



Biological Treatment of Platform Waste-Water Using Bench-Scale Trickling Filters

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ARTICLE INFO	ABSTRACT
Article No.: 121912329 Type: Research DOI: 10.15580/GJBS.2013.2.121912329 Submitted: 19/12/2012 Published: 28/02/2013 *Corresponding Author Onuabuchi Azunna E-mail: onunsco@yahoo.com Keywords: trickling filter, hydraulic loading, platform effluent treatment, biological treatment	The treatment of wastewater from a crude oil platform situated in the shallow offshore of the Atlantic ocean of Nigeria by two standard plants, namely the Wemco Depurator and the Red Fox Treatment Plant have not adequately reduced the levels of oil contaminants and odour to acceptable limits for discharge. A secondary treatment, based on the principles of the trickling filter was therefore investigated to complement the two plants already in operation. A bench-scale trickling filter was assembled and characterized using a mathematical model to understand the effect of hydraulic loading on the dimensionless BOD percentage reduction at various depths of the filter and to determine the operational characteristics of the filter when packed with a plastic medium of specific area 22.96 m²/m³ of bulk volume. The filter was adequately described by the equation $S = e^{0.038 D / L^{0.9}}$ where s is the specific reduction in BOD, D is the depth of packing and L is the hydraulic loading.

INTRODUCTION

Crude petroleum production platforms operating in the shallow offshore of the Atlantic ocean coastlines of Nigeria have in recent times faced the problem of pollution of the water around the platforms. It is claimed that activities at the platforms "have destroyed fishing nets, hooks, sinkers apart from killing fish" (Mudiaga Ofuoku, 1998). The oil companies have in fact been under heavy attack from the inhabitants of the Niger Delta area since 1965. Government environmental agencies have also imposed more severe penalties and monetary compensations on operators that discharge untreated platform effluents into the ocean.

Okan production Platform is a crude oil production platform located in a shallow area off the coast of Warri, which has often been faced with the problem of oil steaks and other chemically hazardous wastes finding their way to the sea shore and beaches around. The platform produces both domestic and oil field waste such as human body waste (faeces and urine) and sullage which is the wastewater resulting from personal washing, laundry, in food preparation and the cleaning of kitchen utensils, in addition to oil fields waste such as dissolved salts, high level of organic materials, odour, phenol and sulfur compounds. Installed at this platform for waste treatment are the "red fox" sewage plant for the treatment of domestic waste and the "Wemco Depurator" for treatment wastes from the process plant. It has been observed that the two treatment plants have not been able to treat the waste to acceptable levels by FEPA as shown in Appendix D, and as such the odour has persisted in the effluent from the plants. Tests have also shown that the WEMCO Depurator has successfully removed oil droplets in the crude wastewater but did not reduce other harmful chemical by-products of the process to their acceptable levels. The Red fox plant produced odour and these were the problems of clogging of air holes and frequent equipment failure. Owing to the above problems, a secondary treatment of effluents from the two plants was proposed based on the principles of a trickling filter. The effectiveness of this secondary treatment is the subject of the present investigation.

MATERIAL AND METHODS

Model Formulation for the Trickling Filter

The purpose of model formulation is to obtain a relationship among BOD removal rate, depth of filter and hydraulic loading. From the model of Eckenfelder (1970), BOD removal expressed as the percent BOD remaining in the effluent has been found to follow a first order exponential decay expressed mathematically as

$$\frac{ds}{dt} = -k'S \quad \text{---- (1)}$$

Which by rearranging and integrating yields

$$\frac{S_e}{S_1} = e^{-k't} \quad \text{----(2)}$$

Where S_e = Effluent BOD mg/l
 S_1 = Influent BOD mg/l
 k' = Removal rate constant
 t = Residence time (min)

But residence time

$$t = CD/L^n \quad \text{-- -- (3)}$$

Where D = Filter depth (m)
 L = hydraulic loading ($\text{m}^3/\text{min} \cdot \text{m}^2$)
 c, n = constants which are function of the filter medium and specific surface.

Substituting 3 into 2 gives

$$\frac{S_e}{S_1} = e^{KD/L^n} \quad \text{---- (4)}$$

Where $K = -k'c$

Equation 4 is the basic equation that describes the trickling filter, providing a relationship between the dimensionless BOD (S_e/S_1), the filter depth (D) and the hydraulic loading (L). The parameter k is a function of the biodegradability of the substrate while c and n depend on the packing medium.

Determination of constants of the filter (k and n)

Taking the $\log_e$ of both sides of equation 4, gives

$$\log_e \frac{S_e}{S_1} = KD/L^n \quad \text{-- -- (5)}$$

hence a plot of $\log_e \frac{S_e}{S_1}$ against D is a straight line of slope k/L^n .

$$\text{slope (R)} = k/L^n \quad \text{-- -- (6)}$$

Taking the $\log_e$ of both sides of 6 gives

$$\log_e R = \log_e k - n \log_e L$$

So that a plot of $\log_e R$ against $\log_e L$ gives a straight line of slope = n and intercept of $\log_e k$ from which k and n may be obtained.

Model Verification Experiments

Design and Assembling of the Trickling Equipment

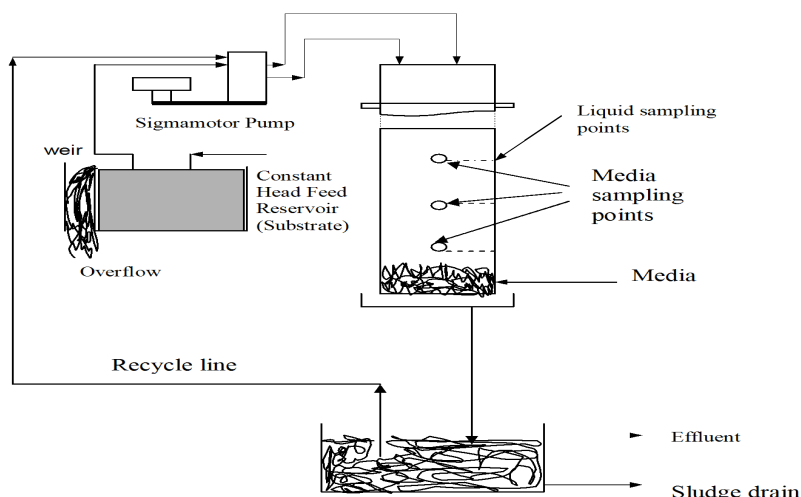


Fig. 1: Experimental Setup of Bench-Scale Trickling Filter

The bench scale trickling filter was assembled as shown in figure 1. It consists of the 1.8 m vertical plexi-glass column; about 20cm diameter containing three sampling ports spaced 2cm apart with a perforated plates on top for fluid distribution and a settling tank at the bottom for sludge collection. The overflow from the settling tank constitutes the effluent stream. The feed line passes through a sigma motor pump to which the recycle line from the settling tank is also connected. Fresh feed is contained in a constant head reservoir fitted with an overflow weir. The filter was operated in both single pass and recycle modes depending on the degree of treatment realized during the pass. A system (not shown in fig. 1) makes it possible to back-mix the contents of the filter where it becomes necessary to dislodge the accumulated microbial flocs as a result of clogging, that is when the effluent flow rate diminishes appreciably. The filter was packed with synthetic materials (plastic) to a depth of 4.5 m. The material has been characterized to provide a specific surfaces area of $22.96 \text{ m}^2 / \text{m}^3$ of bulk volume.

Samples Preparation

All the samples tested were obtained fresh from the platform waste water line and tested immediately after collection.

Determination of Chemical and Biological Parameters

The BOD_5 was obtained by incubating the sample at 20°C for 5 days and monitoring the decreases in oxygen concentration. The PH was measured using an

Orion pH meter calibrated at pH 4.0 and 9.0 with the appropriate buffer solutions. The total organic carbon (TOC) was determined with a carbon analyzer (Beckmans, USA). Total Kjeldahal nitrogen was measured by the improved Kjeldahal method (AOAC, 1980a), phosphorus by the spectrophotometric molybdovanadophosphate method (AOAC, 1980b) after calibration with standard orthophosphate solutions. Samples of influent and effluent streams from both Depurator and the Red fox plants were tested at various flow rates. Suspended solids were determined after centrifugation at 3000 rpm for 10 minutes decanting the top liquid and drying the solids produced, while faecal coliform was counted after incubation of the serially diluted sample at 37°C for 24 hours on Mac Conkey agar.

RESULT AND DISCUSSION

Chemical and Biological Parameters

The oil contents of sampled collected from the WEMCO depurator operating at four different flow rates are shown in Table1 for both the influent and effluent streams, while Table 2 shows the BOD_5 values for the Red Fox plant. The results for suspended solids, faecal coliform, TOC, pH, C_{12} , TKN, TP (total phosphorus) for the effluent from the Red Fox are also shown in Table 4.2. The figures obtained showed that the Wemco depurator effluent with chemical treatment gave a better percentage reduction of oil, although the chemical used in the treatment also have their own side effects on the environment, while effluents without

chemical additives had low percentage oil reduction. The effluent from the Wemco Depurator is mainly responsible for low BOD reduction in the trickling filters (Table 3.) because the oil from this effluent forms a film round the packing; and this reduces the bacteria activity around the filter media. The effluent from the red fox plant show that for the four week period of tests BOD₅ in mg/l gradually fell from above 45 to 38, suspended solids remained relatively content at about

140mg/l while the faecal coliform (per 1000 mg/l) was within a reasonable and manageable range of 185 - 205 , and the pH value was normal.

The residual chlorine was fluctuating and mostly below the recommended level of 0.1 mg/l given by FEPA. This confirms that the effluent being discharged from this unit has not received adequate treatment and disinfection.

Table 1: Oil Content for WEMCO Depurator

Flow rate (m ³ /hr)	Oil content (ppm)		REMARK
	INFLUENT	EFFLUENT	
70.22	95	2	Influent treated With biocide and corrosion inhibitor
	75	4	
	75	4	
	95	3	
	115	4	
24.51	206	20	Influent not treated with chemicals
	104	20	
	252	0	
	176	10	
	200	20	
	190	10	
34.12	300-420	0 -10	Influent treated with chemicals
53.0	300-420	0-18	No chemical treatment

Table 2: Characteristics of Effluent from the Red Fox Plant

WEEK	BOD ₅ (mg/l)	SS (mg/l)	FAECAL COLIFORM (per 1000 mg)	pH	RESIDUAL Cl ₂
1	45	145	200	6.2	0.5
2	48	140	205	6.8	0.2
3	40	140	200	6.5	0.4
4	36	130	105	7.0	1.0

Other Parameters

TKN	1	-	600 mg/l
TOC	150	-	250 mg/l
TP	19	-	500 mg/l

Table 3: BOD Reduction at Various Hydraulic Loading for Increasing Depths of Packing

D: DEPTH, M.	HYDRAULIC LOADING; (m ³ /(min) m ²)			
	L = 0.041	L = 0.081	L = 0.122	L = 0.163
D = 0.45m	2.3417	2.7489	2.9729	3.0951
D = 0.90m	1.3643	1.8734	2.1584	2.3213
D = 1.35m	0.3869	1.2625	1.5516	1.7512
D = 1.80m	0.4602	0.8552	1.484	1.3358

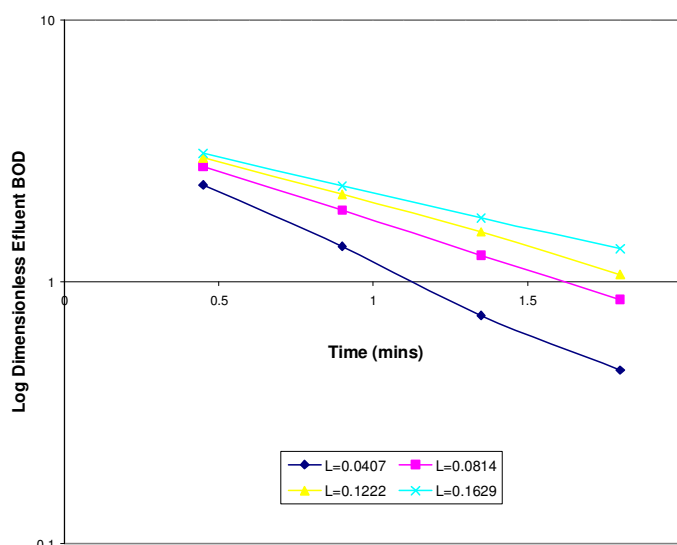


Fig 2: Variation of Log Dimensionless Effluent BOD with Dept of Pavcking for various Hydraulic loading

Table 4: Determination of k and n for filter

L (m ³ / min. m ²)	ABSOLUTE VALUE OF SLOPE (R) from figure 2
0.041	0.567
0.082	0.441
0.122	0.250
0.163	0.380

The graphs used to obtain the values of the slope in Table 4 are shown in Figs 2.

When the effluent underwent the secondary treatment in the trickling filter, the microbes contained therein form flocs around the packing material, which acts as a cleansing process in removing the coliforms, so that, the overflow from the settling tank is virtually free of such organisms thereby making the issue of chlorine disinfection irrelevant. The oil that comes from the Wemco effluent has however proved more difficult as the organism in the activated sludge in the filter have not appreciably removed this oil. As shallow depths, the BOD removal in the trickling filter is higher than further down, showing that the trickling filter is higher than further down, also showing that the effective depth for all hydraulic loadings experimented was between one and two meters for more than 50% of the removal attainable in the test trickling filter system. At the depth of 1 meter approximately 3.5% BOD reduction was attained at the hydraulic loading of 0.1 m³/min.m². While only BOD reduction was achieved at the depth of about 8m. This demonstrates that the active part of the trickling filter is close to the top. This observation is clearly illustrated in figure 4.1 where the % age BOD removed decreased sharply as the packing depth increased.

Performance Characteristic of the Bench-Scale Trickling Filter

From the experiments, the BOD₅ reduction was obtained for samples taken at four depths of 0.45, 0.9, 1.35 and 1.8 meters and from the slopes, the values of k and n were obtained as described below.

The performance of the trickling filter is characterized by the values of the slope of the graph of log_e (BOB Reduction Coefficient) against the depth of the packing material which is directly related to the thickness of the biological active material through which the wastewater has passed in the filter. This graph is presented in figure 2 for each four hydraulic loadings used in this study. The slopes were steep for all the hydraulic loadings tested, showing that the biological active material is efficient in the reduction of the BOD of the waste water. From the plot given in figure 2, the slopes of the curves produced the values in Tables 4, which when plotted according to equation 6, yields the values of 0.038 and 0.9 for k and n respectively.

From our study, mathematical relation evolved that helps us to predetermined the parameters such as required filter Area, filter diameters to cope with specific hydraulic loadings, if not appropriately determined to watch area of filter, and filter diameter, results in unwanted low efficiencies which result from clogging. Trickling filters with recycling proves more efficient at higher hydraulic loadings without clogging. However, if economic considerations would not let us

consider recycling systems, then weekly back-flushing, i.e. reversal of flow path will help in preventing clogging and eventual odour production.

The constants $n = 0.9$ and $k = 0.038$ are reasonable for the type of filter material used and the amount of available void spaces inbetween floe, or pack material.

It is recommended therefore, that any particular media material (since void spaces within the material would depend on the nature of the packing); chinked, rocks or plastic, the constants n and k must be determined, in order to know the required surface and the order of packing necessary to attain any particular BOD removal efficiency.

Generally, for BOD removal efficiencies of about 60%, it is usually found that trickling filters are more economical than activated sludge process; in particular for small flow rates of waste water.

It has been found that presence of oil on the media material chokes the slime material of oxygen and this reduces the efficiency of the bacteria in the process of breaking down the wastes. Such stubborn pollutants will require further studies to design an equipment specific method of removal.

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