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# SEASONAL VARIATION OF HEAVY METAL CONCENTRATIONS IN WATER AND SEDIMENT SAMPLES OF ERELU RESERVOIR (OYO TOWN, NIGERIA) AND THEIR EFFECTS ON ITS MACRO-INVERTEBRATES

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## ABSTRACT

Contamination of water and sediment of aquatic reservoirs with heavy metals is the main ecological problem world over. The present study was conducted to investigate the seasonal variations in heavy metal concentrations of water and sediment samples of Erelu reservoir (Oyo Town, Nigeria) and their impacts on its macro-invertebrates. Water samples were collected monthly in the morning across the seven selected stations. Heavy metal concentrations were determined using Atomic Absorption Spectrophotometer. Macro-invertebrates were collected and identified with standard methods. Data collected were analysed using paired t-test and Pearson's Correlation Coefficient(r). The results showed that the heavy metal concentration in water was in the order of Zn>Pb>Fe>Cr>Cd (mg/L) where asPb>Fe>Zn>Cd>Cr during dry season. Likewise, the concentration in sediment was in the order of Fe>Pb>Cr>Cd>Zn during wet season whereas Pb>Fe>Zn>Cr>Cd during dry season respectively. Fe (mg/L), Zn(mg/L) and Cr(mg/L) in water samples were significantly different ($p<0.05$) across seasons and stations while that of Pb (mg/kg) and Zn (mg/kg) in sediment samples were also significantly different ($p<0.05$) across stations respectively. Zinc(mg/L)in water samples strongly related with Iron (r= 0.894**) while Cadmium mg/kg significantly ($p<0.05$) related with Iron (r=0.837**) and Chromium mg/kg (r= 0.839**) in sediment samples respectively. Water sample Lead had positive correlation with Odonata (r= 0.743*); Zinc related with Unionidea (r= 0.691*) while Cadmium related significantly with Capitellida (r= 0.826**) respectively. However, Lead, Iron, Zinc, Chromium and Cadmium of sediment samples related significantly ($p<0.05$) with majority of macro-invertebrate orders respectively. The result indicated that the heavy metals in sediments were higher in values compared to those in water samples and there were significant seasonal variations. Sediment samples have greater influence on macro-invertebrate abundance of Erelu Reservoir compared to that of water samples.

**Keywords:** Taxonomic keys, Metal concentration, Odonata, Sorbeoconcha, Aquatic Ecosystem.

## 1. INTRODUCTION

Heavy metals are naturally occurring metals which have atomic number greater than 20 and specific gravity greater than $5g/cm^3$ [1]. Heavy metal has its own merit or demerits. Based on this, these are categorized into two: essential and non-essential. Essential heavy metals are important for living organisms and may be required in the body in minute quantity. Non-essential heavy metals have no reasonable biological role in living organisms [2]. The essential metals also known as trace metals, include Manganese, Iron, Copper, Cobalt and Zinc, while the non-essential metals are Cadmium, Lead and Mercury,they are very toxic and are referred to as macronutrients. The trace metal elements are needed in smaller quantity and are important for development and stress resistance and many at times for biosynthesis which are useful for different biomolecules like Carbohydrate, chlorophyll, nucleic acids, growth chemicals and secondary metabolites [3].However, extreme concentrations of important metals may be harmful to living organisms [4].

Metals get into the freshwater due to breaking down of soils and rocksoriginated out of volcanic outbreaks. However, the huge amount of it is discharged by anthropogenic activities [5], as well rocks are broken as a result of different kinds of human activities such as mining, metal processing or utilization or substances that consist of metal contaminants [6, 7]. Natural origin of heavy metals varied from country to country but notably could also be from landfill or discharge waste from tanning, chemical, pharmaceutical, agricultural and different textile industries which resulted to metal pollution in the aquatic environment [8,9,10].Presence of too much heavy metals in freshwaters causes fall in pH of water, metal solubility rises and metal particles are easily mobile which is the reason why metal toxicity occurs in most soft waters and locking up of metal in the bottom sediment of water bodies for a considerable period of time, since they are non-biodegradable [11]. Contamination of heavy metals in the aquaticsystem has drawn attention globally due to its persistence and environmental toxicity [12,13,14,15]. Heavy metals that are extremely toxic such as cadmium, mercury, arsenic and lead are considered as severe contaminant in the aquatic environment [16,17].Toxicity of human energy exchange with heavy metals pose a threat to human health. Examples include Minimata and Itai-itai diseases both reported in Japan which were caused by consumption of mercury-contaminated fish and Cadmium- contaminated rice respectively. These resulted into symptom like ataxia, numbness of hands and feets, damage to hearing and speech, softening of bones and kidney failure. Higher concentration of trace metals in aquatic ecosystems can pose health risk to these organisms or their human consumers, especially organisms of higher trophic levels due to biomagnifications [18]. In order to protect human health from the harmful effects of toxic heavy metals, the human food chains should be constantly monitored for bioaccumulation and biomagnifications of heavy metals [19]. The concentrations of heavy metals are extremely high in sediment than in surface water because metal tends to accumulate in bottom deposits [20, 21, 22]. Sediment in the aquatic environmenthas been broadly used as environmental indicators for the assessment of metal contamination in the natural water [23]. Erelu reservoir is the main source of water supply for domestic, agriculture and fishing activities in Oyo town, Nigeria. The reservoir receives inflow of materials from catchment where various anthropogenic activities occur which could impact its ecosystem. Despite its socio-economic importance, there is paucity of information on the heavy metal concentrations in water and sediment samples and the relationship of these heavy metals with the abundance of macro-invertebrates of the reservoir. Therefore, the objectives of this study are to assess the heavy metal concentration, seasonal variations of heavy metals in water and sediment samples of Erelu reservoir and their impacts on the macro-invertebrates of this reservoir.

## 2.MATERIALS AND METHODS

Vol. 06, No. 02; 2021

ISSN: 2456-8643

**Description of the Study Area**

The study site for this research work was Erelureservoir. Erelureservoir is located inOyo town.It was built on Aawon River along Oyo /Iseyin road in 1959 and was commissioned in 1961 to provide water for drinking, agricultural, irrigational and fishing activities. Currently, it also provides water for International Institute of Tropical Agriculture (IITA) for its nursery unit in Oyo Town. The impoundment of the dam is 161.07ha, and the catchments area is 243.36km. Erelureservoir is approximately 6.4km from the core of Oyo town and it supplies potable water to the town. An output of 7.5million litres is released per day, from a reservoir capacity of 10cm$^3$[24, 25,]. (Fig.1). The region covers rainy period of April to October and dry period of November to March. Vegetation around the reservoir is evergreen, interspersed with grasses and trees. Some of the predominant tree species around the reservoir are,*Anacardiumoccidentale*, *Cocosnucifera*, *Parkiabiglobosa*, *Psidiumguajava*. Reservoir banks are covered with *Pistiastratiotes*, *Eichnorrniacrassipes*, etc. Notable herbs along the banks are *Talinumtriangulare*, *Jatrophagossipiifolia*, *Ocimumbacilicum*,*Amaranthusspinosus* while fish fauna found in the reservoir includes *Coptodonzilli*, *Chrysichthysnigrodigitatus*, *Hepsetusodoe* etc.

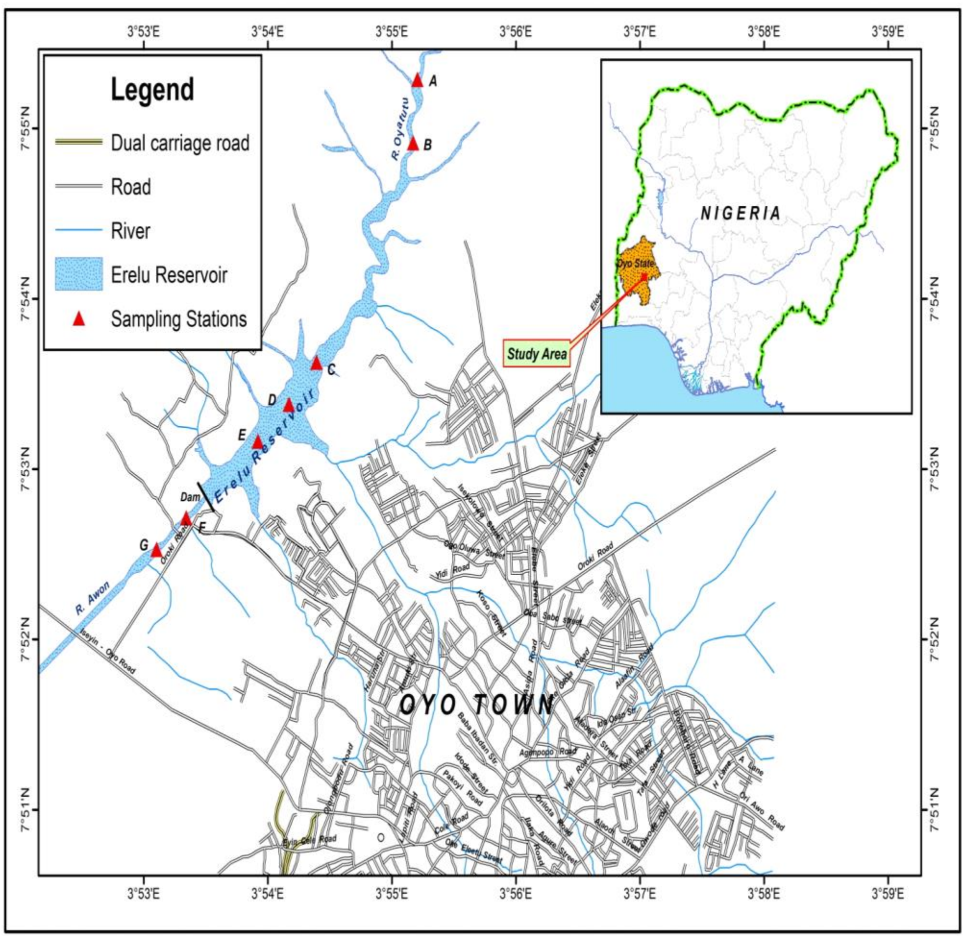


Fig.1: Map of study Area

**Table 1: Description of Sampling Stations**

| Stations | Description |
|---|---|
| Inlet (A&B) | This is located at Oya tutu, 5km away from the reservoir. It has longitude 3º54'0.5''E and latitude 7º52'15.3''N, surrounded by agricultural field with sandy substrate. |
| Reservoir (C,D&E) | This station has longitude 3º53'5.8''E and latitude 7º52'42.8''N, located within the reservoir with muddy substratum and landing stations for the fishermen. Trees provide shade for the water and evergreen vegetations. There are less human activities here. |
| Outlet (F&G) | This location is where water exits into the river, at longitude 3º55'6.0''E and latitude 7º54'5.8''N. This station has sandy substrate with leaf particles, human activities such as ritual bath, cattle grazing, fish catch with Gammalin20 etc.There is overhead bridge that is motorable to villages near the reservoir |

**Water Sample and Sediment Collections**

Water samples were collected from each station very early in the morning (8am-10am) once in a month for the period of two years (June 2013-May 2015). Water samples for heavy metal analysis were collected in plastic container (2-litres) from selected stations. The sample water taken were transported to the research laboratory and analysed instantly to guarantee that the water quality parameters were sustained. Sediment samples of about 200g were collected at the depth of 0-5 cm using Van-veen grab of 66.6cm$^3$ surface area from different sampling locations in the reservoir and kept in a polythene bag [26].

**Heavy Metals Determination in water and sediment samples**

Lead (Pb), Iron (Fe), Zinc (Zn), Cadmium (Cd) and Chromium (Cr) in water samples were determined using an Atomic Absorption Spectrophotometer, Model Analyst A10 PGP.About 2g of sediment collected was grinded and sieved using 2mm diameter sieve and kept in an airtight nylon bag, sediment samples were freeze-dried to obtain constant weight. The samples were homogenized by grinding in a mortar, sieved and store in a labeled glass bottlestill ready for chemical analysis. The digestion was done by heating 1gram of grinded soil sediment with 20ml of mixture of 70% $HClO_4$ and concentrated $HNO_3$ (2:1) to near dryness and 20ml of 0.5M $HNO_3$ was added after cooling, sieved and add up to 50ml with distilled water. The amount of Pb, Cr, Cd, Zn, and Fe were determined using the above model AAS using already prescribed procedure[27, 28].

**Macro-invertebrate Collections**

Vol. 06, No. 02; 2021

ISSN: 2456-8643

The benthic organisms were collected from the sampling stations using a Van-veen grab with a surface area of 66.6cm$^2$. Sediments collected from each station were emptied into a pre-labeled polythene bag and the samples for heavy metals determination were taken. The sample collected from each station was sieved with a net of mesh size of 0.5mm to remove the excess sediments. Macro-invertebrates collected from the residue were air-dried and preserved with naphthalene for onward transfer to the laboratory for identification. Aquatic insect collections were sampled using a dip-net of 500 µm mesh size. The net was dipped in water at different stations and swirled for about 2-3 minutes at the surface of water to allow for the entrance of the aquatic insects and their nymphs which were emptied into pre-labeled plastic bottles according to station numbers. Adult insects like dragonflies, damselflies were also gathered from the vegetation around the reservoir using a sweep net of mesh size of 250µm. The net was swept over vegetation for 2-3 minutes and were emptied into pre-labelled plastic bottles. Aquatic macro-invertebrates were identified using aquatic taxonomic keys [29-32].

**Statistical Analysis**

The results of laboratory analysis of heavy metal concentrations and data collected for aquatic macro-invertebrates were subjected to paired t-test for significance and derivation of Pearson's Correlation coefficient (r).

## 3. RESULTS

**Table 2: Mean Concentration(Mean ± SE) of heavy metals in water sample from Erelu Reservoir compared with National and International Standards**

| Parameters (mg/L) | Reservoir Inlet | Main Reservoir | Reservoir Outlet | Drinking water Limits | NESREA Limits (Aquatic Environment) |
|---|---|---|---|---|---|
| | | | | 0.05$^a$ | |
| **Lead (Pb)** | 0.93±0.10 | 1.85±0.86 | 1.06±0.11 | 0.05$^b$ | 0.05 |
| | 0.05-2.94 | 0.00-3.00 | 0.02-3.22 | 0.01c | |
| | | | | 0.30$^a$ | |
| **Iron (Fe)** | 0.59±0.07 | 0.58±0.06 | 0.58±0.08 | 0.03$^b$ | 1.0 |
| | 0.00-1.56 | 0.00-2.50 | 0.01-1.71 | 0.30$^c$ | |
| | | | | 5.00$^a$ | |
| **Zinc (Zn)** | 1.03±0.31 | 0.89±023 | 0.90±0.27 | 1.5$^b$ | 1.0 |
| | 0.06-8.15 | 0.03-8.55 | 0.02-7.69 | 3.00$^c$ | |

Vol. 06, No. 02; 2021

ISSN: 2456-8643

| | | | | | |
|---|---|---|---|---|---|
| **Chromium (Cr)** | 0.23±0.04<br>0.00-1.17 | 0.30±0.06<br>0.00-3.63 | 0.21±0.03<br>0.00-1.08 | 0.05[a]<br>0.10[b]<br>0.05[c] | 0.03 |
| **Cadmium (Cd)** | 0.22±0.03<br>0.00-0.78 | 0.25±0.03<br>0.00-1.79 | 0.23±0.03<br>0.00-0.88 | 0.005[a]<br>0.01[b]<br>0.003[c] | 0.02 |

**Keys to Abbreviations and Agencies**

NS=Not Specified

a=WHO-World Health Organization

b=NESREA-National Environmental Standard and Regulation Enforcement Agency

c=SON-Standard Organization of Nigeria

**Sample Size = Seven (7)**

**Table 3: Mean concentration (Mean ± SE) of heavy metal in sediment samples from Erelu Reservoir compared with National and International Standards**

| **Parameters (Mg/kg)** | **Reservoir Inlet** | **Main Reservoir** | **Reservoir Outlet** | **Drinking water Limits** | **NESREA Limits (Aquatic and Environment)** |
|---|---|---|---|---|---|
| **Lead (Pb)** | 24.70±3.26<br>1.24-87.51 | 22.86±2.59<br>1.23-96.03 | 24.26±3.23<br>1.06-88.56 | 0.05[a]<br>0.05[b]<br>NS[c] | 0.05 |
| **Iron (Fe)** | 19.26±3.80<br>0.41-90.00 | 23.03±3.71<br>0.00-98.30 | 18.85±4.03<br>ND-91.30 | NS[a]<br>5.00[b]<br>NS[c] | 1.0 |
| | | | | NS[a] | 1.0 |

| | | | | | |
|---|---|---|---|---|---|
| **Zinc (Zn)** | 4.72±1.23 | 4.09±0.77 | 4.70±1.14 | 1.00[b] | |
| | 0.10-38.5 | 0.10-28.1 | 0.10-37.5 | NS[c] | |
| | | | | 0.05[a] | |
| **Chromium (Cr)** | 10.36±2.61 | 12.40±2.56 | 11.20±2.71 | 0.05[b] | 0.03 |
| | 0.00-73.12 | 0.00-88.14 | 0.00-69.00 | 0.05[c] | |
| | | | | 0.005[a] | |
| **Cadmium (Cd)** | 3.10±0.35 | 3.18±0.39 | 3.40±0.46 | 0.01[b] | 0.02 |
| | 0.55-13.65 | 0.00-16.65 | 0.51-17.50 | NS[c] | |

**Keys to Abbreviations andAgencies**
NS=Not specified

a=WHO-World Health Organization (2011)

b=NESREA- National Environmental Standard and Regulation Enforcement Agency (2011)

c=SON-Standard Organization of Nigeria (2007)

**Sample Size = Seven (7)**
Lead (Pb), Chromium (Cr) and Cadmium (Cd) concentration values in water samples were higher than the required standards of national and international limits across the study areas except Zinc (Zn)that recorded lowest values across sampling stations. The concentrations of Iron (Fe) were higher than the permissible limits of 0.30 mg/l (WHO, 2004) and 0.30(SON, 2007) but below 1.0mg/l NESREA limits in all stations (Table 1). Values of heavy metals in the sediment samples such as Pb, Fe, Zn, Cr and Cd concentrations exceeded the limits for drinking water and aquatic life limits across the sampling stations (Table 2).

**Table 4: T-values of significance showing seasonal differences of heavy metals from water samples of EreluReservoir .**

| Parameters | Seasons | Inlet | Reservoir | Outlet |
|---|---|---|---|---|
| Lead (mg/l) | **Rainy** | 0.86±0.09 | 0.91±0.08 | 0.97±0.11 |
| | **Dry** | 1.02±0.10 | 1.17±0.09 | 1.18±0.11 |
| Iron (mg/l) | **Rainy** | 0.52±0.05 | 0.51±0.05 | 0.47±0.71 |
| | **Dry** | 0.68±0.09 | 0.69±0.08 | 0.73±0.10 |
| | | * | * | * |

ISSN: 2456-8643

| | | | | |
|---|---|---|---|---|
| Zinc (mg/l) | **Rainy** | 1.43±0.36 | 1.11±0.33 | 1.21±0.31 |
| | **Dry** | 0.52±0.06 | 0.49±0.07 | 0.47±0.06 |
| | | * | * | * |
| Chromium (mg/l) | **Rainy** | 0.28±0.04 | 0.35±0.07 | 0.22±0.04 |
| | **Dry** | 0.16±0.02 | 0.23±0.03 | 0.19±0.02 |
| | | * | * | * |
| Cadmium (mg/l) | **Rainy** | 0.20±0.02 | 0.25±0.03 | 0.19±0.02 |
| | **Dry** | 0.24±0.04 | 0.25±0.03 | 0.29±0.04 |
| | | * | | * |

***Significant(p<0.05)**

**Table 5: T-values of significance showing seasonal differences of heavy metals from sediments samples of Erelu Reservoir.**

| **Parameters** | **Seasons** | **Inlet** | **Reservoir** | **Outlet** |
|---|---|---|---|---|
| Lead (mg/kg) | **Rainy** | 17.45±1.50 | 14.18±1.16 | 13.80±1.34 |
| | **Dry** | 34.82±=4.66 | 35.03±3.52 | 38.91±4.16 |
| | | * | * | * |
| Iron (mg/kg) | **Rainy** | 17.24±3.92 | 21.82±3.77 | 20.14±5.36 |
| | **Dry** | 25.35±4.75 | 26.72±4.19 | 22.04±4.44 |
| Zinc (mg/kg) | **Rainy** | 2.18±0.23 | 2.01±0.19 | 2.29±0.35 |
| | **Dry** | 8.28±1.92 | 6.10±1.18 | 8.07±1.75 |
| | | * | * | * |
| Chromium (mg/kg) | **Rainy** | 5.69±1.37 | 10.89±2.35 | 12.88±4.91 |
| | **Dry** | 16.90±3.75 | 14.52±2.82 | 13.80±4.27 |
| | | * | | |
| Cadmium (mg/kg) | **Rainy** | 3.43±2.69 | 3.71±3.61 | 4.03±3.92 |

| | | | | |
|---|---|---|---|---|
| | **Dry** | 2.63±1.80 | 2.44±2.12<br>* | 2.52±1.50 |

***Significant (p<0.05)**

T-test of significance showing variations of heavy metals in water samples of the three stations are presented in table 3. The result showed that Lead (mg/L) concentrations did not differ significantly ($p$>0.05) between seasons and across the stations. However, Iron, Zinc and Chromium differed significantly ($p$<0.01), while Cadmium significantly differed only in the inlet and outlet stations. The Lead and Zinc mg/kg in sediment samples differed significantly ($p$<0.01) between seasons and across sampling stations. Differences between concentration of Iron mg/kg was non-significant ($p$>0.05) across seasons and stations, while concentration of Chromium and Cadmium mg/kg were significant only at inlet and reservoir stations respectively (Table 3&4).

**Table 5: Pearson's correlation coefficient (r) between water heavy metals parameters with insect macro-invertebrates abundance of Erelu Reservoir**

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1.Diptera | 1 | | | | | | | | |
| 2.Coleoptera | -0.222 | 1 | | | | | | | |
| 3.Hemiptera | 0.533 | 0.310 | 1 | | | | | | |
| 4.Odonata | 0.490 | -0.155 | 0.555 | 1 | | | | | |
| 5.Lead (mg/l) | -0.185 | -0.070 | 0.212 | 0.743* | 1 | | | | |
| 6.Iron (mg/l) | -0.315 | -0.060 | -0.106 | 0.518 | 0.755* | 1 | | | |
| 7.Zinc (mg/l) | -0.389 | 0.089 | -0.383 | 0.239 | 0.480 | 0.894** | 1 | | |
| 8.Chromium (mg/l) | -0.438 | 0.077 | 0.083 | 0.489 | 0.837** | 0.833** | 0.635 | 1 | |
| 9.Cadmium (mg/l) | -0.335 | 0.141 | -0.326 | 0.346 | 0.588 | 0.854** | 0.951** | 0.594 | 1 |

*. Correlation is (significant, p< 0.05). Number of observation n=7, df =79 **. Correlation is (significant, p< 0.01).

**Table 6: Pearson's correlation coefficient (r) between water heavy metal parameters with benthic macro-invertebrates abundance of Erelu Reservoir**

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Architaenioglossa | 1 | | | | | | | | | | | |
| 2. Capitellida | 0.056 | 1 | | | | | | | | | | |
| 3. Diptera | 0.083 | -0.295 | 1 | | | | | | | | | |
| 4. Hygrophila | 0.637 | -0.132 | 0.005 | 1 | | | | | | | | |
| 5. Pulmonata | 0.211 | -0.134 | 0.322 | 0.045 | 1 | | | | | | | |
| 6. Sorbeoconcha | 0.324 | 0.590 | 0.283 | 0.050 | 0.315 | 1 | | | | | | |
| 7. Unionidea | 0.191 | 0.244 | 0.464 | -0.272 | 0.808** | 0.588 | 1 | | | | | |
| 8. Lead (mg/l) | -0.268 | 0.488 | -0.223 | -0.230 | -0.208 | -0.196 | -0.066 | 1 | | | | |
| 9. Iron (mg/l) | -0.145 | 0.494 | -0.103 | -0.380 | 0.410 | 0.086 | 0.538 | 0.755* | 1 | | | |
| 10 Zinc (mg/l) | -0.126 | 0.633 | -0.173 | -0.441 | 0.494 | 0.354 | 0.691* | 0.480 | 0.894** | 1 | | |
| 11 Chromium (mg/l) | -0.338 | 0.279 | -0.377 | -0.389 | 0.034 | -0.424 | 0.072 | 0.837** | 0.833** | 0.635 | 1 | |
| 12 Cadmium (mg/l) | -0.130 | 0.826** | -0.226 | -0.394 | 0.284 | 0.450 | 0.560 | 0.588 | 0.854** | 0.951** | 0.594 | 1 |

*. Correlation is (significant, p< 0.05). Number of observation n=7, df = 82**. Correlation is (significant, p<0.01).

Pearson's correlation coefficient revealed Lead to have inverse relationship with Diptera (r= -0.185) and Coleoptera (r= -0.070) but a significant correlation with Odonata (0.743*). Iron related with Lead (r= 0.755*) significantly. Chromium has a strong significant (p<0.01) association with lead (r= 0.837**) and Iron (r= 0.833**), while Cadmium had a strong significant (p<0.01) correlation with Zinc (r= 0.951**) and Iron (r= 0.854**) respectively (Table 3). Iron related with Lead (r= 0.755*). Zinc showed positive association with Unionidea (r= 0.691*) and Iron (r= 0.894**) while Cadmium has a closed association with Capitellida (r= 0.826**), Iron (r =0.854**) and Zinc (r= 0.951**) respectively (Table 5&6).

**Table 7: Pearson's correlation coefficient (r) between sediment heavy metal parameters with insect macro-invertebrates abundance of Erelu Reservoir**

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Diptera | 1 | | | | | | | | |
| 2. Coleoptera | -0.222 | 1 | | | | | | | |
| 3. Hemiptera | 0.533 | 0.310 | 1 | | | | | | |
| 4. Odonata | 0.490 | -0.155 | 0.555 | 1 | | | | | |
| 5. Lead (mg/kg) | 0.556 | -0.303 | 0.092 | -0.026 | 1 | | | | |
| 6. Iron (mg/kg) | 0.168 | -0.158 | -0.176 | 0.525 | 0.102 | 1 | | | |
| 7. Zinc (mg/kg) | 0.620 | -0.472 | 0.061 | 0.208 | 0.905** | 0.426 | 1 | | |
| 8. Chromium (mg/kg) | -0.064 | -0.150 | -0.313 | 0.305 | -0.227 | 0.837** | 0.151 | 1 | |
| 9. Cadmium (mg/kg) | -0.130 | 0.032 | -0.316 | 0.400 | -0.208 | 0.912** | 0.065 | 0.839** | 1 |

*. Correlation is (significant, p<0.05). Number of observation n=7, df = 33 **. Correlation is significant, p< 0.01).

**Table 8: Pearson's correlation coefficient (r) between sediment heavy metals parameters with benthic macro-invertebrates abundance of Erelu Reservoir**

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Architaenioglossa | 1 | | | | | | | | | | | |
| 2. Capitellida | 0.056 | 1 | | | | | | | | | | |
| 3. Diptera | 0.083 | -0.295 | 1 | | | | | | | | | |
| 4. Hygrophila | 0.637 | -0.132 | 0.005 | 1 | | | | | | | | |
| 5. Pulmonata | 0.211 | -0.134 | 0.322 | 0.045 | 1 | | | | | | | |
| 6. Sorbeoconcha | 0.324 | 0.590 | 0.283 | 0.050 | 0.315 | 1 | | | | | | |
| 7. Unionidae | 0.191 | 0.244 | 0.464 | -0.272 | 0.808** | 0.588 | 1 | | | | | |
| 8. Lead (mg/kg) | 0.516 | -0.110 | 0.505 | 0.683* | -0.078 | 0.389 | -0.112 | 1 | | | | |
| 9. Iron (mg/kg) | 0.050 | 0.691* | 0.282 | -0.041 | 0.425 | 0.692* | 0.645 | 0.102 | 1 | | | |
| 10 Zinc (mg/kg) | 0.468 | -0.035 | 0.680* | 0.605 | 0.230 | 0.499 | 0.199 | 0.905** | 0.426 | 1 | | |
| 11 Chromium (mg/kg) | 0.099 | 0.457 | 0.202 | -0.173 | 0.779* | 0.531 | 0.878** | -0.227 | 0.837** | 0.151 | 1 | |
| 12 Cadmium (mg/kg) | -0.003 | 0.854** | -0.057 | -0.220 | 0.346 | 0.649 | 0.616 | -0.208 | 0.912** | 0.065 | 0.839** | 1 |

*. Correlation is (significant, p<0.05).Number of observation n=7, df = 69 **. Correlation is (significant, p< 0.01).

Zinc mg/kg related significantly with Lead (r= 0.905**). There was a close association between Chromium and Iron (r= 0.837**), Cadmium and Iron (r= 0.912**). Heavy metal parameters were either positivelyand inversely related with insect orders (Table 7). The benthic order Unionidea related with Pulmonata (r= 0.808**) strongly while Lead had correlation with Hygrophila (r= 0.683*). Iron closely associated with Capitellida (r= 691*) and order Sorbeoconcha (r= 0.692*) respectively.Zinc mg/kg in sediment samples had correlation with Diptera (r= 0.680*), while Chromium mg/kg related strongly with Pulmonata (r= 0.779*); Unionidea (r= 0.878**) and Iron (r= 0.837**) respectively. Cadmium mg/kgrevealed significant ($p$<0.01)relationship with Capitellida (r= 0.854**); Iron (r= 0.912**) and Chromium (r= 0.839**)respectively (Table 8).

## 4. DISCUSSION

### Comparison of Heavy Metals with Standard Limits

The metal concentrations in water samples that revealed higher values across stations could be attributed to waste input, runoff from agricultural field into the reservoir and detergent used for washing and ingredients of local soaps that are being used for ritual baths. Similar observation was reported by Islam *et al*. [33]. The concentrations of metals such as Pb, Fe, Cr and Cd that were higher than the permissible limits of WHO [34] indicated impact of anthropogenic activities because of the houses built near the reservoir. Similar observation was made by Mokaddes *et al.* [35] and higher concentrations of Cr, Pb and Zn more than the present study were as well reported by some other researchers [36, 37]. Lowest value of Zn below permissible limits of agencies that was recorded indicated its low input into the reservoir. Highest values of Zinc more than the permissible limits of WHO was reported by Gupta and Gupta [38] in Bangladesh. However, higher concentrations of metals in the sediment samples examined in this study might be due to natural processes such as metal contents of rocks, effluents from Garri industries, cans of chemicals or pesticides used for agricultural crops. All these sink into the sediment as a result of bioaccumulation. That could be responsible for the exceeded values than the standard limits of WHO, SON and NESREA. Similar observation of highest values of Cd, Cr, Pb was observed in Rupsa River by Proshad *et al.* [39] where the reasons for the exceeded values was attributed to effect from point and non-point sources in Bangladesh [40, 16]

### Seasonal Variations of Heavy Metals in water and Sediments

The non-significant seasonal differences and across stations of leadin water samples ofErelu reservoir could be due to similar source of input into the water body.Similar observation was reported by Taiwo and Adebukola [41] in Opa Reservoir. Significant seasonal variation of Fe, Zn and Cr (mg/L) could be due to waste input or influx of flood during rainy season that might bring the content of the metal into the reservoir. Similar observations were made by Kimani *et al.* [42] for Chania River Kenya and IqraAzam *et al*. [43] in Pakistan who related it to urban expansion, tanneries which enhanced pollution that threat the studied river. The significant differences in the concentration of Pb in sediment samples across year and stations indicated complex sources of anthropogenic input into the river during wet and dry season. Similar observation was made by Kimani *et al.* [42] in Kenya. Significantly higher concentration of Cr and Cd mg/kg that were significant only in the inlet and reservoir stations could be attributed to the fertilizer input from agricultural field in the inlet and runoff into the reservoir especially during wet season. This report is deviated from the observation of Shahadat *et al.* [44] who reported non-significant variation of Cd, Cr, Zn, Pb and Ni across stations in their study area.

**Pearson's Correlation of heavy metals and Macro-invertebrates in water and sediment samples**

The strong significant association of Cr and Iron, Cd and Iron in sediment samples may be attributed to their bioaccumulation in the reservoir sediment. The strong association of Lead in water samples and Odonata indicated that it has a greater influence on the population of Damsel and Dragonflies in the reservoir. Similar observation was made by Girgin*et al*. [45] where the concentrations of Cd, Pb, Cu, Zn and Fe in the water samples were reported to have impact on the composition of insect community of the study area. The present observation disagrees with the report of Friedrick and Hudson [46]. The observed linear relationship between heavy metals such as Fe, Cd, Cr versus Pb and Cd versus Zn in water samples implies that the metals come from similar sources like bathing, faecal contamination e.t.c. into the reservoir. Similar observation of strong relationship was also reported by other researchers [47, 48]. This observation disagrees with the report of Hong-Yan*et al.* [49] who also reported significant higher concentration of metals that come from different sources into the Chinese Rivers investigated. The strong relationship between Iron and lead, Zinc and Fe revealed similar origin into the reservoir. Chromium that strongly related with Pb and Fe, Fe and Zn indicated that these heavy metals probably came from the same waste sources / inputs into the reservoir [47]. Many metals that were not significantly related with the abundance of Diptera, Coleoptera, Hemiptera, is an indication of no effects of these chemicals on the population dynamic of these orders of macro-invertebrates. This report is deviated from with the observation of some other researchers [50, 51] who also reported inverse association of some metals with the abundance of class Insecta. The strong relationship of Zn with Pb, Cr versus Fe, Cd versus Fe and Cr in the sediment samples could be attributed to a similar source of these metals into the reservoir and that the sediment receives the effluents that washed into the reservoir [52]. The Unionidea and Pulmonata that had close relationship in water and sediment samples might be due to their abundance in fairly polluted environment and hibernation in the reservoir sediment. Lead in the sediment samples that showed positive significant correlation with hygrophila (*Lymnae natalensis*) has influence on its abundance but showed no relationship with other groups of benthic macro-invertebrates. This implies that lead has positive influence on *Lymnae species* abundance. Iron in the sediment samples that showed positive correlation with Capitellida and Sorbeoconcha seems to influence their abundance. High incidence of Iron has also been reported in Nigeria soils [53]. The positive significant relationship between Zinc, Lead and Dipteran indicated similar source of pollution by these chemicals in the reservoir and great tolerance of Dipteran in a contaminated environment as Zinc influenced its abundance [54]. Negative correlation of Zinc with Hemiptera was observed by Girgin *et al.* [45]. The positive significant correlation between Chromium with Pulmonata, Unionidea and Iron may be due tocontamination of water by human wastes. Okoro [55] also reported relationship of Iron with coleopteran in their study area. Chromium, Iron and Lead that were significantly related might be due to identical sources of anthropogenic input into the reservoir Ewa *et al.* [56]. The positive significant correlation between cadmium, Iron and Chromium in the sediment with the Capitellidamay be attributed to pollution since it is a worm that dwells directly in the sediment and oxygen depleted environment.

## 5. CONCLUSION

The observed heavy metals in water samples during wet seasons was in the order: Zn>Pb>Fe>Cr>Cd whereas during dry seasons it was: Pb>Fe>Zn>Cd>Cr. Likewise, order of heavy metals in the sediment in wet season was: Fe>Pb>Cr>Cd>Zn whereas during dry seasons it was: Pb>Fe>Cr>Zn>Cd respectively. It was noted that there were significant differences in metal concentrations across stations which implied that sources of metal during wet season is different from that of dry season as a result of flooding and runoff during raining periods and that reduced level of water has implication on the concentration of metals during the dry season. The significant relationship of some heavy metals on the assemblage of macro-invertebrates indicated that they have influencing power on their abundance, while the inverse relationship of some heavy metals with macro-invertebrates impliedthat decrease concentrations of heavy metals caused rise in the abundance of those organisms. Some metals relatedinversely with each other; an indication of varied sources into the reservoir. Heavy metals in the sediment samples have no much impact on the aquatic insects compared to the benthic macro-invertebrates.This is because the benthos inhabit in the sediment and directly experience the impact of metal pollution. However, macro-invertebrates encountered in this study were mostly tolerant organisms to pollution which could be the reason for the negative impact of heavy metals on their abundance. Therefore, the Erelu reservoir should be properly monitored for heavy metal contamination as the tolerant macro-invertebrates encountered confirmed the gradual deterioration of the water body.

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