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QUALITY ASSESSMENT OF VEGETABLE OIL EFFLUENT DISCHARGED INTO A SOUTHEASTERN NIGERIA RIVER

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ABSTRACT: *The aim of this study was to assess the effluent quality in relation to national effluent standards and determine its pollution potential on the receiving Ossah River. Aspects of the physico-chemical characteristics were studied between January and June 2018 in 3 stations. Ten (10) parameters were evaluated using standard methods and compared with Nigerian effluent standard. The mean values recorded were – pH (5.37), Total suspended solids (13.70 mg/l), dissolved oxygen (5.05 mg/l), biochemical oxygen demand (2.65 mg/l), chemical oxygen demand (14.00 mg/l), nitrate (2.82 mg/l), phosphate (2.28 mg/l), sulphate (0.57 mg/l), chloride (69.3 mg/l) and oil and grease (0.1 mg/l). Most of the parameters evaluated were within acceptable limits and indicated that the effluent has low pollution potentials. The Biodegradability Index showed that effluent was not biodegradable and confirms the low pollution potential. However, pH and Total suspended solids deviated from the set acceptable limits with high pollution potentials. This study concluded that the quality of effluent discharged into Ossah River is good but need to be monitored periodically.*

KEYWORDS: Effluent, Vegetable Oil, Pollution Potential, Biodegradability, Limits.

INTRODUCTION

Rivers are systems that carry a significant load of materials in dissolved and particulate phases from both natural and anthropogenic sources in one direction (Zhang *et al*., 2010). Anthropogenic activities result in significantly decrease of surface water quality of aquatic systems in watersheds (May *et al*., 2006, Amah-Jerry *et al*., 2017). The physical and chemical characteristics of water bodies affect the species composition, abundance, productivity and physiological conditions of aquatic organisms (Anyanwu *et al*., 2013; Akaahan *et al*., 2014; Okorafor *et al*., 2014). Rivers in a watershed play a major role in assimilating or carrying off municipal and industrial wastewater and runoff from agricultural land (Wang *et al*., 2007). Industrialization is considered a necessity for the development of a country's economy, through the establishment of plants and factories (Ho *et al*., 2012). However, the waste or by-products discharged from them are destructive to the environment; contaminating the surface water, ground water and soil (Adakole, 2011). The wastewaters are not safely treated because of the lack of highly efficient and economic treatment technology (Ho *et al*., 2012) and failure in institutional monitoring and control. The contaminant from the discharge is directly related to the nature of the industry and characterization is important as it is very useful for control and development of treatment processes (Zhong *et al*., 2003). Its characteristics depend largely on the type of oil processed and, on the process, implemented that are high in COD, oil and grease, sulphate and phosphate content, resulting in both high inorganic as well as organic loading of receiving waterbodies (Aslan *et al*., 2009). Refining crude vegetable oils generates large amounts of wastewater (Tezcan *et al*., 2009). In the vegetable oil industry, wastewaters mainly come from the degumming, deacidification and deodorization and neutralization steps (Kale *et al*., 1999). In the neutralization step, sodium salts of free fatty acid (soap stocks) are produced whose splitting through the use of H_2SO_4 generates highly acidic and oily wastewaters (Decloux *et al*., 2007). Vegetable oil processing wastewater generated during oil washing and neutralization may have a high content of organic material and, subsequently, a high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Wastewater may also have a high content of suspended solids, organic nitrogen, and oil and fat, and may contain pesticide residues from the treatment of the raw materials (World Bank Group, 2007). According to Ikhu-Omoregbe *et al* (2001), most of the effluent is generated during refining and the washing process after neutralization and the discharge of poor-quality effluent by vegetable oil industries poses a threat to water resources. Vymazal (2014) also reported that vegetable oil production sectors generate high levels of oil and grease. High phosphorus levels may also be found, in particular when large quantities of phosphoric acid are used in the de- gumming process of vegetable oils, or in the cleaning (Herold *et al*., 2000; Dhouib *et al*., 2006; Coskun *et al*., 2010; Jail *et al*., 2010). Effluents discharged into natural ecosystems contribute to the change in abiotic factors in the environment (Kherdr and El-Demerdash, 1996; Robach *et al*., 1996; Ghavzan *et al*., 2006). Chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5) found in untreated effluents from food processing industries (including vegetable oil processing) are usually high (Vymazal, 2014), with levels that maybe10–100 times higher than those of domestic wastewater (Benyakhlef *et al*., 2007, Meul *et al*., 2009, Ebenezer *et al*., 2014). Given that these various threats affect aquatic environments, an assessment of the effluent quality was necessary to preserve aquatic resources. The aim of this study was to assess the effluent quality in relation to national effluent standards and determine its pollution potential on receiving Ossah River.

MATERIALS AND METHODS

Description of Study Area and Sampling Station

The vegetable oil processing factory is located in Ossah Community, Umuahia, along Mission Hill Road and discharge into Ossah River through an earth drain (Fig. 1). The factory produces vegetable oil by refining palm oil. The effluent was collected along the drainage channel, 170m to the effluent discharge point (EDP) into the river. Ossah River is used by the community for drinking, bathing, washing, swimming and other domestic activities. The dominant plants were Raffia palm (*Rafia africana*) and bamboo (*Bambusa vulgaris*).

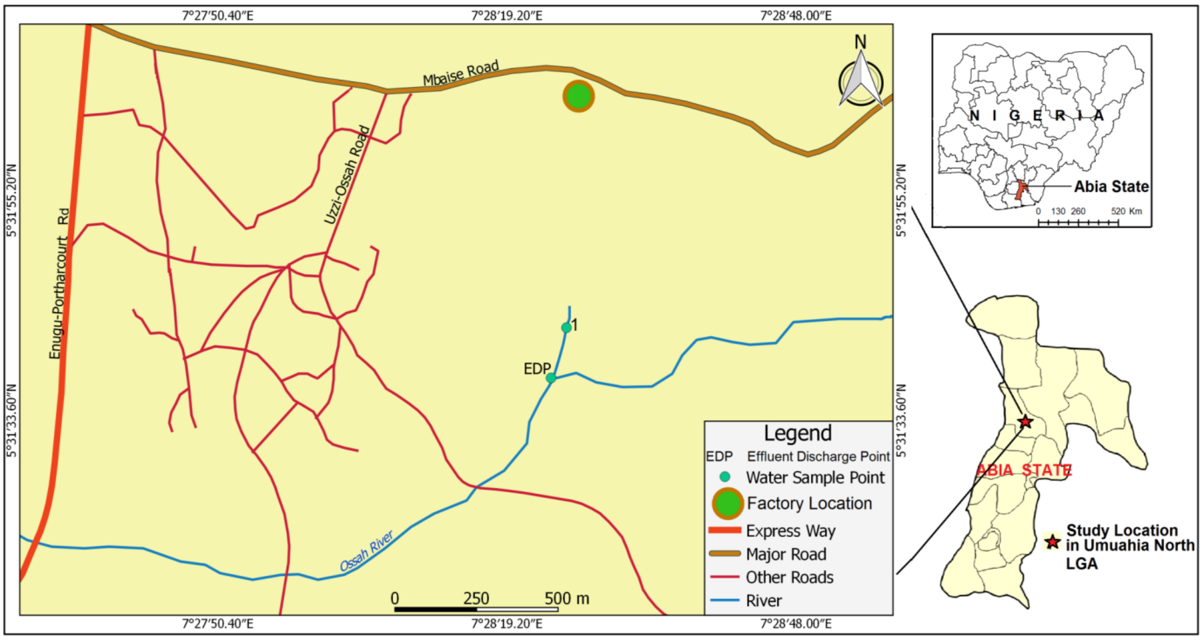

Fig 1: Map of Umuahia, Southeast Nigeria Showing the Effluent Sampling Point.

Samples Collection and Analyses

The effluent samples were collected from the drainage channel (Point 1) monthly from January to June 2018. One litre water sampler was first rinsed with river water before the sample collection and then transferred into sterilized plastic bottles. The samples were transported to the laboratory in ice chests. The collected samples were analysed using standards methods described by American Public Health Association (APHA) (1998). The results were summarised using Descriptive Statistic Package of Microsoft Excel while One-Sample test described by Ogbeibu (2014) was used to test for significant difference between the effluent characteristics and National Effluent Standard. Pearson Correlation analysis was also carried out to determine the relationships between the parameters evaluated at 0.01 level (2-tailed) (Nair *et al.*, 2005). A correlation of +1 indicates a perfect positive relationship between two variables. A correlation of −1 indicates that one variable changes inversely with relation to the other. A correlation of zero indicates that there is no relationship between the two variables (Kapil *et al.*, 2009). Biodegradability index (BOD/COD) was used to measure the effluent's chemical stability/resistance to biological degradation.

RESULTS AND DISCUSSION

The composition of wastewater from the same effluent may vary widely from day to day (Chatoui et al., 2016) and these fluctuations may also be attributed to different types of oils processed and to operating conditions and processes (Verla *et al.*, 2014). Positive and significant correlations were recorded among the physico-chemical parameters evaluated. This overall strong correlation coefficient may indicate their common source of entry (Nasrabadi, 2015). The summary of the effluent physicochemical characteristics and effluent standards are presented in Table 1. The pH values ranged from 4.9 to 5.8. The highest value was recorded in January 2018 while the lowest was recorded in April 2018. All the pH values were acidic and significantly lower than ($P < 0.05$) than effluent limit. The pH is an important indicator of water quality because it controls a number of other chemical processes (Fakayode, 2005). As part of refining process, sulphuric acid is added to the soap stock to cause separation of free fatty acid from the medium. This is the major cause of the effluent being acidic (Decloux *et al*., 2007; Verla *et al.*, 2014). Verla *et al* (2014) recorded a lower mean value of 4.67 in Port Harcourt, Nigeria; Adakole (2011) recorded a higher mean value of 9.15± 0.55 in Zaria, Nigeria while Chatoui *et al* (2016) also recorded higher values of 10.01 – 10.23mg/l in Casablanca, Morocco. Radojevic and Bashkin (1999) observed that extremes of pH are associated with pollution. Below pH 6.5, some species experience slow growth and at lower pH, the organism's ability to maintain its salt balance is affected and reproduction ceases (Lloyd, 1992).

Table 1: Physicochemical Characteristics of the Effluent Samples

Parameters	Units	Effluent Concentration	FMEnv. 2011*	P-Value
pH	-	5.37±0.16 (4.9 – 5.8)	6.5 – 8.5	P < 0.05
Total Suspended Solids	Mg/l	13.7±6.95 (3.1 – 47.3)	0.75	P > 0.05
Dissolved Oxygen	Mg/l	5.05±0.34 (3.5 – 5.9)	4	P < 0.05
Biochemical Oxygen Demand	Mg/l	2.65±0.28 (1.8 – 3.8)	6	P < 0.05
Chemical Oxygen Demand	Mg/l	14.0±1.15 10.3 – 18.2	30	P < 0.05
Nitrate (NO_3)	Mg/l	2.82±0.63 (1.41 – 5.84)	4	P > 0.05
Phosphate (PO_4)	Mg/l	2.28±0.20 (1.78 – 3.15)	3.5	P < 0.05
Sulphate (SO_4)	Mg/l	0.57±0.04 (0.44 – 0.70)	500	P < 0.05
Chloride (Cl)	Mg/l	69.3±4.73 (44.8 – 77.2)	350	P < 0.05
Oil and Grease	Mg/l	0.1±0.03 (0.05 – 0.24)	0.1	P > 0.05

**National Environmental (Surface Water and Groundwater Quality Control) Regulations (2011).*

The total suspended solids (TSS) ranged between 3.1 and 47.3 mg/l. The highest value was recorded in January 2018 while the lowest was recorded in June 2018. The TSS values were higher than standards but not significantly different (P > 0.05) but lower than values recorded in other studies. Verla *et al* (2014) recorded a lower mean value of 563.6mg/l in Port Harcourt, Nigeria and Chatoui *et al* (2016) also recorded higher mean value of 6419mg/l in

Casablanca, Morocco. Ikhu-Omoregbe *et al* (2001) reported that oil and grease content can affect the level of TSS in the effluent because oils can be measured as TSS depending on the temperature and physical state of the sample. This explains the strong positive correlation between them (0.975) (Table 2). High levels of total suspended solids will increase water temperatures, decrease dissolved oxygen (DO) levels and reduce penetration of light (Bilotta and Braziera, 2008; EPA, 2012). As low as 8 mg/l, TSS can reduce primary productivity in phytoplankton and macrophytes, increase the rate of drift in invertebrates (Rosenberg and Wiens, 1978; Lloyd *et al.*, 1987)

Table 2: Correlation Values of the Effluent Parameters Evaluated

	pH	*TSS*	*DO*	*BOD5*	*COD*	*Cl*	*PO4*	*NO3*	*SO4*	*O&G*
pH	1.000									
TSS	0.500	1.000								
DO	-0.250	0.528	1.000							
BOD5	0.107	**0.781**	**0.842**	1.000						
COD	0.185	0.577	0.481	**0.843**	1.000					
Cl	0.127	0.394	0.434	0.754	**0.967**	1.000				
PO4	0.234	0.760	0.643	**0.948**	**0.958**	**0.885**	1.000			
NO3	0.537	**0.871**	0.548	**0.880**	**0.843**	0.755	**0.933**	1.000		
SO4	0.066	0.219	0.421	0.670	**0.854**	**0.892**	0.745	0.596	1.000	
O&G	0.437	**0.975**	0.467	0.685	0.441	0.224	0.639	0.748	0.076	1.000

Correlation Coefficient (8, 0.01) = 0.765

The dissolved oxygen (DO) values ranged from 3.5 to 5.9 mg/L. The highest DO value was recorded in January 2018 while the lowest was recorded in June 2018. All of the DO values but one was above acceptable limit and significantly different ($P < 0.05$). DO correlated negatively with pH (Table 2). Atama and Mgbenka (2005) recorded lower mean values (1.81 – 3.43 mg/l) from vegetable oil effluent discharged into Mmiriele stream in Nnewi, Nigeria. Dissolved oxygen concentrations lower than 5mg/L could adversely affect aquatic organisms while death of most fish could result at concentrations lower than 2mg/L (Chapman and Kimstach, 1996).

Biochemical oxygen demand (BOD) is an important indicator of the pollution status of a freshwater body (Bhatti and Latif, 2011). The values recorded ranged from 1.8 to 3.8 mg/L. The highest and lowest values followed the same trend as dissolved oxygen. The values were significantly lower than the acceptable limit ($P< 0.05$). BOD correlated positively and significantly with TSS and DO (Table 2). Verla *et al* (2014) recorded a higher mean value of 17.83mg/l mg/l in Port Harcourt, Nigeria while Adakole (2011) also recorded higher mean value of 87.39 mg/l in Zaria, Nigeria. The BOD values recorded in this study point to low pollution potentials of the effluent.

Chemical oxygen demand (COD) is a common parameter used in assessing the oxidation potentials of organic and inorganic materials in water bodies (Chapman and Kimstach, 1996).

The chemical oxygen demand (COD) ranged from 10.3 to 18.2mg/L. The highest and lowest values followed the same trend as DO and BOD. The values were also significantly lower than the acceptable limit (*P*< 0.05). COD correlated positively and significantly with BOD (Table 2). A higher mean value (3959.0mg/l) was recorded in Port Harcourt, Nigeria by Verla *et al* (2014) while Chatoui *et al* (2016) also recorded higher mean value of 39138 mg/l in Casablanca, Morocco.

The biodegradability index value (0.19) was low and fall under category of non-biodegradable (Table 3). Biodegradability index helps in predicting the measure of chemical stability/resistance to biological degradation of organic pollutant in the environment (Chatoui *et al*., 2016) as well as for assessing the degree of the potential pollution when the effluent is released to nearby watersheds (Lai et al., 2011). It is generally considered the cut-off point between biodegradable and non- biodegradable waste (Tchobanoglous *et al*., 2003; Turak and Fsar, 2004). The value recorded was low and fall under the category of non-biodegradable signifying low biodegradable portion and pollution potential. However, the low ratio of BOD_5/COD shows that the biological treatment alone is not enough to obtain satisfying removal efficiency (Aslan *et al.,* 2009). Biodegradable portion in wastewater is responsible for fast bacterial growth, which may lead to the deterioration of water quality in natural waters (Escobar et al., 2001). Verla *et al* (2014) and Chatoui *et al* (2016) recorded values of 0.5 and 0.3 respectively. For the treatment of an effluent by conventional methods such as aerobic or anaerobic digestion the ratio of BOD to COD should be >0.6 (Dahamsheh and Wedyan, 2017; Al-Sulaiman, and Khudair, 2018). However, effluent from the vegetable oil industry usually has its BOD/COD ratio around 0.2 which could cause destruction of micro-organisms useful for the biodegradation (Willey, 2001; Abdallaa and Hammam, 2014).

Table 3: Biodegradability Ratios (BOD/COD) and their indication (Bouknana et al. 2014)

BOD/COD Ratio	Indication
> 0.3	Effluent readily biodegradable
0.2 – 0.3	Effluent medium biodegradable
<0.2	Effluent non-biodegradable

The nutrient values were generally low. Nitrate values ranged between 1.41 and 5.84 mg/L and were not significantly different (P>0.05) from the standard. The highest value was recorded in January 2018 while the lowest was recorded in February 2018. Nitrate correlated positively and significantly with TSS, BOD, COD and phosphate (Table 2). Nitrate values were within acceptable limit except for January 2018, which could be attributed to concentration due to intense evaporation associated with that period (dry season). Adakole (2011) also recorded higher mean value of 102.67 mg/l in Zaria, Nigeria. The low nitrate values indicate low pollution potentials of the effluent on the receiving Ossah River.

Phosphate values ranged between 1.78 and 3.15mg/L and were significantly lower (P<0.05) than the standard. The highest and lowest values also followed the trend of nitrate (NO_3). Phosphate correlated positively and significantly with BOD, COD and Chloride (Table 2). Raw vegetable oils contain phospholipids and in the degumming process, phosphoric acid is widely used for removal of phospholipids and lipoproteins; these induce high phosphate concentration in wastewaters (Chatoui *et al.,* 2016). Related studies elsewhere recorded higher values; Verla *et al* (2014) recorded a mean value of 890.0mg/l in Port Harcourt and Adakole (2011) recorded mean value of 2535.87 mg/l in Zaria both in Nigeria.

Sulphate ranged between 0.44 and 0.70 mg/L and were significantly lower ($P<0.05$) than the standard. The highest and lowest values also followed the trend of nitrate and Phosphate. Sulphate correlated positively and significantly with COD and Chloride (Table 2). In literature, wastewaters are associated with high sulphate contents due to usage of sulfuric acid during degradation of soap stock in the neutralization process (Aslan *et al.*, 2009; Verla *et al.*, 2014). The values of sulphate recorded in this study were very low and of no pollution potential. According to Mutlu and Uncumusaoğlu (2017), that certain level of sulphate is necessary to boost biological productivity of natural waters.

The chloride, on the other hand recorded higher values, ranging from 44.8 to 77.2mg/l, though significantly lower ($P<0.05$) than the standard. The Chloride contents have no pollution potential. The highest and lowest values also followed the trend of nitrate, Phosphate and Sulphate. Chloride correlated positively and significantly with COD (Table 2). Chloride is among the contributors of high pollution load in vegetable oil wastewaters (Chatoui *et al*., 2016). Ikhu-Omoregbe *et al* (2001) recorded a higher chloride range of 5.5 – 315.0mg/l in Bulawayo, Zimbabwe. Inhibition of plant growth, impaired reproduction as well as reduced diversity of organisms in streams can be attributed to high chloride values (United States Geological Survey, 2009).

Oil and Grease ranged from 0.05 to 0.24 mg/l. The highest value was recorded in January 2018 while the lowest were recorded in April and June 2018. It followed the same trend as Total Suspended Solids and not significantly different from standard ($P>0.05$). Oil and grease recorded significant positive correlation with TSS (Table 2). Vegetable oil production sectors generate high levels of oil and grease (Vymazal, 2014; World Bank Group, 2015). The oil and grease content of the effluent were generally low though January and February 2018 values exceeded Nigerian effluent limit but within the 10mg/l set by World Bank Group (2015). These slightly higher values could be attributed to concentration due to intense evaporation associated with that period (dry season). Very high values were recorded in related studies - Ikhu-Omoregbe et al (2001) recorded a range of 1600.0 – 2600.0 mg/l in Bulawayo, Zimbabwe while Chatoui et al (2016) recorded a range of 4010.0 – 5670.0 mg/l in Casablanca, Morocco. The presence of oil and grease in water bodies leads to the formation of oil layer, which causes significant pollution problem such as reduction of light penetration and photosynthesis (Alade *et al.*, 2011). It further hinders oxygen transfer from atmosphere to water medium and this leads to decreased amount of dissolved oxygen (DO) at the bottom of the water and this adversely affects survival of aquatic life in water (Mohammadi and Esmaelifar, 2005). Oil and grease of vegetable oil origin are generally classified as serious type of hazardous pollutants particularly when discharged into aquatic environment where they pose high toxicity to aquatic organisms and other ecological damages to the water bodies (Mendiola *et al*., 1998).

CONCLUSION

Most of the parameters evaluated were within acceptable limits and indicated that the effluent has low pollution potentials. The Biodegradability Index showed that effluent was not biodegradable and confirms the low pollution potential. However, pH and Total suspended solids deviated from the set acceptable limits with high pollution potentials. This study concluded that the quality of effluent discharged into Ossah River is good but need to be monitored periodically.

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