An Assessment of Effluent Quality From Selected Small-Scale Palm Kernel Processing Industries In Ibadan, Nigeria

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Abstract

Oil palm (Elaeisguineensis) is an economic plantation crop in Nigeria and other southern countries of West Africa.An assessment of the quality of effluent in four selected small-scale palm kernel processing industries was conducted in Ibadan, Nigeria comprising of Akinyele, Ibadan North-East, Oluyole and Ibadan South-West LGAs. The specific objectives were to examine the nature of effluents generated from these industries operated as batch processes which are scattered in several parts of the city. Triplicate samples of effluent were collected from each of the four study locations. This was done during the day at the end of each production batch. Soil samples were also collected from each site and labeled appropriately according to their locations before carrying out laboratory tests. The soil samples were collected from 0-10cm depth with a trowel. Physicochemical characteristics were determined in a dozen each of wastewater and soil samples obtained from sampled locations within and outside the four industries studied. Comparison of the investigated physicochemical parameters with the standard limits of effluent guidelines revealed that the wastewaters were highly concentrated and soil samples were highly contaminated. For instance, high oil and grease contents in the soil samples ranged from 1,389 mg/kg to 1,671 mg/kg. Finally, it was concluded that there is need to clamor for effective management of effluents generated from these industries to reduce the quantities of pollutants being discharged into the environment.

Keywords — *Palm kernel oil effluent, soil quality, water quality, system production, Nigeria*

I. INTRODUCTION

The problem of waste proliferation has long been a theme in the discourse of environmental management. It has remained a challenge right from the existence of humans due to its implications for health and environmental sustainability.

Oil palm processing generates variety of wastes such as solids, liquids and gases. It is usually carried out using appreciable amounts of water in mills where oil is extracted from palm fruits. During extraction, about half the water results in Palm Oil Mill Effluent (POME), i. e., liquid waste. Okwute and Isu [1] and Wu *et al.* [2] estimated that for every tonne of crude palm oil produced, about 5 to 7.5 tonnes of water end up as POME.

In Nigeria's oil palm industry, most of the POME produced by small scale traditional operators undergo virtually little or no treatment, and are subsequently discharged into the environment to the detriment of both natural and human resources.

This POME pollutes streams, rivers and surrounding land [1]. The rivers then turn murky, smelly and slimy; and in many occasions, fish and other aquatic organisms get killed. Local residents are also denied of the availability of water sources for domestic use as well as for fishing [3]. This prompts the need for an assessment of the possible ecological effects of effluents from oil palm industries on the environment. This study, therefore, examined the impact of effluent from small-scale palm kernel processors in Ibadan, Nigeria.

II. LITERATURE REVIEW

A. Oil Palm in the Value Chain

The oil palm tree (*Elaeisguineensis*) is commonly found in the humid tropics of West Africa. It is one of the major oil crops in the world; producing more oil than all other plants oil [4]. Oils obtained from its fruits are used mainly for cooking, producing margarines, shortenings, etc. [5]. They are important sources for edible oils, and are used as raw materials for production of cosmetics, detergents as well as biodiesel [6];[7].

It would also be interesting to note that as far back as 1848, palm oil gradually replaced slave trade. Oil palm processing production activities were entirely traditional until the middle of the twentieth century.

B. Effluents from Oil Palm Processing

Oil palm processing generates wastes such as Empty Fruit Bunches (EFB), Palm Oil Mill Effluent (POME), Palm Kernel Cake (PKC), Palm Kernel Shell (PKS) and fibre. Every tonne of crude palm oil produced results in emission of about 46 cubic meters of methane which corresponds to 384 cubic meters of $CO_2$and is considered as a major Green House Gas of concern [8]. It is vital to add that the raw POME has biochemical oxygen demand (BOD) values averaging 25,000 mg/L, making it about 100 times more hazardous than the normal domestic sewage [9].

It is interestingly realized that the oil palm industry is one of the largest polluters in the world. Malaysia contributes roughly 83% of total pollution and the case is same for other countries with vibrant oil palm processing industries [10]. Ensuring effective and sustainable management of effluent from these industries is important while grossly enjoying the attendant benefits from the resultant production processes [10].

III. MATERIALS AND METHODS

A. Study Population and Sample Size

The target population for this study consisted of factory owners/managers of the palm kernel processing facilities, their workers and residents of host communities where the processing facilities existed. There were 1,427 respondents, as enumerated during pre-appraisal field visits to the respective study locations.

The sample size of 313 was deduced from the target population 1,427 using the formula recommended by Yamane (1967). This represents 21.93% of the total population. The sample size comprised owners of, and workers in the selected industries (4 owners and 17 workers in total) including; 5 workers from the industry at Igbaroola community (**Site A**) in Akinyele LGA, 4 workers from the industry at Gbelekale community (**Site B**) in Ibadan North–East LGA, 5 workers from the industry at Podo community (**Site C**) in Oluyole LGA, 3 workers from the industry at Eyin Grammar (**Site D**) at Ibadan South–West LGA and 73 residents from each of the four host communities (4 host communities x 73 residents= 292 respondents). The Stratified sampling technique with equal distribution was employed to arrive at 73 residents per host community.

Yamane (1967) sample size formula is given as:

$$n = \frac{N}{\{1+(N \times e^2)\}} \text{where;}$$

n= sample size; N= total population; e= error margin (at 95% confidence level)

Table 1. Numbers of Mill Owners, Workers and Residents Surveyed in Each of the Four Locations.

Site	Mill Owners	Mill Workers	Residents	Total
Igbaroola (A)	1	5	73	79
Gbelekale (B)	1	4	73	78
Podo (C)	1	3	73	79
EyinGrammar (D)	1	3	73	77
Total	4	17	292	313

B. Samples Collection

Triplicate samples of effluent were collected from each of the four study locations. Collection was done during the day at the end of each production batch using the batch sampling technique. The objective of the sampling process was to analyze the nature of effluents generated by these industries. The effluent samples were labeled with subscripts 1, 2 and 3 to create an avenue for the calculation of mean values. The qualities of the samples were examined as per the methods described in "Standard Methods" [11].

C. Physico–Chemical Characteristics of Effluents from the Selected Industries

Table 2 shows an overview of the physicochemical characteristics of thewastewater samples collected from the four selected palm kernel processing industries while Table 3.21 shows effluent quality guidelines recommended by the Malaysian Department of Environment (DOE) [12]. Furthermore, Table 2 shows a comparison of mean values for the effluent test results with DOE (1999) limits.

Table 2. Physico–Chemical Characteristics of Effluents from the Selected Industries

Parameter	**Sample**											
	A_1	**A_2**	**A_3**	**B_1**	**B_2**	**B_3**	**C_1**	**C_2**	**C_3**	**D_1**	**D_2**	**D_3**
Temperature (°C)	35	30	30	31	33	30	31	35	29	34	37	31
pH	4.16	4	4.08	4.13	4.16	4.16	5.02	5	5.03	4.65	4.6	4.47
Conductivity(ms/cm)	9,540	9,640	9,610	10,030	10,130	10,030	2,210	2,210	2,230	3,030	5,080	4,730
TDS (mg/L)	5,710	5,780	5,770	6,030	6,080	6,010	13,240	13,250	13,340	1,820	3,070	2,840
TSS(mg/L)	80.3	72.5	73.9	72.9	85.1	78.3	104.6	95.6	112.5	64	74.5	68.1
DO(mg/L)	0.66	0.47	0.29	1.26	0.24	0.1	0.59	0.29	0.99	3.29	0.47	1.01
BOD(mg/L)	2,790	2,945	3,029	2,975	2,970	2,895	2,930	3,130	2,745	2,870	3,060	2,765
COD(mg/L)	4,185	4,417.50	4,543.50	4462.5	4,455	4,342.50	4,395	4,695	4,117.50	4,305	4,509	4,147.50
Oil & grease (mg/L)	23.15	25.28	14.95	28.76	29.13	16.21	26.55	21.86	25.18	27.87	13.89	29.35

Table 3. Effluent Quality Guidelines

Parameter	DOE	WHO Limits
	Limits for Oil Palm Mills	for Effluent Quality
pH	5-9	6.5-9.5
Total Dissolved Solids (mg/L)	*	1000
Total Suspended Solids (mg/L)	400	30
Biochemical Oxygen Demand	100	50
(BOD; 3-Day, 20oC) (mg/L)		
Chemical Oxygen Demand (mg/L)	*	150
Oil and Grease (mg/L)	50	*
Temperature(o^C)	45	*

Source: Malaysian Department of Environment [12]

Table 4. Comparison of Mean Values for the Effluent Test Results with DOE Limits

Parameter	A	B	C	D	DOE (1999) Limits
Temperature (°C)	32±0.9	31±0.2	32±0.5	34±0.3	45
pH	4.08±0.5	4.15±.0.2	5.02±0.2	4.57±0.5	5–9
Conductivity(ms/cm)	9596±148	10063.±112	2217±.132	4280±305	*
TDS (mg/L)	5753±155	6040±310	13277±521	2576±120	*
TSS(mg/L)	75.6±5.5	78.8±6.6	104.2±11.5	69±9.5	400
DO(mg/L)	0.47±0.06	0.53±0.04	1.87±0.03	1.59±0.2	*
BOD(mg/L)	2921±147	2947±110	2935±125	2898±114	100
COD(mg/L)	4382±224	4420±210	4401.5±115	4320.5±215	*
Oil & grease (mg/L)	21.13±0.9	24.70±0.55	24.50±1.5	23.70±0.5	50

IV. RESULTS AND DISCUSSIONS

A. pH and Conductivity

The pH values of collected wastewater samples ranged from 4.0 – 5.0 (for samples A_2 and C_3 respectively). Those of the other effluent samples were also within the range of 4.0 – 5.0. These values show a fairly high degree of acidity. The pH has a profound effect on the rate of microbial growth. Short–term exposure (exposure lasting less than one minute) to extreme pH causes significant microbial destruction. Some process effluents fall slightly on the basic extreme with pH values ranging between 9.0 and 10.5. Due to the fact that bacteria generate CO_2 (an acidic gas) as a by–product of metabolism, they tend to self–regulate pH to some extent, as long as the pH is not so severe as to completely stop their metabolism.

Conductivity is a general indicator of water quality. It is a function of the amount of dissolved salts, and can be used to monitor processes during wastewater treatment that cause changes in total salt concentration. The results obtained from the analysis showed the limits of the conductivity values ranging between 2, 210µs/cm (for both samples C_1 and C_2) and 10, 130µs/cm (for sample B_2). It was observed that samples collected from site B had the highest conductivity values (10,030, 10,130 and 10,030µs/cm respectively).

B. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

The TDS content of wastewater samples collected from the selected industries were within the range of 1,820mg/L (for sample D1) to 13,340mg/L (for sample C3). The TDS content of the other effluent samples ranged between 1,820mg/L to 13,340mg/L. It can be observed that wastewater samples collected from Site C had considerably high TDS content, while those obtained from Site D had low TDS contents. The TDS content of wastewater samples collected from the four study locations, especially those from Site C, can be said to be on the high side, in comparison with the limits recommended by World Health Organization (1996) guidelines. According to the World Health Organization (1996) guidelines, TDS content of effluents are not supposed to exceed 1000mg/L.

Also, in 1985, the United Nations department of technical cooperation for development categorized domestic effluents with TDS contents of 850mg/L as concentrated, 500mg/L as medium, and 250mg/L as minimal. An elevated TDS concentration does not mean that such wastewater necessarily constitutes a health hazard. The implication of this is that it may be aesthetically repulsive or capable of causing nuisance.

The physico–chemical parameter, total suspended solids, gives a measure of turbidity. It is one parameter which may be visually detected. Unlike pH and other indicators of water quality, visual assessment may offer insight into the levels of TSS. Suspended solids cause water to appear milky or muddy due to the light scattering effects of very small particles in the water. Sometimes, there could be colour interference, but coloured waters may also appear clear. In most instances, the presence of suspended solids is observed firstly before anything else. Polluted waters are mostly turbid and an improvement in the degree of pollution may be marked by greater clarity. The TSS contents of the effluent samples ranged from 64.0mg/L (the lowest TSS content observed for sample D_1) to 112.5mg/L (the highest TSS content observed for sample C_3). The other effluent samples had TSS contents within the range of the two aforementioned values, i.e., 64.0mg/L and 112.5mg/L. It was observed that samples collected from Site C had the highest content of TSS while samples from Site D had the lowest TSS content

C. Dissolved Oxygen, Biochemical Oxygen Demand & Chemical Oxygen Demand

The results obtained for Dissolved Oxygen (DO) contents of the analyzed wastewater samples showed values ranging from 0.10mg/L (the lowest observed DO content for sample B_3) to 3.29mg/L (the highest observed DO content for sample D_1). The DO contents for the other effluent samples were within the range of these two aforementioned values (i.e., 0.10–3.29mg/L). Dissolved oxygen concentrations are constantly influenced by processes such as industrial activities, diffusion, aeration, photosynthesis, respiration and decomposition.

Dissolved oxygen levels fluctuate with temperature, salinity and pressure changes. As such, they can range from less than 1mg/L to about 18mg/L depending on how these factors interact.If DO concentrations drop below a certain level, fish mortality rates tend to be on the rise. Sensitive freshwater fish like salmon cannot even reproduce at levels below 6mg/L. In the ocean, coastal fish begin to avoid areas where DO levels fall below 3.7mg/L, with certain species abandoning an area completely when levels fall well below 3.5mg/L.

Biochemical oxygen demand is the amount of oxygen required for the microbial metabolism of organic compounds in water. It measures the amount of organic compounds in water. This demand occurs over periods of time depending on temperature, nutrient concentrations, and the enzymes makeup of microbial populations. The concentrations ranged from 2,745 mg/L (the lowest observed BOD concentration for sample C_3) to 3,130 mg/L (the highest observed BOD concentration for sample C_2). BOD concentrations for the other effluent samples ranged between 2,745–3,130 mg/L. These values are significantly very high; considering the fact that most pristine rivers have a five-day carbonaceous BOD value below 1 mg/L. Moderately polluted rivers may have BOD values ranging from 2 to 8 mg/L. Efficiently treated municipal sewage, using a three-stage process, would have a value of about 20 mg/L or lesser (DoE, 1999). BOD values for untreated sewage varies, but averages around 600 mg/L in Europe and can be as low as 200 mg/L in the U.S., or in areas with severe ground– or water infiltration.

Chemical Oxygen Demand (COD) helps to indirectly measure the amount of difficultly degradable organic compounds in water. Most COD applications can determine the amount of organic pollutants found in all kinds of water, thereby, making the parameter a useful measure of water quality. COD is similar to BOD, in that they both measure the amount of organic compounds (biodegradable and difficult to degrade) present in water. COD is however, less specific; when biological waste management is concerned.

As shown in the results, COD content of the effluent samples ranged between 4,117.5mg/L (the lowest observed COD concentration for sample C_3) and 4,695 (the highest observed COD concentration for sample C_2). It can be observed also that both the lowest and highest values of COD were obtained for samples collected from Site C. The COD concentrations for the other wastewater samples were within the range of 4,117.5–4,695mg/L. In comparison with limits recommended by WHO, these concentrations are higher. The guidelines of World Health Organization stipulates a limit of 150mg/L. However, in countries such as Switzerland, COD range must be between 200 and 1000mg/L before such wastewater can be discharged into the environment.

D. Oil and Grease

The levels of oil and grease recorded for the effluent samples ranged from 13.89mg/L (the lowest value observed content for sample D_2) to 29.35mg/L (the highest content observed for sample D_3). The other oil and grease concentrations were within the range of 13.89–29.35mg/L. It can be observed also that the oil and grease content of the effluent samples were within limits recommend by DoE (1999). DoE (1999) recommends oil and grease contents of 50mg/L for effluents generated from oil–palm based industries.

E. Management Practices for Effluents Generated from the Selected Industries

The mill owners view wastewater treatment as an unproductive task which is expensive and mostly give it the lowest priority in their maintenance budgets. The common method employed by the industries is an improvisation of the open pond system typified by the use of storage containers instead of ponds. Steam is sometimes used to heat oil–containing wastewaters in the oil trap to improve oil separation and release.

The oil that floats on the wastewater surface is skimmed–off manually and recovered, prior to being stored in metallic drums for reuse.

V. CONCLUSION

The study aimed at investigating the quality of effluents from selected palm kernel processing industries in Ibadan, Nigeria. In Nigeria, palm kernel effluents are discharged into the environment in its raw form, most especially by small-scale operators. Palm kernel processing requires voluminous quantity of water for processing, of which a substantial amount ends up as effluents. In Nigeria, most industrial effluents are discharged into the environment without adequate treatment, where they constituterisks due to stemming from their high pollution potential (in terms of BOD, COD, and oil and grease content).

Some of the major obstacles to the adoption of cleaner technologies in the management of effluent in small-scale oil–palm based cottage industries have been the challenging accessibility to sustainable technologies in terms of costs and technical know-how, and the austere economic conditions being experienced in the country. These are the major pointers as to why effluents have been treated and handled by operators as waste products in preference to resources.

Effective in–plant process control and good housekeeping measures are most essential in helping to minimize pollutant load in effluents during treatment. Control of water usage; oil clarification temperature, oil spillages and leaks are critical in the management of such waste. Environmental best practices in the management of effluents entail proposed by DOE [12].

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