INTRODUCTION

Water is one of the most abundant natural resources to man. The importance of water cannot be over-emphasized as there is no substitute to it in many of its uses. It is essential for everything to grow and prosper in. Rivers are primary sources of potable water for mankind all over the world. They are sources of food as millions of tons of edible fish, lobsters, crabs and other aquatic animals and plants are taken from them (Okebukola, 1998). They are used for the generation of power, recreational activities and for irrigation amongst others. In spite of the important role of water, water bodies are constantly being polluted through anthropogenic activities. In Nigeria today, research indicates that majority of the common fresh water sources are polluted. The pollution and contamination of the aquatic environment in Nigeria are fast increasing in scope and magnitude (Ali et al., 2005). This has occurred as a result of rapid population growth, urbanization, industrialization and non-enforcement of existing environmental laws. Udosen (2006) observed that the uncontrolled release of waste effluents into water bodies have negatively affected both water quality and aquatic life. These discharges affect the physico-chemical properties of the receiving water body. Raw effluents discharge into River Challawa in Kano resulted to high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) (Wakama et al., 2008). Akan et al (2009) also reported that the physicochemical parameters measured for River Challawa are potential for profound effect on the waterbody and resident aquatic life. Indiscriminate dumping of large quantities of domestic and industrial wastes into the RiverKaduna in Kaduna led to its severe pollution with also high levels of COD and BOD (Beecroft et al., 1998). A study on the ground water pollution from abattoir in Minna, Niger State, showed physical, chemical and organic parameters that exceeded the upper boundaries set by WHO (Chukwu,2008). Uncontrolled discharge of untreated wastewater sewage, sediment carrying runoff as well as solid wastes into the Lagos Lagoon have degraded the quality of the surface water beyond the acceptable limits (Enuola et al., 2011).

River Jakara in Kano also receives domestic wastes from
homes, commercial establishments, agricultural fields, abattoir, mechanic workshops and other sources (Dike et al., 2004). The river is used extensively for irrigation of vegetables and fruits which are consumed by the inhabitants of Kano and its environ. This study is therefore aimed at assessing the water quality of River Jakara for drinking and production of vegetables and fruits using some selected physico-chemical parameters. Mustapha (2008) indicated that the use of the physico-chemical properties of water to assess water quality gives a good impression of the status, productivity and sustainability of such water body.

MATERIALS AND METHODS

**Description of the study Area**

Kano town where River Jakara is located, lies on latitude 12-03’N and longitude 8-32’E (Fig.1). It is about 496m above the sea level and is located in the northern central rolling plains of Nigeria (Travelion, 1963). Kano urban areas fall within the Sudan savannah zone of tropical continental type of climate. The drainage system is characterized by two major rivers (Rivers Jakara and Getsi) into which tributary streams converge. River Jakara has three major drainage areas – the Upper Jakara, the Middle Jakara and the Lower Jakara (see Fig.1).

**FIG 1. MAP OF THE STUDY AREA SHOWING THE SAMPLING POINTS.**

**Sites, Sampling and Analyses**

Water samples were collected manually at the surface in triplicates from both the banks and middle of the river with a beaker into clean dark two-litre plastic containers with screw caps monthly from five designated points between January and December 2003. Samples for dissolved oxygen and biochemical oxygen demand were collected separately in air-tight pre-washed amber glass bottles. Site 1 is at the “T” junction of Ibrahim Babangida and Taiwo roads and near the origin of the river. It receives little pollution when compared to the other sites and hence the choice. Site 2 is at the Abattoir and Katsina roads junction where the river receives sewage and other wastes from Fagge and the abattoir. Site 3 is at the Burma and Zuungeru roads junction. It receives domestic sewage and solid wastes from Sabon Gari, hospital wastes from infectious disease hospital (IDH) and wastes from mechanic workshops from Egbe Street and off Katsina road. Site 4 which is at the Airport Road Bridge, receives domestic sewage and solid wastes from Sabon Gari extension (Noman’s land). Choices of sites 2, 3 and 4 were based on the irrigation activities. Site 5 is at the PRP village and receives wastes from Nigerian Airport Authority quarters, Gwagwarwa and PRP quarters. This site was chosen because of its nearness to the confluence of Rivers Jakara and Getsi.

The various parameters were determined using appropriate analytical methods. Surface water temperature (°C) of the river was measured at the five designated points with hand-held mercury thermometer. Electrical conductivity (EC) (µmhos/cm), pH, and total dissolved solids (TDS) (mg/l) were measured with Hanna portable pH/EC/TDS combined waterproof tester model HI 99300 as described by the manufacturer. Total solids (TS), suspended solids (SS), dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) (in mg/l respectively) were analysed according to procedures outlined in American Public Health Association (APHA) (1985). Total solid was determined by the evaporation method; suspended solid was determined by the difference between total and dissolved solids, DO and BOD analyses involved the Azide modification of the Winkler method, and COD involved the reflux titrimetric methods. Chloride concentration (mg/l) was determined by the Argentometric (Mohr’s) method as described by Hanson (1974) and APHA (1985), which requires titration with silver nitrate (AgNO₃). The indicator method (Ademorati, 1996) was used to measure alkalinity concentration (mg/l) which involved titration with sulphuric acid phenolphthalein as indicator. Digestion of samples for calcium (Ca), magnesium (Mg), sodium (Na) and potassium(K) was carried out following standard methods (APHA, 1985) using concentrated nitric acid. All the analyses were done at the department of Water Resources Laboratory of Ahmadu Bello University, Zaria, Nigeria, except those of the metals which were determined using UNICAM 969 Atomic Absorption Spectrophotometer (AAS) at National Research Institute for Chemical Technology, Basawa, Zaria, Nigeria.

**Statistical Analysis**

Data collected were subjected to statistical analysis. One-way analysis of variance (ANOVA) was used to compute the variations in the physico-chemical parameters of water samples between the sampled sites, seasons, months and interaction of sites and seasons. Line graphs were used to show the relationship between the physico-chemical parameters and the months of study. The data was also subjected to correlation analysis to estimate the degree of association between the physico-chemical parameters.

**RESULTS**

The mean surface temperature for the river ranged between 24.0°C and 29.5°C. The lowest mean value (23.0°C) was at
site 1 in the dry season (November and February) and the highest (29.8°C) at site 5 in the wet season (June) (Fig. 2).

The mean values of TDS, TS and SS ranged between 315.33 to 1007.67 mg/l, 392.17 to 1471.00 mg/l and 91.50 to 463.33 mg/l respectively. Analysis of variance of each of the solids did not vary significantly (p>0.05) from one month to another. Their mean monthly variations presented in Figs. 3, 4 and 5 show that the highest mean values of TDS and TS in October (893.4 mg/l and 1209.0 mg/l) and SS in November (402.6 mg/l) were significantly different (p<0.05) from other months. Analysis of degree of association shows positive correlation between TDS and TS (r = 0.95), SS (r = 0.62), chloride (r = 0.52), BOD (r = 0.51) and Mg (r = 0.42), and low negative correlation with DO (r = -0.35). Total solid had positive correlation with SS (r = 0.82), conductivity (r = 0.88), chloride (r = 0.53), alkalinity (r = 0.40), BOD (r = 0.59), COD (r = 0.56), Mg (r = 0.46) and low negative correlation with DO (r = -0.39). Positive correlation was also established between SS and conductivity (r = 0.66), chloride (r = 0.40), alkalinity (r = 0.45), BOD (r = 0.57), COD (r = 0.48), Mg (r = 0.40) and low negative correlation with DO (r = -0.31).

There was an insignificant difference (p>0.05) in the mean pH values (7.08 and 7.10) observed at sites 2 and 3, and so was the values (7.25 and 7.29) observed at sites 4 and 5 respectively. The mean pH had a narrow range of 7.01 to 7.36 with the lowest value at site 3 and the highest at site 5, both in the dry season. There was no significant difference (p>0.05) in pH values between seasons and months. The lowest mean pH value (7.04) was in March while the highest values (7.32 and 7.35) were in February and October respectively (Fig. 6).

Low mean value of conductivity (671.58 µmhos/cm) recorded at site 1 was significantly different (p<0.05) with other sites that had higher values. No significant difference (p>0.05) was revealed in conductivity between seasons. Lower dry season mean value of 668.50 µmhos/cm was observed at site 1 and higher dry season value of 1791.50 µmhos/cm at site 3. The highest conductivity value (1868.80 µmhos) was in October and significantly different (p<0.05) from the rest of the other months while lowest value (1225.20 µmhos/cm) was in July (Fig. 7). There was a high positive correlation between conductivity and dissolved, total and suspended solids (r = 0.86, 0.88 and 0.66 respectively) and low positive correlation between conductivity and chloride (r = 0.50), BOD (r = 0.45), COD (r = 0.51), Mg (r = 0.45), and Na (r = 0.31) and a negative correlation between conductivity and DO (r = -0.41).

The chloride and alkalinity concentrations varied from site to another with the lowest values (103.14 mg/l and 178.67 mg/l) at site 1 and highest (500.38 mg/l and 385.50 mg/l) at site 5 in the wet season (June) (Fig. 2).
The mean DO varied significantly from one site to another with higher mean value (6.60 mg/l) at site 1 than the other sites. There was a significant difference (p<0.05) in DO between seasons. High dry and wet season mean DO values (6.57 mg/l and 6.63 mg/l) were observed at site 1. The other sites recorded relatively low values with the lowest (2.57 mg/l) at site 5 in the wet season. There was significant difference (p<0.05) in DO concentration between months, with the lowest value (2.68 mg/l) in May and highest (5.12 mg/l) in November (Fig. 10). There were low negative correlations between DO concentration and BOD (r = -0.29), COD (r = -0.31), and Ca (r = -0.32).

The lowest mean concentration of BOD (189.17 mg/l) recorded at site 1 varied from the other sites with the highest value (754.17 mg/l) at site 4. Biochemical oxygen demand varied significantly between seasons and analysis of the degree of interaction revealed that both the lowest mean value (160.83 mg/l) and the highest (983.33 mg/l) at sites 1 and 4 respectively occurred in the dry season. The lowest BOD mean value (338.00 mg/l), and the highest (1004 mg/l) which had significant difference (p<0.05) with the other months were in October and March respectively (Fig. 11). There was a high positive correlation between BOD and COD (r = 0.76) and BOD and Mg (r = 0.60) and low positive correlation between BOD and Ca (r = 0.48), and K (r = 0.50).

Lowest and highest COD mean values (479 mg/l and 1750.80 mg/l) occurred at sites 1 and 3 respectively and were significantly different (p<0.05) from the other sites. High values at sites 4 and 5 showed insignificant variation (p>0.05). There was a significant difference (p<0.05) in COD between seasons. The lowest concentration (467.67 mg/l) was at site 1 and the highest (2219.00 mg/l) at site 5, both in the dry season. Low COD mean values (927 mg/l and 910 mg/l) recorded in June and August respectively were not significantly different (p>0.05) from the other months but the highest value (2012.0 mg/l) in March was significantly different (p<0.05) (Fig. 12). COD showed positive correlation with Mg (r = 0.63), Ca(r = 0.37) and K (r = 0.44).
FIG 12. MEAN MONTHLY VARIATION OF CHEMICAL OXYGEN DEMAND OF SURFACE WATER ALONG RIVER JAKARA.

The lowest mean value of Ca (13.43 mg/l) was recorded at site 1 while the highest value was at site 5 (32.114 mg/l). There was significant difference (p<0.05) in the Ca concentration between seasons and the lowest concentration (13.32 mg/l) and highest (42.44 mg/l) was in June. Analysis of the degree of association shows a high positive correlation between Ca and Na (r = 0.76) and Ca and K (r = 0.74) and low positive correlation between Ca and Mg (r = 0.57). The lowest mean concentration of Mg (3.35 mg/l) which occurred at site 1 showed a significant variation (p<0.05) and the highest value (8.59 mg/l) at site 5 varied insignificantly (p>0.05) with the other sites. Magnesium varied significantly (p<0.05) between seasons with the lowest concentration (2.91 mg/l) at site 1 in the wet season and the highest (11.94 mg/l) at site 5 in the dry season. Figure 13 revealed that the lowest value (4.15 mg/l) was in August while the highest (10.99 mg/l) was in February and both varied significantly (p<0.05) from the other months. There was a low positive correlation between Mg and Na (r = 0.39) and K (r = 0.55). Site 1 had the lowest concentration of Na (18.35 mg/l) while other sites had higher values with the highest (32.91 mg/l) at site 3. There was a significant difference (p<0.05) in Na concentrations between seasons. The lowest concentration was at site 1 in the wet season, while the highest was at site 2 in dry season. The lowest mean monthly value of Na (9.99 mg/l) was in August and the highest (65.95 mg/l) in June (Fig.14). Low positive correlation was observed between Na and K (r = 0.36). The mean concentrations of K showed significant difference (p<0.05) between sites with the lowest value (9.29 mg/l) at site 1 and the highest (22.23 mg/l) at site 5. There was also significant difference (p<0.05) in the concentrations of K between seasons. Analysis of the degree of interaction shows that the lowest concentration of K was at site 1 in the wet season and the highest at site 5 in the dry season. The concentration of K varied significantly (p<0.05) between months with the lowest value (4.16 mg/l) in January and the highest (52.07 mg/l) in April (Fig.15).

FIG 13. MEAN MONTHLY VARIATION OF THE CONCENTRATION OF CALCIUM OF SURFACE WATER ALONG RIVER JAKARA.

FIG 14: Mean monthly variation in the concentrations magnesium of surface water along River Jakara.

FIG 15. MEAN MONTHLY VARIATION IN THE CONCENTRATIONS OF SODIUM OF SURFACE WATER ALONG RIVER JAKARA.

FIG 16. MEAN MONTHLY VARIATION IN THE CONCENTRATIONS OF POTASSIUM OF SURFACE WATER ALONG RIVER JAKARA.

DISCUSSION

Values of the monthly surface temperature varied and the highest was in June during the rainy season. Lower values between November and February are directly related to the characteristic cold North-East trade winds that blow across this region during the harmattan. Similar observations were made by Awanda (1987) in River Kaduna and Oniye et al., (2002) in Zaria Dam. The annual mean temperature (26.62°C) is within the range of 10°C to 50°C for river meant for domestic purposes and 20°C to 50°C for irrigation (National Guidelines and Standards for Water Quality in Nigeria, 1999). Dissolved, total and suspended solids were higher during the dry season at all the sites but site 1. Site 1 is very close to the origin of River Jakara and is devoid of irrigational activities and basically receives no noticeable waste compared to the other sites. The sites (2-5) receive domestic wastes (including faeces), abattoir wastes and wastes from mechanic workshops. In addition, dry season irrigational activities which include loosening of the soil and production of post-harvest debris end up in the river creating high dissolved, total and suspended solids. The high values of dissolved and total solids in October and suspended solids in November may be attributed to a combination of factors such as additional soluble/semi-soluble dust particles introduced into the river by the harmattan wind during the period and anthropogenic wastes. Lawal et al. (2001) also reported high dry season values of the solids in the same river. Though the annual
mean dissolved solid (733.50 mg/l) exceeds the international level of 500mg/l for drinking, it was within the acceptable level of 500-3500 mg/l for irrigation (National Guidelines and Standards for Water Quality in Nigeria, 1999). The annual mean suspended solid (320.55 mg/l) also exceeds the international level of 25.0 mg/l for drinking and 10.0 mg/l for irrigation (WHO, 1984). The high suspended solid load in irrigation water fills could block soil pore spaces, thus reducing soil air and infiltration and encouraging soil anaerobism and perhaps endanger soil microbes (Shuval et al., 1986).

Dry and wet seasons pH mean values (7.01-7.36) were essentially neutral. The annual mean pH (7.18) was within the acceptable level of 6.0 to 8.5 for drinking(WHO,1984) and 6.0 to 9.0 for irrigation (FAO, 1985). Higher mean values of electrical conductivity in all the sites (except site 1) could be attributed to the high dissolved solids and cations such as Ca, Mg and potassium. High dry season values at sites 2,3 and 5 could be due to the reduced water volume and other phys-chemical changes (pH, temperature, etc) that might have occurred during this period. Kolo and Olademeji (2004) observed a similar effect in Shiroro dam during the dry season. Conversely, lower wet season mean values from May to July are therefore associated with “dilution effect” from high rainfall. The annual mean conductivity value (1417.43 µmhos/cm) is within the tolerable limits for drinking water and for irrigation as it did not exceed 1500 µmhos/cm and 200 µmhos/cm respectively (FAO, 1985).

High mean concentration of chloride in the sites (except site 1) could be an indication of salinity. The alkaline and alkaline earth metals (Na, K, Ca and Mg) were higher in all sites except site 1; this is also an indication that the water is saline. The higher dry season chloride concentration may be due to evaporation which results in high salt concentrations while low concentration between May and September could be attributed to dilution by high rainfall. This finding supports the report of Lawal et al. (2001) in the same river. The annual mean chloride (291.16mg/l) is higher than the maximum limit (250mg/l) for drinking and maximum limit of 92.50mg/l for irrigation (FAO, 1985). This suggests that the water may not be good for irrigation. Water may be drawn out of the plants resulting in dehydration or plasmolysis of the plant cells. Highest alkalinity mean value at site 5 may be associated with the higher alkaline and alkaline earth metals and release of carbonate ions (CO$_3^{2-}$) or bicarbonate ions (HCO$_3^-$) by sediments. Ogbalor (1991) reported that bicarbonate concentration in the same river was slightly higher downstream. Higher dry season values may be linked to high concentrations of these salts during this period and lowest value found in August was as a result of high rainfall. Mustapha (2008) reported that alkalinity is a buffer for pH changes that helps stabilizing the pH of a reservoir. High concentrations of alkalinity in all the sites may be the reason why the river was essentially neutral throughout the study period. The annual mean alkalinity concentration (312.45mg/l, CaCO$_3$) is not within the range of 35-200mg/l in streams as stipulated by WHO (1984). Dissolved oxygen is important as a respiratory gas. The low DO mean values in all the sites (except site 1) could be attributed to the discharges of organic matter that requires high oxygen demand for biodegradation purposes. The nitrifying activities of nitrifying bacteria depleted the DO in the river and created anaerobic conditions in water. Furthermore, oils and greases which formed surface films on the water may have inhibited transfer of oxygen from the atmosphere to the water. This may have contributed immensely to the low value of DO at site 3 because this site receives waste from mechanic workshops from Egbe Street and off Katsina Road. The site also exhibited characteristic foamy appearance indicating the presence of detergent. Okuofu (2004) linked surface foam which restricts surface reoxygenation to hard detergents discharged into the water bodies. The high DO at site 1 when compared to the other sites may be related to the little organic wastes received at this site. Maitland (1978), attributed the amount of oxygen consumed by the water body as one of the factors that affects its concentration. The dry and wet seasons DO mean concentrations which were less than 5mg/l at the sites (except site 1) appeared to be too low to support benthic organisms. High mean values between November and February (i.e. the cold harmattan periods) confirm the effect of temperature on DO and hence the inverse correlation between DO and temperature. Similar observations were made by Onyie et al. (2002) in Zaria Dam and Ekanem and Ikrepita (2004) in Zaria rivers of Kaduna State, Nigeria. The annual mean concentration of DO (4.15mg/l) is lower than the international level of 7.5mg/l for irrigation (National Guidelines and Standards for Water Quality in Nigeria, 1999).

The presence of organic wastes in aquatic environment often initiates various microbial activities thereby creating high biochemical oxygen demand. The high organic wastes in sites 2-5 may be responsible for the low level of DO, thus leading to oxygen deficit and hence the insignificant negative correlation (r=-0.29) between BOD and DO. The organic load at site 4 is such that some sections of it remain clogged from November to March (field trip observation) which could have contributed to the highest BOD mean value at the site. The higher wet season mean concentration observed at site 2 could be linked to large amounts of chemical leachates or runoff such as fertilizer and pesticide residues from the nearby farmland into the site. Presence of large amounts of biodegradable material results in high BOD and according to Barliet (1979), this may mean large amounts of dissolved salts which explains the positive correlation (r=0.52) between BOD and dissolved solids. The annual mean value of BOD (553.23mg/l) exceeds the maximum permissible limit of 10mg/l recommended by FEPA (1991) for drinking water and 2.0mg/l for irrigation (National Guidelines and Standards for Water Quality in Nigeria 1999). Biochemical oxygen demand and total suspended solids of irrigation water are evidences of the amount of organic matter that could be added to the soil (Ogbalor, 1991), and hence the positive correlation (r=0.57) between the two parameters. The high BOD and suspended solids in the river may therefore limit its use in irrigation. Biodegradation activities initiated by microorganisms that often increase BOD also increase COD and decrease DO.
This may be the reason for the high mean concentration of COD in the same sites (2-5) as the BOD. Lower values of COD in June and August may be associated with dilution of the organic wastes. The annual mean concentration of COD obtained (1311.8mg/l) exceeds the range (50-500mg/l) approved for drinking (WHO, 1984).

Though Gotterman and Kouwe (1980) observed that Ca is the dominating cation in fresh water, the ionic composition of River Jakara is dominated by Na followed by Ca, K and then magnesium. Erosion and leaching of natural deposits of these ions as carbonates, phosphates, sulphates or silicates could have contributed to their various concentrations in all the sites. The majority of soils contain these elements at less than 200ppm but values in excess of 1000ppm are not uncommon (Mohammed, 1995). The pH of the different sites which were neutral to slightly alkaline may also be related to their high values at the sites. Increasing acidity tends to decrease the availability of these cations (Mohammed, 1995). Their high concentrations could further be attributed to their ionic behavior, solubility and mobility. It has been reported (Marschner, 1995) that the salts of these cations such as calcium chloride, magnesium chloride, sodium chloride etc. have high solubility. The annual mean concentration of Na (29.48mg/l) is within the acceptable level of 30mg/l for drinking and 93.8mg/l and 200mg/l for irrigation respectively. The annual mean concentration of K (18.26/l) however is higher than the acceptable level of 12mg/l for drinking but within the acceptable level of 180mg/l for irrigation (WHO, 1984 and FAO, 1985). Though the ranges of some of the physico-chemical parameters are within the international acceptable limits for drinking, in all, the overall assessment indicates that the surface water of River Jakara is already polluted. The variations of the physico-chemical parameters applied were due to the continuous dumping of both solid and liquid wastes to it through anthropogenic sources which has completely undermined its portability. The concentrations of chloride and electrical conductivity (going by the monthly values) exceed the international desirable limits for irrigation indicting high salinity that is not safe for use to grow most crops. The use of River Jakara for irrigation of soils used for planting vegetables and fruits could therefore present a public health risk. There is need to further assess the Sodium Adsorption Ratio (SAR) of the river to be able to classify it and draw up reliable management plans for it. The source of the domestic pollution to the river should be tackled to reduce the amount of pollutants being discharged into it. This includes the adoption of close sewer system in Kano metropolis which will connect buildings and terminate at sewage treatment facilities before being discharged into the river. The relevant organ of government should also find alternative sites for the abattoir located on the Abattoir Road to check the abattoir waste and effluents that are currently discharged into the river.

References


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