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# Effluent and Receiving Water Quality near Food Processing Industries in Ibadan Metropolis

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**Abstract:** The effluent and receiving water quality from ten food processing industries, comprising beverage, confectionery and oil processing industries, in Ibadan metropolis was investigated. The heavy metal, minerals and physicochemical properties of the effluents and receiving waters were determined using standard methods. Results show that cobalt, chromium, copper, iron, magnesium, manganese, lead and zinc contents range between 0.46-2.75, 0.06-0.11, 0.01-0.02, 0.02-0.06, 0.20-1.81, 0.09-1.38, 0.11-0.14 and 0.07-0.29 mg $L^{-1}$ respectively. Anions (chlorides and nitrates) , cations (phosphate, ammonium), biological and chemical oxygen demand were higher in the effluents. Sodium and potassium were the most predominant minerals in the effluents and receiving waters. Receiving water quality was significantly ($p<0.05$) influenced by effluent discharge by these industries.

**Key words:** Effluents, receiving water, food industries, Ibadan

## INTRODUCTION

The need to process and preserve foods is an integral part of the development process in many countries of the world. With the ease and extended shelf life of industrial product comes the issue of waste generation and management. Industrial waste consists of both organic and inorganic substances. Organic wastes include pesticide residues, solvents and cleaning fluids, dissolved residue from fruit and vegetables and lignin from pulp and paper to name a few. Effluents can also contain inorganic wastes such as brine salts and metals. Industries which use large amounts of water in their processes (chemical manufacturers, steel plants, metal processors, textile manufacturers and fruit and vegetable processing industries) generate waste water containing high concentrations of dissolved organic matter and may be highly alkaline from the use of lye. Run-off from crops contains pesticides, fertilizer and sediment while those from animal production facilities contain bacteria, organic matter, nitrates and phosphates (US EPA, 1980; Anonymous, 2006).

Kakulu (1985) reported that pollutants in the Niger Delta area of Nigeria were the results of the activities of petroleum industries around the area. (Okoye *et. al.,* 1991) showed that minerals and heavy metals are contained in the Lagos lagoon sediments. The results revealed largely anthropogenic heavy metal enrichment and low mineral levels which was attributed to

- Urban and industrial waste and run off water transporting metals from land derived wastes and
- The lagoon's continued renewal of water, high dilution and sedimentation.

Food processing industries release of large quantity of wastes (effluents) into streams and rivers (receiving waters). These discharges are capable of influencing aquatic and terrestrial ecosystems. Presently, there is limited information on the quality of effluent discharged by food processing industries in Ibadan and its impact on receiving water quality. Ibadan is a city in the hilly (3,500-5,000 m above sea level) forested region of Southwestern Nigeria.

The objective of this work was to assess effluent quality from food industries in Ibadan and its effect on receiving waters in the metropolis.

## MATERIALS AND METHODS

This study was conducted in Ibadan metropolis located between latitudes 7° 22$^1$ and 7° 24$^1$ north and longitudes 3° 50$^1$– 3°53$^1$ east of the Greenwich Meridian. The study involved collection of effluents from ten food processing industries as follows: two oil processing, three beverage and five confectionery industries. Water samples were collected at receiving waters at locations down and upper the water course adjacent to the carriage system around the effluents outfall of the industries. Samples were collected in acid-leached 1-litre polyethylene sample bottles and stored under refrigeration at 4° C. Water samples collected upstream before the discharge of the effluent into the stream served as control.

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Table 1: Heavy metal mg $L^{-1}$ composition of effluents from confectionery industries in Ibadan metropolis

| Industry | Cobalt | Chromium | Copper | Iron | Magnesium | manganese | lead | Zinc |
|---|---|---|---|---|---|---|---|---|
| Diamond foods | 2.75±0.08b | 0.06±0.01a | 0.02±0.003b | 0.03±0.004b | 0.20±0.01a | 0.31±0.01b | 0.14±0.01c | 0.16±0.01c |
| Sword sweets | 0.46±0.01a | 0.09±0.01b | 0.01±0.002b | 0.06±0.01c | 1.44±0.04c | 1.38±0.04b | 0.13±0.01bc | 0.09±0.01b |
| EFCO | 0.60±0.02a | 0.10±0.01c | 0.01±0.003a | 0.02±0.002a | 1.81±0.05d | 0.09±0.01a | 0.12±0.01ab | 0.07±0.01a |
| Sumal foods | 2.03±0.06b | 0.11±0.01d | 0.01±0.01a | ND | 0.80±0.02b | 0.47±0.01c | 0.11±0.01a | 0.29±0.01d |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

Table 2: Heavy metal mg $L^{-1}$ composition of receiving water from confectionery industries in Ibadan

| Industry | Cobalt | Chromium | Copper | Iron | Magnesium | Manganese | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|
| Diamond foods | 0.33±0.03b | 0.42±0.01c | 0.18b±0.05c | 1.74±0.54b | 2.19±0.34ab | 1.51±0.06a | 0.11±0.01ab | 0.84±0.22 |
| Sword sweets | 0.15±0.07a | 0.04±0.01a | 0.01±0.003a | 0.53±0.18a | 0.65±0.08a | 3.48±0.72ab | 0.13±0.02ab | 1.34±0.23 |
| EFCO | 0.46±0.05b | 0.04±0.01a | 0.25±0.02c | 0.95±0.18ab | 1.83±0.47ab | 7.31±0.16c | 0.09±0.01a | 1.45±0.23 |
| Sumal foods | 0.37±0.06b | 0.08±0.01b | 0.12±0.01b | 0.95±0.03ab | 2.89±1.13b | 5.75b±1.65c | 0.16±0.02b | 1.36±0.23 |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

Table 3: Heavy metal (mg $L^{-1}$) content of effluent and receiving waters from oil processing industries in Ibadan

| Oil industry | Location | Cobalt | Chromium | Copper | Iron | Magnesium | Manganese | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|---|
| Best oils ltd | Effluent | 2.08±0.06cD | 0.06±0.01aA | ND | 0.01±0.001aA | 1.35±0.04cD | 0.43±0.01aA | 0.10±0.01aA | 0.040.01aA |
| | Receiving (Upper) | 0.22±0.01bB | 0.13±0.01bC | 0.21±0.01bC | 0.78±0.02bC | 0.61±0.02bC | 11.70±0.34bB | 0.10±0.01aA | 0.760.02bB |
| | Receiving (Lower) | 0.36±0.01bC | 0.68±0.02cD | 0.09±0.01aA | 0.37±0.01bB | 3.78±0.11dE | 10.98±0.32bB | 0.20±0.01bB | 1.76±0.05cC |
| Premier agro oils | Effluent | 0.48±0.01cC | 0.07±0.01bA | 0.02±0.003aA | ND | 2.17±0.06cE | 0.15±0.01aA | 0.14±0.01bB | 0.10±0.01aA |
| | Receiving (Upper) | 0.17±0.01bB | 0.05±0.01bA | 0.14±0.01bB | 0.19±0.01aB | 1.83±0.05bcD | 11.67±0.34bcB | 0.08±0.01aA | 1.46±0.04bC |
| | Receiving (Lower) | 0.20±0.0bB1 | 0.02±0.01aA | 0.06±0.01aA | 0.93±0.03bC | 1.36±0.04bD | 10.33±0.30bB | 0.16±0.01bB | 2.46±0.07bDSS |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters under each industry are significantly different ($p<0.05$), Means followed by different uppercase letters in each column are significantly different ($p<0.05$)

Table 4: Heavy metal (mg $L^{-1}$) composition of effluents from beverage industries

| Industry | Cobalt | Chromium | Copper | Iron | Magnesium | Manganese | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|
| FAN milk | 0.75±0.02c | 0.06±0.01b | 0.01±0.003a | 0.03±0.001a | 0.39±0.01b | 1.29±0.04b | 0.13±0.003a | .08±0.002a |
| Nig. brew. Plc | 0.13±0.01a | 0.05±0.01a | 0.02±0.004b | 0.03±0.002a | 0.10±0.01a | 0.78±0.02a | 0.18±0.01c | 0.32±0.01c |
| Quality foods | 0.20±0.01b | 0.09±0.01c | 0.02±0.003b | 0.06±0.001b | 2.28±0.07c | ND | 0.15±0.01b | 0.22±0.01b |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

Table 5: Heavy metal (mg $L^{-1}$) composition of receiving waters from beverage industries in Ibadan

| Industry | Cobalt | Chromium | Copper | Iron | Magnesium | Manganese | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|
| FAN Milk | 0.24±0.04 | 0.10±0.01ab | 0.09±0.04 | 0.54±0.03 | 0.83±0.02a | 1.00±0.45 | 0.12±0.03a | 0.59±0.24 |
| Nig. Brew. Plc | 0.29±0.04 | 0.14±0.05b | 0.09±0.02 | 0.49±0.11 | 3.57±0.95b | 2.86±0.06 | 0.15±0.02a | 1.49±0.61 |
| Quality Foods | 0.19±0.01 | 0.05±0.001a | 0.04±0.001 | 0.65±0.08 | 0.62±0.01a | 2.30±1.03 | 1.02±0.39b | 0.82±0.34 |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

Samples were analyzed for physical and chemical characteristics. Temperature was measured using a standard size field thermometer; pH was measured as described by Anderson and Ingram using a Model 3020 pH meter (JENWAY, UK). Heavy metals (Ca, Cr, Cu, Fe, Mg, Mn, Pb, and Zn) were determined using AAS (Buck Scientific model 500A) as described by Juo. A Conductivity meter (Model 4010, JENWAY, UK) calibrated with a conductivity standard (0.01 m KCl with conductivity 1413 $\mu scm^{-1}$) was used for conductivity measurements at 25°C. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were determined as described by Turner and Carawan APHA (1992). Hardness, turbidity, total dissolved solids, total solids, dissolved oxygen, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) were determined using standard methods. Sodium and potassium were determined using a flame photometer. Phosphate, nitrate, ammonium and chlorides were determined using standard methods (APHA 1992 and Taras 1950). The results are expressed in mg $kg^{-1}$. Means of triplicate readings obtained in the study were subjected to analysis of variance (ANOVA) and Duncan's multiple range test using the Statistical Package for Social Scientist (SPSS 10.0) computer software (Oloyo, 2001).

## RESULTS AND DISCUSSION

The average temperatures of receiving waters before and after discharge of effluents are 25 2° and 35 1°C respectively. The temperature differentia shows an increase of between 6–13°C rise in temperature. At higher temperatures, the ability of water to solubilise and hold oxygen is reduced. Low oxygen levels may handicap some species while higher temperatures can kill animals and plants accustomed to living at lower temperatures, thus disrupting the biological balance of aquatic systems.

**Heavy metals:** Mean heavy metal composition of effluents and receiving waters from confectionery, oil processing and beverage industries in Ibadan, Nigeria are presented in Tables 1 to 5. There are significant differences ($p<0.05$) in the heavy metal composition of effluents from confectionery industries studied in Ibadan. The chromium, copper, manganese, lead and zinc contents are within allowable range. The chromium content of receiving water from Diamond Foods is significantly higher than others. The value obtained for this industry is higher than the recommended 0.1 mg $L^{-1}$ (FEPA 1991) but within the range specified by Tang and Ferris. All other heavy metals are within recommended ranges. A comparison of Tables 1 and 2 showed that cobalt contents are generally higher in the receiving waters than in the effluent discharged into receiving waters by confectionery industries. Chromium, copper, iron, manganese and zinc were lower in the effluents discharged, while lead content did not differ remarkably. Among oil processing industries (Table 3), cobalt content is highest in effluents from Best Oils Ltd. Chromium, copper, iron and lead values obtained for receiving waters are comparable and within recommended limits. Manganese contents are higher in the receiving waters than in the effluent and are higher than recommended values (< 10 mg $L^{-1}$). Zinc is highest in receiving waters from Premier Agro Oils (2.46 mg $L^{-1}$). This value is higher than 1.0 mg $L^{-1}$ recommended by FEPA, 1991 but lower than 5.0 mg $L^{-1}$ recommended by Significant increases were observed in the lead and zinc contents following effluent discharge into receiving waters by the oil processing industries. They are, however within Residual[!]. allowable limits. Chromium, copper, iron, magnesium and zinc contents of effluents from beverage industries (Table 4 and 5) are lower than values obtained for receiving waters. Lead contents in the effluent and receiving waters are comparable. However, values obtained fo effluents from beverage industries are within recommended values.

Table 6: Mineral composition (mg $L^{-1}$) of effluents and receiving waters from confectionery industries in Ibadan.

| Industry | Location | Sodium | Calcium | Potassium | Phosphate | Ammonium | Nitrate | Chloride |
|---|---|---|---|---|---|---|---|---|
| Diamond Foods | Effluent | 60.45±1.75d | 3.61±0.10e | 25.79±0.74d | 1.44±0.04e | 2.48±0.07f | 5.23±0.15g | 80.00±2.31e |
| | Receiving (Upper) | 108.43±3.13h | 1.94±0.06b | 88.79±2.56i | 0.01±0.001a | 0.02±0.001a | 0.19±0.01b | 40.00±1.15b |
| | Receiving (Lower) | 126.84±3.66i | 2.82±0.08cd | 75.56±2.18h | 0.03±0.001a | 0.02±0.001a | 0.52±0.02c | 60.00±1.73c |
| Sword Sweets | Effluent | 24.70±0.71b | 3.61±0.10e | 35.45±1.02e | 1.91±0.06e | 37.72±1.09j | 0.71±0.02c | 96.00±2.77fg |
| | Receiving (Upper) | 85.05±2.46f | 2.82±0.08cd | 110.80±3.20j | 0.08±0.01a | 0.98±0.03d | 0.08±0.01a | 58.00±1.67c |
| | Receiving (Lower) | 251.08±7.25j | 2.68±0.08c | 246.18±7.11k | 2.15±0.06f | 1.82±0.05e | 0.58±0.02c | 50.00±1.44bc |
| EFCO | Effluent | 14.92±0.43a | 3.79±0.11e | 29.22±0.84d | 3.83±0.11g | 18.01±0.52i | 1.33±0.04d | 100.00±2.89gh |
| | Receiving (Upper) | 67.87±1.96de | 10.61±0.31j | 218.18±6.30k | 0.12±0.01b | ND | 0.03±0.001a | 48.00±1.39b |
| | Receiving (Lower) | 115.23±3.33h | 6.58±0.19h | 142.48±4.11 | 0.52±0.02c | 0.65±0.02c | 0.32±0.01c | 56.00±1.62c |
| Sumal foods | Effluent | 67.40±1.95de | 2.50±0.07c | 41.32±1.19f | 0.96±0.03d | 55.67±1.61k | 0.42±0.01c | 108.00±3.12h |
| | Receiving (Upper) | 94.67±2.73fg | 5.32±0.15g | 88.58±2.56i | 0.01±0.001a | 0.07±0.003a | 1.02±0.03d | 104.00±3.00h |
| | Receiving (Lower) | 136.34±3.94i | 7.64±0.22h | 84.85±2.45i | 0.80±0.02d | 2.48±0.07f | 2.14±0.06e | 128.00±3.70i |
| Quality foods | Effluent | 83.79±2.42f | 7.74±0.22h | 11.38±0.33bc | 15.61±0.45h | 0.03±0.002a | 3.28±0.09f | ND |
| | Receiving (Upper) | 383.28±11.06k | 0.45±0.01a | 58.86±1.70g | ND | 0.92±0.03d | 0.03±0.002a | 104.00±3.00h |
| | Receiving (Lower) | 480.84±13.68l | 2.46±0.07c | 210.21±6.07k | 0.08±0.01a | 1.28±0.04e | 0.01±0.002a | 60.00±1.73e |
| Nigeria eagle flour mills | Effluent | 13.70±0.40a | 2.42±0.07c | 7.58±0.22a | ND | 1.12±0.03e | 0.21±0.01b | 44.00±1.27b |
| | Receiving (Upper) | 181.27±5.23 | 4.18±0.12f | 18.44±0.53c | ND | 2.18±0.06f | 0.02±0.001a | 58.00±1.67c |
| | Receiving (Lower) | 72.14±2.08e | 4.62±0.13f | 44.84±1.29f | 0.03±0.002a | 0.02±0.001a | 0.04±0.002a | 120.00±3.46i |

Values are means of triplicate readings±SEM, Means followed by different l owercase letters in each column are significantly different ($p<0.05$)

Table 7: Mineral composition (mg $L^{-1}$) of effluents and receiving waters around oil processing industries in Ibadan

| Industry | Location | Sodium | Calcium | Potassium | Phosphate | Ammonium | Nitrate | Chloride |
|---|---|---|---|---|---|---|---|---|
| Best oils ltd | Effluent | 26.85±0.78b | 2.55±0.07c | 9.13±0.26b | 0.01±0.002a | 2.23±0.06f | 0.24±0.01b | 36.00±1.04a |
| | Receiving (Upper) | 43.84±1.27c | 3.10±0.09de | 4.05±0.02a | 0.03±0.002a | 0.05±0.01a | 55.00±1.59h | 38.00±1.10a |
| | Receiving (Lower) | 22.58±0.65b | 2.27±0.07c | 8.63±0.25a | 3.24±0.09g | 0.46±0.01bc | 2.69±0.08e | 44.00±1.27b |
| Premier agro oils | Effluent | 64.58±1.86de | 4.63±0.13f | 25.97±0.75d | 14.32±0.41h | 0.25±0.01b | 0.72±0.02c | 268.00±7.74j |
| | Receiving (Upper) | 35.60±1.03c | 2.90±0.08cd | 14.00±0.40c | 0.08±0.01a | 1.06d±0.03e | 6.81±0.20g | 98.00±2.83fg |
| | Receiving (Lower) | 109.65±3.17h | 0.89±0.03a | 42.58±1.23f | 0.42±0.01c | 1.08±0.03de | 5.21±0.15g | 42.00±1.21b |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters in each column are significantly different (p<0.05)

Table 8: Mineral composition (mg $L^{-1}$) of effluents and receiving waters around beverage industries in Ibadan

| Industry | Location | Sodium | Calcium | Potassium | Phosphate | Ammonium | Nitrate | Chloride |
|---|---|---|---|---|---|---|---|---|
| FAN Milk | Effluent | 67.25±1.94b | 1.67±0.05a | 34.04±0.98c | 1.33±0.04b | 0.78±0.02c | 0.83±0.02c | 60.00±1.73c |
| | Receiving (Upper) | 123.20±3.56d | 2.80±0.08b | 34.63±1.00c | 0.06±0.003a | 0.21±0.01a | 0.01±0.002a | 44.00±1.27b |
| | Receiving (Lower) | 85.65±2.47c | 3.83±0.11b | 28.68±0.83b | 0.01±0.002a | 0.58±0.02b | 0.01±0.002a | 62.00±1.79c |
| NBL | Effluent | 17.27±0.50a | 1.32±0.04a | 5.42±0.16a | 0.01±0.002a | 4.49±0.13f | 0.17±0.01b | 32.00±0.92a |
| | Receiving (Upper) | 120.78±3.49d | 6.08±0.16c | 53.50±1.54d | 0.02±0.002a | 3.26±0.09e | 0.29±0.09b | 68.00±1.96c |
| | Receiving (Lower) | 72.06±2.08b | 8.64±0.25d | 31.78±0.92c | 0.04±0.002a | 2.06±0.06d | 0.14±0.01b | 92.00±2.66d |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters in each column are significantly different (p<0.05)

Table 9: Mean heavy metal (mg $L^{-1}$) contents of effluent and receiving water from food processing industries in Ibadan

| Source | Cobalt | Chromium | Copper | Iron | Magnesium | Manganese | Lead | Zinc |
|---|---|---|---|---|---|---|---|---|
| Effluent | 0.99±0.16b | 0.07±0.01a | 0.10±0.05 | 0.15±0.07a | 1.11±0.14a | 0.53±0.08a | 0.13±0.01a | 0.15±0.02a |
| Receiving (Upper) | 0.27±0.02a | 0.15±0.03a | 0.15±0.02 | 0.92±0.14b | 1.43±0.26a | 5.26±0.67b | 0.08±0.01a | 1.17±0.11b |
| Receiving (Lower) | 0.29±0.02a | 0.24±0.05c | 0.10±0.01 | 0.61±0.05b | 1.98b±0.31 | 5.35±0.80b | 0.33±0.10b | 1.53±0.18b |

Values are means of 3 readings each from 5 industries (3×5)±SEM, Means followed by different letters are significantly different (p<0.05)

**Mineral composition:** The mineral composition of effluent and receiving waters from confectionery, oil processing, beverage industries are presented in Table 6-8. The phosphate, ammonium (cations), nitrate and chloride (anions) contents of effluents and receiving waters are within recommended limits. However, potassium content is very much higher in all the industries. The only exception is the potassium content of effluents from NBL (a brewing industry) which falls within recommended limits 5 mg $L^{-1}$. Generally, significant increases were observed in the sodium, potassium, phosphate, nitrate and chlorides following the discharge of effluents (lower receiving) in some confectionery industries (Table 6). In receiving waters from oil industries (Table 7), decreases were observed in the calcium and nitrate contents while other minerals measured increased significantly. In beverage industries (Table 8), significantly lower (p<0.05) values were obtained following discharge of effluent (lower receiving) for sodium, potassium and phosphate while other parameters increased.

Moors *et. al* . (1979) stated further that certain foods cooked in water containing lead have been shown to concentrate the metal and hence be a potential hazard to the populace. Thus, it is essential that Pb contamination be minimized via adequate treatment so that rivers and streams, which serve many communities in the area, do not become a source of public health concern.

Table 9 summarises the impact of food processing industries on receiving waters in the environment. Results show that Co, Cr, Mn and Zn contents were not significantly influenced by the discharge of effluents into receiving waters. Although Co content is significantly higher (p<0.05) in the effluent discharged, the level in the receiving waters remains comparable. Effluent levels of Cr, Mn and Zn are significantly lower (P<0.05). Pb content was accentuated following effluent discharge. The high levels of some of these heavy metals in the receiving water before effluent discharge may be due to other urban and industrial waste
and run-off water transporting metals from land-derived wastes (Okoye, 1991).

**Physicochemical properties:** The physicochemical properties of effluents and receiving waters from all food processing industries studied are shown in Tables 10-12.

Table 10: Physicochemical properties of effluents from different food processing industries in Ibadan, Nigeria

| Industries | pH<br>Conductivity | Electrical | Hardness | Turbidity | Dissolved Solids | Total Solids | Dissolved Oxygen | BOD | COD |
|---|---|---|---|---|---|---|---|---|---|
| Confectionery | | | | | | | | | |
| | 9.10±0.26c | 12.00±0.35e | 27.50±0.79a | 35.21±1.02d | 1000.00±28.87e | 2800.00±80.83g | .50±0.22v | 41.00±1.18a | 52.00±1.50b |
| Diamond foods | | | | | | | | | |
| Sword sweets | 7.50±0.22b | 8.40±0.24c | 125.00±3.61g | 21.10±0.61c | 1000.00±28.87e | 2400.00±69.28f | 5.22±0.15a | 142.00±4.10e | 160.00±4.62e |
| EFCO | 7.40±0.21b | 10.00±0.29d | 85.00±2.45e | 18.41±0.53c | 800.00±23.09d | 1800.00±51.96d | 14.15±0.41d | 161.00±4.65f | 180.00±5.20e |
| | 7.50±0.22b | 10.00±0.29d | 80.00±2.31de | 5.17±0.15b | 1000.00±28.87e | 3600.00±103.92h | 8.00±0.23b | 59.00±1.70b | 36.00±1.04a |
| Sumal foods | | | | | | | | | |
| Quality foods | 5.20±0.15a | 16.00±0.46f | 135.00±3.90g | 144.00±4.16f | 1300.00±37.53f | 1800.00±51.96h | 11.34±0.33c | 48.00±1.39a | 59.00b±1.70c |
| Nigeria eagle flour mills | 7.00±0.20b | 3.10±0.09b | 70.00±2.02cb | 3.84±0.11a | 200.00±5.77a | 800.00±23.09a | 6.00±0.17a | 46.00±1.33a | 61.00±1.76c |
| Beverage | | | | | | | | | |
| FAN milk | 10.20±0.29c | 14.00±0.40e | 100.00±2.89f | 152.00±4.39f | 1600.00±46.19f | 3400.00±98.15h | 17.41±0.50e | 95.00±2.74d | 136.00±3.93d |
| NBL | 6.50±0.19ab | 1.70±0.05b | 50.00±1.44b | ND | 300.00±8.66b | 1000.00±28.87b | 13.00±0.38cd | 72.00±2.08c | 63.00±1.82c |
| Oil processing | | | | | | | | | |
| Best oils ltd | 6.70±0.19b | 2.10±0.06a | 65.00±1.88c | 2.65±0.08a | 400.00±11.55c | 1200.00±34.64c | 31.62±0.91g | 149.00±4.30e | 172.50±4.98e |
| Premier Agro Oils | 5.50±0.16a | 17.00±0.49c | 55.00±1.59b | 96.40±2.78e | 800.00±23.09d | 2200.00±63.51e | 24.00±0.69f | 180.00±5.20g | 130.00±3.75d |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

Table 11: Physicochemical properties of receiving water before effluent discharge by food industries.

| Industry | pH | Electrical conductivity | Hardness | Turbidity | Dissolved solids | Total solids | Dissolved oxygen | BOD | COD |
|---|---|---|---|---|---|---|---|---|---|
| Upper diamond foods | 7.20±0.21b | 29.30±0.85l | 100.00±2.89g | 21.91±0.63d | 400.00±11.55ef | 170.00±4.91a | 8.40±0.24e | 39.17±1.13a | 29.41±0.85a |
| Sword sweets | 7.80±0.23bc | 16.40±0.47i | 44.00±1.27b | 2.77±0.08a | 550.00±15.88g | 1750.00±50.52f | 7.20±0.21d | 120.30±3.47f | 65.80±1.90c |
| EFCO | 7.40±0.21b | 3.65 0.11d | 36.00±1.04a | 4.92±0.14b | 200.00±5.77b | 1200.00±34.64c | 6.40±0.18c | 91.50±2.64e | 50.24±1.45b |
| Sumal foods | 7.30±0.21b | 0.53±0.02a | 600.00±17.32k | 128.00±3.70g | 150.00±4.33a | 1400.00±40.41d | 6.00±0.17bc | 90.90±2.62e | 70.20±2.02d |
| Quality foods | 7.90±0.23bc | 10.37±0.30g | 92.00±2.66fg | 54.70±1.58f | 850.00±3.22h | 3100.00±23.45 | 5.60±0.10b | 110.50±2.18f | 62.55±1.89c |
| Nigeria eagle flour mills | 8.60±0.25cd | 3.08±0.09d | 46.00±1.33b | 23.10±0.67d | 1100.00±31.75i | 2300.00±66.40h | 12.40±0.36i | 52.50±1.52b | 78.64±2.27d |
| FAN milk | 8.60±0.25cd | 29.13l±0.84 | 61.00±1.76d | 6.29±0.18c | 300.00±8.66d | 800.00±23.09b | 7.80±0.23de | 53.00±1.53b | 125.00±3.61f |
| NBL | 5.20±0.15a | 18.73±0.54j | 800.00±23.09l | 182.00±5.25h | 1700.00±49.07k | 3850.00±111.14j | 4.00±0.12a | 110.00±3.18f | 70.62±2.04d |
| Best oils ltd | 7.30±0.21b | 24.00±0.69k | 70.00±2.02e | 202.00±5.83i | 350.00±10.10de | 1100.00±31.75c | 4.52±0.13a | 56.80±1.64b | 130.00±3.75f |
| Premier agro oils | 9.50±0.27d | 15.75±0.45i | 160.00±4.62h | 33.20±0.96e | 550.00±15.88g | 1600.00±46.19e | 7.11±0.21d | 95.00±2.74e | 25.10±0.72a |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

The pH range obtained falls within 5–9 recommended by (FEPA 1991). There were marked variations in the electrical conductivity, hardness, turbidity, total and dissolved solids of effluents from the various industries; they did not follow clearly discernible pattern. Dissolved oxygen is significantly higher in effluents from oil processing industries (Table 10). Significant decreases were obtained in the electrical conductivity, hardness, turbidity, total solids, dissolved solids and BODs of receiving water around some food processing industries following effluent discharge. COD increased with effluent discharge into receiving water. There are no (FEPA 1991) recommended values for conductivity, total solids, turbidity and dissolved oxygen. The highest BODs were obtained for effluents from Sword sweet (142.00 mg $L^{-1}$), EFCO (161.00 mg $L^{-1}$) (confectionery industries), Best Oils (149.00 mg $L^{-1}$) and Premier Agro Oil (180.00 mg $L^{-1}$) (Oil processing industries). The BOD and COD values obtained for all the industries are significantly higher than FEPA (1991) recommended values (30 and 40 mg $L^{-1}$ respectively). A comparison of values in Tables 10- 12 show that BOD levels of receiving wasters around sword sweets, EFCO, FAN milk, Best Oils and Premier Agro Oils dropped after discharge while others increased with effluent discharge. With the exception of NBL (a beverage industry), all other industries which brought about increases in BOD are confectionery industries. COD levels were higher after effluent discharge by Diamond Foods, Sword Sweets, EFCO, Sumal Foods, Quality Foods, NBL and Premier Agro Oils. Many of the wastes in the effluent from food processing plants are organic compounds and some lost product. As these substances undergo oxidation, they combine with some of the oxygen dissolved in the water. The amount of

Table 12: Physicochemical properties of receiving water after effluent discharge by food industries

| Industry | pH | Electrical conductivity | Hardness | Turbidity | Dissolved solids | Total solids | Dissolved oxygen | BOD | COD |
|---|---|---|---|---|---|---|---|---|---|
| Diamond foods | 6.90±0.20b | 18.50±0.53j | 84.00±2.42f | ND | 350.00±10.10de | 850.00±24.54b | 11.10±0.32h | 68.00±1.96c | 51.00±1.47b |
| Sword sweets | 7.40±0.21b | 2.05±0.06c | 40.00±1.15b | ND | 350.00±10.10de | 1050.00±30.31c | 8.40±0.24e | 98.00±2.83e | 125.00±3.61 |
| EFCO | 7.20±0.21b | 1.76±0.05b | 46.00±1.33b | ND | 300.00±8.66d | 1100.00±31.75c | 9.60±0.28f | 70.60±2.04cd | 70.62±2.04d |
| Sumal foods | 7.10±0.21b | 0.37±0.01a | 240.00±6.93j | ND | 250.00±7.22c | 1550.00±44.74d | 10.80±0.31gh | 181.00±5.23i | 78.80±2.27de |
| Quality foods | 7.60±0.22b | 1.67±0.05b | 70.00±2.02e | 55.70±1.61f | 450.00±12.99f | 2400.00±69.28h | 5.00±0.14ab | 130.00±3.75g | 80.00±2.31e |
| Nigeria eagle flour mills | 8.20±0.24cd | 2.18±0.06c | 70.00±2.02e | ND | 1050.00±30.31i | 2000.00±57.74g | 10.00±0.29fg | 106.38±3.07f | 60.42±1.74c |
| FAN milk | 7.30±0.21b | 7.25±0.21f | 53.00±1.53c | 7.29±0.21d | 250.00±7.22c | 950.00±27.56c | 9.60±0.28f | 37.69±1.09a | 84.00±2.42e |
| NBL | 4.80±0.14a | 8.45±0.24f | 600.00±17.32k | 183.00±5.28h | 1350.00±38.97j | 2700.00±77.94i | 7.40±0.21d | 161.00±4.65h | 180.00±5.20g |
| Best oils ltd | 7.20±0.21b | 13.10±0.38h | 50.00±1.44c | 203.00±5.86i | 350.00±10.10de | 1400.00±40.41d | 5.60±0.16b | 32.25±0.93a | 78.34±2.26de |
| Premier agro oils | 9.30±0.27d | 4.86±0.14e | 182.00±5.25i | 34.20±0.99e | 450.00±12.99f | 1850.00±53.40f | 7.00±0.20f | 76.26±2.20d | 32.00±0.92a |

Values are means of triplicate readings±SEM, Means followed by different lowercase letters are significantly different ($p<0.05$)

oxygen used is therefore a good indicator of the amount of organic waste present. The BOD values obtained following discharge of the effluents into receiving water by flour and confectinery industries indicates that the amount of oxygen (mg $L^{-1}$) needed to oxidize these products is high. COD values are generally higher since it measures oxygen demand by biodegradable and non-biodegradable p ollutants (Turner and Carawan, 1996). The high BOD and COD values obtained may suggest that a high amount of biodegradable and non- biodegradable product is lost to the receiving waste stream.

## CONCLUSION

This study has shown that the quality of receiving water is influenced significantly by the chemical composition of effluents discharged into them. Processing industrial waste before discharge into streams and rivers is essential since a large number of the population still rely on surface waters for drinking, washing, fishing and swimming. This is important so that pollutants which may pose health risks and hazards are not discharged into the surrounding ecosystems.

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