EVALUATION OF POLLUTANT LOADS: ORGANIC AND INORGANIC IN RIVER UKOGHOR OF THE LOWER BENUE BASIN, NIGERIA

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ABSTRACT

This study was carried out to determine the organic and inorganic pollutant loads in River Ukoghor of the Lower Benue Basin. Grab water samples were collected from the outlet of the River into River Benue, twice a month in three replications for a period of eight months (April November, 2002) using sterilized one-litre plastic bottles. The entire depth of the river was covered by submerging the bottles several times across the vertical depth. The samples were collected from the river section where there was a complete lateral mixing. Laboratory analyses were carried out to determine BOD, COD, Ca, Mg, Na, and TDS concentrations from which the loads were computed. The result of laboratory analysis shows that the inorganic pollutant loads include calcium (Ca), Sodium (Na), and Magnesium (Mg). The high loading of Ca (25g/day) and Mg (15g/day) were attributed to the crushing of rocks used for building and road construction, while the high loading of Na (18.18g/day) was attributed to the presence of brewing industries. The high level of TDS (7.30g/day) was due to agricultural activities within the area. High values of BOD (12.22mg/l) and COD (20.47mg/l) obtained indicated pollution due to organic (biodegradable) and inorganic (nonbiodegradable) substances. It was evident that watershed vegetation characteristics and anthropogenic activities are important factors that influence water quality.

KEYWORDS: *pollution, watershed, pollutant, runoff, water quality*
RUNNING TITLE: *Evaluation of Pollutant loads: Organic and Inorganic ……*

INTRODUCTION

Agriculture in the modern times is characterised by the use of chemicals (fertilizers and pesticides) to increase production and protection of crops. The environmental effect of these substances is determined by removal phenomena (adsorption onto the solid matrix, chemical and microbiological degradation, uptake by plants, photodecomposition) and transport phenomena. In water these processes are surface flow, solid transport and erosion, subsurface flow, and percolation (Greppi and Preti, 1999).

The identification and quantification of sources of quality impairment is essential for the water quality management programme in river basins (Isikwue, 2005). Water quality in estuaries, lakes, and reservoirs depends upon the quantity and quality of inflows from the upstream catchments, recycling within the water body and, in case of estuaries, exchanges with the ocean. Of these processes, inflows are usually the most significant source of pollutants. Stream flow is therefore of primary importance to the health of receiving waters and its evaluation is crucial to our ability to manage those ecosystems in an environmentally healthy manner. The ability of a river to get rid of waste naturally is called its purification or assimilation capacity (Pescod,1977). The assimilation capacity of a river is directly proportional to the volume of runoff. Hence all the factors that normally influence the quantity of runoff will also affect assimilation capacity. Such factors include wind velocity, precipitation, landform, vegetative cover, topography and temperature. Since runoff varies from month to month, it implies that assimilation capacity will vary according to months (Agunwamba, 2001).

Two general sources of pollutants (point and nonpoint) are usually considered while studying water quality management. Attempts are made to quantify and reduce the impact of point source pollution because this source can readily be collected and treated by well known processes. In contrast, the role and impact of nonpoint source pollution has not been comprehended fully due to its diffuse nature and high variability both in time and space. In fact the nonpoint source of pollution is a major contributor to pollutant loads in most receiving water bodies. The pollutant load of runoff into receiving water may differ with the nature of the river basin and the flow regime (Yamada et al., 1991, and Yamada et al., 1993). Therefore, it is necessary to study the site specific relationship between the basin cover characteristics and pollutant load into the water bodies. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-caused pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even underground water sources.

The Biochemical Oxygen Demand (BOD) is the most widely used parameter of organic pollution. This is because it is used to determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present. Also it is used to determine the size of waste treatment facilities and to measure the efficiency of some treatment processes (Tchobanoglous et al., 2003).

According to Punmia et al. (1998), BOD is the most widely used parameter of organic pollution applied to both wastewater as well as surface water. It is the oxygen required for the microorganisms to carry out biological decomposition of dissolved solids or organic matter in the wastewater under aerobic conditions at standard temperature. Further the BOD test results are used for the following: determination of size of wastewater treatment facilities; measurement of efficiency of some treatment processes; determination of strength of sewage; determination of amount of clear water required for the efficient disposal of wastewater by dilution. Generally, a 5-day (BOD_5) period is chosen for standard BOD test during which oxidation is about 60 70 percent complete, which within 20days period, the oxidation is about 95 99 percent complete. A constant temperature of 20^oC is maintained during the incubation. Agunwamba (2001) reported that BOD is described by simple first order kinetics. The reaction constant, K values at 20^0C are usually from 0.10 0.20 day^{-1}. For highly polluted water it can be as high as $0.25 day^{-1}$.

Uchegbu (1998) said that BOD is the rate of oxygen use. It is a measure of amount of oxygen required by bacteria and other microorganisms to stabilize degradable organic matter and not a measure of some specific pollutant. Chemical Oxygen Demand (COD) is always higher than BOD values.

Punmia et al. (1998) reported that COD can be used to measure content of organic matter of wastewater as well as natural waters. COD can be determined in three hours in contrast to 5 days for BOD test.

COD test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g lakes and rivers), making it a useful measure of water quality. According to Sawyer et al (2003), both BOD and COD tests are a measure of the relative oxygen-depletion effect of a waste contaminant. Both have been widely adopted as a measure of pollution effect. The BOD test measures the oxygen demand of biodegradable pollutants whereas the COD test measures the oxygen demand of both biodegradable and non-biodegradable pollutants. For typical untreated domestic wastes, the ratio of COD/BOD is found to vary from 1.25 2.50. A higher value of the ratio indicates that the wastewater is difficult to biodegrade. For non-biodegradable wastewater, the ratio exceeds 10.

Loadings are estimated by multiplying the concentration values by stream discharge for a given time period (equation 1).

$$P_L = C \times Q \quad (1)$$

where, P_L = Loading for each parameter, (g/day); C = concentration of parameter (mg/l); Q = discharge of river (m^3/s).

Concentration for time periods not accounted for can be estimated using integration techniques (mass accumulation) or regression models. The regression method uses the relation between concentration and or load and daily average flow to estimate daily concentration or loads of constituents (Cohn et al., 1989; Cohn et al., 1992a; Cohn et al., 1992b;). The regression approach has come into widespread use because it requires less data and can be used to produce estimates for periods beyond when concentration data were collected, and enables confidence limits to be placed on the estimates as a measure of the regression model error.

The objectives of the study were to determine the pollutant loads of the river within the period of study, identify the probable sources and effects of these pollutants, and highlight the loading pattern of the pollutants and their correlation with each other.

MATERIALS AND METHOD

The study Area

The Ukoghor agricultural watershed which is situated in Southwest of Makurdi, Benue State (Lower Benue River Basin) of Nigeria drains into River Benue the second largest river in Nigeria. River Ukoghor small agricultural watershed is 720ha and lies between latitudes 7°39' and 7° 45' N and longitudes 8°33' and 8°35' E. Makurdi lies essentially in a zone of transition within a sub-humid tropical climate. The zone in which Makurdi lies is a tropical savannah with distinct wet and dry seasons. The relative movement of inter-tropical convergence zone (ITCZ) governs the rainfall pattern of Makurdi, which has a characteristic bimodal distribution with peaks in June and in September with a period of lower rainfall in August (August break). In the recent years there is fluctuation in this bimodal characteristic probably due to global environmental changes (Isikwue et al, 2009). The topography of the watershed is typical of undulating farmland consisting of few sloping areas. The principal soil types are clay and sandy loam, which are well drained. Local soil conservation practices in use in the area include stone/sand sack lines across gullies, trash lines, mound making and agro-forestry. These are to reduce impact of raindrop, stabilize the soil, improve soil fertility and reduce erosion. According to Isikwue (2005), the farming history of the area reveals that farmers rarely use fertilizers because of the difficulty in procuring them. The application rate (2.0kg/ha) is low and when it is used it is applied by broadcasting. The pollutants come mainly from domestic wastes and agricultural and non-agricultural activities other than from inorganic fertilizers. These activities include bush burning, crushing of rocks for construction works and fermenting of agricultural produce like cassava. The predominant crops grown in this agricultural watershed are rice, cassava, guinea corn, groundnut, yam, maize, melon and millet.

The relative humidity depends on the season. It ranges from 50% during the dry months of December to February to 80% during the rainy months of June to September. The mean annual maximum temperature range is from 32°C to 33°C while the mean annual minimum is between 21° C and 22° C. The mean annual rainfall is 1250mm.

Sampling Points and Method:

In order to estimate the pollution level, water samples from the outlet were collected at three different sampling points across the river - one in the middle and two at each edge of the river. At this cross-section, there was complete lateral mixing. The experimental design adopted was Randomised Complete Block Design (RCBD) with three replications. The grab water samples were collected manually twice a month for eight months (April November 2002), in properly sterilized one-litre plastic bottles. The entire depth of the river was covered by submerging the bottles several times across the vertical depth. The samples collected at the downstream (outlet) represent runoff contribution from the whole cropland area. The laboratories used for the analysis were Benue State Water and Sanitation Agency (BEWASA), Makurdi and the Benue State Environmental Protection Agency (BSEPA), Makurdi. Analysis of Variance (ANOVA) was used to determine significant differences and Coefficient of Variation (CV) was used to verify the reliability of the results obtained.

Table 1: Water quality parameters measured

Water Quality Parameter	Analysis Method
Biochemical Oxygen Demand (BOD)	BOD_5
Chemical Oxygen Demand (COD)	COD
Calcium (Ca)	EDTA
Magnesium (Mg)	EDTA
Sodium (Na)	Flame photometric
Total Dissolved Solid (TDS)	Conductivity/TDS meter

RESULTS AND DISCUSSION

The values of the pollutant loads at the discharge of $5.55m^3/s$ are presented in Table 2 below. The values of CV (%) of all the parameters show the reliability of the experiment and results obtained. According to Gomez and Gomez (1984), CV indicates the degree of precision with which the treatments were compared and is a good index of the reliability of the experiment. Salako (2004) reported that CV should normally not be higher than 10%.

Relationship between DO and BOD are of concern to water quality investigators

(Nash, 1993, Srivastava et al, 1996, and Isikwue et al. 2001). The high values of BOD (12.22mg/l) and COD (20.47mg/l) as in Table 2 indicate pollution due to biodegradable and nonbiodegradable substances. This is because very clean bodies of surface water usually has a BOD of about 1mg/l (Nathanson, 2006) and the higher the BOD the higher the organic pollution. Further, Sawyer et al (2003) stated that most pristine rivers will have a BOD below 1mg/l. Moderately polluted rivers may have a BOD value in the range of 2 8 mg/l. Municipal sewage that is efficiently treated by a three-stage process would have a value of about 20mg/l or less. Ogazi (1992) has noted that BOD is an important factor in corrossivity, septicity and photosynthetic activity of water supply. It gives insight into the organic pollution load of any system.

The ratio of BOD to COD values gives indication of the level of degradability of the waste and hence guides the choice of treatment method (Agunwamba, 2000). In this study, the ratio of COD to BOD is 1.68 which is in consonance with Punmia et al (1998)'s finding that COD/BOD varies from 1.25 to 2.5. COD values are generally higher than BOD values because of the presence of biologically resistant organic matter in the wastewater which are not measurable by the BOD.

Table 2: The pollutant load of River Ukoghor Agricultural watershed

Water Quality Parameter	Pollutant Conc (mg/l)	Pollutant Load (g/day)	$LSD_{0.05}$	CV(%)	Natural Max for Rivers (mg/l)[1,2]
Biochemical Oxygen Demand (BOD)	12.22	0.45	0.067	3.7	1[1]
Chemical Oxygen Demand (COD)	20.47	0.76	0.029*	1.0	-
Calcium (Ca)	681.91	25.24	6.31	6.3	210[2]
Magnesium (Mg)	428.1	15.85	1.50	2.4	80[2]
Sodium (Na)	491.21	18.18	1.60	1.5	350[2]
Total Dissolved Solid (TDS)	197.15	7.30	0.40*	1.4	-

* Significant at 5% level of probability (P = 0.05).
1. Nathanson, 2006
2.Meybek et al, 1989

In conjunction with BOD test, the COD indicates toxic conditions and the presence of biologically resistant organic substances. The loading pattern of BOD fluctuated mildly (figure 1) at the beginning and ending of the rainy season. This coincided with the peak of agricultural activities (clearing, planting and harvesting) within the basin and as such runoff carried more biodegradable materials into River Ukoghor. In between the two periods the loading was more or less steady showing that the runoff carried less biodegradable materials into the surface water.

The loading of COD fluctuated throughout the study period (Figure 2). The high positive R^2-value of about 77% portrays that COD loading was highly significant. The presence of brewing industries within the reach of this river may have contributed a lot to the loading of some biodegradable materials. Ca had a higher unsteady loading during the period (Figure 3). This confirms the flow across rock outcrops and crushing activities within the watershed. The loading of Mg (Figure 4) was highly significant as observed by the high R^2-value of 75%. The fluctuation in loading was not much pronounced. The fluctuation of Na loading was nearly uniform around an average value (Figure 5), that was why the R^2-value is about 53%. This means that the loading pattern of Na was constant during the study.

The value of Total dissolved solids (TDS) broadly reflects the pollutant burden of the aquatic systems. It should be noted that what is measured as TDS is comprised of colloidal and dissolved solids. The highest value of TDS recorded at an event was 70.30mg/l, which was very low when compared to the 1000mg/l (WHO); 500mg/l (USA and Canada) (WHO, 1984); and 500mg/l (NAFDAC, Nigeria) recommendations for drinking water. It also agreed with 20 100mg/l range recommended by Sawyer and McCarty (1978), who also suggested that waters with TDS less than 500mg/l are most desirable for domestic uses. The TDS values were statistically significant throughout the period. This could be as a result of increasing farming activities within the watershed. The loading pattern was very high at the second month (Figure 6).

The seasonality in loadings was also examined in the River Ukoghor agricultural watershed. This shows the constant discharge of wastes from residential area and limited contribution of nonpoint source pollution on BOD loading. Agriculture is the major land use (85%) in this watershed. Crushing of rocks and road constructions was very high within the watershed during the study period. This accounted for the high Ca, Na and Mg loadings (Table 2). The non-decomposed or partially-decomposed vegetation (from agricultural activities) were washed away by the storm into the water body and activity of microorganism increased which led to the increase in oxygen demand. The high loading of Na was attributable to the presence of brewing industries (Benue Breweries and Nigerian Bottling Company) situated within the watershed.

Higher loadings were observed during the rainy season. Therefore one can say that the major source of the pollution is nonpoint sources from higher surface runoff in the rainy season. The harvesting activities led to the disturbances in land cover which ultimately increased the loadings of COD and TDS towards the end of rainfall.

A correlation between BOD, COD, Ca, Mg, Na, and TDS concentrations was performed (Table 3). There was high positive correlation between Mg and COD, and BOD and Ca concentrations. This implies that one parameter increases as the other increases with time. Na correlated negatively with BOD, COD, Ca, and Mg meaning that as concentrations of these other parameters increased, Na concentration decreased with time. The higher values show strong correlation while the lower values show weak correlation. This is confirmed by figures 1 5.

Table 3: Correlation between the monitored water quality parameters.

	BOD	COD	Ca	Mg	Na	TDS
BOD	1.00	0.15	0.62	0.18	-0.19	0.27
COD		1.00	0.23	0.74	-0.86	-0.33
Ca			1.00	0.40	-0.06	0.14
Mg				1.00	-0.53	-0.52
Na					1.00	0.25
TDS						1.00

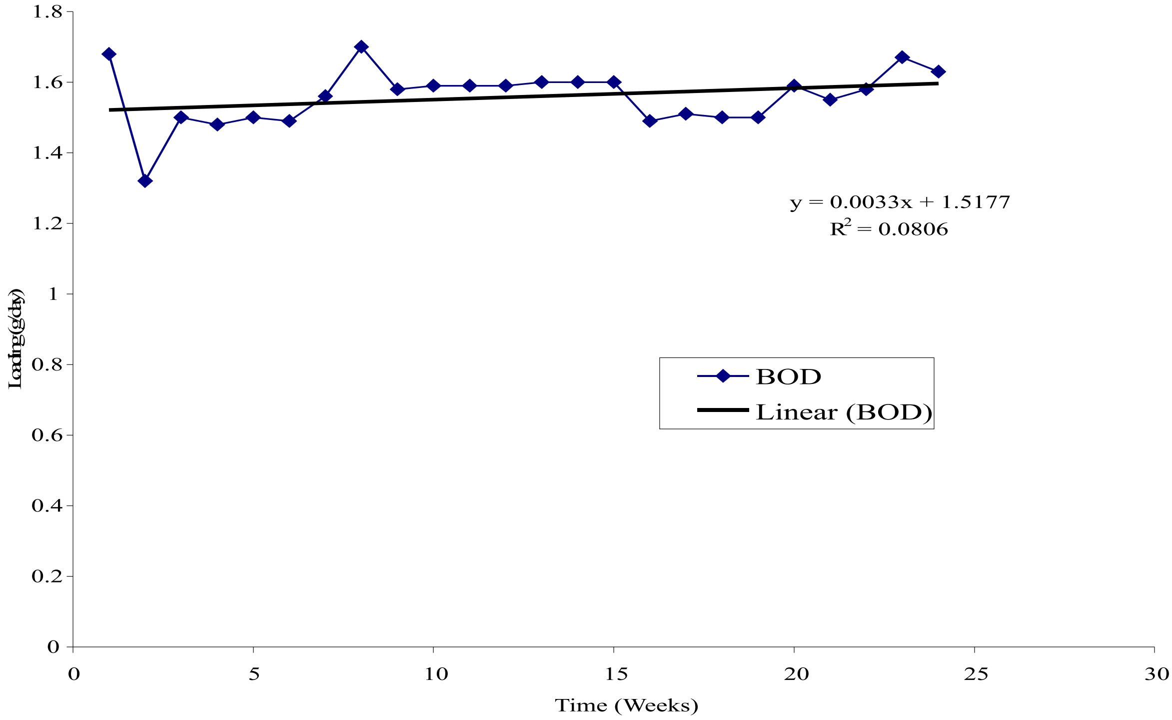

Fig 1 BOD loading during the study

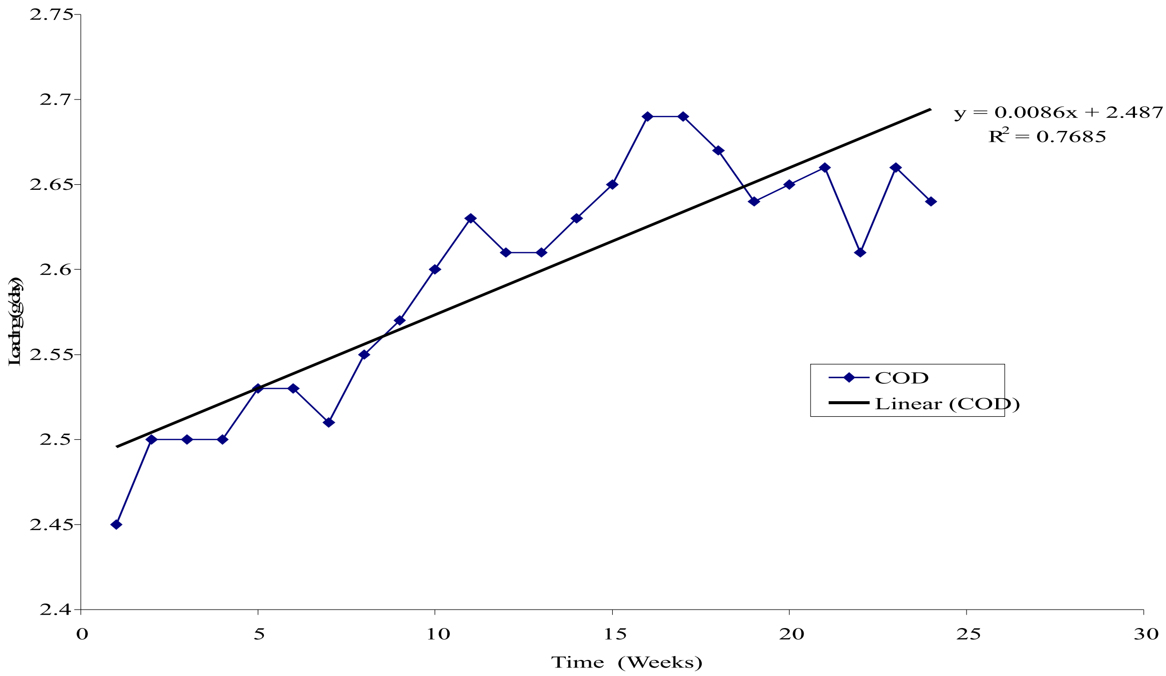

Fig 2: COD loading during the study

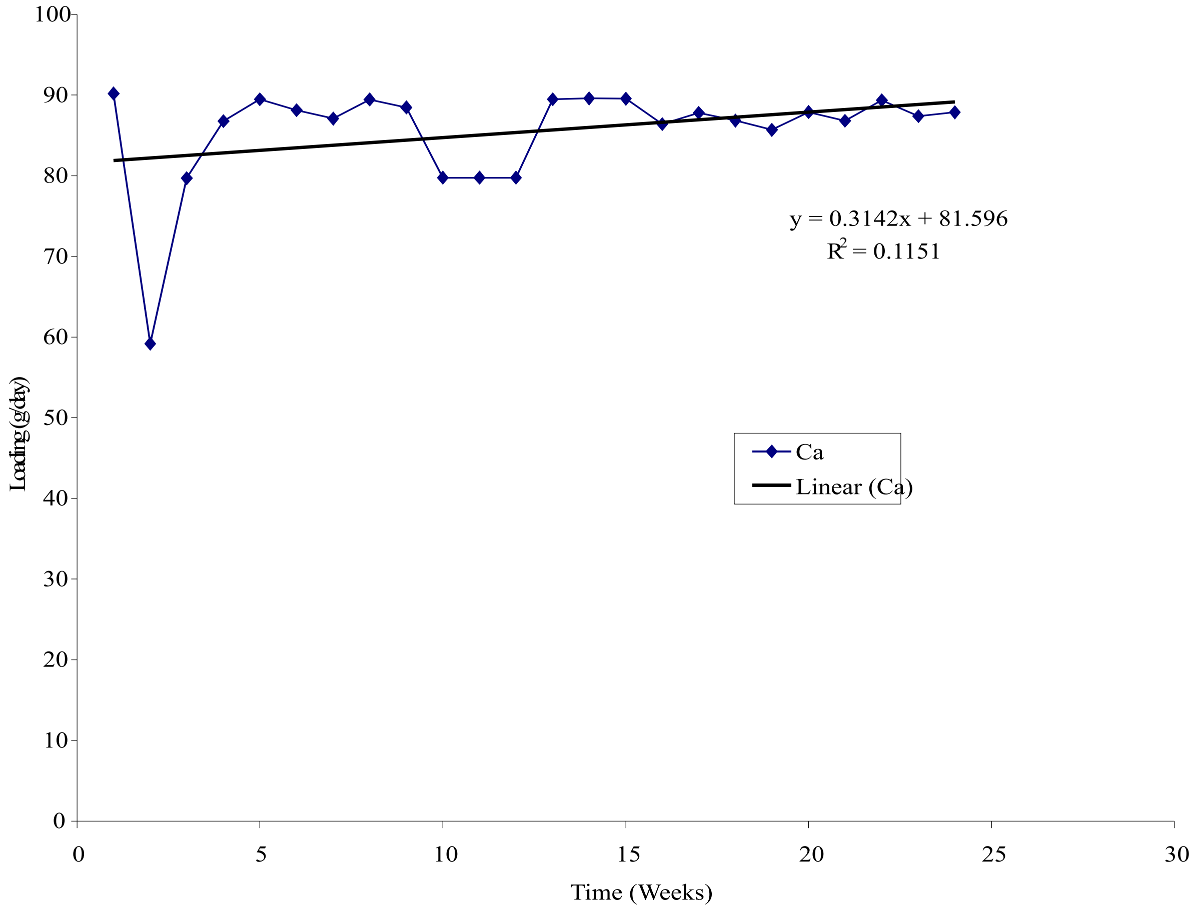

Fig 3: Ca loading during the period of study

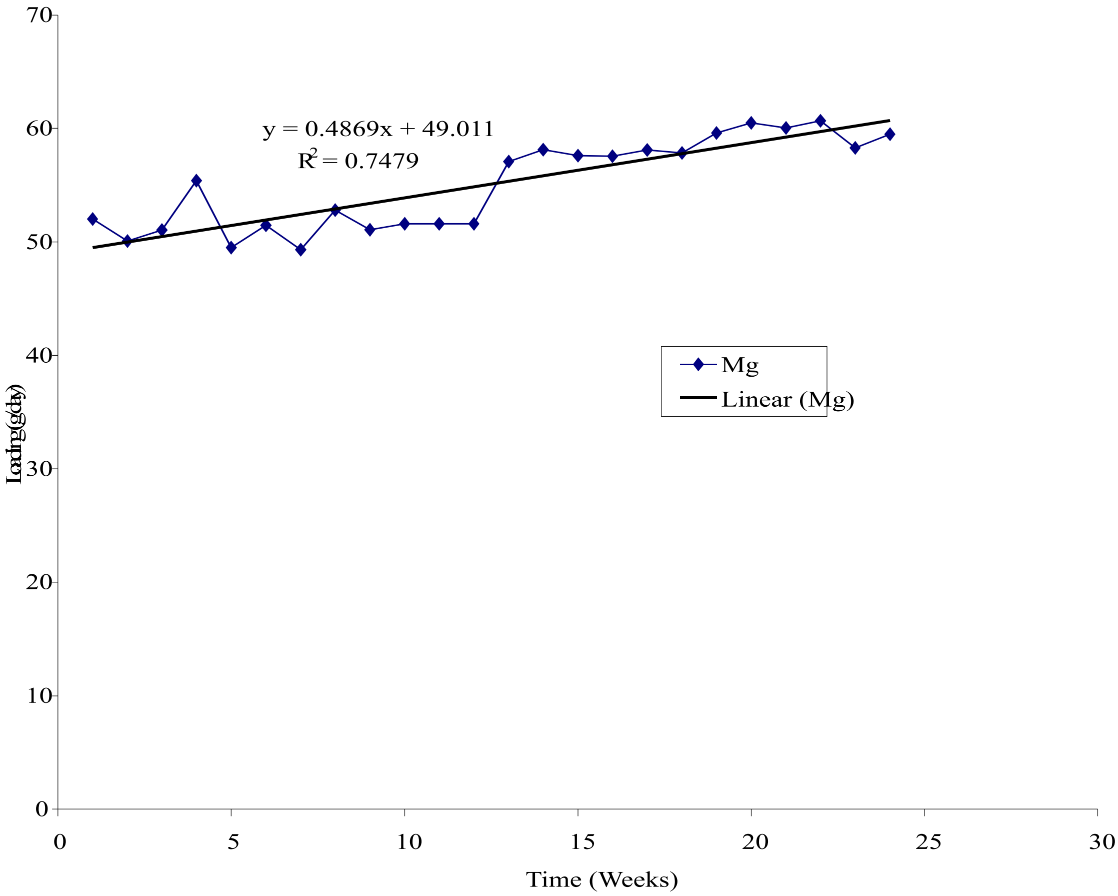

Fig 4: Mg loading during the period of study

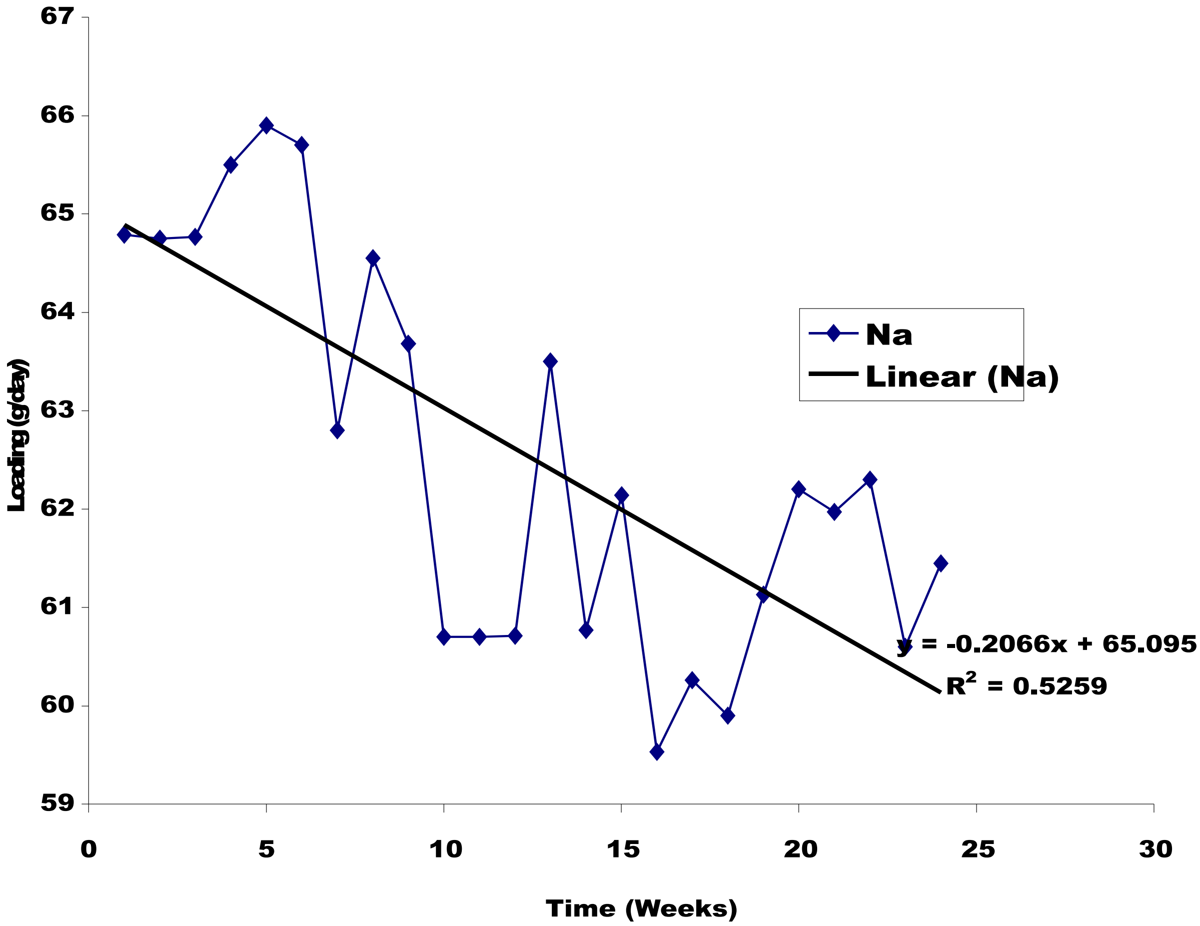

Fig 5: Na loading during the period of study

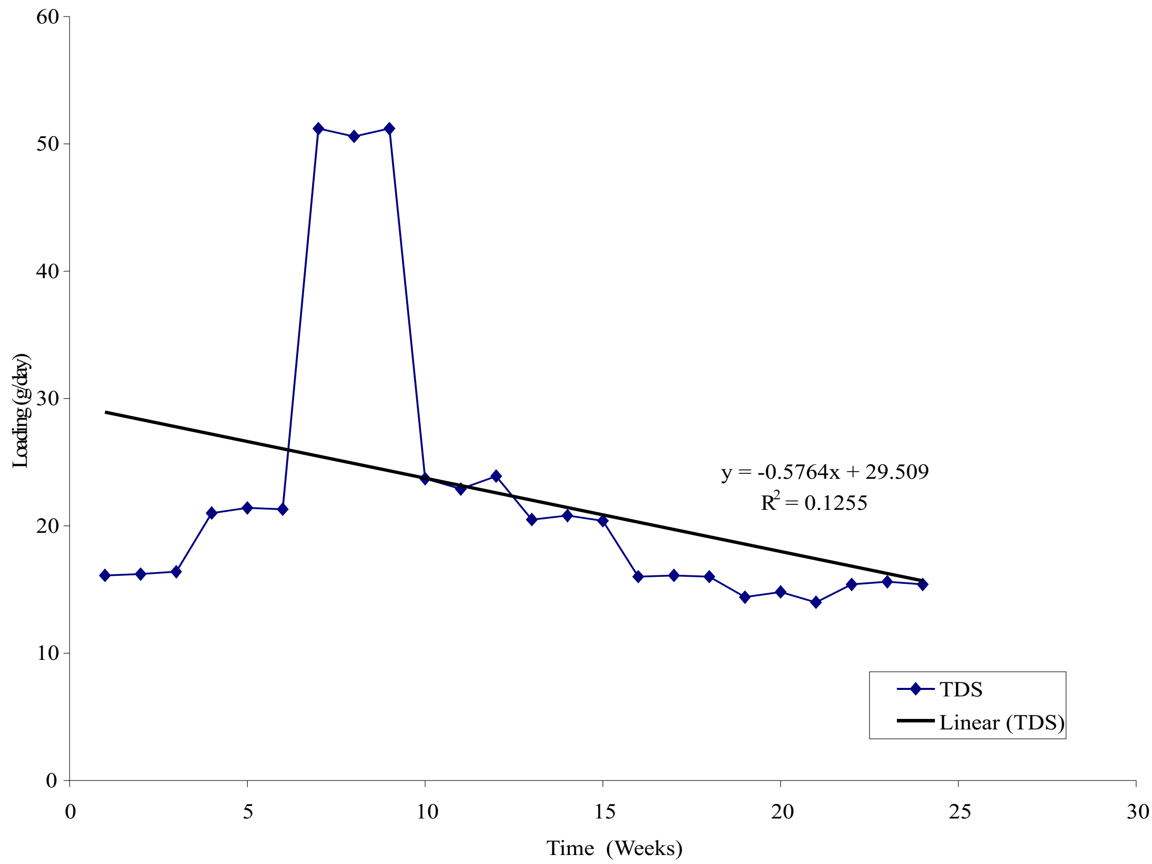

Fig 6: TDS loading during the study

CONCLUSION

Water quality parameters BOD, COD, Ca, Mg, Na and TDS were used to study the major sources and level of organic and inorganic loadings of River Ukoghor in Lower Benue River Basin. The mean annual yields of Ca, Mg, Na and TDS are higher than BOD and COD**.** The study has also shown that there were higher yields of the organic and inorganic loadings in the rainy season. These results show that the watershed cover characteristics and anthropogenic activities are important factors that influence water quality. The need for investigation about the distance of source area and sampling point is realized as it affects the contaminant transport mechanism in the watershed. Careful need of management and planning of the watershed with respect to agricultural and urban activities especially during rainy season are emphasized to reduce the loadings of organic and inorganic pollutants into River Ukoghor.

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