# Assessment of Macronutrients in a Tropical Rainforest Stream, Southern Nigeria

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**Abstract.** The macronutrients of water samples from Ogbei Stream in Nkpologwu, Aguata Local Government Area of Anambra State, Nigeria was investigated between May 2008 and April 2009. Water samples were collected fortnightly using sterilized plastic containers fresh from factory. The pattern of cationic dominance in the study was Ca>Mg>Na>Fe. The calcium concentration was highest in station 4 (7.54±0.82 mg/l). The highest and lowest mean values of magnesium, iron and sodium occurred in station 6 (6.16±6.40 mg/l, range 0.60 – 7.60 mg/l) and lowest in station 5 (5.97 ± 0.42 mg/l), range 0.70 – 8.30 mg/l), station 2 (1.46±0.34 mg/l, 0.10 – 4.60 mg/l) and station 6 (1.27±0.32 mg/l, range 0.00 – 4.30 mg/l), and station 1 (2.13±0.78 mg/l, range 0.30 – 12.90 mg/l) and station 3 (1.99±0.73 mg/l, range 0.30 – 12.90 mg/l) respectively. No significant difference ($p>0.05$) existed between the various mean values recorded for the different parameters at the study stations. The highest mean calcium concentration value of 12.42±0.16 mg/l recorded in March was significantly different ($p<0.05$) from the mean values of all other months. The mean magnesium concentration was maximum (7.56±0.08 mg/l) in February. The June and September mean values for iron differed significantly ($p<0.05$) from each other and from the values of all other months. Sodium was highest in June (4.48±1.21 mg/l) and lowest (0.35±0.02 mg/l) in November. T-test showed that calcium, magnesium and iron mean values recorded in the dry season and rainy season were significantly different ($p<0.05$). There was no significant difference ($p>0.05$) in the sodium mean values obtained for dry season and rainy season.

**Keywords**: assessment, macronutrients, tropical rainforest, stream

## 1 INTRODUCTION

Water is one of the basic necessities of life. It has both agricultural, economic, industrial and domestic uses. It is one of the classes of food and contains macronutrients which Dedeke et al. (2010) called macrominerals and Roberts (1976) referred to as major nutrients. Macronutrients includes calcium, magnesium, iron and sodium. These macrominerals at high levels are of health concern to man. Ogbei Stream is the main surface water in Nkpologwu community. Most often whenever the town borehole fails, the stream serves as an alternative source of drinking water for the community and her environs. Since concrete structure has been erected at the source of the stream and several other human activities occur within the watershed, there is need to conduct the present study to assess the level of the macronutrients which usually pose health risks at high levels.

## 2 MATERIALS AND METHODS

### Description of the Study Area

The study area is Ogbei Stream in Nkpologwu town, Aguata Local Government Area, Anambra State, Nigeria. Ogbei Stream, a perennial stream tributary of Ota-Alu River lies between latitudes 5° 58' - 6° 01' N and longitudes 7° 06' - 7° 08' E (Fig. 1). The study area is characterized by two seasons namely rainy season (April – September) and dry season (October – February). A concrete structure was erected at source of the stream in 2005.

**Collection of Water Samples**

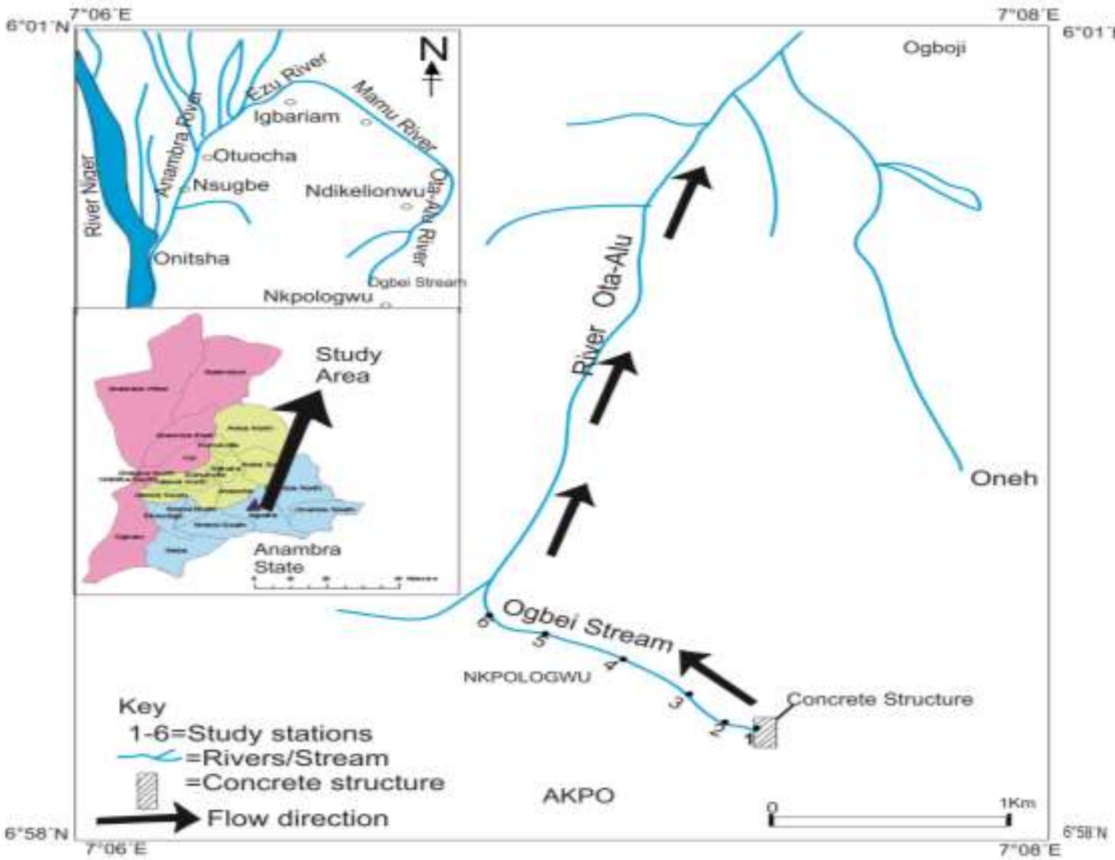


Fig.1: Map of the Study Area

Six sampling stations namely stations 1, 2, 3, 4, 5 and 6 were studied for a period of twelve months from May 2008 – April 2009. Water samples for analyses were collected using new and sterilized plastic containers with cover. Each container was carefully labeled according to sampling stations. Collected samples were conveyed to laboratory for analyses.

**Analyses of Water Samples**

Calcium and magnesium were determined titrimetrically. Iron and sodium were determined using orthophenonthroline method (Allen, 1989) and flame emission photometric method (APHA, 1998) respectively.

**Statistical Analysis**

Data were analyzed using SPSS version 2.0. All data on macronutrients were assessed for normality and homogeneity of variance. Non-normal data were transformed using appropriate transformation before analysis of variance (ANOVA). When the effects are significant in the ANOVA, Duncan's New Multiple Range Test (DNMRT) was used to separate monthly and station means. Paired t-test was performed to compare rainy and dry season values.

## 3 RESULTS

**Macronutrient variations in relation to stations**

Table 1 shows the results of macronutrients of Ogbei Stream according to stations.

**Table 1: Variations in mean (±S.E.) values of macronutrients according to stations at Ogbei Stream, Nigeria (May 2008 – April 2009)**

| Parameter | Stations | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Calcium (mg/l) | $6.82 \pm 0.72^{a}$ (0.90 – 12.70)* | $7.14 \pm 0.83^{a}$ (0.40 – 12.50) | $6.90 \pm 0.78^{a}$ (0.40 – 12.50) | $7.54 \pm 0.82^{a}$ (0.90 – 13.30) | $7.49 \pm 0.78^{a}$ (0.90 – 13.50) | $7.06 \pm 0.87^{a}$ (0.20 – 13.50) |
| Magnesium (mg/l) | $6.23 \pm 0.0.39^{a}$ (0.60 – 7.70) | $6.03 \pm 0.40^{a}$ (0.70 – 7.70) | $6.14 \pm 0.48^{a}$ (0.80 – 11.20) | $6.03 \pm 0.40^{a}$ (0.70 – 7.70) | $5.97 \pm 0.42^{a}$ (0.70 – 8.30) | $6.16 \pm 0.40^{a}$ (0.60 – 7.60) |
| Iron (mg/l) | $1.42 \pm 0.33^{a}$ (0.10 – 4.40) | $1.46 \pm 0.34^{a}$ (0.10 – 4.60) | $1.35 \pm 0.33^{a}$ (0.10 – 4.50) | $1.28 \pm 0.31^{a}$ (0.40 – 4.20) | $1.41 \pm 0.34^{a}$ (0.10 – 4.40) | $1.27 \pm 0.32^{a}$ (0.00 – 4.30) |
| Sodium (mg/l) | $2.13 \pm 0.78^{a}$ (0.30 – 12.70) | $1.99 \pm 0.73^{a}$ (0.30-12.90) | $1.97 \pm 0.73^{a}$ (0.30 – 12.20) | $2.08 \pm 0.74^{a}$ (0.30 – 12.50) | $2.03 \pm 0.75^{a}$ (0.20 – 12.80) | $2.11 \pm 0.77^{a}$ (0.30 – 12.70) |

The mean (± S.E) values with same superscript on the same row are not significantly different from each other at $p>0.05$

*The figures in parenthesis show range in station samples

The mean concentration of calcium recorded at the study stations varied between 6.82±0.72 mg/l in station 1 and 7.54±0.82 gm/l in station 4 ( Fig. 2). These values were not significantly different ($p>0.05$) from the values recorded at stations 2, 3, 5 and 6.

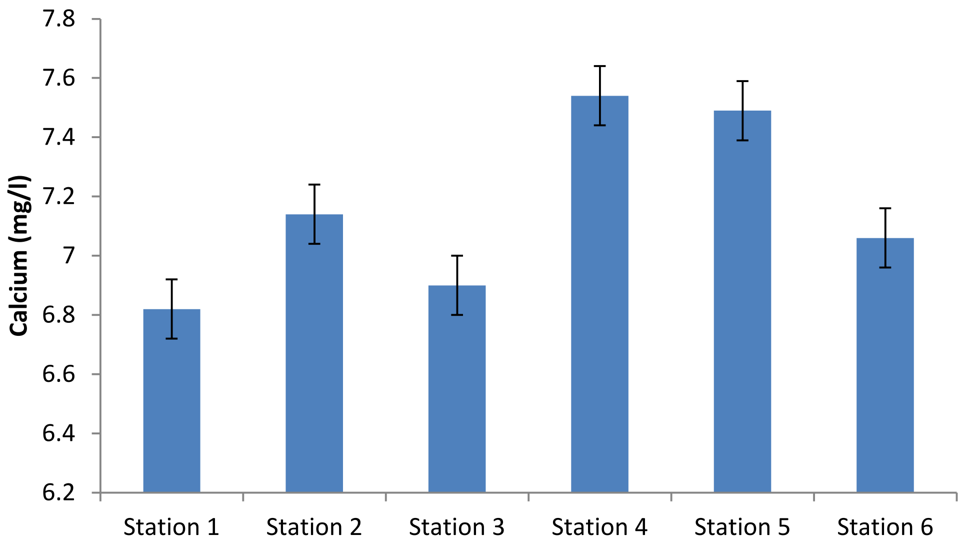


Fig. 2: Mean variations in calcium concentration in relation to stations

Generally magnesium decreased. The highest mean magnesium value (6.23±0.39 mg/l, range 0.60 – 7.70 mg/l) was recorded in station 1 while station 5 had the lowest mean value (5.97±0.42 mg/l, range 0.70 – 8.30 mg/l) (Fig. 3). No significant difference ($p>0.05$) existed between the mean magnesium values in all the study stations.

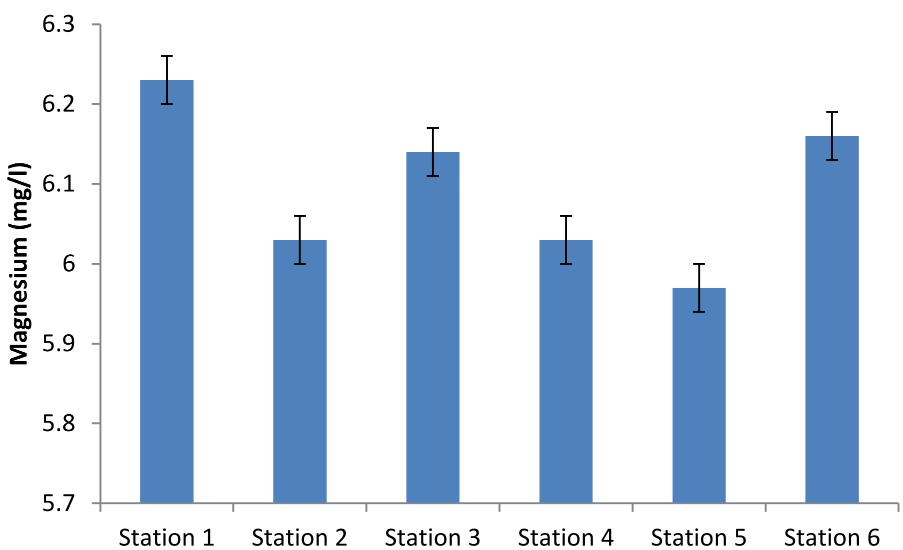


Fig. 3: Mean variations in magnesium concentration in relation to stations

The mean value of iron recorded at the stations showed that station 2 had the highest mean value of 1.46±0.34 mg/l (Fig. 4). This was followed by stations 1 (1.42±0.33 mg/l), 5 (1.41±0.34 mg/l), 3 (1.35±0.33 mg/l), 4 (1.28±0.31 mg/l) and 6 (1.27±0.77 mg/l). These values were not significantly different ($p>0.05$).

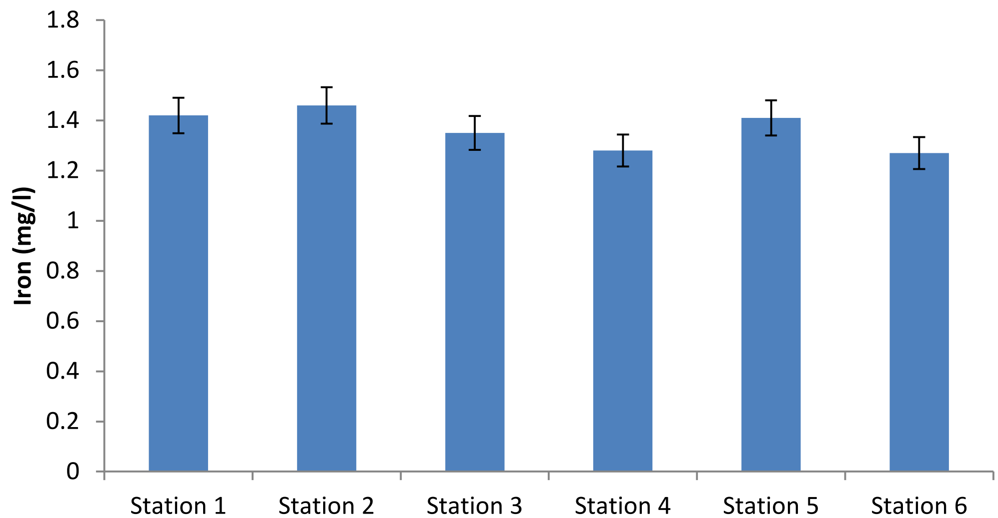


Fig. 4: Mean variations in iron concentration in relation to stations

Sodium concentration recorded in the study was highest in station 1 (2.13±0.78 mg/l) with a range of 0.30 – 12.170 mg/l. The lowest value of 1.97±0.73 mg/l, range 0.30 – 12.20 mg/l was recorded in station 3 (Fig. 5). These values and the values of all other stations were not significantly different ($p>0.05$).

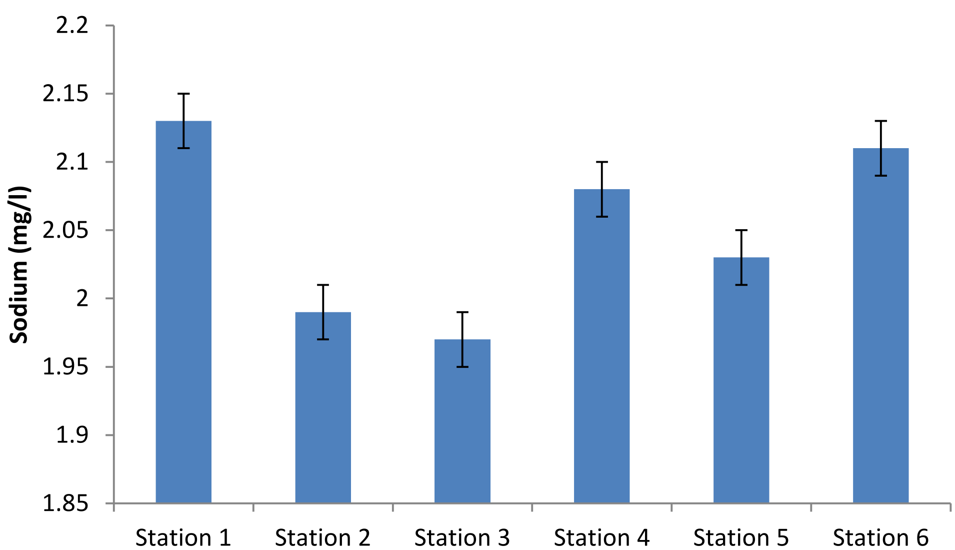


Fig. 5: Mean variations in sodium concentration in relation to stations.

**Table 2: Mean (±S.E.) macronutrients of Ogbei Stream, Nigeria (May 2008 – April 2009)**

| Parameter | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rainy season | | | | | | Dry season | | | | | Rainy season |
| | May | Jun. | Jly. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar | Apr. |
| Calcium | 11.18±0.47$^{b}$ | 9.13±0.87$^{de}$ | 3.88±0.26$^{g}$ | 6.41±0.62$^{f}$ | 6.41±0.53$^{f}$ | 0.63±0.84$^{h}$ | 6.17±0.18$^{f}$ | 8.33±0.35$^{e}$ | 9.59±0.53$^{cd}$ | 10.53±0.08$^{bc}$ | 12.42±0.16$^{a}$ | 1.19±0.06$^{h}$ |
| (mg/l) | (8.80-12.40) | (6.10-13.30) | (1.90-4.90) | (4.10-9.70) | (4.10-9.80) | (0.20-0.90) | (5.10-7.40) | (7.00-9.70) | (9.20-10.00) | (10.10-11.00) | (11.60-13.50) | (0.90-1.60) |
| Magnesium | 6.96±0.50$^{abc}$ | 6.08±0.12$^{c}$ | 3.56±0.07$^{de}$ | 4.11±1.03$^{d}$ | 2.94±0.21$^{e}$ | 7.35±0.06$^{ab}$ | 7.41±0.03$^{ab}$ | 6.94±0.15$^{abc}$ | 6.63±0.06$^{abc}$ | 7.56±0.08$^{a}$ | 7.33±0.04$^{ab}$ | 6.26±0.46$^{bc}$ |
| (mg/l) | (4.30-11.20) | (5.00-6.50) | (3.10-3.90) | (6.60-7.80) | (1.10-4.00) | (7.10-7.70) | (7.30-7.60) | (6.30-7.60) | (6.40-7.00) | (7.20-8.30) | (7.20-7.60) | (3.30-7.50) |
| Iron (mg/l) | 2.37±0.58$^{c}$ | 4.30±0.05$^{a}$ | 2.40±0.07$^{c}$ | 1.79±0.64$^{c}$ | 3.51±0.11$^{b}$ | 0.36±0.02$^{d}$ | 0.38±0.03$^{d}$ | 0.21±0.03$^{d}$ | 0.26±0.12$^{d}$ | 0.13±0.02$^{d}$ | 0.22±0.02$^{d}$ | 0.46±0.01$^{d}$ |
| | (0.40-4.40) | (4.00-4.50) | (2.20-2.80) | (0.30-4.30) | (3.10-4.60) | (0.20-050) | (0.20-0.60) | (0.10-040) | (0.07-1.60) | (0.00-0.19) | (0.20-0.30) | (0.40-0.50) |
| Sodium | 0.72±0.07$^{d}$ | 4.48±1.21$^{b}$ | 2.63±0.64$^{c}$ | 0.53±0.08$^{d}$ | 0.42±0.04$^{d}$ | 0.78±0.06$^{d}$ | 0.35±0.02$^{d}$ | 0.46±0.01$^{d}$ | 0.40±0.00$^{d}$ | 12.44±0.10$^{a}$ | 0.45±0.01$^{d}$ | 0.97±0.07$^{a}$ |
| (mg/l) | (0.40-1.10) | (0.40-10.60) | (0.20-5.40) | (0.30-0.90) | (0.30-0.70) | (0.60-1.20) | (0.30-0.40) | (0.40-0.50) | (0.00-0.40) | (11.70-12.90) | (0.40-0.50) | (0.40-1.30) |

**Macronutrient Variations in Relation to Months**

Changes in mean macronutrient variations in relation to months is presented in Table 2.

The values for calcium in relation to months showed some variations (Table 2). The highest mean calcium concentration of 12.42±0.16 mg/l (range 11.60 – 13.50 mg/l) was recorded in March (dry season) (Fig. 6). This value was significantly different ($p<0.05$) from the mean values recorded for all other months. The lowest mean value (0.63±0.84 mg/l, range 0.20 – 0.90 mg/l) recorded in October was not significantly different ($p>0.05$) from April mean value but was significantly different ($p<0.05$) from the values of all other months.

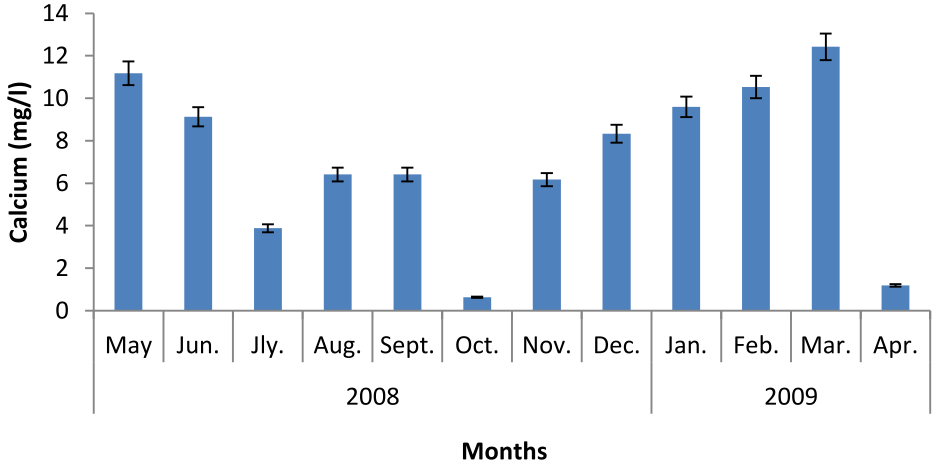


Fig. 6: Mean variations in calcium concentration in relation to months

Magnesium varied over the study period. The highest mean value (7.56±0.08 mg/l, range 7.20 – 8.30 mg/l) was recorded in February (dry season) (Fig. 7). This value was significantly different ($p<0.05$) from June, July, August, September (2008) and April (2009) values but similar with values recorded for all other months.

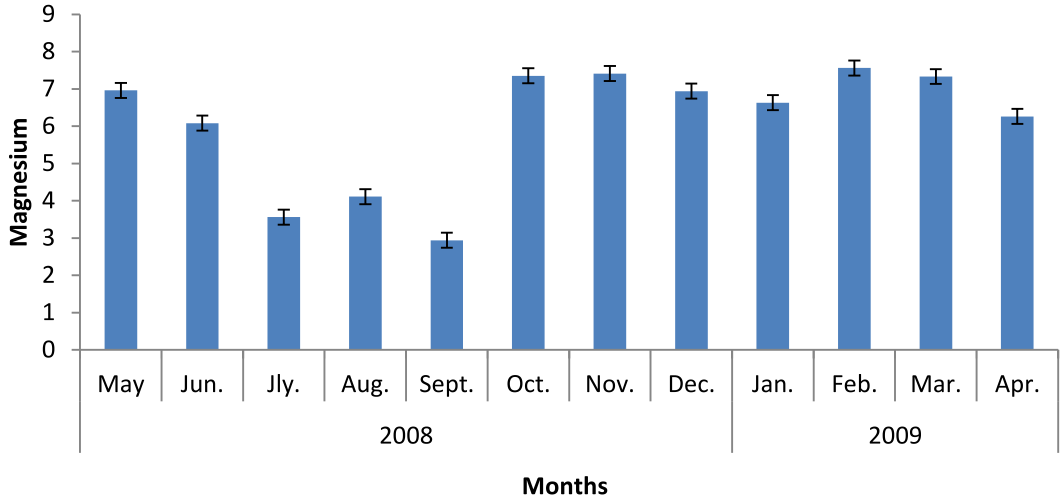


Fig. 7: Mean variations in magnesium concentration in relation to months

The mean monthly iron concentration which varied over the months was higher in the rainy season than in the dry season. The maximum mean value (4.30±0.05 mg/l, range 4.00 – 4.50 mg/l) recorded in June (rainy season) was followed by the mean value of 3.51±0.11 mg/l (range 3.10 – 4.60 mg/l) recorded in September (Fig. 7). These values were significantly different ($p<0.05$) from each other and from the mean values of all other months. The lowest mean value was recorded in February. This value which was similar to values obtained in October, November and December 2008 and January, March and April values obtained 2009 was significantly different ($p<0.05$) from the values of all other months.

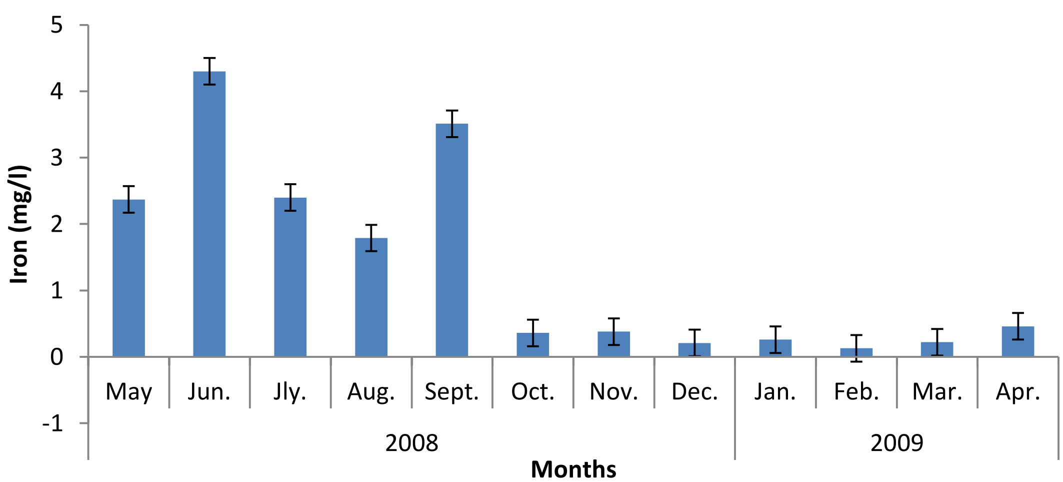


Fig. 8: Mean variations in iron concentration in relation to months

Sodium mean monthly values varied over the period of study (Table 2). Higher mean monthly values were recorded in the dry season than in the rainy season. February (dry season) had the highest mean value (12.44±0.10 mg/l) followed by June (4.48±1.21 mg/l) and July (2.63±0.64 mg/l) (rainy season) (Fig. 8). These values which were significantly different ($p<0.05$) from each other were significantly different ($p<0.05$) from the mean values recorded for all other months. The lowest mean value of 0.35±0.02 mg/l was recorded in November.

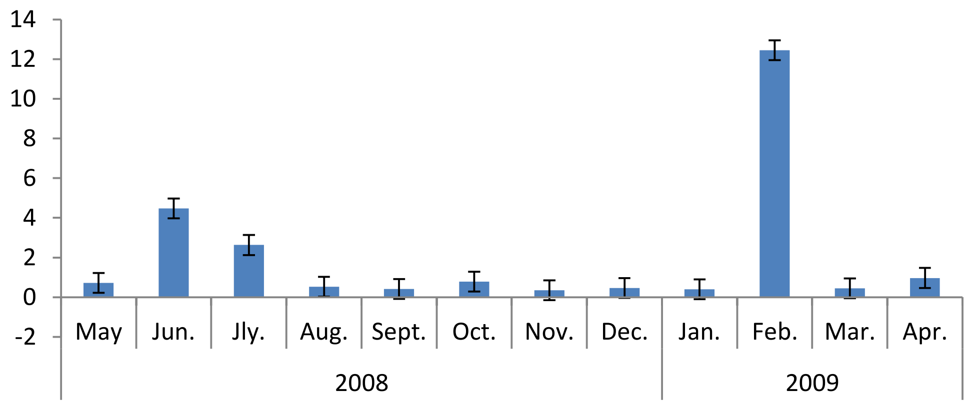


Fig. 9: Mean variations in sodium concentration in relation to months

**Seasonal Variations in Macronutrients**

Table 3 shows the seasonal variation of macronutrients. The dry season values for calcium, magnesium and sodium were higher than the rainy season values. T-test performed showed significant difference ($p<0.05$) between dry season and rainy season values. Iron was higher in the rainy season than in the dry season ($p<0.05$). There was no significant difference ($p>0.05$) between sodium values obtained in both seasons.

**Table 3: Seasonal variations of macronutrients at Ogbei Stream, Nigeria (May 2008 – April 2009)**

| Macronutrient | Season | |
|---|---|---|
| | Rainy season (Means ±S.E.) | Dry season (Mean ± S.E.) |
| Calcium (mg/l) | 6.375±0.441[a] | 7.942±0.456[b] |
| Magnesium (mg/l) | 4.983±0.271[a] | 7.204±0.049[b] |
| Iron (mg/l) | 2.471±0.189[a] | 0.260±0.024[b] |
| Sodium (mg/l) | 1.622±0.282[a] | 2.479±0.529[a] |

Mean values with the same superscript on the same row are not significantly ($p>0.05$)

## 4 DISCUSSIONS

Among the macronutrients studied, calcium dominated. The pattern of the cationic dominance in the study was Ca > Mg > Na > Fe and this did not conform to the order of dominance of cations in the streams in Eastern Nigeria where sodium is the most important. Umeham (2000) in his studies obtained similar cationic dominance. The dominance of calcium $Ca^+$ would be attributed to the dissolution in the water of cement from the constructed walls of the concrete structure. Schmidt (1973) in his studies on chemical composition of some waters in tropical region of Amazolina reported the dominance of $Ca^+$ in the Amazolinian Lake, Castanho. The highest mean concentration of calcium at station 4 in March which was higher than the mean concentration of 6.25 mg/l Onojake *et al*. (2017) obtained in Bonny/Calabar River Estuary was within US EPA (1978) stipulated limits of 5 – 500 mg/l. The highest mean concentration of calcium in station 4 could be due to lime washed by flood into the stream from surrounding farmlands. Liming is the main anthropogenic activity that would lead to an increase of calcium in the drainage system. Other anthropogenic sources include cement factories, fertilizers, dust (Reimann and de Caritat, 1998) and stream concrete structures. Calcium, an alkaline earth metal constitutes one of the most abundant ions in freshwaters (Reid and Wood, 1976). Calcium is necessary for teeth and bone formation. In children, calcium deficiency causes rickets due to insufficient calcification by calcium phosphate of the bones of growing children (Soetan *et al*., 2010). Thus the bones become softened and deformed in adult due to body weight. Calcium deficiency also lead to osteoporosis, a metabolic disorder resulting in decalcification of bone with high incidence of fracture, a condition where calcium is withdrawn from the bones and the bones become weak and porous and then breaks (Hayes and Swenson, 1985; Malhotra, 1998 and Murray *et al*., 2000).

High levels of magnesium observed at the study stations is in line with the observation of Omo-Irabor and Olobaniyi (2007) who obtained high levels of magnesium in Ethiope River. An inverse relationship between calcium and magnesium at the study stations in this study was confirmed by Potasznik and Szymczyk, 2015) who attributed this to the reduced absorption by plant as well as the release of calcium from partially uncovered bottom deposits. The highest mean value recorded at station 1 may be associated with laundry activities and fertilizer wash off into the station from surrounding farms. This is supported by Lentech (2012) who reported that magnesium from fertilizer application, cattle feed and washed rocks subsequently end up in water.

The highest mean value of magnesium recorded in the dry season month of February may be due to intense evaporation during the period. Magnesium concentration was lower in the rainy season month of September due to use of detergents and soap for domestic washing which increased in the dry season.

The mean concentrations of magnesium obtained in the study period were below the WHO (1993) recommended level of 30 mg/l for drinking water. Magnesium, an active component of several enzyme systems in which thymine pyrophosphate is a cofactor (Soetan *et al*., 2010) can cause disorders when depleted. Toxicity diseases of symptoms of magnesium deficiency in humans include depressed deep tendon reflexes and respiration (Murray, 2000).
The concentration of iron obtained at the study stations were higher than the WHO (1997) permissible level of 0.3 mg/l. The maximum iron concentration recorded in station 2 could be attributed to mineralization of organic matter and sediments.

Iron was generally highest in June (rainy season) and lowest in February (dry season). The entry of iron into the stream during the rainy season may be responsible for the high iron mean value recorded during this period. The high iron concentration obtained in the study is not surprising because Nwajei and Gagophien (2000), and Asaolu and Olaofe (2004) have reported that iron occurs at high concentration in Nigeria soils. The high level of iron obtained in the study agrees with the report of Ibitoye (1996) and Folorunsho *et al*. (2011) for high contents of iron in water from different sources in other parts of Nigeria.

An important pathway for iron into surface waters is leaching from organic forest and wetland soils in complex with organic matter (Maranger *et al*., 2006; Kriszberg and Ekstrom, 2012). Hart (1993) classified water with 1.9 ml/l of iron as slightly polluted, 2.7 mg/l as polluted and values above 2.7 mg/l as heavily polluted. Based on Harts classification, Ogbei Stream with the annual mean iron concentration of 1.37 ±1.3 mg/l of iron may be classified as slightly polluted.

The iron level of 0.37 mg/l is particularly alarming, it can be taken care of during water treatment (Umeham, 2000). Iron exposure at high levels has been shown to result in vomiting, diarrhoea, abdominal pain, seizures, shock, low blood glucose, liver damage, convulsions, coma and possible death after 12 – 48 hours of ingesting toxic level of iron (Nwidu *et al*., 2008). Death may also occur if children ingest sufficient iron to exceed the body's iron-binding capacity, the metal-binding proteins that make ionic iron available (Conrad, 2004; Amangabara and Ejenma, 2012). Iron contributes to staining of teeth.

The concentration of sodium which ranged between 0.20 – 12.90 mg/l varied slightly in Ogbei Stream over the study period. The highest mean value of 2.13±0.78 mg/l recorded in station 1 could be due to increased mineralization associated with microbial activity.

Fasae and Omolaja (2014) attributed minimum sodium values to lower microbial activity and higher values to rate of mineralization in the sediments. Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to groundwater and surface water (WHO, 2006). It has been estimated that a total daily intake of 120-400 mg will meet the daily needs of growing infants and young children and 500 mg those of adults (NRC, 1989; WHO, 2006). An excess of sodium disturbs the critical balance and human excess salt (sodium chloride) intake has been linked to heart disease and high blood pressure (Patterson, 1997).

## Conclusion

Cement from the walls of concrete structure in Ogbei Stream contributed to the dominance of calcium over other macronutrients. The high iron concentration in station 2 was due to mineralization of organic matter and sediments. The maximum sodium concentration in station 1 was due to mineralization associated with microbial activity. Calcium, magnesium and sodium values were higher in the dry season than in the rainy season.

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