www.ajbrui.org

*Afr. J. Biomed. Res. Vol. 22 (May, 2019); 207- 214*

*Research Article*

# Heavy metals Contamination in Soil and Water Samples in Omo Forest Reserve, Nigeria

***Omonona, A. O., Ajani, F, Adetuga, A. T. and Koledoye, O. J.**

*Department of Wildlife and Ecotourism Management, University of Ibadan, Ibadan. Nigeria*

**ABSTRACT**

The study examined heavy metal levels in soil and water samples and also determined the water quality parameters of water samples in Omo Forest Reserve. Water samples from River Omo (upper, middle and lower courses) and soil samples (at different locations in the reserve) were randomly collected for two seasons (one wet and one dry) and taken to the laboratories for heavy metal analyses and evaluation of water quality parameters using standard methods. Data collected were presented and expressed as Mean ± Standard Deviation and statistical significance was set at $\alpha_{0.05}$. The result showed that the soil samples had more heavy metal contamination during the wet season than the dry season with iron (Fe) having the highest mean concentration in the soil and water samples. Phosphate was not detected in the water samples during the dry season. The average values of sulphate (except dry season), phosphate, nitrate, chloride, alkali, TDS, TSS and TS observed from this study were below the WHO permissible limits. The high BOD values obtained from the study indicates heavy pollution of the river. *Escherichia coli*, *Staphyloccocus aureus* and fungi had no counts during the wet and dry season periods. The absence of Escherichia coli indicates no faecal contamination in the River. There is a great impact of anthropogenic activities on the ecosystem of the Omo Forest Reserve based on the concentration level of heavy metals investigated. There is need for government to explicitly curtail the high level of environment-degrading anthropogenic activities within and around the reserve.

**Keywords:** *Heavy metals, Ecotoxicology, Water quality parameters, Omo Forest Reserve*

*Author for correspondence: *E-mail*: ao.omonona@gmail.com; Tel. +23437258481

*Received: August 2018; Accepted: March, 2019*

***Abstracted by:***

*Bioline International, African Journals online (AJOL), Index Copernicus, African Index Medicus (WHO), Excerpta medica (EMBASE), CAB Abstracts, SCOPUS, Global Health Abstracts, Asian Science Index, Index Veterinarius*

## INTRODUCTION

Recent years have witnessed significant attention being paid to the problems of environmental contamination by a wide variety of contaminants (Omonona *et al*., 2014). One of such contaminants is heavy metals. Although there is no clear definition of what a heavy metal is, density has been in most cases taken to be the defining factor. As such, heavy metals are naturally occurring elements that have a high atomic weight and a density at least five times greater than that of water (Ming-Ho, 2005). They are ubiquitous in the environment and most of them have been found in elemental form and in a variety of other chemical compounds (Iwegbue *et al*., 2008). Anthropogenic activities have contributed to elevated and toxic levels of heavy metals when compared to those contributed from geogenic or lithological processes (Pam *et al*., 2013). Relevant exposure routes to heavy metals are the conventional ingestion, inhalation, and dermal absorption (Sardar *et al*., 2013). Environmental contamination by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms especially when permissible concentration levels are exceeded (Emmanuel *et al*., 2014).With the aid of rapid urbanization and industrialization, heavy metals are continually being introduced into soils, water and biota through several pathways including fertilizer application/utilisation, irrigation, rivers run-off, atmospheric deposition and mining (Nicholson *et al*., 2003; Emmanuel *et al*., 2014). Prolonged exposure to environmental contaminants even in very low concentrations have been reported to induce morphological, histological and biochemical alterations in the tissues of animals (Kaoud and El-Dahshan, 2010). In fact, a major global problem posing serious significant threats to flora and fauna including wildlife has been reported to be heavy metal contamination (Gupta, 2016). Changes in the characteristics of water quality parameters have also been reported to be indicative of changes in the condition of water samples (Gulson *et al*., 1997). This study was therefore aimed at evaluating heavy metal concentrations in soil and water samples as well as evaluating the water quality parameters in Omo Forest Reserve, Nigeria.

## MATERIALS AND METHODS

**Study Area:** The study was carried out in Omo Forest Reserve, located north of Sunmoge in the Ijebu area of Ogun State in Southwestern Nigeria between latitude 6° 35” to 7° 05” N and longitude 4° 19” to 4° 40” E and covering about 130,500 hectares. The reserve was constituted in 1925 as part of a bigger Shasha Forest reserve. Shasha was later split into Omo, Oluwa and Shasha forest reserves, the last two lying to the east and north-east of the present Omo. Geologically, the reserve lies on crystalline rocks of the undifferentiated basement complex which in the southern parts is overlain by Eocene deposits of sand, clay, and gravel.. The terrain is undulating and has a maximum elevation of 150m above sea level. The vegetation of the reserve is in the mixed moist, semi-evergreen rainforest zone, in the Congolian sub-unit of the Guinea-Congolian centre of endemism with dominant tree species like *Diospyros spp*, *Strombosia pustulata, Rinorea dentate, Nauclea diderrichii*, *Mansonia altissima*, *Terminalia spp, and Milicia excels.* The reserve is also rich in fauna species such as Forest Elephant (*Loxondata cycloti*s), White-throated monkey (*Cercopithecus albogularis*), Red river hog (*Potamochoerus porcus*), Duiker (*Cephalophus spp*), Small spotted genet cat *(Genetta genetta),* Civet cat*(Viverra civetta*), Brush tailed porcupine (*Atherurus africanus)*, Pangolin (*Manis spp*), Monitor Lizard *(Vananus niloticus*), Rock python *(Python regius*) and Chimpanzee *(Pan troglodytes*) and so on.

**Samples collection and Sampling Procedure:** Soil and water samples were collected from the study area using different techniques. For soil sampling, seven (7) soil samples of the topsoil (0 – 15 cm depth) were collected randomly from the study area into polythene bags, labelled appropriately and subsequently investigated for heavy metals. For water sampling, water samples were collected at the upper, middle and lower courses of the River Omo at a depth of 0 - 20 cm into sample bottles and were subsequently analyzed for heavy metals, physicochemical and microbial characteristics. Sample collection was done between June 2017 to January 2018 across two seasons (one wet and one dry) so as to assess the impact of seasonality on the parameters evaluated. All analyses were done at the Geo-Environmental Research Centre (GRC) Laboratory, Nigeria (Basel Convention Coordinating Centre for Training and Technology Transfer for the African Region, Federal Ministry of Environment - University of Ibadan linkage Centre for Cleaner Production Technology and Hazardous Waste Management, University of Ibadan) and the Department of Microbiology Laboratory, University of Ibadan.

**Parameters Evaluated:** For the heavy metals, Cadmium (Cd), Copper (Cu), Lead (Pb), Chromium (Cr), Zinc (Zn), Nickel (Ni), Iron (Fe) and Manganese (Mn) were analyzed in soil, plant and water samples due to their toxicity and easy exposure.

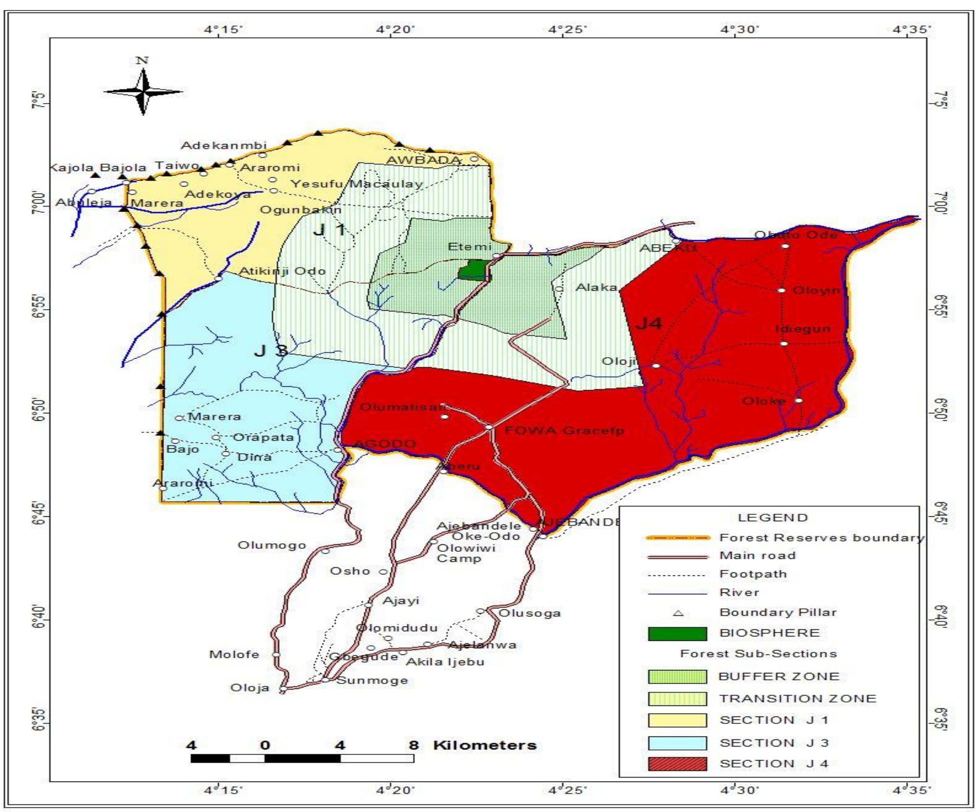


**Figure 1:**
Map of Omo Biosphere Reserve (*Source: Omo Biosphere Reserve, 2017*)

Physico-chemical characteristics of the water samples such as temperature, pH, electrical conductivity (EC), total dissolved solid (TDS), Total Suspended Solids (TSS), Total Solid (TS), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Alkali, Nitrate ($NO_3^-$), Chloride ($Cl^-$), Phosphate ($PO_4^{3-}$) and Sulphate ($SO_4^{2-}$) were evaluated while the microbial characteristics were also determined.

**Laboratory Analyses and Methods:**
Heavy metals in the samples were determined by Atomic Absorption Spectrophotometer (AAS) using standard procedures at specified wavelengths (Schleich *et al.*, 2010) sequel to complete digestion using concentrated nitric acid. The pH of the water samples was determined *in-situ* using a pH meter (Waterproof portable HI9813-5) while the temperature, EC and TDS were determined by using HM Digital Waterproof EC/TDS/TEMP Combo Meter Model COM-100 *in-situ* as well after calibration at 25ºC. Physico-chemical parameters such as TSS, TS, DO, COD, BOD, Alkali, $NO_3^-$, $Cl^-$, $PO_4^{3-}$ and $SO_4^{2-}$ and microbial characteristics were analyzed *ex-situ* (in the laboratory) according to the method as described by APHA (2008).

**Statistical Analysis:**
Data collected were presented and expressed descriptively as Mean ± Standard Deviation and subjected to inferential statistics (T-test) using Statistical Package for Social Sciences (version 20). Statistical significance was set at $\alpha_{0.05}$.

**RESULTS**

**Heavy metals concentration in soil samples:**
The result showed that the soil samples had more heavy metal contamination during the wet season than the dry season with Fe having the highest concentration in the soil samples for both seasons while Cd had the least concentration during the wet season with Cr having the least concentration during the dry season as shown in Tables 1 and 2. The mean values of heavy metals in soil samples of Omo Forest Reserve is presented in Table 3. The result showed that Zn (156.13 ± 167.67) and Cd (1.07 ± 0.64) levels during wet season were above the comparable WHO Permissible Limit.

**Table 1:**
Heavy metal concentration in soil samples of Omo Forest Reserve (June, 2017)

| Sample Codes | Coordinates | Cu (mg/kg) | Ni (mg/kg) | Cr (mg/kg) | Zn (mg/kg) | Fe (mg/kg) | Pb (mg/kg) | Mn (mg/kg) | Cd (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| **$SS_1$** | N 06°49.928’ E004°22.200’ | 7.25 | ND | 0.00 | 15.80 | 5120.00 | 11.30 | 74.00 | 0.25 |
| **$SS_2$** | N 06°49.870’ E004°22.301’ | 11.25 | 3.75 | 0.00 | 202.00 | 4550.00 | 9.73 | 75.50 | 2.00 |
| **$SS_3$** | N 06°49.928’ E004°22.200’ | 3.75 | ND | 0.00 | 117.00 | 3130.00 | 2.83 | 59.00 | 0.50 |
| **$SS_4$** | N 06°53.469’ E004°20.309’ | 7.25 | 2.00 | 0.00 | 479.00 | 5720.00 | 12.40 | 53.00 | 1.25 |
| **$SS_5$** | N 06°49.928’ E004°22.200’ | 4.75 | ND | 0.00 | 33.30 | 8050.00 | 3.15 | 148.00 | 0.75 |
| **$SS_6$** | N 06°49.849’ E004°22.297’ | 9.75 | 2.00 | 0.00 | 232.00 | 14700.00 | 0.28 | 161.00 | 1.00 |
| **$SS_7$** | N 06°44.675’ E004°17.429’ | 6.25 | 3.50 | 0.00 | 13.80 | 8310.00 | 8.08 | 220.00 | 1.75 |

Note: ND – Not Detected

**Table 2:**
Heavy metal concentration in soil samples of Omo Forest Reserve (January, 2018)

| Sample Codes | Coordinates | Cu (mg/kg) | Ni (mg/kg) | Cr (mg/kg) | Zn (mg/kg) | Fe (mg/kg) | Pb (mg/kg) | Mn (mg/kg) | Cd (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| **$SS_1$** | N 06°49.928’ E004°22.200’ | 0.00 | 0.00 | 0.00 | 0.32 | 17.20 | 10.43 | 1.62 | 0.00 |
| **$SS_2$** | N 06°49.870’ E004°22.301’ | 0.00 | 0.00 | 0.00 | 0.919 | 4.32 | 0.00 | 0.90 | 0.00 |
| **$SS_3$** | N 06°49.928’ E004°22.200’ | 0.00 | 0.00 | 0.00 | 2.85 | 7.30 | 0.00 | 1.83 | 0.00 |
| **$SS_4$** | N 06°53.469’ E004°20.309’ | 0.00 | 0.00 | 0.00 | 4.10 | 12.10 | 0.00 | 5.73 | 0.00 |
| **$SS_5$** | N 06°49.928’ E004°22.200’ | 0.00 | 0.00 | 0.00 | 3.17 | 9.36 | 0.00 | 1.92 | 0.00 |
| **$SS_6$** | N 06°49.849’ E004°22.297’ | 0.00 | 0.00 | 0.00 | 0.55 | 29.30 | 0.00 | 4.96 | 0.00 |
| **$SS_7$** | N 06°44.675’ E004°17.429’ | 0.00 | 0.00 | 0.00 | 3.13 | 15.20 | 10.72 | 1.20 | 0.00 |

**Heavy metals concentration in water samples:**
The result showed that Fe had the highest concentration in the water samples of River Omo during the wet season with Cr having the least concentration while Mn had the highest concentration during the dry season as shown in Tables 4 and 5. The mean values of heavy metals in River Omo of Omo Forest Reserve are presented in Table 6. The result showed that Ni (wet season), Zn (wet season), Fe (wet and dry seasons), Pb (wet season), Mn (wet and dry seasons) and Cd (wet season) levels were above the comparable WHO and NSDWQ Permissible Limits while Cu (wet season) was only above the NSDWQ Permissible Limit.

**Physicochemical Characteristics of Water Samples (River Omo):**
The result showed that PO43- was not detected in the water samples during the dry season. The pH, temperature, EC, TDS, TSS, TS, COD, BOD and SO42- values were higher during the dry season as compared with those of wet season while DO, NO3- and Cl- values were higher during the wet season than the dry season as shown in Tables 7 and 8. The mean values of physicochemical parameters in River Omo of Omo Forest Reserve are presented in Table 9. The result showed that COD (wet and dry seasons) and BOD (wet and dry seasons) levels were above the comparable WHO and NSDWQ Permissible Limits while SO42- (dry season) was only above the NSDWQ Permissible Limit**.**

**Table 3:**
Mean values of heavy metals in soil samples of Omo Forest Reserve

| Parameters | Mean Values ± Std. Deviation | | WHO Permissible Limit (2008) |
|---|---|---|---|
| | Wet Season (June 2017) | Dry Season (January 2018) | |
| **Cu (mg/kg)** | 7.18 ± 2.64* | 0.00 ± 0.00 | 30 |
| **Ni (mg/kg)** | 2.81 ± 0.94* | 0.00 ± 0.00 | NG |
| **Cr (mg/kg)** | 0.00 ± 0.00 | 0.00 ± 0.00 | NG |
| **Zn (mg/kg)** | 156.13 ± 167.67 | 2.15 ±1.51 | 50 |
| **Fe (mg/kg)** | 7082.85 ± 3834.33 | 13.54 ± 8.25 | - |
| **Pb (mg/kg)** | 6.82 ± 4.72* | 3.02 ± 5.16* | 85 |
| **Mn (mg/kg)** | 112.93 ± 63.80* | 2.59 ± 1.93* | NG |
| **Cd (mg/kg)** | 1.07 ± 0.64* | 0.00 ± 0.00* | 0.3 |

*****Indicates mean values are statistically significant at P<0.05, NG – Not Given

**Table 4:**
Heavy metal concentration in River Omo in Omo Forest Reserve (June, 2017)

| | Sample Codes | Coordinates | Cu (mg/l) | Ni (mg/l) | Cr (mg/l) | Zn (mg/l) | Fe (mg/l) | Pb (mg/l) | Mn (mg/l) | Cd (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| **DS** | N 06°44.675' E004°17.429' | 2.00 | 2.25 | 0.00 | 7.25 | 80.00 | ND | 11.30 | 0.75 | |
| **MS** | N 06°53.469' E004°20.309' | 2.25 | 2.00 | 0.00 | 11.30 | 99.50 | 30.80 | 22.30 | 1.75 | |
| **US** | N 06°49.928' E004°22.200' | 1.00 | 2.00 | 0.00 | 3.50 | 82.20 | 3.93 | 9.75 | 2.25 | |

*DS – Downstream, MS – Midstream, US – Upstream, ND – Not Detected*

**Table 5:**
Heavy metal concentration in River Omo in Omo Forest Reserve (January, 2018)

| Sample Codes | Coordinates | Cu (mg/l) | Ni (mg/l) | Cr (mg/l) | Zn (mg/l) | Fe (mg/l) | Pb (mg/l) | Mn (mg/l) | Cd (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| **DS** | N 06°44.675' E004°17.429' | 0.00 | 0.00 | 0.00 | 0.01 | 1.70 | 0.00 | 2.88 | 0.00 |
| **MS** | N 06°53.469' E004°20.309' | 0.00 | 0.00 | 0.00 | 0.00 | 1.76 | 0.00 | 2.97 | 0.00 |
| **US** | N 06°49.928' E004°22.200' | 0.00 | 0.00 | 0.00 | 0.03 | 1.62 | 0.00 | 0.10 | 0.00 |

*DS – Downstream, MS – Midstream, US - Upstream*

**Table 6:** Mean values of heavy metals in River Omo of Omo Forest Reserve

| Parameters | Mean Values ± Std. Deviation | | WHO Permissible Limit (2011) | NSDWQ Limit (2007) |
|---|---|---|---|---|
| | Wet Season (June 2017) | Dry Season (January 2018) | | |
| **Cu (mg/l)** | 1.75 ± 0.66* | 0.00 ± 0.00 | 2.0 | 1.0 |
| **Ni (mg/l)** | 2.08 ± 0.14* | 0.00 ± 0.00 | 0.07 | 0.02 |
| **Cr (mg/l)** | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.05 | 0.05 |
| **Zn (mg/l)** | 7.35 ± 3.90 | 0.01 ± 0.02 | 5.0 | 3.0 |
| **Fe (mg/l)** | 87.23 ± 10.68 | 1.69 ± 0.07 | 0.3 | 0.3 |
| **Pb (mg/l)** | 17.37 ± 18.99 | 0.00 ± 0.00 | 0.01 | 0.01 |
| **Mn (mg/l)** | 14.45 ± 6.84 | 1.98 ± 1.63 | 0.4 | 0.2 |
| **Cd (mg/l)** | 1.58 ± 0.76 | 0.00 ± 0.00 | 0.003 | 0.003 |

*****Indicates mean values are statistically significant at P<0.05

**Table 7:**
Physicochemical Characteristics of River Omo (June, 2017)

| Sample Codes | Coordinates | pH | Temp ($^{O}C$) | EC (µS) | TDS (mg/l) | TSS (mg/l) | TS (mg/l) | Alkali (mg/l) | DO (mg/l) | COD (mg/l) | BOD (mg/l) | $SO_4^{2-}$ (mg/l) | $PO_4^{3-}$ (mg/l) | $NO_3^-$ (mg/l) | $Cl^-$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DS** | N 06°44.675’ E004°17.429’ | 7.52 | 28.50 | 76.20 | 39.00 | 231.00 | 270.00 | 50.00 | 7.00 | 120.00 | 30.80 | 80.90 | 0.21 | 0.41 | ND |
| **MS** | N 06°53.469’ E004°20.309’ | 6.79 | 26.40 | 84.60 | 43.20 | 242.00 | 285.20 | 40.00 | 8.30 | 140.00 | 50.80 | 97.60 | 0.28 | 1.33 | 35.7 |
| **US** | N 06°49.928’ E004°22.200’ | 7.52 | 25.70 | 80.80 | 41.10 | 255.00 | 296.10 | 30.00 | 6.10 | 112.00 | 68.30 | 94.50 | 0.20 | 0.48 | 11.9 |

DS – Downstream, MS – Midstream, US – Upstream, ND – Not Detected

**Table 8:**
Physicochemical Characteristics of River Omo (January, 2018)

| Sample Codes | Coordinates | pH | Temp ($^{O}C$) | EC (µS) | TDS (mg/l) | TSS (mg/l) | TS (mg/l) | Alkali (mg/l) | DO (mg/l) | COD (mg/l) | BOD (mg/l) | $SO_4^{2-}$ (mg/l) | $PO_4^{3-}$ (mg/l) | $NO_3^-$ (mg/l) | $Cl^-$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DS** | N 06°44.675’ E004°17.429’ | 6.61 | 30.00 | 90.00 | 44.50 | 259.00 | 303.50 | 60.00 | 5.80 | 176.00 | 60.00 | 156.00 | ND | 0.036 | 3.97 |
| **MS** | N 06°53.469’ E004°20.309’ | 6.66 | 28.90 | 101.00 | 52.00 | 264.00 | 316.00 | 50.00 | 6.30 | 200.00 | 90.00 | 148.00 | ND | 0.037 | 1.99 |
| **US** | N 06°49.928’ E004°22.200’ | 6.45 | 28.80 | 103.00 | 53.80 | 270.00 | 323.80 | 40.00 | 5.40 | 128.00 | 50.00 | 129.00 | ND | 0.036 | 3.97 |

DS – Downstream, MS – Midstream, US – Upstream, ND – Not Detected

**Table 9:**
Mean values of Physicochemical Parameters in River Omo of Omo Forest Reserve

| Parameters | Mean Values ± Standard Deviation | | WHO Permissible Limit (2011) | NSDWQ Limit (2007) |
|---|---|---|---|---|
| | Wet Season (June 2017) | Dry Season (January 2018) | | |
| **pH** | 7.28 ± 0.42 | 6.57 ± 0.11 | 6.5 – 8.5 | 6.5 – 8.5 |
| **Temp (ºC)** | 26.87 ± 1.46 | 29.23 ± 0.67 | 25 - 30 | Ambient |
| **EC (µS/cm)** | 80.53 ± 4.20* | 98.00 ± 7.00* | 250 | 1000 |
| **TDS (mg/l)** | 41.10 ± 2.10 | 50.10 ± 4.93 | 500 | 500 |
| **TSS (mg/l)** | 242.67 ± 12.01 | 264.33 ± 5.51 | - | - |
| **TS (mg/l)** | 283.77 ± 13.11* | 314.43 ± 10.24* | - | 1500 |
| **Alkali (mg/l)** | 40.00 ± 10.00 | 50.00 ± 10.00 | 100 | 100 |
| **DO (mg/l)** | 7.13 ± 1.11 | 5.83 ± 0.45 | 7.5 | - |
| **COD (mg/l)** | 124.00 ± 14.42 | 168.00 ± 36.66 | 7.5 | - |
| **BOD (mg/l)** | 49.97 ± 18.76 | 66.67 ± 20.82 | 2.0 – 6.0 | - |
| **$SO_4^{2-}$ (mg/l)** | 91.00 ± 8.88 | 144.33 ± 13.87 | 400 | 100 |
| **$PO_4^{3-}$ (mg/l)** | 0.23 ± 0.04* | ND | 5.0 | - |
| **$NO_3^-$ (mg/l)** | 0.74 ± 0.51 | 0.04 ± 0.00 | 10 | 50 |
| **$Cl^-$ (mg/l)** | 23.80 ± 16.83 | 3.31 ± 1.14 | 200 | 250 |

*****Indicates mean values are statistically significant at $P<0.05$

**Table 10:**
Microbial Characteristics of River Omo (June, 2017)

| Sample Codes | Coordinates | Total Heterotrophic Bacteria count ( $\times 10^4$ ) | *E. coli* count | *Staphylococcus aureus* count ( $\times 10^2$ ) | Salmonella /Shigella count( $\times 10^2$ ) | Fungi count ( $\times 10^2$ ) | Coliform count( $\times 10^2$ ) | Microflora Obtained |
|---|---|---|---|---|---|---|---|---|
| **US** | N 06°44.675’ E004°17.429’ | 2.80 | 0.00 | 0.00 | 2.08 | 0.00 | 300.00 | *Bacillus sp., Actinobacter sp., Enterobacter sp., Salmonella sp., Shigella sp.* |
| **MS** | N 06°53.469’ E004°20.309’ | 1.50 | 0.00 | 0.00 | 1.88 | 0.00 | 500.00 | *Bacillus sp., Actinobacter sp., Enterobacter sp., Salmonella sp., Shigella sp., Flavobacter sp.* |
| **DS** | N 06°49.928’ E004°22.200’ | 2.60 | 0.00 | 0.00 | 2.27 | 0.00 | 500.00 | *Bacillus sp., Actinobacter sp., Enterobacter sp., Salmonella sp., Shigella sp.* |

**Table 11:**
Microbial Characteristics of River Omo (February, 2018)

| Sample Code | Coordinates | Total Heterotrophic Bacterial Count ( ($\times 10^3$) | *E. coli* count | Staphylococcus Count ( $\times 10^2$ ) | Salmonella/Shigella Count ( $\times 10^2$ C) | Fungi count( $\times 10^2$ ) | Coliform Count (MPN index/100ml) | Microflora Obtained |
|---|---|---|---|---|---|---|---|---|
| **US** | N 06°44.675’ E004°17.429’ | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 170.00 | *Bacillus* sp., *Enterobacter* sp. |
| **MS** | N 06°53.469’ E004°20.309’ | 6.40 | 0.00 | 0.00 | 0.00 | 0.00 | 350.00 | *Bacillus* sp., *Pseudomonas* sp., *Enterobacter* sp. |
| **DS** | N 06°49.928’ E004°22.200’ | 7.30 | 0.00 | 0.00 | 0.00 | 0.00 | 350.00 | *Bacillus* sp., *Pseudomonas* sp., *Flavobacterium* sp. |

**Table 12:**
Mean values of Microbial Characteristics of water samples (River Omo)

| Parameters (CFU/ml) | Mean Values ± Standard Deviation | |
|---|---|---|
| | Wet Season (June 2017) | Dry Season (January 2018) |
| **Total Heterotrophic Bacteria count** | 2.30 ± 0.70 | 4.80 ± 3.58 |
| **Escherichia coli count** | 0.00 ± 0.00 | 0.00 ± 0.00 |
| **Staphylococcus aureus count** | 0.00 ± 0.00 | 0.00 ± 0.00 |
| **Salmonella / Shigella count** | 2.08 ± 0.20* | 0.00 ± 0.00 |
| **Fungi count** | 0.00 ± 0.00 | 0.00 ± 0.00 |
| **Coliform count** | 433.33 ± 115.47 | 290.00 ± 103.92 |

***Indicates mean values are statistically significant at P<0.05

**Bacteriological Characteristics of Water Samples (River Omo)**

The result showed that E. coli, Staphyloccocus aureus and fungi had no counts during the wet and dry season periods while there was no Salmonella / Shigella count during the dry season as shown in Tables 10 and 11 below. The mean values of microbial characteristics of River Omo of Omo Forest Reserve are presented in Table 12. The result showed that the Salmonella / Shigella and Coliform counts were higher during the wet season while the total heterotrophic bacteria count was higher during the dry season. Escherichia coli, Staphylococcus aureus and fungi load had no count.

## DISCUSSION

Heavy metals enter and often circulate within the environment as a result of different anthropogenically-induced activities and their concentration in soil samples vary according to the rate of heavy metals deposition, soil particle size and the availability of organic matter in the soil samples (Wang and Qin, 2005). From this study, it was discovered that the soil and water samples were contaminated more during the wet season than the dry season. This may be as a result of run-off as averred by Jung (2001) and Ajibade *et al.* (2008). Of noteworthy is the fact that Fe had the highest concentration in the soil samples for both seasons. This agrees with Adefemi *et al.* (2007) who posited that Fe occurs at high concentrations in most Nigeria soils. The implication of this is that there is enough Fe concentration for plant uptake in maintaining proper metabolic and physiological cellular processes such as chlorophyll biosynthesis, nitrogen fixation, DNA replication and reactive oxygen species (ROS) scavenging (Yruela, 2013). Meanwhile Cd was discovered to have the least concentration during the wet season with Cr having the least concentration during the dry season. The mean values of all the metals except that of Cr were found to be higher than the WHO limits. For the water samples, the result showed that Fe had the highest concentration during the wet season (this may be as a result of surface run-off into the water body) with Cr having the least concentration while during the dry season, Mn had the highest concentration followed by Cu, Ni, Cr, Pb and Cd having the same least concentration. The mean values of Ni, Zn, Mn (except for dry season), Fe, Pb and Cd were found to be higher than the WHO and NSDWQ limits. The implication of this is that River Omo is not safe for drinking. Statistically, for the soil samples, only the variance between the mean values of Zn and Fe showed no significant difference ($P<0.05$) while for the water samples, the variance between the mean values of Cu and Ni showed significant difference ($P>0.05$). The level of heavy metal concentration observed in the soil and water samples may be attributed to the dominant anthropogenic activities such as sawmill industry, massive logging, heavy-duty vehicular movement, and farming being carried out within/around the study area. Exhaust from vehicles plying the ever-busy Benin-Ore-Sagamu expressway may also be a contributing source of heavy metals.

The physicochemical characteristics of water samples obtained from this study can be compared with those of tropical rivers. The pH ranged from 6.79 to 7.52 in the wet season and between 6.45 and 6.66 in the dry season with an average of 7.28 and 6.57 respectively. This implies that the River Omo is not potable mostly during the dry season. The higher values observed in the wet season compared to dry season maybe due to increase in water level with greater retention capacity. The temperature of all the water samples ranged from 25.7ºC to 28.6ºC in the wet season and between 28.8 – 30.0ºC in the dry season with an average of 26.87ºC and 29.2ºC respectively, falling within the temperature range recommended for aquatic life in the tropical environment (Ayodele and Ajani, 1999). The higher values recorded in the dry season could be attributed to the warming effect of the solar radiation as averred by Ajibade *et al.* (2008). The EC values observed in this study ranged between 76.2 – 84.6 µS in the wet season and 90 – 103 µS in the dry season with an average of 80.53 µS and 98.00 µS respectively. This is contrary to Ajibade *et al*. (2008) who reported higher values during the wet season due to the leaching of the mineral salt from the bedrock and re-suspension of solids. The average values of sulphate (except dry season), phosphate, nitrate, chloride, alkali, TDS, TSS and TS observed from this study were below the permissible limits (WHO, 2011). The low nitrate and phosphate levels observed could be attributed to the negligible run-off of chemical fertilizers and other sources of phosphate and nitrate into the river as corroborated by Dami *et al*. (2013). Statistically, the variance between the mean values of EC, TS and phosphate showed significant difference ($P>0.05$). The low phosphate levels may be attributed to dilution and movement of water which could not allow aquatic sedimentation and decay of organic matter (Keke *et al.*, 2015). Of noteworthy is the fact that the average values of DO (except dry season), COD and BOD from our study are far above the permissible limits of WHO (2011). The higher values obtained during the wet season may be as a result of agitation and frequent wind current in the water (Kolo, 1996). The higher values of COD and BOD observed during the dry season may be attributed to decay of organic matter favoured by high temperature. The high BOD values obtained from the study indicates heavy pollution of the river and poor water quality (Adakole *et al.*, 2008; Samuel *et al.*, 2015) and can as well lead to ammonia and hydrogen sulphide production as reported by Ajibade *et al. (* 2008).

The water quality standards are often expressed not only in terms of the physicochemical parameters but also microbiological characteristics. Microbiological quality of drinking water is usually expressed in terms of the concentration and frequency of occurrence of particular species of bacteria (Sandy and Richard 1995). As such, water is usually tested either for the presence of the total coliform group or for the presence of faecal coliform (Ajibade *et al.*, 2008). From our study, it was discovered that higher microbial load was observed during the wet season probably due to run-off. These findings disagree with Venkateesharaju *et al.* (2010) but agrees with Nnane *et al*. (2011) who opined that greater incidence of pathogen loads is likely to occur when there is high rainfall. The absence of *Escherichia coli* indicates no faecal contamination of the river (Davies-Colley, 2013). This is contrary to Ajibade *et al*. (2008) who reported faecal pollution through the presence of *E. coli* in the rivers of Kainji Lake National Park, Nigeria. Statistically, the variance between the mean values of Salmonella/Shigella showed significant difference (P>0.05) during the dry season.

The concentrations of the heavy metals examined in the study except for chromium were above permissible limits by the World Health Organization. The high BOD values obtained from the study indicates heavy pollution of the River Omo and the absence of *E. coli* in the waters of River Omo indicated no faecal contamination of the river. There is a great impact of anthropogenic activities on the ecosystem of the Omo Forest Reserve which may result in gradual species decline. There is need for government or designated agency to explicitly curtail the high level of anthropogenic activities within the reserve through proper monitoring backed by adequate law enforcement and not keeping a docile watch to reduce pollution of the reserve's ecosystem.

### *Acknowledgement*

The authors are grateful to the management of Omo Biosphere Reserve for the access and opportunity to conduct the research, and also appreciate the critical evaluations of the anonymous reviewers.

### *Conflict of Interest*

The authors have not declared any conflict of interest.

## REFERENCES

**Adakole, J. A., Abulode, D. S. and Balarabe, M. L. (2008)** Assessment of Water Quality of a Man-Made Lake in Zaria Nigeria. Sengupta, M. and Dalwani, R., Eds., *Proceedings of Taal* 2007: *The* 12*th World Lake Conference*, 1373-1382.

**Adefemi, O. S., D. Olaofe and S. S. Asaolu, (2007).** Seasonal variation in heavy metal distribution in the sediment of major dams in Ekiti-State. Pakistan J. Nutrition, 6(6): 705-707.

**Ajibade, W.A., Ayodele, I.A. and Agbede, S.A. (2008).** Water quality parameters in the major rivers of Kainji Lake National Park, Nigeria. *African Journal of Environmental Science and Technology* vol 2(7) pp 185-196

**Akoleowo, O. A. (2002).** Abattoir Waste Water Constituents and Its Effects on the Underground Water at Bodija Demonstration Abattoir, Ibadan. Unpublished M.Sc. Thesis. University of Ibadan.

**APHA. (2008).:** Standard methods for the examination of water and wastewater, 19th Edn. APHA, Washington, D.C.

**Ayodele, I. A. and Ajani, E. K. (1999).** Essential of Fish Farming. Pub. Odua Printing Co. Ltd. Ibadan p. 39.

**Dami, A., Ayuba, H. K. and Amukali, O. (2013).** Groundwater pollution in Okpai and Beneku, Ndokwa East local Government, Delta State, Nigeria. *J. Env. Res & Mgt.* 4(1): 0171- 0199.

**Davies-Colley, R. J. (2013).** River water quality in New Zealand: an introduction and overview. *In* Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

**Emmanuel, A., Cobbina, S. J., Adomako, D., Duwiejuah, A. B. and Asare, W. (2014).** Assessment of heavy metals concentration in soils around oil filling and service stations in the Tamale Metropolis, Ghana. *Afr. J. Environ. Sci. Tech* Vol 8(4) pp 256-266

**Gulson, B.L., Sheehan, A., Giblin, A.M., Chiaradia, M. and Conradt, B. (1997).** The efficiency of removal of lead and other elements from domestic drinking waters using a bench-top water filter system. *Sci. Tot. Environ*. 196:205-216.

**Gupta, V. (2013).** Exposure of Captive Wild Mammals in Kota Zoo India to Urban Air Pollution. Indian Journal of Applied Research. 3.3: 139-142

**Iwegbue, C. M. A., Nwajei, G. E and Iyoha, E. H. (2008).** Heavy metal residues of chicken meat and gizzard and turkey meat consumed in southern Nigeria. Bulg. *J. Vet. Med*.11 (4): 275−280.

**Jung, M.C. (2001).** Heavy metal contamination of soils and waters in and around the Imcheon Au–Ag mine, Korea. *Applied Geochemistry* 16 pp 1369-1375

**Kaoud, H. A. and El-Dahshan, A. R. (2010).** Bioaccumulation and histopathological alterations of the heavy metals in Oreochromis niloticus fish. *Nature and Science* 2010; 8(4) 147-156

**Keke, U. N., Arimoro, F. O., Ayanwale, A. V. and Aliyu, S. M. (2015).** Physicochemical Parameters and Heavy Metals Content of Surface Water in Downstream Kaduna River, Zungeru, Niger State, Nigeria. *Applied Science Research Journal*, Vol. 3(2): 46 -57

**Kolo, A. I. (1996).** The Assessment of Physio-Chemical Parameters of Shiroro Lake and Its Major tributries. *Proceedings of 1996 FISON Conference*. pp 260-268.

**Ming-Ho, Y. (2005).** Environmental Toxicology: Biological and Health Effects of Pollutants, Chap. 12, CRC Press LLC, ISBN 1-56670-670-2, 2nd Edition, BocaRaton, USA**.**

**Nicholson F.A., Smith, S.R. and Alloway, B.J. (2003).** An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci. Total Environ.* 311: 205-219.

**Nnane, D. E., Ebdon, J. E. and Taylor, H. D. (2011).** Integrated analysis of water quality parameters for cost-effective faecal pollution management in river catchments. *Water Research* 45(6): 2235-2246.

**Omonona, A.O., Adetuga, A. T., and Jubril, A. J. (2014).** Micronucleus as a Biomarker of Genotoxicity in Village Weaver Birds (*Ploceus cucullatus*). *World's Veterinary Journal* Vol. 4 No 4: 48-53

**Pam, A. A., Ato, R. S. and Offem, J. O. (2013).** Contribution of Automobile Mechanic Sites to Heavy Metals in Soil: A case study of North Bank Mechanic village, Makurdi, Benue State, Central Nigeria. Journal *of Chemical, Biological and Physical Sciences* 3(3) 2337-2347

**Samuel, P. O., Adakole, J. A. and Suleiman, B. (2015).** Temporal and Spatial Physicochemical Parameters of River Galma, Zaria, Kaduna State, Nigeria. *Resources and Environment* 5(4): 110-123

**Sandy C, Richard F (1995).** Quality and Standard for Drinking Water Chapter 3 Environmental Health Engineering in the Tropics. And Introductory Textbook Wiley Inter Science. 2nd Edition. ISBN 0471938858, p. 294.

**Sardar, K., Ali, S., Samra, H., S., Sana, A., Samar, F., Shakoor, M.B. Bharwana, S.A. and Tauqeer, H.M. (2013).** Heavy Metals Contamination and what are the Impacts on Living Organisms. *Greener Journal of Environmental Management and Public Safety* Vol. 2 (4), Pp. 172-179

**Schleich, C.E., Beltrame, M.O. and Antenucci, C.D. (2010).** Heavy metals accumulation in the subterranean rodent Ctenomys talarum (Rodentia: Ctenomyidae) from areas with different risk of contamination. *Folia Zool.* 59 (2): 108– 114.

**Venkatesharaju, K., Ravikumar, P., Somashekar, R. K. and Prakash, K. L. (2010).** Physicochemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. *Kathmandu University J. Sci, Eng Technol*., 6 (1): 50- 59.

**Wang, X.S. and Qin, Y. (2005).** Accumulation and Sources of Heavy Metals in Urban Top soils: A Case Study from The City of Xuzhou, China. // *Environ. Geol.*, v. 48, p. 101–107.

**WHO (2011).** Guidelines for Drinking – Water Quality. Vol 1. (Geneva: WHO).

**Yruela, I. (2013).** Transition metals in plant photosynthesis. *Metallomics.* 5: 1090–1109