of BOD, TSS and Faecal Coliform.