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Effect of Environmental Pollution on the Quality of River Ngada, Maiduguri Metropolis, Borno State, Nigeria

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ABSTRACT

This study was carried out in Maiduguri Metropolis, Nigeria to determine the effect of environmental pollution on the quality of River Ngada, which has been polluted by physical and chemical waste. In order to achieve this study, eight sampling points (S_1-S_8) were chosen along the river's course corresponding to the points where notable discharged of wastewater into River Ngada occurs. Several water quality parameters (pH, temperature, conductivity, TDS, TSS, turbidity, COD, BOD, DO and heavy metals) were determined using standard procedures. The levels of pH ranged from 7.97 ± 2.60 to 9.42 ± 0.32; 31.30 ± 1.34 to 35.40 ± 0.84°C for temperature; 32.02 ± 0.12 and 78.34 ± 2.43 mg/l TSS; 31.12 ± 1.53 to 58.22 ± 0.71 NTU turbidity; 2.32 to 8.23 mg/l DO; 235.12 to 522.12 mg/l BOD and 854.33 and 2874.45 mg/l COD. The levels of the above parameters increase with an increase in distance from point S_1 to S_8 with the exception of DO. Analysis of variance (ANOVA) results revealed that the levels of all the anions and heavy metals were statistically significant among the various sampling points. Our study reveals that the levels of all the parameters studied were higher than the WHO's standard limits for water meant for drinking and other domestic uses. The study also indicates that domestic wastes and abattoir wastewater have an impact on the organic content, anions and heavy metals, resulting in a significant effect on the ecological balance of the river. Based on the above results, the current water quality status of River Ngada poses both environmental and health hazards to users. The results of this study need immediate remediation programmes to ameliorate the poor water status of these sections of River Ngada.

Keywords: abattoir, physicochemical, pollutants, residential, wastewater, water

INTRODUCTION

The pollution of aquatic environments by heavy metals and other pollutants is of serious concern to environmentalists. This is probably because of the high level of pollution of surface waters arising from the discharge of industrial and domestic wastes into rivers and lakes (Ezeronye and Ubalua 1995), especially those running through major commercial cities. As a result, these rivers carry large quantities of contaminants, including heavy metals. Previous work (Ezeronye and Ubalua 1995; Ramos *et al*. 1999; Francis *et al*. 2007) revealed that high concentrations of heavy metals such as Cd, Pb, Fe, Cu, Ni, Zn, Mn, Mg and Co in some rivers within the proximity to some industrial toxic heavy metals into water bodies may affect fish and other aquatic organisms, which may endanger public health through consumption of contaminated seafood and irrigated food crops. Pollution can either be of a point source or a non-point source. Point sources of pollution occur when pollutants are emitted directly into the water body from industries or municipal wastewater pipes, while a non-point source delivers pollutants indirectly through environmental changes such as pollution from urban run-off (TCEQ 2002; Krantz and Kifferstein 2005). Three major known sources of water pollution are: municipal, industrial and agricultural. Industrial effluents mostly contain heavy metals, acid, hydrocarbons and atmospheric deposition (Alam *et al*. 2007). Work from Alam *et al*. (2007) also revealed that agricultural run-off is a major source of water pollution as it contains nitrogen compounds and phosphorus from fertilizer, pesticides, salts, poultry wastes and washes down from abattoirs. Contamination is usually of varied composition ranging from simple organic substances to complex inorganic compounds with varying degrees of toxicity. Pollution of surface water, the natural habitat for aquatic animals could have a consequential impact on man either directly or indirectly since less than 1% of the world's freshwater, about 0.007% of all water on earth is directly accessible for direct human use (Krantz and Kifferstein 2005; UNESCO 2006). The pollution of a surface water body in any form is critical issue in water resources management. However, reports claim that large numbers of water bodies in developing nations of the world are grossly polluted. The water quality situation therefore becomes very critical in these countries with great environment and public health concerns (World Bank 1995; WHO/UNICEF 2005; UNESCO 2006).

The River Ngada is a River in Maiduguri Metropolis, Borno State, Nigeria. The river is used for various human activities including domestic, car washing, irrigation of vegetables and fishing activities. The river originates from the Rivers Yedzram and Gombole – both in Nigeria – which meet at a confluent at Sambisha, and flow as the River Ngada into Alau Dam and stretches down across Maiduguri Metropolis where it empties into Lake Chad. The river receives copious amounts of wastes from residential houses and abattoirs along its course. Urban waste management and garbage disposal practices in the city are very poor. Processed water from munucipal waste and abattoir located near the river contains large amounts of pollutants including heavy metals, which, when in great abundance may cause disruption to the ecological balance of the river. In view of the growing concern of the use of River Ngada by resident along the river banks, this study aims to assess the quality of water samples from the River Ngada.

MATERIALS AND METHODS

Sample area and collection points

Water samples were collected from 8 points along the River Ngada designated as S_1 to S_8 and corresponding to the points where notable discharged of wastewater into the river occurs (**Map**). 45

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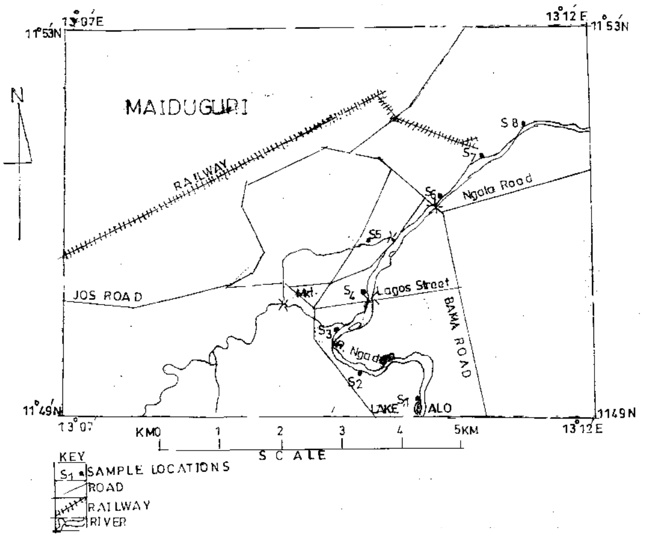

samples were collected from each sampling point. Samples were collected 5 times a month for a period of 9 months. Samples were collected from: Alau Dam bridge (S_1); the point of discharge of wastewater from the water treatment plant (S_2); 100 m away from the water treatment plant (S_3); the Lagos bridge (S_4); the Gwenge Bridge (S_5); the Custom Bridge (S_6); the point of discharge of abattoir wastewater into River Ngada (S_7); 2 Km after discharge of abattoir wastewater into River Ngada (S_8).

Sample collection

Water samples were collected in plastic containers previously cleaned by washing in non-ionic detergent, rinsed with tap water and later soaked in 10% HNO_3 for 24 hrs and finally rinsed with deionized water prior to use. During sampling, sample bottles were rinsed with sampled water three times and then filled to the brim at a depth of 1 m below the river water from each of the eight designated sampling points (S_1 to S_8). At each sampling point, water samples were collected in triplicate from three points and pooled. The samples were labelled and transported to the laboratory, stored in the refrigerator at about 4°C prior to analysis. Samples were collected from November 2008 to August 2009.

Analysis of physicochemical pollutants indicator

Temperature, pH, and salinity were determined using a pH/conductivity meter; the levels of total dissolved solid (TDS) and conductivity were determined using a C0150 conductivity meter at the point of sample collection. Dissolved oxygen (DO) and biological oxygen demand (BOD) were determined by a dissolved oxygen meter model Acorn DO using standard methods 4500-OG and 5210B (Standard Methods 1976), respectively. Chemical oxygen demand (COD) was determined using the closed reflux method (Standard Methods 1976). Turbidity was estimated by the nephelometeric method (Standard Methods 1976) using a Lamotte 2020 portable turbidity meter. For total suspended solid (TSS), 100 ml of the water samples were filtered through a pre-weighed filter paper, which were dried at 103-105°C. TSS was determined by using the following formula (Anon 1992).

$$\text{TSS (mg/l)} = \frac{\text{(final wt} - \text{initial wt)}}{\text{Amount of sample taken}} \times 1000$$

To determine chloride, 100 ml of the water sample was measured into a 250-ml conical flask and pH was adjusted to 8 with 1 M NaOH. One ml of K_2CrO_4 indicator was then added and titrated with the $AgNO_3$ solution. A blank titration was carried out using distilled water. Chloride (mg/l) was calculated as follows (Ademoroti 1996):

$$\text{Chloride (mg/l)} = 70900 \times M \frac{(V_1 - V_2)}{Vs}$$

where V_1 = volume of titrant for the sample, V_2 = volume of titrant for the blank, M = molarity of $AgNO_3$, Vs = volume of sample used (100 ml).

Determination of heavy metals in water samples

The water samples were digested as follows. The samples (100 cm^3) were transferred into a beaker and 5 ml concentrated HNO_3 was added; this was placed on a hot plate and evaporated down to about 20 ml. The beakers were cooled and another 5 ml of concentrated HNO_3 was added. The beakers were covered with a watch glass and returned to the hot plate. Heating was continued for 20 min, and then a small portion of HNO_3 was added until the solutions appear light coloured and clear. The beaker wall and watch glass were washed with distilled water and the samples were filtered to remove some insoluble materials that could clog the atomizer. The volume of the samples was adjusted to 100 cm^3 with distilled water (Radojevic and Bashkin 1999). A blank sample was digested so as to allow a blank correction to be made. This was done by transferring 100 ml of distilled water into a beaker and digested as described above.

Determination of Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd As, Ni and Pb were made directly on each final solution using atomic absorption spectroscopy (AAS) with a Perkin-Elmer AAnalyst 300 atomic absorption spectrophotometer.

Determination of some anions in water samples

The concentration of nitrate, sulphate and phosphate was determined in the water samples. Because these parameters contribute to water pollution within certain limits they were determined using a DR/2010 HACH Portable Data Logging spectrophotometer. The spectrophotometers were checked for malfunctioning by passing standard solutions of all the parameters to be measured; Blank samples (deionized water) were passed between every three measurements of water samples to check for any eventual contamination or abnormal response of equipment. Nitrate as N was determined by the cadmium reduction metal method 8036 (Standard Methods 1976; DWAF 1992). The cadmium metal in the added reagent reduced all nitrate in the sample to nitrite; while sulphate was determined by using Sulfa Ver method 8051 (Standard Methods 1976; DWAF 1992).

Experimental design an statistical analyses

Data collected are presented as mean and standard deviation and were subjected to Pearson's correlation analysis, while one-way analysis of variance (ANOVA) ($P < 0.05$) was used to assess whether samples parameters varied significantly between sampling points. All statistical calculations were performed with SPSS 9.0 for Windows (Ozdamar 1991).

RESULTS

The concentrations of physical parameters in the water samples from different points of the River Ngada are as presented in **Table 1**. The pH values for points S_1 to S_8 ranged from 7.97 ± 2.60 to 9.42 ± 0.32. The mean values of temperature for points S_1 to S_8 ranged from 31.30 ± 1.34 to 35.40 ± 0.84°C. Temperature was lowest at point S_1 and increased toward point S_8. The least mean conductivity level was observed at point S_1 and increased toward point S_8. These values fluctuated between 132.30 ± 3.23 and 390.00 ± 3.78 $\mu S/cm^{-1}$. Results of ANOVA also indicated that the levels of conductivity were significantly different ($P < 0.05$) among the various sampling points. The concentrations of TSS in all the sample points are as presented in **Table 1**. The mean TSS values fluctuate between 32.02 ± 0.12 and 78.34 ± 2.43 mg/l. Point S_1 shows the least concentration, while the highest level was observed in point S_8. The mean turbidity values ranged from 31.12 ± 1.53 to 58.22 ± 0.71 NTU. Point S1 showed the least concentration for turbidity, while point S_7 showed the highest value. The concentration of TDS ranged from 1678.00 ± 23.56 mg/l to 2745.00 ± 28.54 mg/l and increases toward point S_8. Significant variation was observed for points S_1 to S_8.

Table 1 Concentrations of some physical parameters in water samples from different point of River Ngada.

	pH	Temperature OC	Conductivity (μScm^{-1})	TDS (mg/l)	TSS (mg/l)	Turbidity NTU
S1	9.42 ± 0.34 a	31.50 ± 2.10 a	132.30 ± 3.23 a	1678.00 ± 23.56 a	32.02 ± 0.12 a	31.12 ± 1.53 a
S2	8.24 ± 1.06 b	31.30 ± 1.34 b	157.00 ± 2.56 b	1722.00 ± 28.76 b	39.23 ± 0.54 b	38.21 ± 1.23 b
S3	8.66 ± 0.65 c	35.40 ± 0.84 c	147.00 ± 2.87 c	1834.00 ± 34.05 c	41.43 ± 1.34 c	34.33 ± 2.21 c
S4	8.85 ± 1.56 d	33.30 ± 1.22 b	164.00 ± 1.89 d	1944.00 ± 24.33 d	44.61 ± 1.05 d	36.43 ± 1.43 d
S5	8.13 ± 0.43 e	33.70 ± 0.87 d	193.00 ± 4.11 e	2218.00 ± 43.98 e	55.45 ± 1.22 e	45.34 ± 0.43 e
S6	8.27 ± 1.06 f	32.90 ± 2.08 e	281.00 ± 1.98 f	2468.00 ± 33.21 f	64.32 ± 1.54 f	52.13 ± 2.13 f
S7	7.97 ± 2.60 g	32.20 ± 0.34 b	355.00 ± 5.63 g	2745.00 ± 28.54 g	74.18 ± 0.54 g	58.22 ± 0.71 g
S8	8.03 ± 1.76 h	32.10 ± 2.11 b	390.00 ± 3.78 h	2633.00 ± 41.14 h	78.34 ± 2.43 h	42.02 ± 0.55 h

Within column mean with different letters are statistically different at $P < 0.05$ according to DMRT.

The concentrations of BOD, COD and DO in all the sampling points are as presented in **Fig. 1**. The concentration of DO ranged from 2.32 to 8.23 mg/l. The concentration of BOD for points S_1 to S_8 ranged from 235.12 to 522.12 mg/l, while that of COD for points S_1 to S_8 ranged between 854.33 and 2874.45 mg/l.

The mean concentrations of nitrate and phosphate for all the sample points are as illustrated in **Fig. 2**. The values of nitrate and phosphate ranged between 34.20 and 88.35 mg/l nitrate and 7.45 and 43.04 mg/l phosphate. The mean levels of sulphate and chloride are also presented in **Fig. 2**.

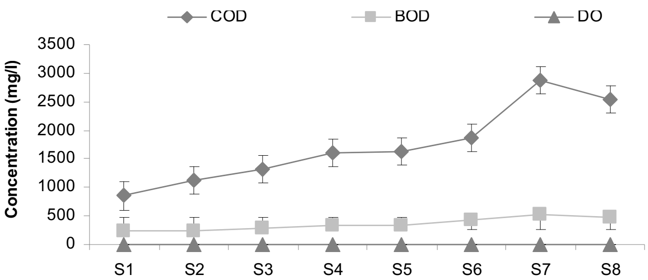

Fig. 1 Mean concentrations of BOD, COD and DO in water samples from different points of the River Ngada. COD: chemical oxygen demand; BOD: biochemical oxygen demand; DO: dissolved oxygen.

The values of sulphate and chloride varied between 132.00 and 283.66 mg/l sulphate and 32.43 and 42.46 mg/l chloride.

The mean concentrations of heavy metals in water samples for all the sample points are as presented in **Fig. 3**. The concentration of Cr ranged from 0.12 to 3.45 mg/l; 0.45 to 2.58 mg/l Pb; 1.6 to 4.88 mg/l Cu; 2.65 to 1.6.86 mg/l Fe; 0.12 to 5.45 mg/l Ni; 0.21 to 3.22 mg/l Co; 1.22 to 4.02 mg/l Mn, 1.34 to 5.33 mg/l Cd; 0.34 to 4.02 mg/l As and 3.98 to 8.02 mg/l Zn. Point S_1 showed the least concentrations, while the highest were observed for point S_8.

An attempt was made to investigate any relationship between BOD, COD and DO. The correlation coefficient as shown in **Figs. 4** and **5** revealed an inverse linear correlation showing that as BOD and COD increases in values DO decreases with a correlation of r = -0.92 and r = -0.85, respectively. The correlation of -0.92 and -0.85 between BOD, COD and DO suggest similar sources, while TDS and COD are presented in **Fig. 6**. A high TDS concentration also corresponds to a high BOD (**Fig. 7**). A plot of TDS versus BOD and COD gives a linear correlation showing that as TDS value increases BOD and COD also increase with a correlation value of r = 0.88 and 0.77, respectively. These correlations indicate that levels of TDS, BOD and COD are affected by same activities within the study area.

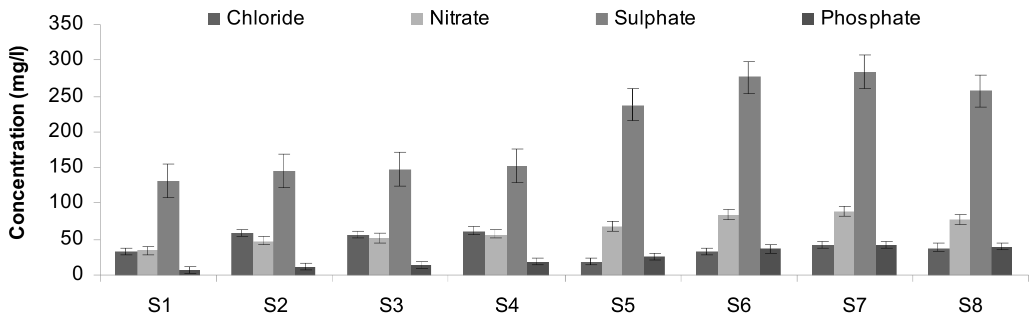

Fig. 2 Mean concentrations of some anions (chloride; nitrate; sulphate; phosphate) in water samples from different points of the River Ngada.

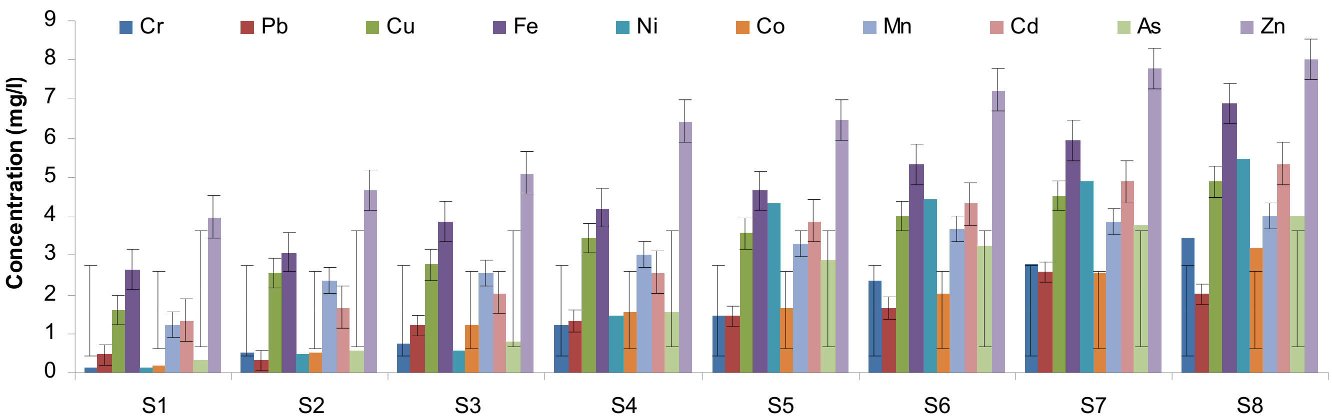

Fig. 3 Mean concentrations of heavy metals in water samples from different points of the River Ngada. Cr: chromium; Pb: lead; Cu: copper; Fe: iron; Ni: nickel; Co: cobalt; Mn: manganese; Cd: cadmium; As: arsenic; Zn: zinc.

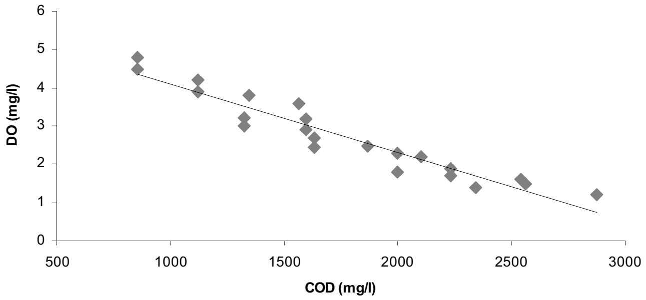

Fig. 4 Scatter gram of DO and COD in water sample from river Ngada. DO: dissolved oxygen; COD: chemical oxygen demand.

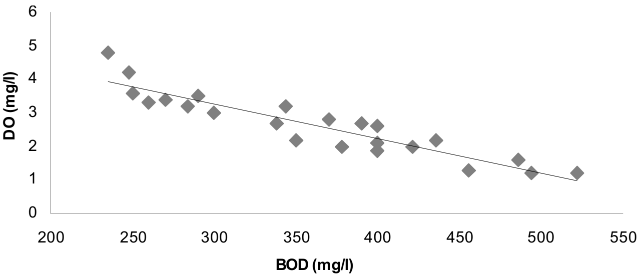

Fig. 5 Scatter gram of DO and BOD in water sample from river Ngada. DO: dissolved oxygen; BOD: biochemical oxygen demand.

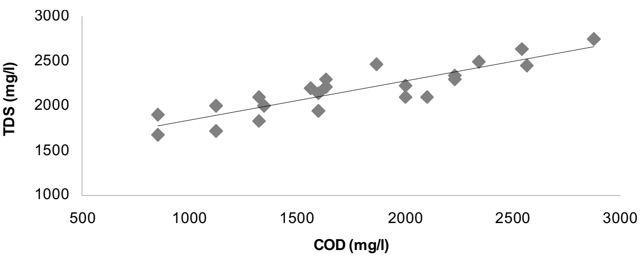

Fig. 6 Scatter gram of TDS and COD in water sample from river Ngada. TDS: total dissolved solid; COD: chemical oxygen demand.

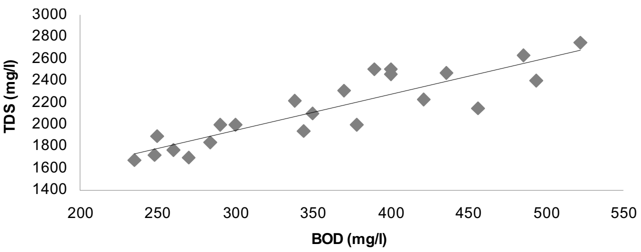

Fig. 7 Scattergram of TDS and BOD in water sample from river Ngada. TDS: total dissolved solid; BOD: biochemical oxygen demand.

DISCUSSION

Variations between sampling points and parameters studied

Point S_1 was slightly polluted in term of all the heavy metals; this is due to the fact that there are fewer anthropogenic activities at this point than at other points. For point S_2 the increase in concentrations of all the metals is due to the discharge of wastewater from the water treatment plant located closed to it; during water processing and treatments, wastewater from this treatment plant is discharged to the River Ngada, thereby increasing the levels of all the metals at this point. Point S_3 is located 200 m away from point S_2 with a higher concentration of all the parameters when compared to points S_1 and S_2. The high levels of heavy metals in point S3 are due to the addition of wastewater from residential areas. Point S_4 has higher metal concentrations than points S_1 to S_3; such variation is due to the fact that this point is located near Lagos bridge and roads where high anthropogenic activities take place and also the discharge of sewage sludge from residential areas. For point S_5 the high levels of all parameters is likely due to the discharge of wastewater from residential areas and urban garbage into this area. Point S_6 was located at the custom bridge and within the market areas where heavy discharge of wastewater from both residential and market areas occur. Also, a large quantity of garbage from the custom market is also discharged into this point which eventually contributes to high concentration of all the parameters compared to points S_1 to S_5.

The organic load from abattoirs could be very high. For all the metals studied Zn was the highest, Cu the second highest and Fe the third highest, while Pb shows the least concentrations. The high levels of Zn, Cu and Fe might be due to the disposal of solid waste from residential areas which might contain higher levels of these metals. Tritt *et al.* (1992) reported a COD level as high as 2,785,000 mgL^{-1} for raw bovine blood. Comparatively, in another study conducted by Mittal (2004) on abattoirs in Quebec, Canada, typical values for a range of parameters in abattoirs wash down were provided: TS concentrations (2333-8620 mgL^{-1}); TSS (736-2099 mgL^{-1}). Hence, abattoir effluents could increase the levels of N, P and total solids considerably in the receiving water body. Excess nutrients cause the water body to become choked with organic substances and organisms. When organic matter exceeds the capacity of the microorganisms in water that break down and recycle the organic matter, it encourages rapid growth, or blooms, of algae, leading to eutrophication. Improper management of abattoir wastes and subsequent disposal either directly or indirectly into river bodies portends serious environmental and health hazards both to aquatic life and humans. Also for point S_7 the concentrations of all the parameters in this study were higher than points S_1 to S_6; such levels are due to the fact that this point is located at the immediate discharge of abattoir wastewater into the River Ngada.

Physical parameters in water samples

The above pH values in guidelines have been associated with adverse effects. However, one of the most significant impacts of pH in water bodies is the effect that it has on the solubility and thus the bioavailability of other substances such as iron, manganese and ammonia. The pH values for point S_1-S_8 were within the stipulated values of 6.0-9.0. According to the WHO guideline the pH values obtained for rivers make it unsuitable for potable water and recreational purposes. The EU also sets pH protection limits of 6 to 10 for fisheries and aquatic life (Chapman 1997). The pH values obtained for River Ngada (S_1-S_8) fell within this range. Therefore, the parameter does not give cause for concern in the present study.

Total suspended solids (TSS) include all particles suspended in water that will not pass through filter paper. Abundant suspended solids such as clay and silt, fine particles of organic matter, inorganic particulates (such as Fe), soluble coloured compounds and phytoplankton can result in a decreased light penetration in water body, reduced photosynthesis of aquatic plants, decreased water depth due to sediment build up, smothering of aquatic vegetation, habitat and food, smothering of macro and micro-organisms larva, eggs and the clogging of fish gills, reduced efficiency of predation by visual hunters and increased absorbed heat by the water which results in lowering dissolved oxygen, facilitating parasite and disease growth and increasing the toxicity of ammonia (USEPA 1995; Mason 1998). From the results of this analysis the levels of TSS in the entire sample points exceeded the WHO/EU guideline of 50 mg/l for the protection of fisheries and aquatic life (Chapman 1997).

There were variation in the levels of turbidity, TSS and conductivity between sampling points. Turbidity is a measure of the ability of water to absorb light, and is caused by small particles; turbidity affects fish and aquatic life by interference with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light photosynthesis and the production of oxygen for fish and aquatic life will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. Similarly when the rate of photosynthesis is low, then oxygen concentration become low and CO_2 concentration become higher (Akan *et al.* 2007). From the results of this analyses the levels of turbidity and TSS in the entire sampling points exceeded the WHO/EU guidelines of <5 NTU and 50 mg/l respectively for the protection of fisheries and aquatic life (Chapman 1997).

TDS is a measure of the concentration of dissolved constituents in water, which commonly include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium and organic ions. A certain level of these ions in water constitutes essential nutrients for aquatic life. Changes in TDS concentrations can be harmful to aquatic organisms by affecting the density of water. Excessive TDS can reduce water clarity, hinder photosynthesis and increased water temperatures (USEPA 1995; Mason 1998). However, the TDS levels recorded in the entire sampling points were higher than the WHO guideline of 1000 mg/l for the protection of fisheries, aquatic life and domestic water supply.

DO is a measure of the degree of pollution by organic matter, the destructive of organic substances as well as the self purification capacity of the water body. The drop in DO levels from 8.23 ± 1.06 mg/l in point S_1 to 2.32 ± 0.23 mg/l in S_8 is an indication of high organic load. Observation on the field shows an evidence of eutrophication process setting in at this point. Eutrophication results when fresh water is artificially supplemented with nutrients, it occurs as a result of abnormal increase in the growth of water plants. This process could lead to increase in the growth of water plants, which eventually could lead to a decrease in DO. The standard value for sustaining aquatic life is stipulated at 5 mg/l, a concentration below 5 mg/l would adversely affects aquatic biological life, while concentration below 2 mg/l may lead to death for most fishes (Chapman 1997). Dissolved oxygen (DO) is one of the most fundamental parameters in water, as it is essential to the metabolism of all aerobic aquatic organisms. It is added to the water column via photosynthesizing plants and stream flow aeration, and is consumed from the water body by bacterial, plant and animal respiration, decaying plants and organisms and chemical oxidation (Fripp *et al.* 2000). The CCME guideline values for dissolved oxygen is between 5.5 and 6.0 mg/l. virtually all samples analysed were below the minimum guideline value of 5.5 mg/L. The levels of dissolved oxygen generally decreased with an increase in sampling points. The levels of DO (4.83 ± 1.06 mg/l and 2.32 ± 0.23 mg/l) were below the (USEPA 1999; WHO 2000) permissible limit of 4 and 5 mg/l.

Chemical and biological oxygen demand in water samples

Both BOD and COD are important water quality parameters, and are essential in water quality assessment. Therefore, the more is the organic material from wastewater, the higher the BOD and COD. COD is a measure of the amount of oxygen required to chemically oxidize reduced minerals and organic matter. In general, the greater the COD value in water, the more oxygen demands from the water body, thus resulting in depleted dissolved oxygen which is essential to the metabolism of all aerobic aquatic organisms (Fripp *et al.* 2000; Cusso *et al.* 2001). However, the COD concentrations observed in all the sampling points are notably higher. Generally, the BOD and COD levels recorded in the entire sampling points were higher than the EU guidelines of 3.0 to 6.0 mg/l (BOD) and 200 mg/l (COD) for the protection of fisheries, aquatic life and for domestic water supply (Chapman 1997). It was also observed that the values of all the parameter studied increase from points S_1 to S_8 with exception of DO, such variations is due to difference in activities within the river banks such untreated wastewater from residential areas and abattoir wastes.

Comparison of heavy metals in water sample with standard values

Chromium is a relatively scarce metal that occurs in several states. The most toxic of these states is the chromium VI or hexavalent state. According to the WHO/USEPA guideline value, the concentration of 0.1 mg/l is acceptable (Radojevic and Bashkin 1999) while above 0.1 mg/l, a condition known as allergic dermatis could result (EPA 1999). From the result of these analyses, the concentrations of chromium in all the sampling points exceeded the regulating limit, indicating severe pollution of River Ngada.

Lead is a non-essential trace element (Ewers *et al.* 1991). The toxicity of lead is dependent on the life stage of the organism, and the presence of organic material (Ewers *et al.* 1991). Decreases in water pH can increase the bioavailability of lead in the system (Hellawell 1986). Lead in aquatic environment is risky to life since aquatic organisms which are used as food are particularly very sensitive to lead and often retain about a percent of ingested lead which could be taken up by man through the food chain (Ewers *et al.* 1991). Lead can cause damage to the nervous system and the kidneys and it is suspected to be carcinogenic (Radojevic and Bashkin 1999). Children exposed to high lead levels are particularly at risk. The levels of lead in the analyzed water sample showed that the limiting value by USEPA of 0.01 mg/l were exceeded, indicating contamination of River Ngada and may pose a hazard to the aquatic biota and for irrigation activities.

Copper is a common environmental metal and is essential in cellular metabolism, but at high concentrations it can be highly toxic to fish (Grosell *et al.* 1997). Copper is an essential substance to human life, however, in high concentrations, it can cause anaemia, liver and kidney damage, stomach and intestinal irritation (Turnland 1988). Copper is generally remobilised with acid-base ion exchange or oxidation mechanism (Gomez *et al.* 2000). Long term exposure of copper may lead to liver and kidney damage (EPA 1999). The levels of copper in the water samples for all the sampling points were above the (WHO 2000) standard values of 1.00 mg/l for the survivor of aquatic organism.

The concentrations of iron in all the sampling points were generally high. Although, iron is one of the essential elements in human nutrition, however, their presence at elevated concentration in aquatic ecosystems, poses serious pollution and health problems. Toxicity of iron in humans has been found to bring about vomiting, cardiovascular collapse and diarrhoea. While iron deficiency may lead to failure of blood clotting (Turnland 1988). According to USEPA guideline value, the maximum contaminant level of 0.30 mg/l for Fe is acceptable. Above 0.3 mg/l a condition known as haemo-chromatosis could result. From the result of this study, the concentrations of iron in the water samples exceeded the guideline limit indicating severe pollution of River Ngada.

The levels of nickel were spatially and temporary high in the water samples. A comparison of Ni concentrations in the water samples with WHO guideline value of 0.02 mg/l and USEPA maximum concentration level of 0.1 mg/l indicate that the concentrations of Ni in River Ngada was very high. However, nickel limiting levels were exceeded and River Ngada could be said to be contaminated by nickel. Long-term exposure can cause decreased body weight, heart and liver damage and skin irritation.

Cobalt is an essential element which could be introduced anthropogenically into aquatic ecosystem as runoff from industrial activities. The levels of copper in the water sample did not exceed the WHO guideline value of 2.00 mg/l, with exception of point S1 and S8. However, exposure to very high doses could cause severe health effect.

Manganese is an essential element (Health and Welfare Canada 1980) that is a functional component in nitrate assimilation and is used as a catalyst in many enzymatic systems in both plants and animals (DWAF 1996). Manganese is readily oxidisable and settles out of the water column as MnO_2 (DWAF 1996). The levels of manganese in the analyzed water samples showed that the USEPA standard value of 0.1 mg/l was exceeded, indicating contamination of River Ngada and may pose a hazard to the aquatic biota.

Cadmium is a non-essential trace element that enters the environment via anthropogenic activities such as industrial effluent, sewage-sludge, fertilisers and pesticides (DWAF 1996). Cadmium has a range of negative physiological effects on organism, such as decreased growth rates and negative effects on embryonic development (Newman and McIntosh 1991). The levels of cadmium in the water samples are above the (WHO 2000) standard values of 0.01 mg/l for the survival of aquatic organism.

Arsenic is a highly toxic metalloid element (Pizzaro *et al.* 2003; Rodriguez *et al.* 2003). It is widely distributed as a trace element in rocks and soils and is mainly mobilised by microbial activities (Garcia-Sanchez and Alvarez-Ayuso 2003). The levels of arsenic in the analyzed water samples showed that the WHO standard value of 0.10 mg/l was exceeded, indicating contamination of River Ngada.

Zinc is equally an essential element in the human diet. Zn deficiency in the diet may be more detrimental to human health than too much of it in the diet (ATSDR 1994). In aquatic ecosystem, Zn is highly toxic to some aquatic organisms. Although Zn is not a human carcinogenic, ingestion of large doses can cause death (ATSDR 1994). Zinc is also an essential micronutrient for all organisms and forms the active site for various metalloenzymes (DWAF 1996) Excessive intake of Zn may lead to vomiting, dehydration, abdominal pain, nausea, lethargy and dizziness (ATSDR 1994). The levels of zinc in the water samples exceed the WHO guideline value of 3.00 mg/l.

Anions in water samples

Nitrate is an inorganic compound of nitrogen which is bioavailable for plant uptake and is essential to plant growth (Mason 1998; Cameron *et al.* 2003). Natural levels of nitrate in water bodies are typically lower than 1 mg/L. Where nitrite and ammonia are toxic, nitrate is virtually harmless, with direct toxic effects typically not observed until concentrations greater than 45 mg/l. However, if phosphorus concentrations are sufficient, high nitrate content in waters can increase the severity of eutrophication, which can have chronic effects on aquatic life. The nitrate water quality guideline established by CCME for the protection of aquatic life is 13 mg/L. Overall, the nitrate levels observed in the entire sampling point were higher than the WHO limit of 45 mg/l. In the eight sampling points, there was an increase in nitrate concentration as water flows from point S_1 to S_8.

Phosphorus is an essential macronutrient that is a limiting factor to plant growth. It is essential to all life as a component of nucleic acids and a universal energy molecule (Sharpley *et al.* 1994). In excess, phosphorus triggers eutrophic conditions which involve the prolific growth of algal and other aquatic plants. In waters, phosphorus is often biologically unavailable as it binds readily to particles. Soluble phosphorus which is available for uptake is called phosphate. The levels of sulphate and phosphate in the entire sample points exceeded the 200 mg/l WHO maximum permissible and 5 mg/l phosphate levels (DWAF 1996).

CONCLUDING REMARKS

From the result of this study, the levels of DO, BOD, COD, TDS, TSS, conductivity, turbidity, anions and heavy metals in all the sampling points were higher than the FEPA, USEPA, and WHO regulatory limits for water meant for drinking and other domestic uses. This is an indication that urban and residential waste, abattoir wastewater and solid waste discharge into River Ngada has had a significant effect on the ecological balance of the River. Based on the above results, the current water quality status of River Ngada poses both environmental and health hazards to users. The results of this study need immediate remediation programmes to ameliorate the poor water status of these sections of River Ngada.

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