Global Sustainability Research
https://doi.org/10.56556/gssr.v1i1.298
ISSN: 2833-986X

RESEARCH ARTICLE

# Characterisation of Physico-Chemical Properties and heavy metal concentrations of Surface Water receiving effluent from champion breweries PlC in Uyo, Akwa Ibom State, Nigeria

**Akpan, S. Udeme[1], Umana, S. Umana*[2]**

[1]Department of Soil Science and Land Resources Management, University of Uyo, Uyo, Akwa Ibom State, Nigeria
[2]Department of Geology, University of Calabar, Calabar, Cross River State, Nigeria

*Corresponding author email: Umana, S. Umana, umanaedo@yahoo.com
Received: 18 July, 2022, Accepted: 17 August, 2022, Published: 18 August, 2022

**Abstract**
Physico-chemical properties and heavy metal concentrations of surface water receiving effluent from Champion Breweries Plc, Uyo, Akwa Ibom State were analysed to evaluate the effect of the effluent on the physico-chemical properties and heavy metal concentrations of the surface water. The water samples were collected using polyethylene bottles that were initially rinsed with 10% hydrochloric acid (HCl) then with the sample water. Two samples were collected at each sampling point. One was for physicochemical properties determinations while the other sample was for heavy metal analysis. $HNO_3$ was added in the samples for heavy metal analysis for preservation of the metals. The collected samples were stored in an ice-packed cooler kit and taken to the laboratory for analysis. The results showed that the temperature of the water was within the permissible limit. Mean pH was lower than the permissible range for drinking water especially during the dry season. Turbidity was above the permissible limit in both dry/wet seasons. Dissolved oxygen was below the permissible limit. Mean biochemical oxygen demand was above the permissible limit. The result of the ratio of chemical oxygen demand to biochemical oxygen demand showed that the compounds in the water were relatively biodegradable. Total suspended solid was above the permissible limit. Mean total dissolved solid was below the permissible limit. Mean electrical conductivity was also below the permissible limit. The concentration of $NH_4$ was at toxic level. The concentrations of nitrate, nitrite, phosphate and sulphate were below the permissible limits indicating non-toxicity and lack of these nutrient elements in the water. The contents of Fe, Pb, Zn, Cd, Cr, Co and Mn were above permissible levels. The effluent from Champion breweries is considered to be one of the major sources of pollutants of surface water in this area, which efficient treatment of effluent before disposal is recommended.

**Keywords**: Champion Breweries; surface water; effluent; pollution

## Introduction

Contamination of surface water quality such as streams, springs and rivers has been evident over the years in areas where industrial, agricultural and other intensive human activities are carried out (Abua and Okpiliya, 2005). As observed by Asthana and Asthana (2001), thousands of industrial plants discharge effluents into sewage plants that are unequipped to process many of the industrial pollutants, which are then discharged into the natural environment. Accordingly, industrial establishments, end up in discharging various heavy or trace metals, organic and inorganic compounds and acids into surface waters thus altering their pH, other parameters as well as upsetting the biological system (Sule, 2001). Equally, research conducted on surface and groundwater from the coastal areas of Oron, Mbo, Ibeno and Ikot Abasi both in Akwa Ibom State, indicated anomalous occurrence of coliform bacteria (*Escherichia coli*) heavy metals in surface and groundwater sources and the values were far in excess of the World Health Organisation (WHO) stipulated standards (Amah *et al.*, 2007).

In line with the research topic, Ekhaise and Anyasi (2005), assessed the extent of pollution on surface water due to effluent discharged from the two brewery industries in Benin City. The population of total coliform bacteria in all the water samples obtained from Ikpoba river were generally high likewise some physico-chemical properties whose values were higher than the WHO tolerant level while Adediran et al. (2004) reported of pollution of streams, well-water and soil with cadmium, chromium, copper and nickel by a brewery industry

located in Ibadan, Oyo State, Nigeria. It is quite glaring that effluent discharged into surface water, underground water and soil from brewery plants is capable of causing pollution. Brewery effluent is comprised of wastewater from washing bottles, water treatment plant, carbon dioxide generating plant, bottling and production hall and general wastewater from domestic washing. Losses in beer production process and the clean-in-place (CIP) located in the brewery house, cellar house and bottling house also form part of the effluent from brewery plants (Techobanoglous *et al*., 1991).

Untreated brewery effluent contains basically, suspended solids in the ranges of 10-60 mg/l, biochemical oxygen demand (BOD) in the range of 1000 – 1500 mg/l, chemical oxygen demand (COD) in the range of 1800 – 3000 mg/l and nitrogen in the range of 30-100mg/l (Alao *et al*., 2010). The effluent also contains organic materials such as spent grains, waste yeast, spent hops and grit. The average range of effluent pH is about 7 for combined effluent but can fluctuate from 3-12 depending on the use of acid or alkaline cleaning agent (World Bank, 1997). Pollutants arising from brewery effluent have the potentials to affect aquatic ecosystem. The productivity and growth of aquatic organisms depend on the physical, chemical and microbiological characteristics of the water body (Olagbemide, 2017). Maximum productivity of aquatic lives can only be obtained in water with optimal level of physical, chemical and microbiological parameters (Olagbemide, 2017). It is therefore very essential and important to test water before it is used for drinking, other domestic agricultural or industrial purposes.

Therefore, this study was carried out to evaluate the physicochemical parameters and heavy metal concentrations of surface water receiving effluent from Champion Breweries, Uyo and to assess the quality of this water to aid in decision making and policy formulation.

## Materials and methods

### Study Area

The study was carried out at Aka-Offot Industrial Layout in Uyo Metropolis where Champion Breweries Plc is located. It lies between longitudes $7^0$ 55" E - $7^0$ 56" E and latitudes $5^0$ 00" N -$5^0$ 01" N (Figure 1). The area has a humid tropical climate with an annual rainfall ranging from 2500-3000mm and annual mean temperature of about $27^0$C and the relative humidity ranging from 75% to 79%. The topography of the area is low-lying with coastal plain sand as parent material (Petters *et al.*, 1989). It has a level to gently undulating topography with a gradient of less than five per cent (Tahal, 1979; Okoji, 1988). The surface geology is unconsolidated Sand Formations ranging from Coarse to Fine Sands.

### Water Sampling Method

The water samples were collected using polyethylene bottles that were initially rinsed with 10% hydrochloric acid (HCl) then with the sample water. Two samples were collected at each sampling point. One sample was used for physicochemical properties determinations. The other sample was for heavy metal analysis. Nitric acid ($HNO_3$) was added in the samples for heavy metal analysis for the preservation of the metals. Electrical conductivity, pH, temperature of the samples were determined in the field using standard equipment (Century Water Analysis Kit). The collected samples were stored in an ice-packed cooler kit and taken to the laboratory for analysis. The samples were collected in both wet and dry seasons. A total of 18 samples were collected at 9 locations in each season for laboratory analysis.

### Laboratory analysis

In the laboratory, analysis was done by volumetric analysis using standard methods given in APHA, (1992). Atomic absorption spectrophotometer UNICAM model 93 was used in carrying out heavy metal analysis using Whitehead (1979) method.

## Results and Discussion

### Physico-chemical properties

### Physical parameters

The physical parameters of the surface water of the study area for both dry and wet seasons are presented in Table 1

### Temperature

The temperature of the surface water in the study area varied from 30.0 to 37.0 $^0$C with a mean of 35.1 $^0$C in the dry season and 32.0 to 37.1$^0$C with a mean of 33.9 $^0$C in the wet season. Mean temperature was higher in the dry season than wet season. There was no significant difference ($p < 0.05$) in temperature between the permissible limit and that of the surface water during both wet and dry seasons in the study area... Temperature affects the amount of dissolved oxygen in water, rate of photosynthesis in plant, the metabolic rate of aquatic animals and so on. The moderate temperature of the surface water in the study area could be attributed to the temperature of the environment (Gupta *et al.*, 2003).

### Turbidity

The turbidity of the surface water within the study area varied from 304.0 to 910.0 NTU with a mean of 668.9 NTU in the dry season and 250.0 to 1702.0 NTU with a mean of 756.6 NTU in the wet season. Mean turbidity

was higher in the wet season than dry season. Mean turbidity of the surface water of the study area was significantly higher ($p < 0.05$) than the permissible limit of 5.0 for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. Turbidity is a measure of the ability of light to pass through water. It measures water's murkiness which gives an estimate of suspended solids in the water. High turbidity prevents sufficient light from entering the water for photosynthesis by submerged plants (Gupta *et al.*, 2003). The high turbidity in the study area could be attributed to the effluent discharged into the surface water by Champion Breweries Plc.

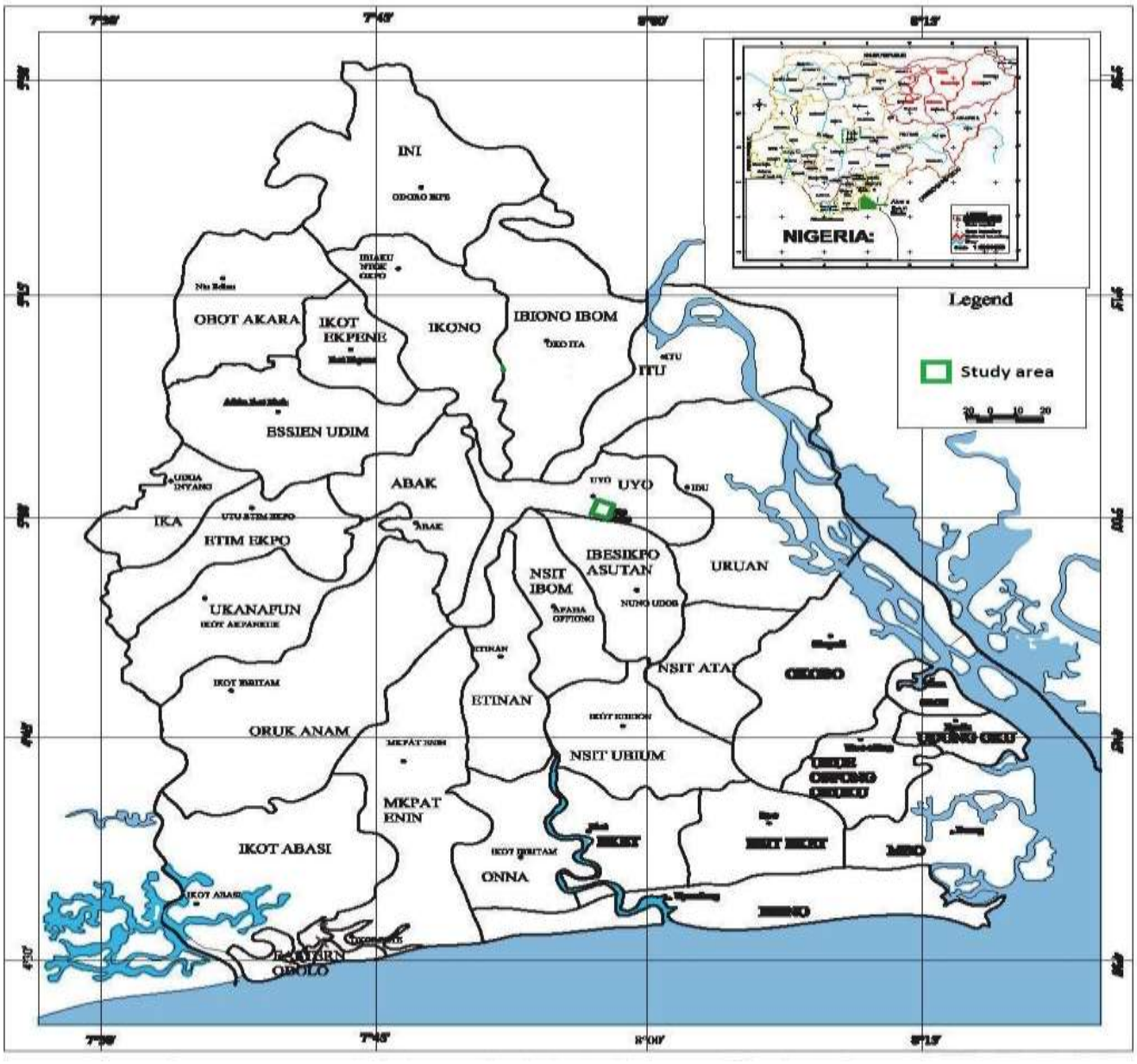


**Figure 1:** Map of Akwa Ibom State showing Champion Breweries Plc, Uyo (study area).
Source: Agate Geographic Services (2008).

**Chemical parameters**

The chemical parameters of the surface water of the study area for both dry and wet seasons are presented in Table 2.

**pH**

The pH of the surface water in the study area varied from 5.23 to 5.52 with a mean of 5.5 in the dry season and 5.49 to 6.79 with a mean of 6.5 in the wet season. Mean pH

was higher during the wet season than dry season. This means that the surface water was more acidic in the dry season than wet season. Mean pH of the surface water of the study area was significantly lower ($p < 0.05$) than the permissible range of 6.5-8.5 for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during the dry season but no significant difference from the permissible range during the wet season. Water pH is the measure of hydrogen ion concentration in water. Better fish production is possible in water with pH range of 6.5 to 9.0 (Olasoji *et al*., 2019). The lower pH of the surface water during the dry season than the permissible limit may be attributed to acid cleansing agent in the effluent discharged from Champion Breweries Plc (Olasoji *et al*., 2019).

**Dissolved oxygen (DO)**

The dissolved oxygen of the surface water in the study area varied from 1.20 to 2.20 mg/l with a mean of 1.40 mg/l during dry season and 1.10 to 2.20 mg/l with a mean of 1.52 mg/l during wet season. Mean dissolved oxygen was higher during the wet season than dry season. Dissolved oxygen is a measure of the amount of oxygen in water. Mean dissolved oxygen of the surface water of the study area was significantly lower ($p < 0.05$) than the permissible limit of 6.0 mg/l for drinking water (United States Environmental Protection Agency, 2022) during both wet and dry seasons. The values indicate that the amount of oxygen in the water was not within the permissible limit. The low amount of oxygen in the surface water in the study area could be attributed to organic pollutants, inorganic reductants and other oxidizable substances in the effluent from the Champion Breweries Plc that consumes large amount of dissolved oxygen in the water (Olasoji *et al*., 2019).

**Biochemical Oxygen Demand (BOD)**

The biochemical oxygen demand of the surface water in the study area varied from 0.00 to 10.8 mg/l with a mean of 6.1 mg/l during dry season and 3.14 to 11.19 mg/l with a mean of 6.6 mg/l during wet season. Mean biochemical oxygen demand was higher during the wet season than dry season. Biochemical oxygen demand measures the amount of oxygen that bacteria take from water when they oxidized organic matter. It determines the amount of oxygen required for biological oxidation of organic matter with the help of microbial activities. High BOD above permissible limit indicated the polluted status of the water. The mean biochemical oxygen demand of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 2.0 mg/l for drinking water (United States Environmental Protection Agency, 2022) during both wet and dry seasons. The high biochemical oxygen demand of the surface water of the study area could be attributed to the organic pollutants from the effluent discharged from the Champion Breweries Plc (Olasoji *et al*., 2019).

**Chemical Oxygen Demand (COD)**

The chemical oxygen demand of the surface water in the study area varied from 0.50 to 1.60 mg/l with a mean of 1.24 mg/l during dry season and 0.40 to 0.80 mg/l with a mean of 0.61 mg/l during wet season. Mean chemical oxygen demand was higher during the dry season than wet season. Chemical oxygen demand is a measure of the oxygen equivalent of the organic matter content of water sample that is susceptible to oxidation by a strong oxidant. It is a measure of combined effect of many industrial pollutants. High COD above permissible limit indicates the polluted status of the water. The mean chemical oxygen demand of the surface water of the study area was significantly lower ($p < 0.05$) than the permissible limit of 150 mg/l for drinking water (United States Environmental Protection Agency, 2022) during both wet and dry seasons. The low chemical oxygen demand of the surface water in the study area could be attributed to the low inorganic pollutant from the effluent discharged from Champion Breweries Plc (Olagbemide, 2017).

**Table 1:** The physical parameters of the surface water of the study area during dry and wet seasons

| Parameter | Minimum | Maximum | Sample Mean | Permissible Limit | T-test Value | Significance ($p < 0.05$) |
|---|---|---|---|---|---|---|
| | | | **Dry season** | | | |
| Temperature ($^0$C) | 30.0 | 37.0 | 35.1 | Ambient (35.0) | 0.078 | 0.94 NS |
| Turbidity (NTU's) | 304.0 | 910.0 | 668.9 | 5.0 | 9.614 | 0.001S |
| Total suspended solid (TSS) (mg/l) | 786.0 | 1960.0 | 1384.9 | 25 | 12.905 | 0.001S |
| Electrical conductivity (µS/cm) | 218.0 | 551.0 | 470.6 | 1000 | -15.913 | 0.001S |
| | | | **Wet season** | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Temperature ($^0$C) | 32.0 | 37.1 | 33.9 | Ambient (35.0) | -2.0104 | 0.07 NS |
| Turbidity (NTU's) | 250.0 | 1702.0 | 756.6 | 5.0 | 5.237 | 0.001S |
| Total suspended solid (TSS) (mg/l) | 11.58 | 2015.0 | 1137.7 | 25 | 6.450 | 0.001S |
| Electrical conductivity (µS/cm) | 340.0 | 833.0 | 450.0 | 1000 | -10.636 | 0.001S |

**Table 2:** Chemical parameters of the surface water of the study area during dry and wet seasons

| Parameter | Minimum | Maximum | Sample Mean | Permissible Limit | T-test Value | Significance ($p < 0.05$) |
|---|---|---|---|---|---|---|
| | | | **Dry season** | | | |
| pH | 5.23 | 5.52 | 5.5 | 6.5 | -13.964 | 0.001S |
| Dissolved oxygen (DO )(mg/l) | 1.20 | 2.20 | 1.40 | 6.0 | -44.773 | 0.001S |
| Biochemical oxygen demand (BOD)(mg/l) | 0.00 | 10.8 | 6.09 | 2.0 | 3.409 | 0.001S |
| Chemical oxygen demand (COD)(mg/l) | 0.50 | 1.60 | 1.24 | 150 | -1314.38 | 0.001S |
| Ratio of COD to BOD | | 0.15 | 0.20 | | | |
| Total dissolved solid (TDS) (mg/l) | 151.0 | 276.0 | 242.2 | 500 | -20.212 | 0.001S |
| Ammonium ($NH_4$) (mg/l) | 0.00 | 12.61 | 4.71 | 0.05 | 3.615 | 0.001S |
| Nitrate ($NO_3$) (mg/l) | 0.72 | 1.34 | 1.098 | 50.0 | -771.28 | 0.001S |
| Nitrite ($NO_2$) (mg/l) | 0.00 | 0.02 | 0.0096 | 0.20 | -156.79 | 0.001S |
| Phosphate ($PO_4$) (mg/l) | 0.03 | 0.51 | 0.42 | 0.5 | -1.394 | 0.001S |
| Sulphate ($SO_4$) (mg/l) | 8.08 | 27.9 | 23.4 | 100 | -38.528 | 0.001S |
| Iron (Fe) (mg/l) | 0.11 | 4.97 | 2.75 | 0.3 | 5.252 | 0.001S |
| Lead (Pb) (mg/l) | 0.03 | 4.62 | 3.47 | 0.01 | 7.523 | 0.001S |
| Zinc (Zn) (mg/l) | 0.07 | 5.67 | 3.92 | 3.0 | 1.604 | 0.147NS |
| Cadmium (Cd) (mg/l) | 0.01 | 0.31 | 0.15 | 0.003 | 4.350 | 0.002S |
| Chromium (Cr) (mg/l) | 0.01 | 6.42 | 4.80 | 0.05 | 7.389 | 0.001S |
| Cobalt (Co) (mg/l) | 0.04 | 7.69 | 4.39 | 0.02 | 6.344 | 0.001S |
| Manganese (Mn) (mg/l) | 0.03 | 5.72 | 3.62 | 0.2 | 5.826 | 0.001S |

**Wet season**

| Parameter | Minimum | Maximum | Sample Mean | Permissible Limit | T-test Value | Significance ($p < 0.05$) |
|---|---|---|---|---|---|---|
| pH | 5.49 | 6.79 | 6.5 | 6.5 | 0.290 | 0.779NS |
| Dissolved oxygen (DO )(mg/l) | 1.10 | 2.20 | 1.52 | 6.0 | -39.709 | 0.001s |
| Biochemical oxygen demand (BOD)(mg/l) | 3.14 | 11.19 | 6.60 | 2.0 | 4.60 | 0.002S |
| Chemical oxygen demand (COD)(mg/l) | 0.40 | 0.80 | 0.61 | 150 | -2649.6 | 0.002S |
| Ratio of COD to BOD | 0.13 | 0.07 | 0.09 | | | |
| Total dissolved solid (TDS) (mg/l) | 125.0 | 357.0 | 203.9 | 500 | -6.404 | 0.001S |
| Ammonium ($NH_4$) (mg/l) | 3,19 | 13.05 | 6.77 | 0.05 | 4.987 | 0.001S |
| Nitrate ($NO_3$) (mg/l) | 0.42 | 0.93 | 0.63 | 50.0 | -795.26 | 0.001S |
| Nitrite ($NO_2$) (mg/l) | 0.01 | 0.01 | 0.0097 | 0.20 | -284.25 | 0.001S |
| Phosphate ($PO_4$) (mg/l) | 0.04 | 0.04 | 0.04 | 0.5 | -1889.47 | 0.001S |
| Sulphate ($SO_4$) (mg/l) | 3.21 | 57.0 | 23.56 | 100 | -11.94 | 0.001S |
| Iron (Fe) (mg/l) | 0.23 | 1.22 | 0.995 | 0.3 | 6.843 | 0.001S |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lead (Pb) (mg/l) | 0.04 | 0.08 | 0.057 | 0.01 | 8.784 | 0.001S |
| Zinc (Zn) (mg/l) | 0.16 | 0.31 | 0.20 | 3.0 | -166.649 | 0.001S |
| Cadmium (Cd) (mg/l) | 0.00 | 0.01 | 0.005 | 0.003 | 3.333 | 0.001S |
| Chromium (Cr) (mg/l) | 0.00 | 0.04 | 0.008 | 0.05 | -10.304 | 0.001S |
| Cobalt (Co) (mg/l) | 0.03 | 0.05 | 0.04 | 0.02 | 8.068 | 0.001S |
| Manganese (Mn) (mg/l) | 0.10 | 0.15 | 0.11 | 0.2 | -15.322 | 0.001S |

**Source:** Researchers' fieldwork (2021)

**Ratio of Chemical Oxygen Demand to Biochemical Oxygen Demand (COD: BOD) (Biodegradability index)**

The ratio of chemical oxygen demand to biochemical oxygen demand of the surface water in the study area was 0.20 during the dry season and 0.09 during the wet season. The ratio was higher during the dry season than the wet season. The ratio of chemical oxygen demand to biochemical oxygen demand assesses whether the compounds in water are biodegradable. It helps in monitoring the presence of toxic and non-degradable substances in water. A ratio greater than 100 means that the compounds in water are relatively non-biodegradable and a ratio of less than 10 means that the compounds are relatively degradable. The ratio of chemical oxygen demand to biochemical oxygen demand of the surface water in the study area shows that the compounds in the surface water are relatively biodegradable (Olagbemide, 2017).

**Total Dissolved Solid (TDS)**

The total dissolved solid of the surface water in the study area varied from 151.0 to 276.0 mg/l with a mean of 242.2 mg/l during dry season and 125.0 to 357.0 mg/l with a mean of 203.9 mg/l during wet season. Mean total dissolved solid was higher during the dry season than wet season. Total dissolved solid is a measure of the amount of dissolved salts in water. Salty water conducts electricity more readily than pure water. The mean total dissolved solid of the surface water in the study area was significantly lower ($p < 0.05$) than the permissible limit of 500 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the amount of dissolved salts in the water was not up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019). Total dissolved solid just like electrical conductivity serves as a tool for assessing the purity of water.

**Ammonium ($NH_4$)**

The ammonium ($NH_4$) content of the surface water in the study area varied from 0.00 to 12.61 mg/l with a mean of 4.71 mg/l during dry season and 3.19 to 13.05 mg/l with a mean of 6.77 mg/l during wet season. Mean $NH_4$ content was higher during the wet season than dry season. Ammonium ($NH_4$) is a source of nitrogen in water. High concentration is toxic to aquatic life. The mean $NH_4$ content of the surface water of the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.05 mg/l for drinking water (United States Environmental Protection Agency, 2022) during both wet and dry seasons. The values indicate that the $NH_4$ content in the surface water of the study area was at toxic level. This concentration is toxic to aquatic life. This could be attributed to the effluent discharged into the surface water by Champion Breweries Plc (Olasoji *et al*., 2019).

**Nitrate ($NO_3$)**

The nitrate ($NO_3$) content of the surface water in the study area varied from 0.72 to 1.34 mg/l with a mean of 1.1 mg/l during dry season and 0.42 to 0.93 mg/l with a mean of 0.6 mg/l during wet season. Mean $NO_3$ content was higher during the dry season than wet season. Nitrate is a source of nitrogen in water. High concentration causes excessive growth of algae and water weeds. It can contribute to eutrophication in aquatic ecosystem. The mean $NO_3$ content of the surface water of the study area was significantly lower ($p < 0.05$) than the permissible limit of 50.0 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the $NO_3$ content in the surface water of the study area was not up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019)

**Nitrite ($NO_2$)**

The nitrite ($NO_2$) content of the surface water in the study area varied from 0.00 to 0.02 mg/l with a mean of 0.0096 mg/l during dry season and 0.01 to 0.01 mg/l with a mean of 0.0097 mg/l during wet season. Nitrite ($NO_2$) is a source of nitrogen in water. High concentration could be toxic to aquatic life. The mean $NO_2$ content of the surface water in the study area was significantly lower ($p < 0.05$) than the permissible limit of 0.02 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the concentration of $NO_2$ in surface water in the study area was not up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019).

**Phosphate ($PO_4$)**

The phosphate ($PO_4$) content of the surface water in the study area varied from 0.03 to 0.51 mg/l with a mean of 0.42 mg/l during dry season and 0.04 to 0.04 mg/l with a mean of 0.04 mg/l during wet season. Mean $PO_4$ content was higher during dry season than wet season Phosphate ($PO_4$) is a source of phosphorus in water. High concentration is associated with eutrophication in water. The mean $PO_4$ content of the surface water of the study area was significantly lower ($p < 0.05$) than the permissible limit of 0.5 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the $PO_4$ content of surface water in the study area was not up to the level that can cause eutrophication in water (Olasoji *et al*., 2019).

**Sulphate ($SO_4$)**

The sulphate ($SO_4$) content of the surface water in the study area varied from 8.08 to 27.9 mg/l with a mean of 23.4 mg/l during dry season and 3.21 to 57.0 mg/l with a mean of 23.6 mg/l during wet season. Sulphate ($SO_4$) is a source of sulphur in water. High concentration can impair photosynthesis and increase respiration. The mean $SO_4$ content of the surface water in the study area was significantly lower ($p < 0.05$) than the permissible limit of 100 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the concentration of $SO_4$ of in the surface water in the study area was not up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019).

**A. Heavy metal concentrations**

**Iron (Fe)**

The iron (Fe) content of the surface water in the study area varied from 0.11 to 4.97 mg/l with a mean of 2.75 mg/l during dry season and 0.23 to 1.22 mg/l with a mean of 0.99 mg/l during wet season. Iron (Fe) content was higher during dry season than wet season. The mean Fe content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.3 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the concentration of Fe in surface water of the study area was up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019).

**Lead (Pb)**

The lead (Pb) content of the surface water in the study area varied from 0.03 to 4.62 mg/l with a mean of 3.47 mg/l during dry season and 0.04 to 0.08 mg/l with a mean of 0.057 mg/l during wet season. Lead (Pb) content was higher during the dry season than wet season. The mean Pb content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.01 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the concentration of Pb in the surface water of the study area was up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019).

**Zinc (Zn)**

The zinc (Zn) content of the surface water in the study area varied from 0.07 to 5.67 mg/l with a mean of 3.92 mg/l during dry season and 0.16 to 0.31 mg/l with a mean of 0.20 mg/l during wet season. The mean zinc (Zn) content was higher during the dry season than wet season. The mean Zn content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 3.0 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during dry season and below the permissible limit during the wet season. The values indicate that the concentration of Zn in the surface water of the study area was up to the level that constitutes danger to human health and aquatic life during dry season and not so during wet season (Olasoji *et al*., 2019).

**Cadmium (Cd)**

The cadmium (Cd) content of the surface water in the study area varied from 0.01 to 0.31 mg/l with a mean of 0.15 mg/l during dry season and 0.00 to 0.01 mg/l with a mean of 0.005 mg/l during wet season. The mean cadmium (Cd) content was higher during dry season than wet season. The mean Cd content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.003 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during both wet and dry seasons. The values indicate that the concentration of Cd in the surface water of the study area was up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019).

**Chromium (Cr)**

The chromium (Cr) content of the surface water in the study area varied from 0.01 to 6.42 mg/l with a mean of 4.80 mg/l during dry season and 0.00 to 0.04 mg/l with a mean of 0.008 mg/l during wet season. The mean chromium (Cr) content was higher during dry season than wet season. The mean Cr content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.05 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015)

during dry season and below the permissible limit during the wet season. The values indicate that the concentration of Cr in the surface water of the study area was up to the level that constitutes danger to human health and aquatic life during dry season but not so during wet season (Olasoji *et al*., 2019).

**Cobalt (Co)**

The cobalt (Co) content of the surface water in the study area varied from 0.04 to 7.69 mg/l with a mean of 4.39 mg/l during dry season and 0.03 to 0.05 mg/l with a mean of 0.04 mg/l during wet season. The mean cobalt (Co) content was higher during dry season than wet season. The mean Co content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.02 mg/l for drinking water (United States Environmental Protection Agency, 2022) during both wet and dry seasons. The values indicate that the concentration of Co in the surface water of the study area was up to the level that constitutes danger to human health and aquatic life (Olasoji *et al*., 2019).

**Manganese (Mn)**

The manganese (Mn) content of the surface water in the study area varied from 0.03 to 5.72 mg/l with a mean of 3.62 mg/l during dry season and 0.10 to 0.15 mg/l with a mean of 0.11 mg/l during wet season. The mean manganese (Mn) content was higher during dry season than wet season. The mean Mn content of the surface water in the study area was significantly higher ($p < 0.05$) than the permissible limit of 0.2 mg/l for drinking water (Nigerian Standard for Drinking Water Quality, 2015) during dry season and below the permissible limit during the wet season. The values indicate that the Mn content in the surface water of the study area was up to the level that constitutes danger to human health and aquatic life during dry season but not so during wet season (Olasoji *et al*., 2019). Chronic manganese exposure resulting from inhalation of manganese dioxide over a period of years, attacks the human nervous system (Asthana and Asthana, 2001).

**Conclusion/ Recommendation**

The study reveals that the temperature of the surface water was within the permissible limit. The average pH of the surface water in the study area was lower than the permissible range for drinking water especially during dry season. This implies that the water was acidic for optimal use by human and aquatic lives. Turbidity of the surface water was above the permissible limit in both wet and dry seasons, indicating low light penetration into the water. Dissolved oxygen (the amount of oxygen in water) was below the permissible limit, indicating lack of sufficient oxygen in water in both wet and dry seasons. Mean biochemical oxygen demand of the surface water was above the permissible limit, indicating high level of organic pollutants in the water. The ratio of chemical oxygen demand to biochemical oxygen demand of the surface water in the study area shows that the compounds in the surface water were relatively biodegradable. Total suspended solid in surface water was above the permissible limit, indicating low water clarity. Mean total dissolved solid of the surface water was below the permissible limit, indicating low amount of dissolved salts in water. Mean electrical conductivity of the surface water was also below the permissible limit, equally indicating low amount of dissolved salts in water during wet and dry seasons. The concentration of $NH_4$ in the surface water was at toxic level. The contents of nitrate, nitrite, phosphate and sulphate were below permissible limits, indicating non-toxic and lack of these nutrient elements in water. The contents of Fe, Pb, Zn, Cd, Cr Co and Mn were above permissible levels, implying that these elements were at various toxic levels in the surface water. Therefore, the effluent from Champion breweries Plc is considered to be one of the major sources of pollutants of the surface water in this area, with the tendency of affecting human health, aquatic organisms and soil contamination as well.

However, the management of Champion Breweries Plc should as a matter of urgency, improve upon their effluent treatment method by installing anti-pollution equipment for the treatment of their effluent before disposal, which is based on the Best Available Technology (BAT).

**Declarations**

**Ethics approval and consent to participate**

Not applicable

**Consent for publication**

Not applicable

**Availability of data and material**

All data are contained within the manuscript

**Competing interests**

All authors declare zero financial or inter-personal conflict of interest that could have influenced the research work or results reported in this research paper.

**Funding**

This research was not funded by any Governmental or Non-governmental agency.

**References**


Abua, M. A.; Okpiliya, F. I. (2005) Water quality status near human and animal dump sites in Calabar Municipality, Calabar. *Journal of Liberal Studies*, 2: 61 -85.

Adediran, J. A.; Taiwo, L. B.; Sobulo, R. A.; Ogunfowokan, A. O.; Fatoki, O. S. (2004) Impact of the effluent discharge from a breweries plant on three communities in Ibadan Municiapality, southwestern Nigeria. *Global Journal of Pure and Applied Science*, 10(1):211-216.

Agate Geographic Services (2008) Digitalization of map of Akwa Ibom State: 1997 edition, Uyo: Agate Geographic Services.

Alao, O.; Arojojoye O.; Ogunlaga O. and Famuyiwa, A. (2010). Impact assessment of brewery effluent on water quality in Majawe, Ibadan, SouthWestern Nigeria. *Research* 2(5): 21-28.

Amah, E. A.; Ntekim, E. E. U.; Udom, G. J. (2007) Anomalous occurrence of Eschericha coli (E. coli) bacteria in water samples from coastal areas of Akwa Ibom State, southeastern Nigeria. *Journal of Environmental Studies*, 3(2): 109-115.

APHA (1992). Standard method for water and wastewater examination, 18th Edition. American Public Health Association, Washington D.C.

Asthana, D. K.; Asthana, M. (2001) Environment: Problems and solutions (2nd ed.) New Delhi; S. Chad and Company.

Ekhaise, F. O.; Anyasi, C. C. (2005) Influence of breweries effluent discharge on the microbiological and physico-chemical quality of Ikpoba river, Nigeria. *African Journal of Biotechnology*, 4(10): 1062-1065.

Gupta, A.K.; Gupta S.K and Patil R.S. (2003). A comparison of water quality indices for coastal waters. *J. Environ Sci. Heal*. 38(11):2711-2725.

Isichei, T. O.; Oluwaniyi, M. O. (2004) Biological treatment of brewery effluent using water hyacinth (Eichormia crassipes). Paper presented at the Nigerian Environmental Society Conference, Umuahia, November, 27-28.

Kanagachandran, K.; Jayaratne, R. (2006) Utilization potentials of brewery waste water sludge as an organic fertilizer. *Journal of the Institute of Brewing*, 112(2): 92-96.

Nigerian Standard for Drinking Water Quality (2015). Guidelines for drinking water quality. Nigerian Industrial Standard.

Okoji, M. A. (1988) Soil resources of Cross River State, Nigeria. *Journal of Governmental Management*, 26, 28-42.

Olagbemide, P.T. (2017). Application of water quality index for the assessment of Eleyele Lake, Ibadan, Nigeria. *Archives of Applied Science Research*, 3: 16-23

Olasoji, S.O.; Oyewole, N.O.; Abiola, B.; Edokpayi, J.N. (2019). Water quality assessment of surface and underground water sources using a water quality index method: A case study of a Peri-Urban town in southwestern Nigeria. *Environment*, 6, 23

Orhue, E. R; Osaigoboro, A. U.; Wvioko, D. E. (2005). Growth of maize (Zea mays L.) and changes in some chemical properties of an utisol amended with brewery effluent. *African Journal of Biotechnology*, 4(9) 973-978.

Petters, S.W.; Usoro E.J.; Udo, E.J.; Obot, U.W. and Okpon S.N. (1989). Akwa Ibom State physical background, soils and landuse. The Taskforce on Soils and Landuse. Govt. Printer Uyo. 602p.

Sule, R. A. O. (2001) Urban environmental pollution: Criticality and synopsis. Calabar: BAAS International Publishers.

Tahal Consultants (1979). Qua Iboe river basin pre-feasibility study (2): Soil survey and land capability classification, water resources potentials; fisheries and forestry resources, Ibadan, Tahal Consultants.

Techobanoglous, G.; Burton, F.I. and Stensel, H.D. (1991). Waster Water Engineering Treatment, Disposal and Reuse. 4th Edition, NcGraw Hill Book Company, New York.

United States Environmental Protection Agency. (2022). Standards for Water Body Health. Water Quality Standards Academy.

Whitehead, P. J. (1979) An introduction to atomic absorption spectrophotometer (AAS) (1st ed.) Rye UNICAM.

Work Bank (1997). Industrial Pollution, Prevention and Abatement: Breweries Draft Technical Background Document. Environmental Department, Washington D.C.