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SEASONAL CHANGES IN PHYSICO-CHEMICAL PARAMETERS AND NUTRIENT LOAD OF RIVER SEDIMENTS IN IBADAN CITY, NIGERIA

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ABSTRACT
Seasonal variations in ecological parameters exert a profound effect on the distribution and population density of both animal and plant species (Odum, 1971). The productivity in terms of planktonic biomass in freshwater bodies is regulated by various physico-chemical factors viz., temperature, transparency, pH, total hardness, nitrates, phosphates etc. A field study was conducted (October 2003 and March 2004) to develop a data-base on seasonal changes of physico-chemical parameters and nutrient load of the river sediment in Ibadan metropolis. Quantitative samples of sediments were collected during dry and rainy seasons from 11 stations and analyzed for various physico-chemical parameters and nutrient load. All (except dissolved oxygen) physico-chemical parameters assessed in this study were higher than the recommended standard (EPA, 2002). The nutrient load of pore water of Ibadan river system sediments during rainy and dry seasons was found in the range of: phosphate (2.23-16.2 ppm and 0.35-2.8 ppm respectively); nitrate (0.22 to 0.9 ppm and 0.47-3.3 ppm respectively); Nitrite (0.2-0.42 ppm and 0.03-0.3 ppm respectively); Total nitrogen (0.13-0.9ppm and 0.47-3.4 ppm respectively) and sulphate (70-99.4 ppm and 26.6-120 ppm respectively). The levels of parameters downstream were significantly elevated than the corresponding levels upstream. This result suggests that the water quality of Ibadan river system is adversely affected and impaired by the discharge of domestic, agricultural and industrial wastes, which is the usual practice in Ibadan. The data generated from this study will guide potential remediation and other management decisions.

KEYWORDS: Limnology, Eutrophication, water quality, freshwater, Nigeria

INTRODUCTION

Aquatic ecosystems are affected by several health stressors that significantly deplete biodiversity. In the future, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems (Sala *et al.*, 2000). Rivers are subjected to various natural processes taking place in the environment, such as the hydrological cycle. As a consequence of unprecedented development, human beings are responsible for choking several lakes to death. Storm water runoff and discharge of sewage into rivers are two common ways that various nutrients enter the aquatic ecosystems resulting in the pollution of those systems (Sudhira and Kumar, 2000; Adeyemo, 2003).

Sediments form a natural buffer and filter system in the material cycles of waters. Sediment in our rivers is an important habitat as well as a main nutrient source for aquatic organisms. Furthermore, sediments have an impact on ecological quality because of their quality, or their quantity, or both (Stronkhorst *et al*., 2004). Waters are subject to strong variations of flow rate, substance input and transport, and sedimentation. Sediment analysis is increasingly important in evaluating qualities of the total ecosystem of a body of water, in addition to the water sample analysis practiced for years. In comparison to water testing, sediment testing reflects the long-term quality situation independent of current inputs (Hodson, 1986; Haslam, 1990). In water testing it is not possible to clearly divide between true suspension substances and temporary suspension substances stirred-up from the sediments. Sediment testing is not, or only minimally, affected by other influences.

The suspended and precipitated (non-floating) substances and organic substances in waters are capable of adhering pollutant particles (adsorption). The sediments, both suspended and precipitated substances stored on the water bottom, form a reservoir for many pollutants and trace substances of low solubility and low degree of degradability (Biney *et al.*, 1994; Barbour *et al.*, 1998, 1999). Pollutants are conserved in sediments over long periods of time according to their chemical persistence and the physical-chemical and biochemical characteristics of the substrata. This can also allow conclusions to be drawn regarding sources of contamination. This work presents the results of our field study, which assessed seasonal and spatial changes in the physico-chemical parameters and nutrient load of pore water of sediments of randomly selected rivers in Ibadan, a metropolitan city in Nigeria.

MATERIALS AND METHODS

Study Area

Ibadan (Oyo state, Nigeria) is the largest city in West Africa and the second largest in Africa, with land size covering an area of 240 km^2. The city is located on geographic grid reference longitude 3^o 5E, latitude 7^o 20N (Filani, 1994).

Sediment Sampling Procedure

Using a 12 channel global positioning system navigator (GPS Magellan 315®) to locate the sample site, sediment samples were collected from Rivers in twenty-two sites comprising of one upstream and one downstream sample per each of the eleven local government areas in Ibadan metropolis between October 2003 and March, 2004 during the dry season. This was repeated between August and September, 2004 during the rainy season. Samples were collected using plastic spatulas and stored in pre-cleaned 500ml plastic containers. Once collected, the samples were immediately stored on ice in a dark cooler box and transported to the laboratory and analysed within twenty-four hours of collection.

Physical and Nutrient load analysis

The following physical parameters were assessed using standard methods for examination of water and wastewater (APHA, 1998): pH, total solids (TS), total hardness, total organic carbon (TOC), dissolved oxygen (DO), chemical oxygen demand (COD) and bicarbonates. Nutrient Load was assessed using the following parameters: phosphates, sulphates, nitrite, nitrate and total nitrogen.

Statistical Analysis

The values were computed, analysed and presented as mean ± standard deviation. Regression analysis was conducted to determine spatial and temporal correlations between locations and seasons respectively. Levels of significance of differences in the values of the parameters determined during dry and rainy seasons were assessed using student's *t*-test. Upstream and downstream samples within and between seasons were also subjected to *t*-test. Differences were regarded to be significant at 95% confidence limit ($p \leq 0.05$).

RESULTS AND DISCUSSION

Sediments comprise an important component of aquatic ecosystems, providing habitat for a wide range of benthic and epi-benthic organisms. Exposure to certain substances in sediments represents a potentially significant hazard to the health of these organisms. Effective assessment of this hazard requires an understanding of the relationships between concentrations of sediment-associated chemicals and the occurrence of adverse biological effects. Sediment quality guidelines are scientific tools that synthesize information regarding the relationships between the sediment concentrations of chemicals and any adverse biological effects resulting from exposure to these chemicals.

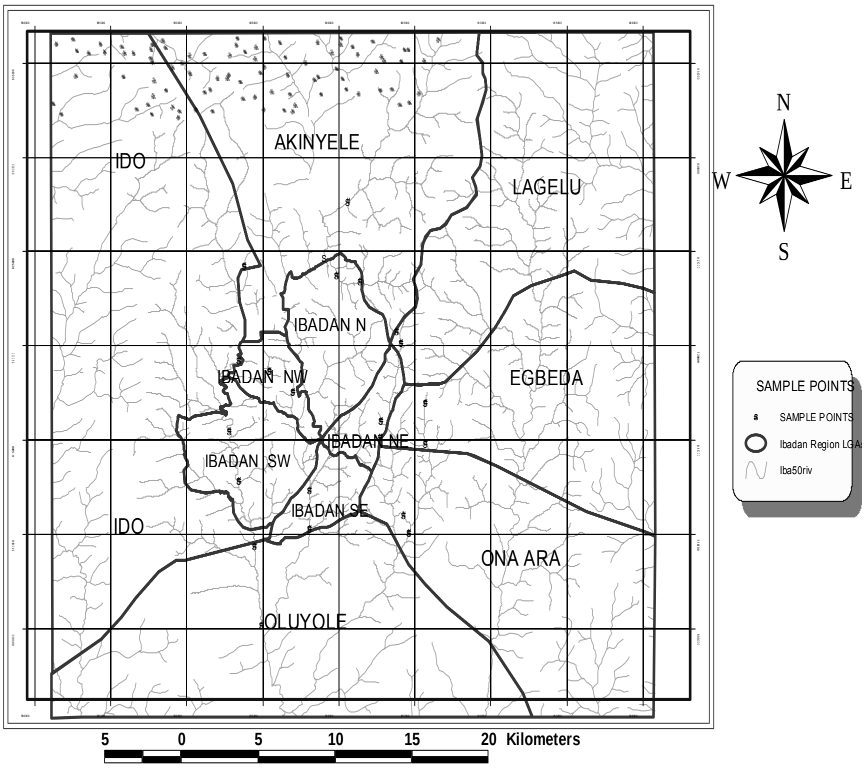

Figure 1. The study area (Ibadan) showing the sampling points

This study provides data on the physico-chemical parameters and inorganic nutrient load of pore water of Ibadan river system sediments. Results of the assessment of physical parameters during dry and rainy seasons are presented in Figures 2 to 7. The results of the nutrient loads in the rivers are presented in Figures 8 to 12. The majority of the water quality variables studied can be assigned to one of two seasonal influences: dry season “concentration” and rainy season run-off.

Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent (Wang *et al*., 2002). Optimal pH range for sustainable aquatic life is pH 6.5 - 8.2 (Murdock *et al.,* 2001). Figure 1 displays the variations in pH levels at each site location, for dry and rainy seasons respectively. The results indicate slightly acidic pH levels in two local government areas (Ibadan NW and Ibadan NE) during the dry season and one of them (Ibadan NW) was still acidic during the rainy season; these could be adduced to the mechanic workshops located close to the watershed in these areas. All other areas had pH within optimal level. There was no significant difference ($p = 0.74$) between seasons and also between upstream and downstream samples during dry season ($p = 0.65$). However, if urbanization continues, in or around the watershed, the increase/decrease in pH levels will have damaging effects on the watershed. A particular problem associated with acidification is the solubilisation of some metals, when the pH falls below 4.5. The resultant increased metal concentrations can be toxic to fish and render the water unsuitable for other uses. Monitoring and reducing human actions will help keep the Ibadan Watershed at an optimal pH level.

Dissolved oxygen was significantly lower ($p = 0.0001$) during the dry season compared to rainy season. DO was also significantly lower ($p = 0.012$) downstream compared to upstream samples (EPA 2002). Seasonal variations observed in DO content with higher values in rainy season could be due to increased aeration because of rainfall. Ayoade *et al.* (2006) reported that DO concentration at Asejire Lake attained its peak at the height of rainy season. The lower DO downstream also implies that the rivers were more polluted downstream. Domestic, agricultural, industrial effluent and waste discharge into rivers is a usual practice in Ibadan and is the main reason for the high pollution of the water downstream. Also, high total solid (TS), high number of aquatic plants and algae affects DO along rivers in daytime

There was no significant difference in the COD, and total hardness during the two seasons, although the parameters were higher than the recommended standard (EPA 2002); which is indicative of pollution. The COD at the downstream stations were significantly ($p=0.0043$) higher than those from the upstream stations during dry season. These non-biodegradable compounds might accumulate and biomagnify in living organism tissue, which might have a high potential of adverse health effects on human.

Total organic carbon (TOC) was significantly higher ($p=0.0010$) during the dry season but the difference in the upstream and down stream samples was not significant ($p = 0.87$). TOC can have its origin either from organic matter from natural sources such as plant materials deposited on sediments or anthropogenic inputs to aquatic systems.

Temporal variations in aquatic systems can have direct and indirect effects on factors influencing nutrient fluxes (Thayer, 1971). Nutrient concentrations and distributions have therefore been documented as having seasonal patterns (Baird and Ulanowicz, 1989; Morris, 2000). Seasonal variations are evident in all the physico-chemical parameters examined in this study. Seasonal cycles are due to imbalances in the processes of mineralization and consumption (Morris, 2000). Raw sewage is the source of nitrates and phosphates in rivers (Aggarwal *et al.*, 2000; Adeyemo, 2003).

The phosphate concentration in the pore water in the sediments was very high as compared to the standard guidelines (EPA, 2002); however phosphate was exceptionally high during the rainy season, while nitrate was higher during the dry season. Land use around riverine areas in Nigeria is predominantly for farmland and could be a possible explanation for the high levels of phosphate from run-off during rainy seasons as observed in this study. There are various sources of phosphate to rivers, such as firm rock deposit, runoff from surface catchments, and interaction between the water and sediment from dead plant and animal remains at the bottom of rivers. Phosphate is considered to be the most significant among the nutrients responsible for eutrophication of lakes, as it is the primary initiating factor. The result reveals that the nutrient load in the watershed is high; destruction of the rivers can therefore result because of nutrient enrichment, productivity, decay and sedimentation (Adeyemo, 2003).

Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction, and the survival of organisms. High nitrate levels (>1 mg l^{-1}) are not good for aquatic life (Johnson *et al.,* 2000).The high level of nitrate observed during this study is in agreement with Wolfhard and Reinhard, 1998 who concluded that nitrates are usually built up during dry seasons and that high levels of nitrates are only observed during early rainy seasons. This is because initial rains flush out deposited nitrate from near-surface soils and nitrate level reduces drastically as rainy season progresses

High Levels of both phosphate and nitrate can lead to eutrophication, which increases algae growth and ultimately reduces dissolved oxygen levels in the water (Murdoch *et al.,* 2001). It is widely assumed that nitrite concentrations in freshwaters are negligible (Stanley and Hobbie, 1981; Paul and Clarke, 1989), and the worldwide average concentration has been estimated to be 1 mg of nitrite/liter (Meybeck, 1982). Nitrite levels were lower than 1 mg l^{-1} during the two seasons. Regression analysis reveals that physicochemical parameters and nutrient load values varied from one location to another and without any significant spatial correlation, which may be due to different land use practices around the rivers.

The deterioration in the physicochemical quality and rise in the nutrient level observed in this study is alarming, and periodic monitoring and preventative measures are required to save the aquatic system from eutrophication. Further work is therefore needed to determine the dynamics of the watershed’s response to runoffs and land management practices under varying climatic conditions to better understand the complex physical and chemical processes causing the degradation observed in the present study. The findings also have important implications for the development of effective watershed management strategies for the control of point and diffuse-source pollution.

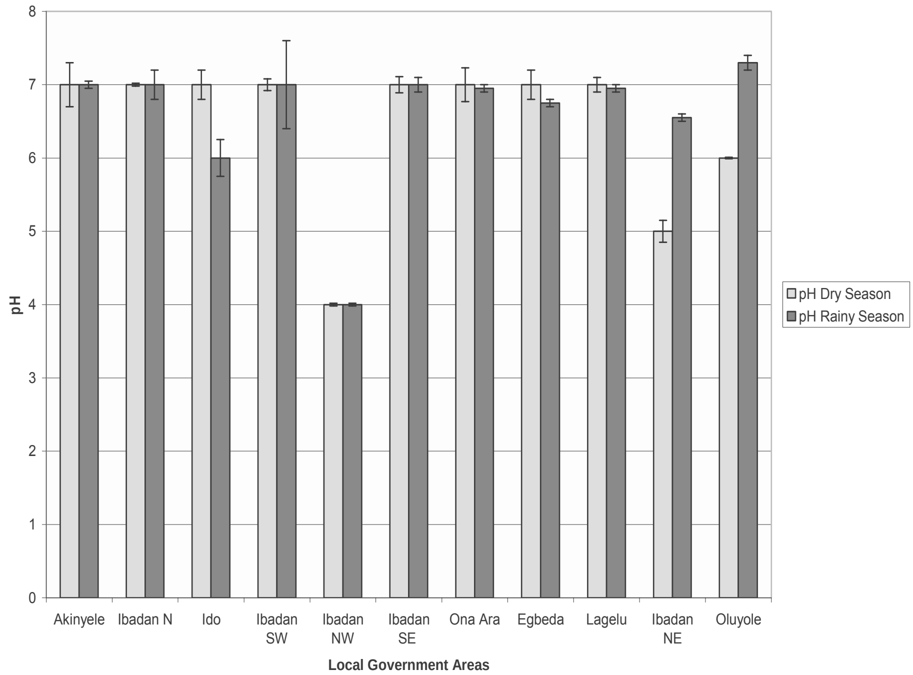

Figure 2. pH of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

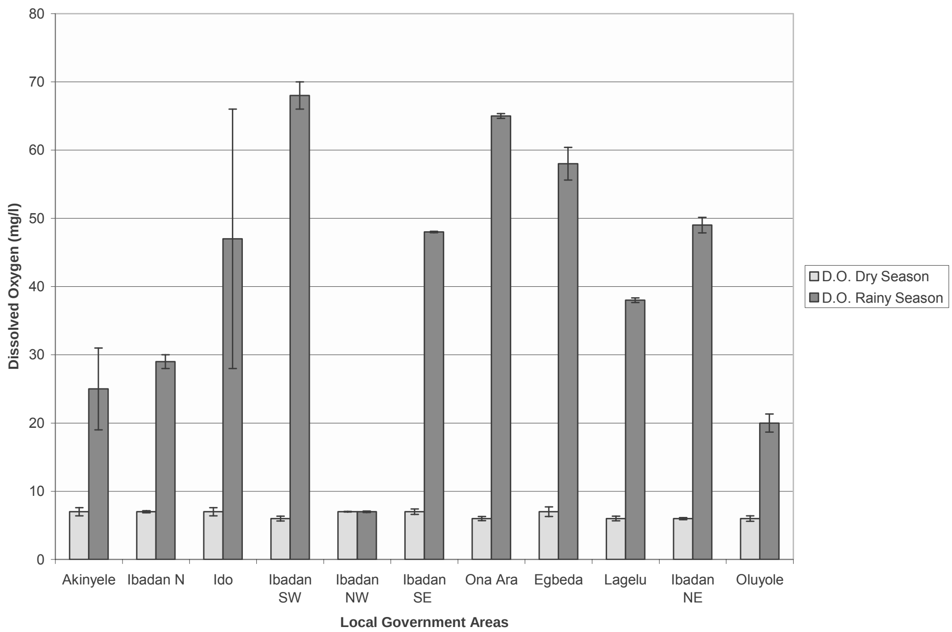

Figure 3. Dissolved Oxygen (D.O) of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

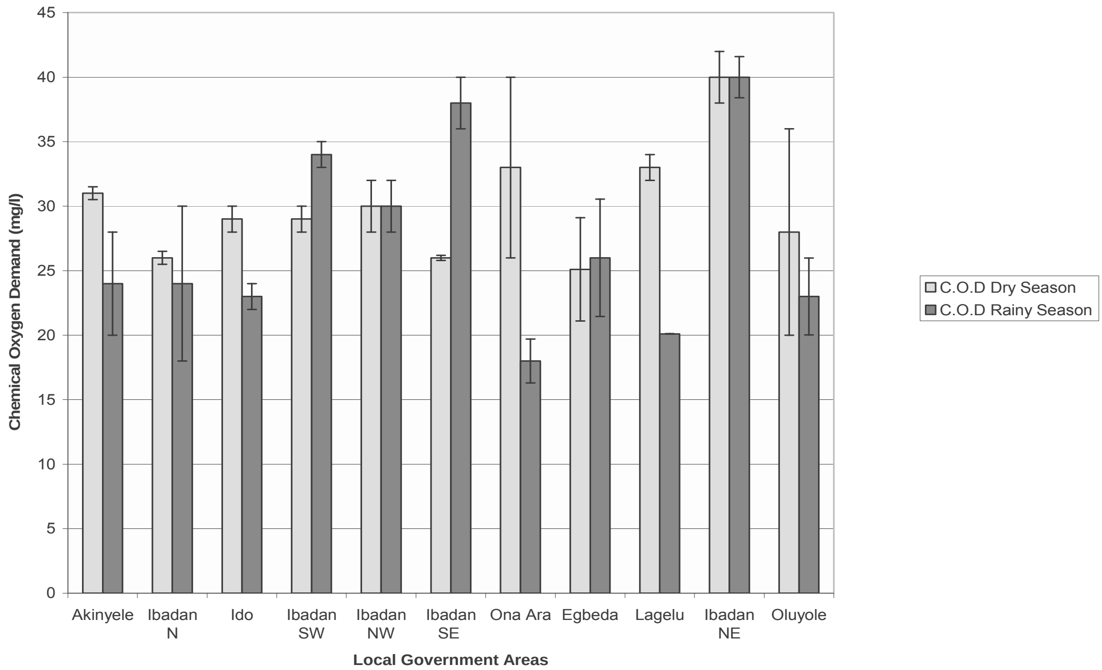

Figure 4. Chemical Oxygen Demand (C.O.D) of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

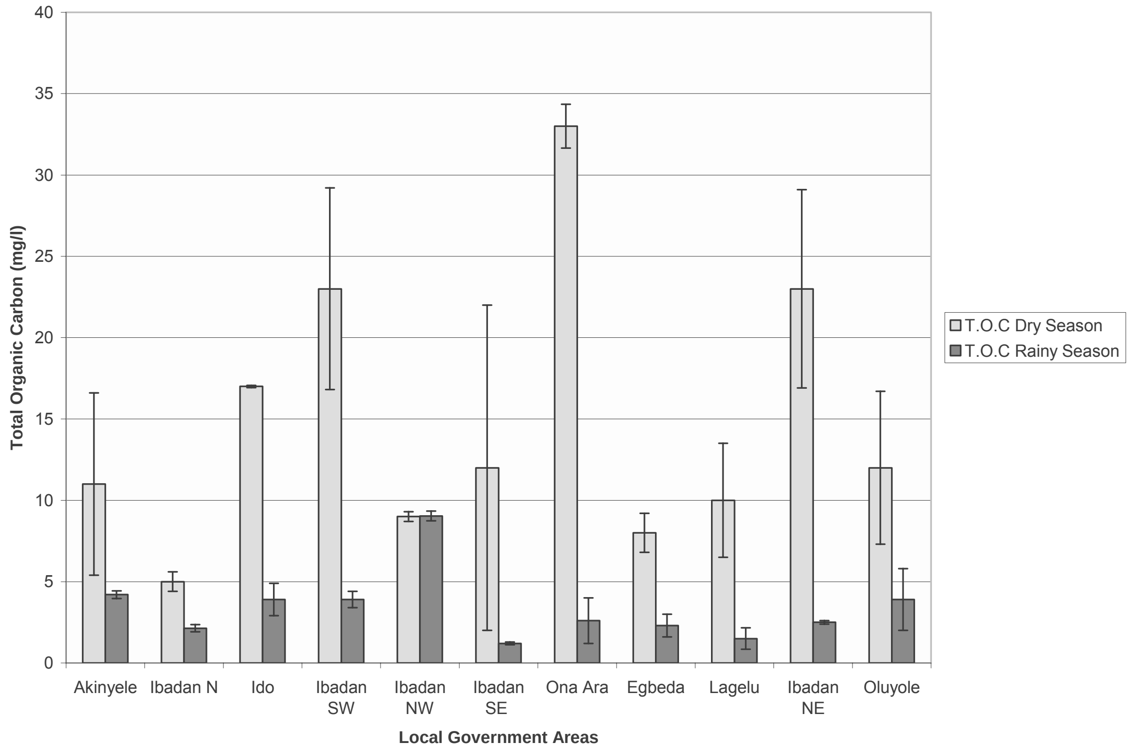

Figure 5. Total Organic Carbon (T.O.C) of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

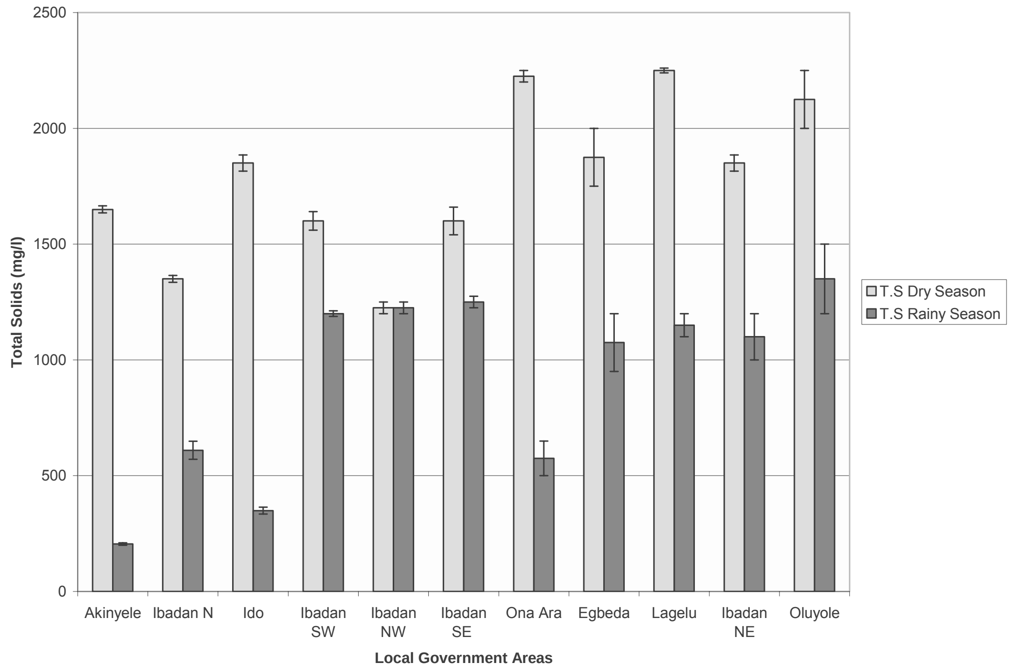

Figure 6. Total Solids of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

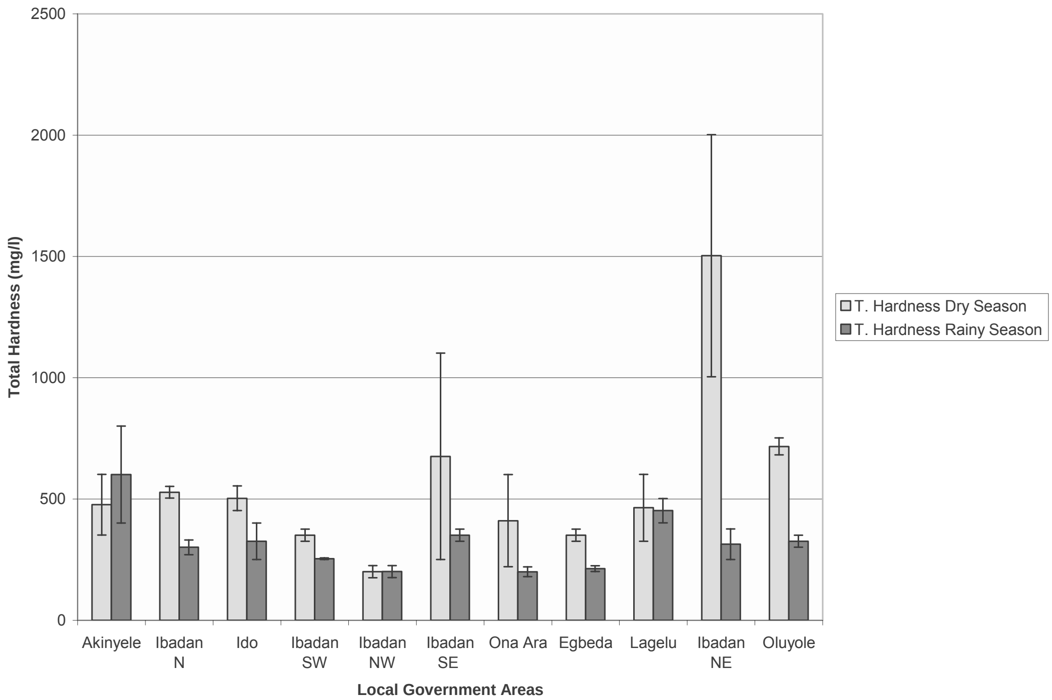

Figure 7. Total Hardness of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

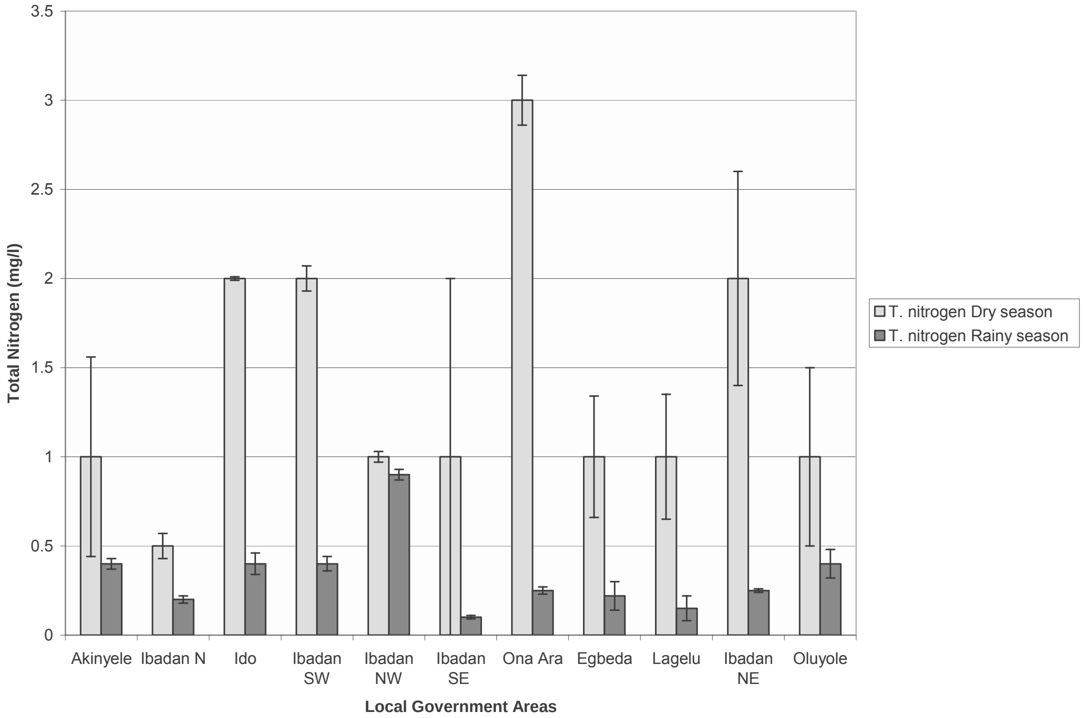

Figure 8. Total nitrogen level of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

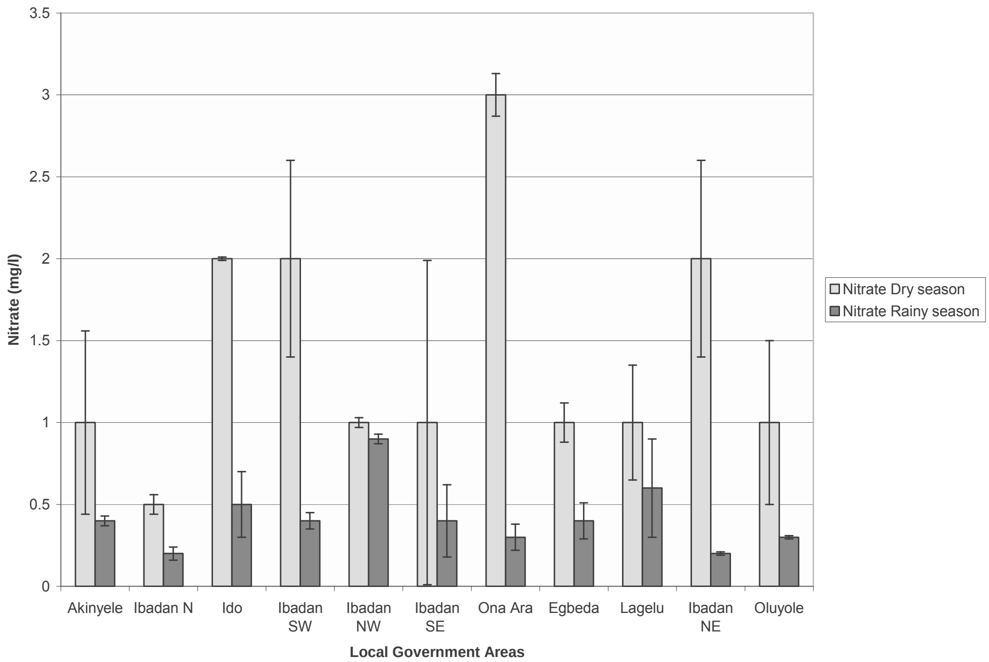

Figure 9. Nitrate level of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

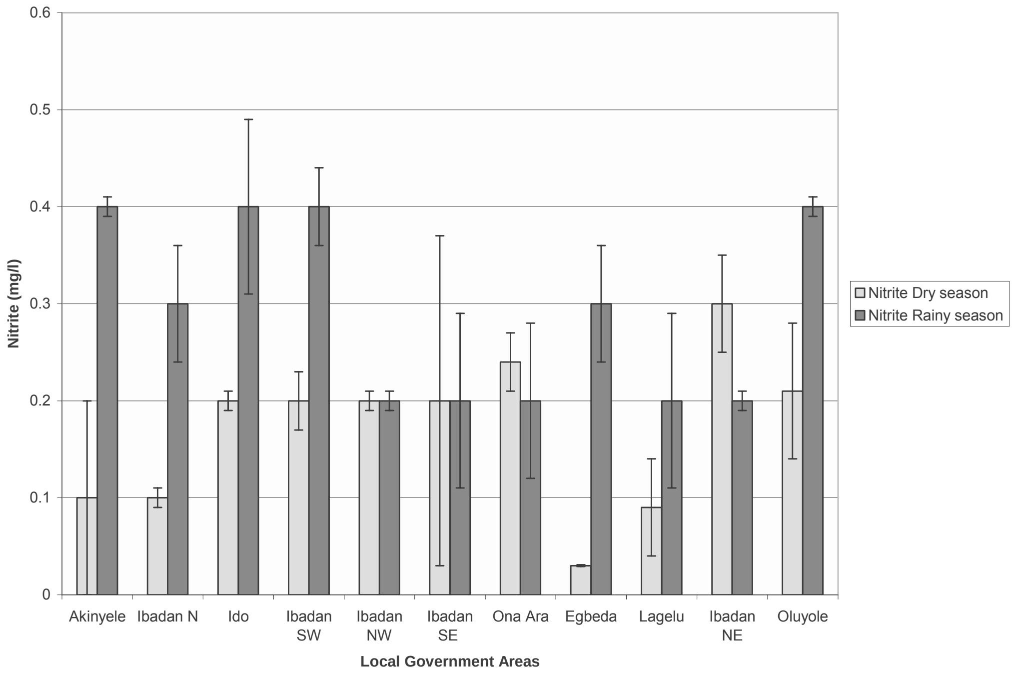

Figure 10. Nitrite level of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

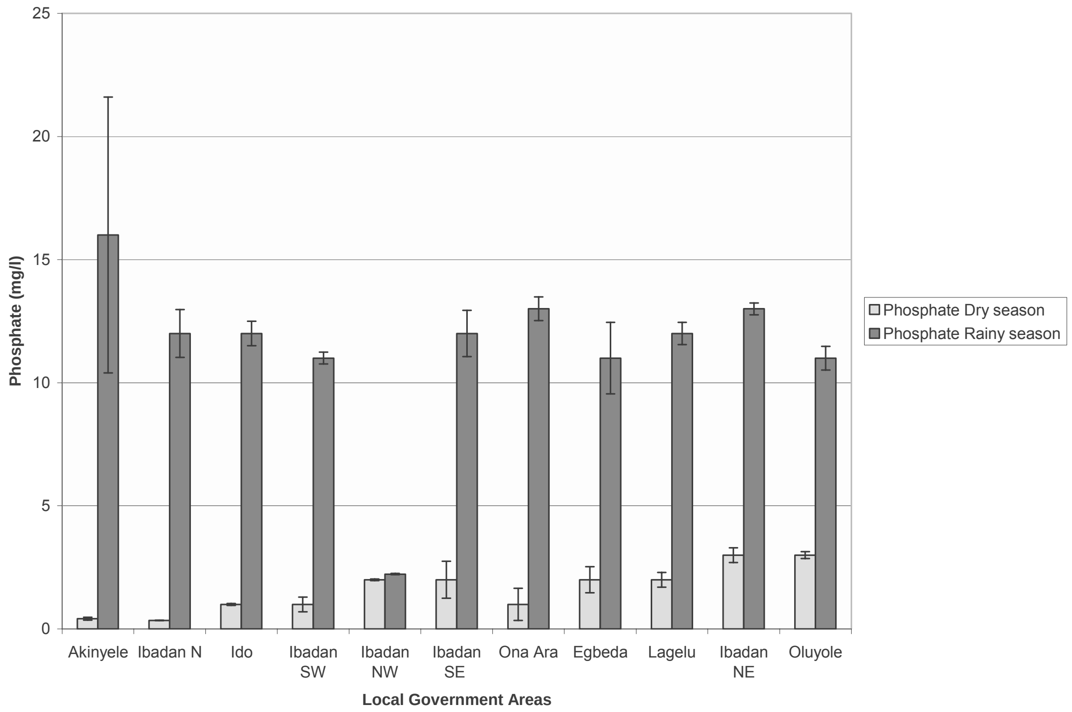

Figure 11. Phosphate level of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

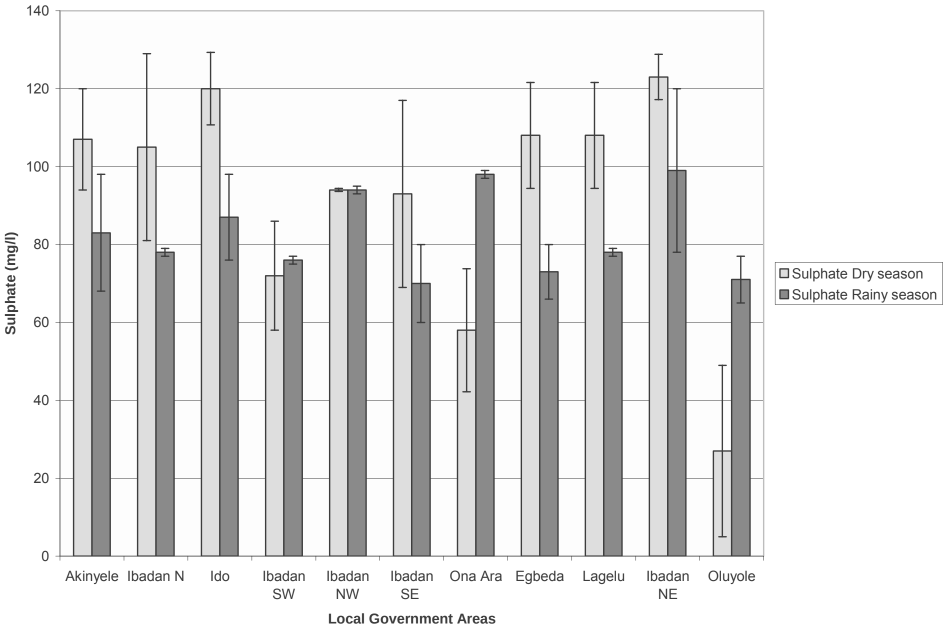

Figure 12. Sulphate level of pore water in the sediments in Ibadan Local Government Areas during dry and rainy seasons

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