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Water Quality Assessment and Application of the Hydrochemistry Specific Ion Ratios at Lake Nyamagoma

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Abstract
Attempts have been made to investigate the water quality aspects at 8 sampling sites in Lake Nyamagoma by applying the hydrochemistry specific ion ratios during both wet and dry seasons. Standard methods and experimental procedures were acquired to analyze the filtered water samples in the laboratory using the Inductively Coupled Plasma (ICP) machine for chemical determination. Data from the study depict significant variations in the water quality parameters across the two seasons amongst the sampling sites. This phenomenon hampers the water quality in the lake. Various processes are inferred as driving forces including dissolution, precipitation, decomposition, nitrification, denitrification, fixation, evaporation-crystallization, cation exchange, adsorption, photosynthesis and dilution effect. The geology of the area also seems to favor the observed trends. It is recommended that a long term water quality assessment be acquired to sustainably address the environmental management aspects of the Lake Nyamagoma within the Malagarasi Wetland Ecosystem.
Keywords: Water quality, hydrochemistry, specific ion ratio, processes, man-made activities, Lake Nyamagoma.

1. Introduction

Water is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to continuous increase in its demand and rapid increase in population along with the climatic pressures. It is important to understand and predict their effects; particularly in lakes and reservoirs, where all processes in the catchment and climate variability are integrated. Water totally dominates the chemical composition of all organisms (Wetzel 2001). It is an essential physiological requirement of humans for survival and for provision of food and basic living needs when maintained in its appropriate quality. According to Wetzel (2001) and Dojlido and Best (1993) water quality is a diverse topic that includes the physical, chemical and biological characteristics of water in relation to all other hydrological properties.

Natural water contains solutes derived from the environment, both natural and fabricated (Drever 1982). Fluvial transport of the solutes into lakes has impacts on water quality. According to Cohen (2003), this is due to the fact that the transport of solutes depends on topography, climate and land use activities within the lake's riparian catchment and the hydrological as well as the ecological processes in the lake. The water quality parameters that can be affected include temperature, pH, turbidity, conductivity, alkalinity, dissolved oxygen, nitrate, phosphates, silicates, chlorides, sulfate and iron along with calcium, magnesium, sodium and potassium. Most of these parameters may pose some health risks if they are above the standards (Williams & Langley 2001). In any evaluation of water resources, the quality of water is of almost equal importance to the quantity available (Bell 1998). In other words, the abiotic characteristics of the water are of major importance in determining whether it is or not suitable for domestic or agricultural use due to pollution consequences (Dojlido & Best 1993). The pollution may in turn lead to poor water quality and thus increased waterworks operational costs and eventually pose health risks.

The growing influence of anthropogenic activities in the catchment area of the Malagarasi-Muyovosi Wetland Ecosystem within the Lake Tanganyika basin is quite alarming and hence, learning to explicate them is inevitable (Cohen *et al*. 2005; Nkotagu 2005). The present study therefore trucked down water quality assessment using the hydrochemistry specific ion ratios technique to address the seasonal abiotic threats at Lake Nyamagoma within the Malagarasi Wetland Ecosystem.

2. Materials and Methods

2.1 Study Area

The study was limited primarily to Lake Nyamagoma within the Malagarasi wetland ecosystem. A total number of eight (8) sites were chosen consequent to their accessibility (Figure 1).

2.2 Geology and Geomorphology of the Study Area

The topographic variations in Tanzania are strongly controlled by geology. The study area falls in a depression formed through faulting at the mesoproterozoic sandstones of about 1,200 million years old with lithology covering shales, quartzites, dolomitic limestones, gneisses and basalts along with quarternary sediments (Nkotagu & Athuman 2008; Pina *et al*. 2004).

2.3 Water sampling, Analysis and Interpretation

Sampling was conducted during the dry season and wet season as per Crosby and Patel (1995). Water samples were collected depth wise using a 2-Litre water sampler, filtered using 0.45µm size filter membrane, kept into half-litre plastic bottles and then stored at 4°C for chemical determination. Standard methods and experimental procedures were acquired in the laboratory to analyze the water samples as follows; unfiltered water samples were tested for alkalinity using a titrimetric method with 0.1 N HCl and results expressed as HCO_3^- (mg l^{-1}) as explained by APHA *et al*. (1998). Nutrients including SiO_2, NO_3^-, PO_4^{3-} and Fe^{2+} were determined from the filtered water samples using a HACH Spectrophotometer DR/2010 model according to HACH (2002). The cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) were measured from filtered water samples using the Inductively-Coupled Plasma (ICP) machine following APHA *et al.* (1998) and WHO (1993). The obtained data were analyzed using Sigma Plot 8.0 and Microsoft Excel packages and interpretation followed Bluman (2007), Gupta (2006), Kothari (2004), Davis (1986) and Drever (1982).

3. Results and Discussion

In the present study, sodium was considered as a numerator in calculating the specific ion ratios and as an ideal standard for comparison consequent to being found in higher concentrations in African waters (Nkotagu & Athuman 2008; Bajjali 1996; Appelo & Postma 1994; Kilham 1990; Kilham 1971). Various water quality parameters were analyzed by the specific ion ratios technique and found the results as discussed hereunder.

3.1 Sodium / Potassium Ratio

Potassium ions show the correlation values less than 50% in both seasons (Figures 2a & 2b). This implies that, aquatic macrophytes and animals might be redirecting the natural geochemical cycle of potassium by the consumption and releasing from decaying plants. Similarly, Eugster (1970) and Winton and McCabe (1970), add that this could be the exchange on clay minerals together with the precipitation of potassium feldspar.

3.2 Sodium / Calcium Ratio

The calcium ions show the significant values $r^2 = 52\%$ and $r^2 = 53\%$ in dry and wet seasons respectively. This observation may be attributed to precipitation from calcium rich mineral and cation exchange in the bottom waters.

3.3 Sodium / Magnesium Ratio

Magnesium ions do not show significant values in both seasons (Figures 3a & 3b). This may probably be due to magnesium's solubility characteristics than their calcium counterparts. As a result, significant amounts of magnesium rarely precipitate as $MgCO_3$ and $Mg(OH)_2$ (Horne & Goldman 1994). Magnesium carbonates and magnesium hydroxide precipitate significantly only at very high pH values (> 10) under most natural conditions (Eugster 1970; Winton & McCabe 1970).

3.4 Sodium / Sulphate Ratio

Sulphate ions at various sampling sites show poor correlation of $r^2 = 13\%$ and $r^2 = 4\%$ in dry and wet seasons respectively (Figures 4a & 4b). This indicates the influence of anaerobic condition and microbial activities involved in the sulphur cycle at the lake. Under the anaerobic conditions, sulphate is reduced to H_2S (Wetzel 2001; Horne & Goldman 1994). Bacteria catalyze sulphate reduction by organic matter as per the overall reaction reported in equation (1) by Wetzel (2001):

$$2CH_2O + SO_4^{2-} \longrightarrow 2HCO_3^- + H_2S \quad (1)$$

Where; CH_2O represents organic matter. The H_2S produced later forms major part, which react with Fe-oxides in the sediment to form iron sulphide minerals.

3.5 Sodium / Chloride Ratio

The chloride ions at the sampling sites show a significant value $r^2 = 71\%$ in the dry season. This may be due to evaporation-crystallization process (Winton & McCabe 1970). However, in the wet season, the chloride ions showed

poor correlation value of $r^2 = 43\%$. According to Wetzel (2001) and Eugster (1970), this observation could probably be due to dilution effects triggered by surface runoff as the result of poor agricultural practices and bush fires along with overstocking within the entire Malagarasi Wetland Ecosystem. Kilham (1990) points that, these dense surface runoffs contain less dissolved salts leading to dilution process.

3.6 Sodium / Alkalinity (CO_3^{2-} + HCO_3^-) Ratio

CO_3^{2-} + HCO_3^- ions from Lake Nyamagoma waters (Figures 5a & 5b) show significant correlation values of $r^2 = 59\%$ and $r^2 = 62\%$ in dry and wet season respectively. The observed phenomenon is consequent to CO_2 added in the water by the macrophytes during the respiration process. High dissolution of calcium magnesium rich rocks may also reflect the relatively higher concentrations of calcium and magnesium in waters along with CO_3^{2-} + HCO_3^- (Winton & McCabe 1970).

3.7 Sodium / Phosphate Ratio

The phosphate ions show poor correlation value ($r^2 = 46\%$) in the dry season (Figure 6a), indicating the utilization by macrophytes and adsorption process to inorganic colloids and particulate matter. In the wet season, the phosphate ions show a significant correlation value ($r^2 = 63\%$) (Figure 6b). PO_4^{3-} is readily adsorbed on silt particles (Golterman 1973) thus; the latter observation may probably be due to sediment trap by adsorption process on to ferric hydroxide, $Fe(OH)_2$ particles as inorganic phosphate (Lehman & Bronstrator 1994; Kilham, 1990; Mortimer 1971). This is a consequence of increased mixing process. Higher values were observed at Chagu in both seasons. According to Nkotagu & Athuman (2008), (2007) and (2004) this is attributed to inputs from the agricultural and overgrazing activities.

3.8 Sodium / Silica Ratio

The silica ions from Lake Nyamagoma waters show poor correlation value ($r^2 = 22\%$) during the dry season (Figure 7a) indicating the adsorption of silica to the dead cells and utilization of silica by diatoms (Nkotagu & Athuman 2008, 2007, 2004; Wetzel 2001; Wetzel & Likens 1990; Werner 1977; Wetzel & Hough 1973). However, a significant value ($r^2 = 64\%$) is shown during the wet season (Figure 7b). This may essentially be consequence of dissolution of silicate minerals due to the low pH and low temperature, which seems to control silica chemistry at the lake. The study by Nkotagu & Athuman (2008) found the same trend of water quality parameters with high values measured during the wet season. The inferred observation may be further supported by the geology of the study area (Bell 1998; Davis 1986).

4. Conclusions and Recommendations

This study addressed the water quality assessment using the hydrochemistry specific ion ratios technique to explain the seasonal abiotic threats at Lake Nyamagoma. The data in the study reveal that the levels of water quality parameters vary significantly along the seasons amongst the sampling sites. Various processes are responsible as driving forces including dissolution, precipitation, decomposition, nitrification, denitrification, fixation, evaporation, cation exchange, adsorption, photosynthesis and dilution effect. However, most of the elevated levels of water quality parameters were recorded during the wet season compared to the dry season and vary across the sampling sites attributing to inputs via inflows from the catchment disturbances by man-made activities. A long term water quality assessment is recommended to sustainably address the environmental management aspects of the Lake Nyamagoma within the Malagarasi Wetland Ecosystem.

5. Acknowledgements

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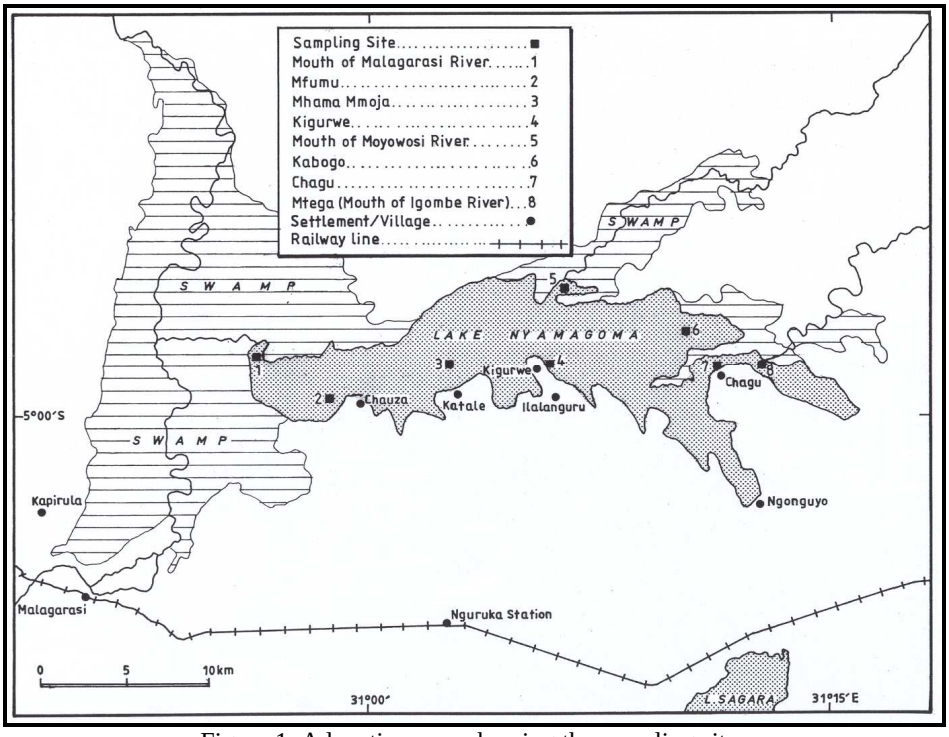


Figure 1. A location map showing the sampling sites

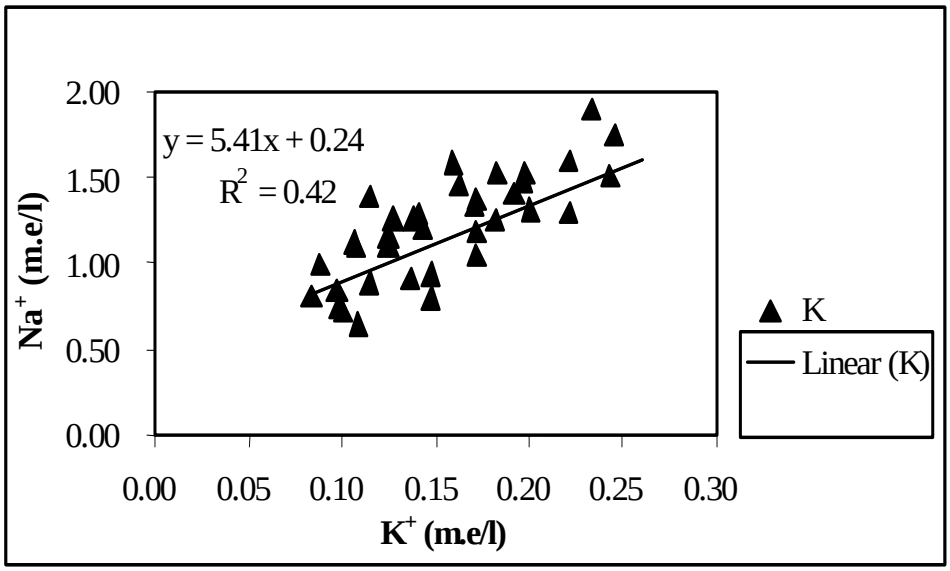


Figure 2a. Variation of Na^+ and K^+ during the dry season

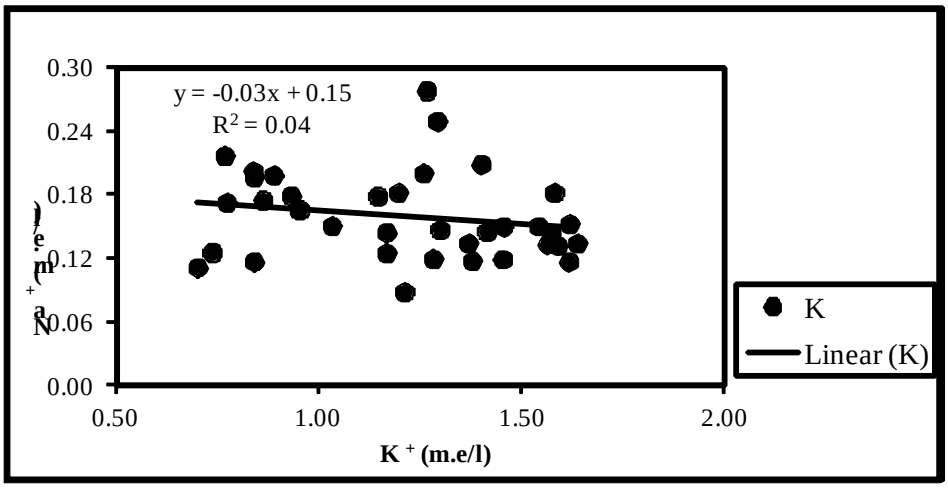


Figure 2b. Variation of Na^+ and K^+ during the wet season

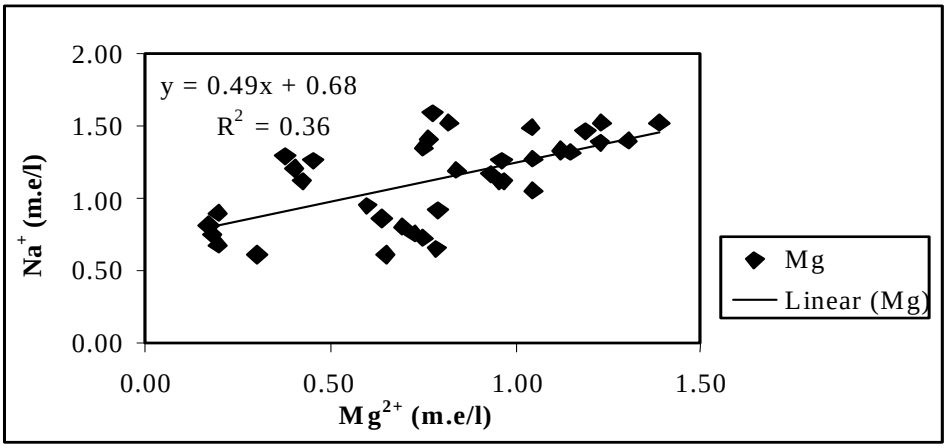


Figure 3a. Variation of Na^+ and Mg^{2+} during the dry season

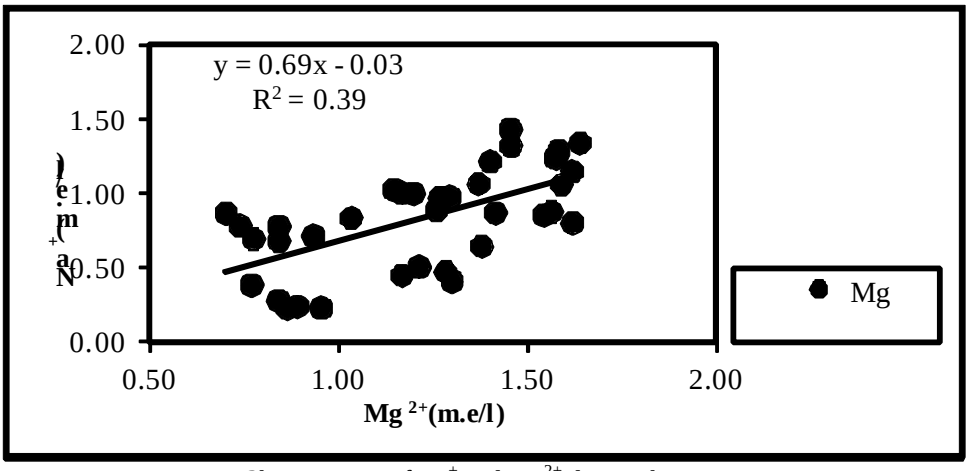


Figure 3b. Variation of Na^+ and Mg^{2+} during the wet season

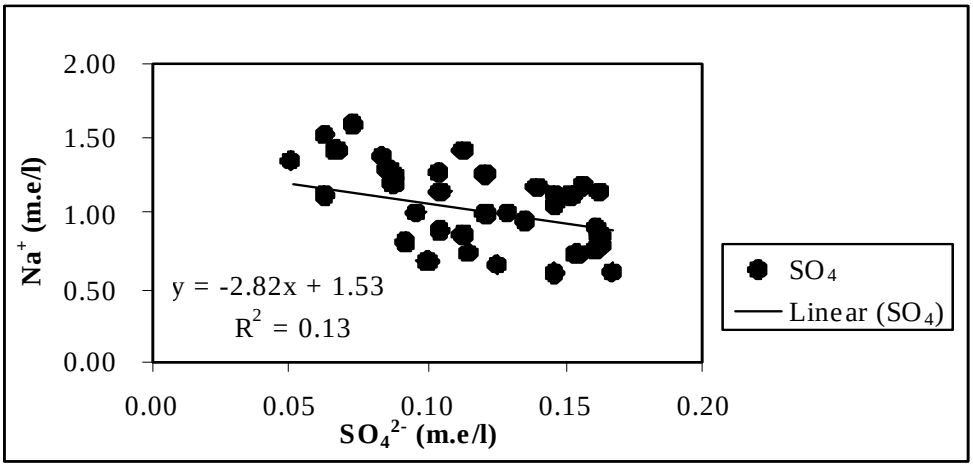


Figure 4a. Variation of Na^+ with SO_4^{2-} during the dry season

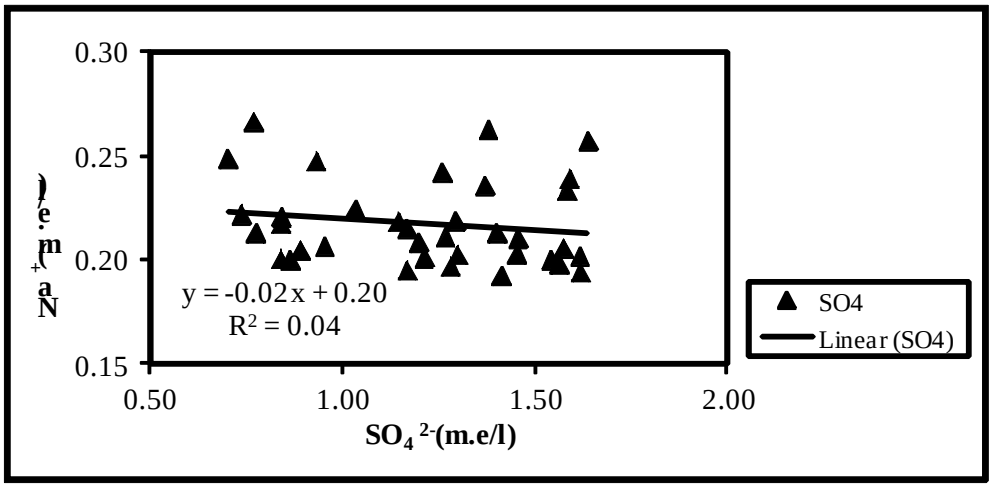


Figure 4b. Variation of Na^+ and SO_4^{2-} during the wet season

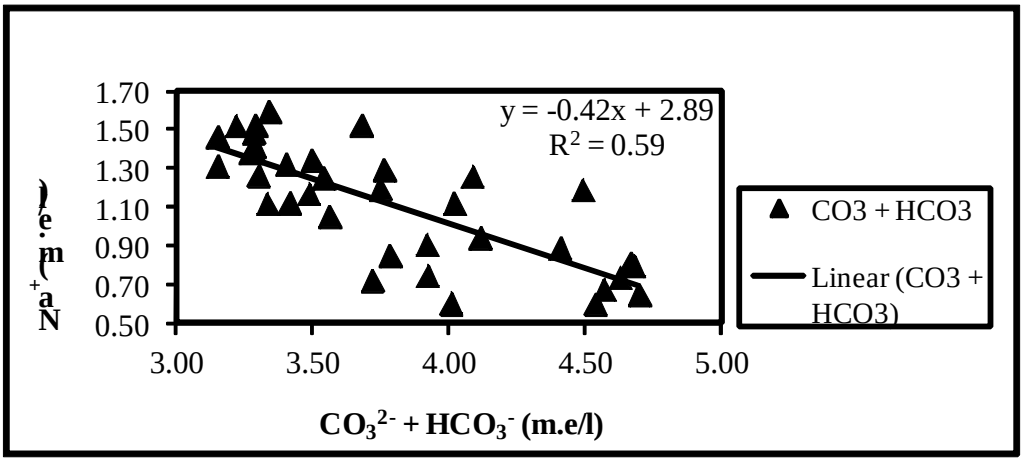


Figure 5a. Variation of Na^+ and HCO_3^- during the dry season

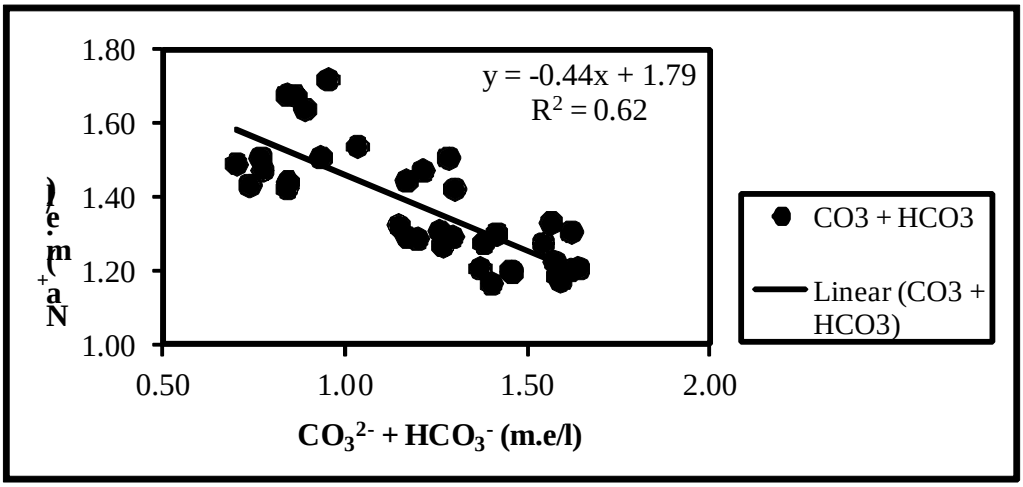


Figure 5b. Variation of Na^+ and HCO_3^- during the wet season

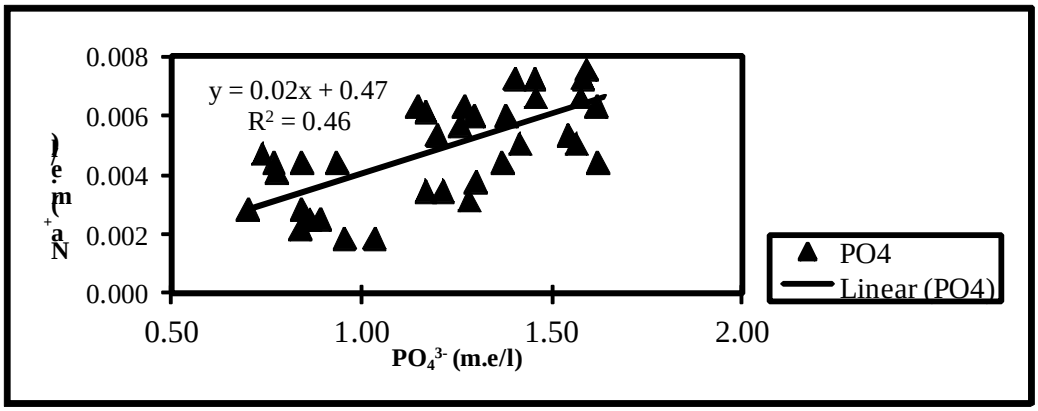


Figure 6a. Variation of Na^+ and PO_4^{3-} during the dry season

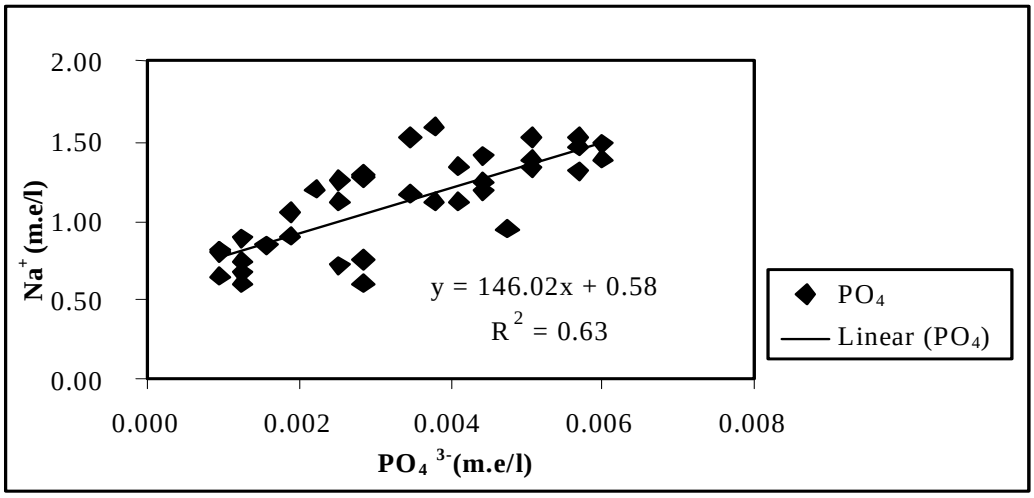


Figure 6b. Variation of Na^+ and PO_4^{3-} during the wet season

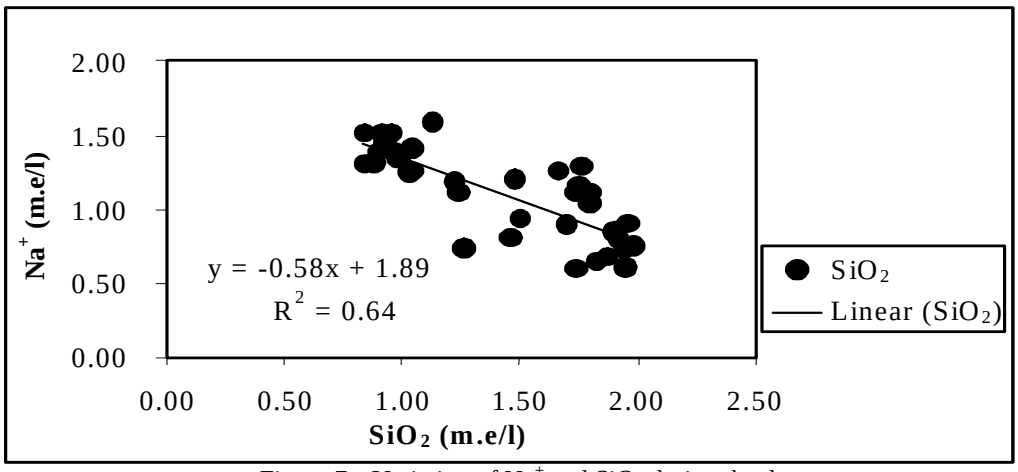


Figure 7a. Variation of Na^+ and SiO_2 during the dry season

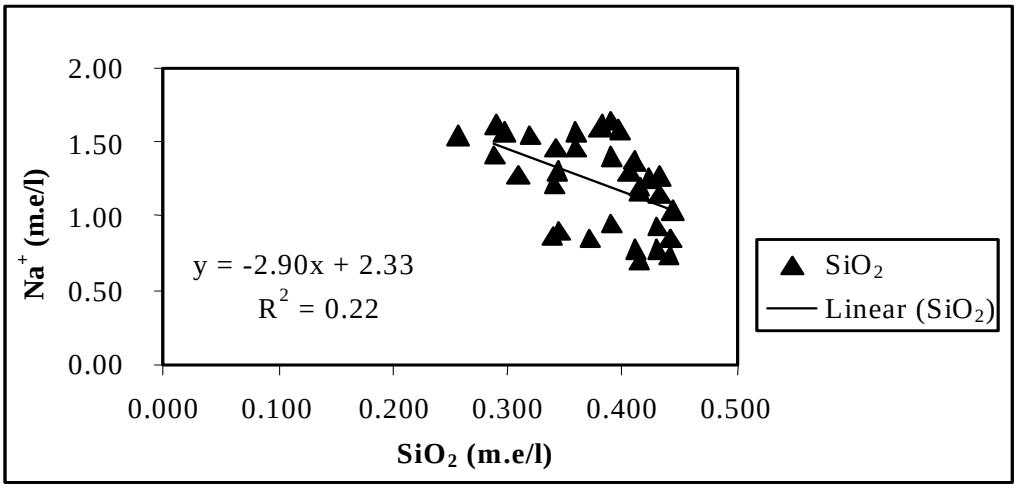


Figure 7b. Variation of Na^+ and SiO_2 during the wet season

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