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Full Length Research Paper

The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria

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Samples of water from two rivers (River Ona and River Alaro) in Oluyole Industrial Estate, Ibadan, Nigeria were analysed to evaluate the impact of industrial discharges on the surface water quality. The results obtained indicated that most of the parameters analysed (pH, total hardness, sulphate, chloride, nitrate and dissolved solids) were lower than the World Health Organisation (WHO) maximum permissible limit for drinking water. However, the levels of nitrate, chloride, total phosphorus, total solids and oil and grease were higher in the industrial zones than those found in the upstream of both rivers. These ranged between 3.00 – 8.55, 7.48 – 11.78, 2.14 – 3.57, 260 – 520 mg/l and 381.20 – 430.80 mg/l, respectively. Nitrate and total phosphorus which are essential nutrients for plants were the most accumulated in both rivers. The gross organic pollution indicators monitored (chemical oxygen demand and oil and grease) revealed that River Alaro was more polluted than River Ona. It was established from the results of this study that industrial discharges had negative impact on the surface water qualities of both rivers. Hence, extraction of water from both rivers for domestic and agricultural purposes requires some forms of physical and chemical treatment.

Key words: River Ona, River Alaro, industrial discharges, surface water quality.

INTRODUCTION

One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities. More challenging is the unsafe disposal of these wastes into the ambient environment. Water bodies especially freshwater reservoirs are the most affected. This has often rendered these natural resources unsuitable for both primary and/or secondary usage (Fakayode, 2005).

Wastes entering these water bodies are both in solid and liquid forms. These are mostly derived from Industrial, agricultural and domestic activities. As a result, water bodies which are major receptacles of treated and untreated or partially treated industrial wastes have become highly polluted. The resultant effects of this on public health and the environment are usually great in magnitude. These include endangering of aquatic resources and other commercially important marine flora and fauna. The outbreaks of water-borne diseases like cholera, hepatitis, gastro-enteritis, etc, are possible health effects of polluted water (Adesina, 1986; Frontiers, 1996; Jhingan, 1997; Brown et al., 2008).

Contributing to the menace of indiscriminate discharges of industrial effluents in receiving water bodies is the improper disposal of domestic wastes, particularly in urban centres of most developing countries. Presently,

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Abbreviations: MEHHs, Modern environmental health hazards; **COD,** chemical oxygen demand; **AF,** accumulation factor; **DO,** dissolved oxygen.

open and indiscriminate dumping of solid wastes in drainages and riverbanks is one of the most critical problems facing the city of Ibadan (Omoleke, 2004). This practice contributes significantly to environmental degradation caused by incessant flooding in most parts of the city in recent times. Other notable effects of this practice include proliferation of insects, aesthetic nuisance, bad odour, fire outbreak, amongst others. Since there is no clear cut between the pollution caused by industrial activities and that contributed by improper management of domestic wastes, nobody is willing to accept the blame for the pollution of these water bodies.

It is a policy in Nigeria that industries be located in specific areas within the urban centres to minimise the effects of industrial pollution on public health. However, rapid urbanisation in most Nigerian cities has led to encroachment of residential areas by industries. Oluyole Industrial Estate is one of some areas, designated for industrial activities but now extends towards adjacent residential areas. Diverse industrial activities take place in this estate; the production processes of individual industry require different raw materials that generate varying degree of by-products or wastes. With increasing economic growth and urbanisation in Nigeria, the nature and quantity of wastes generated have changed significantly. Most domestic wastes in the country like in many other developing countries now contain modern environmental health hazards' (MEHHs) substances thus posing additional risk to public health (Nweke and Sanders, 2009). The volume of industrial wastes is growing at an alarming rate. Unfortunately, the country still lacks adequate technology, resources and manpower required to effectively manage these wastes in an environmentally safe manner. To date, common means of solid waste disposal in most Nigerian cities still remain open dumping, land-filling in unlined sanitary landfill sites, open burning, incineration, etc. (Adeyemo, 2003).

Most industries in Oluyole Industrial Estate use large volume of water but without efficient wastewater treatment plants; and so, routinely discharge their wastes directly into streams and rivers. Periodic monitoring of chemical and physical water quality indicators is therefore essential for assessing and/or protecting the integrity of the ecosystem. It has the advantages of identifying changes in water quality, early discovery of emerging water quality problems, the evaluation of pollution control measures, the effectiveness of compliance and how to respond in an emergency response (Adedokun et al., 2008). The need for a careful selection of these water quality indicators, therefore, cannot be over-emphasised. In this study, all parameters monitored were selected to account for diverse activities taking place in the catchment areas of the rivers investigated. Our objective is to establish whether the pollution of the two major rivers (River Ona and River Alaro) within Oluyole Industrial Estate was due to Industrial discharges or as a result of indiscriminate disposal of municipal wastes and transportation of pollutants into these rivers via urban run-offs during heavy rainfall. To achieve this, however, the study was conducted at the peak of the rainy season so that the influence of urban run-off on water quality could be evaluated.

MATERIALS AND METHODS

The study area

The industrial estate is located in the south-western part of the ancient city of Ibadan, Nigeria (7°N, 3°E). The city is the second largest in Africa and third most populated in Nigeria with an estimated population of about 4 million people (www.tageo.com/index-e-ni-cities-NG.htm). Oluyole Industrial Estate consists of different industries which include food and beverage processing, organic chemicals manufacturing, basic steel production, agricultural produce processing and production, auto repair workshops, concrete production, pharmaceuticals, agro-allied chemicals and manufacturing. Effluents from these industries are collected via a network of well-designed drainage system where they are channelled into adjoining rivers.

Apart from the industries in the study area, there are also several residential estate and local communities. The two major rivers (River Ona and River Alaro) that flowed through the industrial estate are free-flowing and highly turbid, particularly at the points of effluents' discharge in the industrial zone. River Ona is larger and deeper with huge volume of water than River Alaro. These rivers were investigated over a stretch of distance (approximately 10 km) for water quality parameters at the peak of the rainy season in August 2006. The maps of the study area showing the sampling sites are presented in Figure 1.

Methodology

The sampling sites were carefully selected to include the upstream, industrial zones and the downstream regions (Figure 1). At each sampling location, water sample was collected at the region of good mixing in the river and stored in clean polyethylene bottle. The samples were kept in ice on the field and thereafter refrigerated at 4°C in the laboratory. The physico-chemical analyses of water samples were performed using standard analytical methods. Parameters with extremely low stability such as temperature and pH were determined on the field. Other parameters analysed include acidity, alkalinity, total solids, dissolved and suspended solids, total hardness, sulphate, total phosphorus, chloride, nitrate, dissolved oxygen content, chemical oxygen demand (COD) and oil and grease.

All parameters except nitrate were determined using standard methods for the examination of water and wastewater (APHA, 1985). Nitrate was determined by nitration of 3,4-xylenol in acidic medium followed by the extraction of the nitration product with suitable organic solvent (toluene). This was further treated with a strong alkali solution (NaOH) to form a coloured product whose absorbance was read at 432 nm using CECIL CE202 UV-spectrophotometer (Osibanjo and Ajayi, 1980).

RESULTS AND DISCUSSION

The results of the physico-chemical parameters, inorganic and organic contents obtained from the assessment of surface water of River Ona and River Alaro in Oluyole

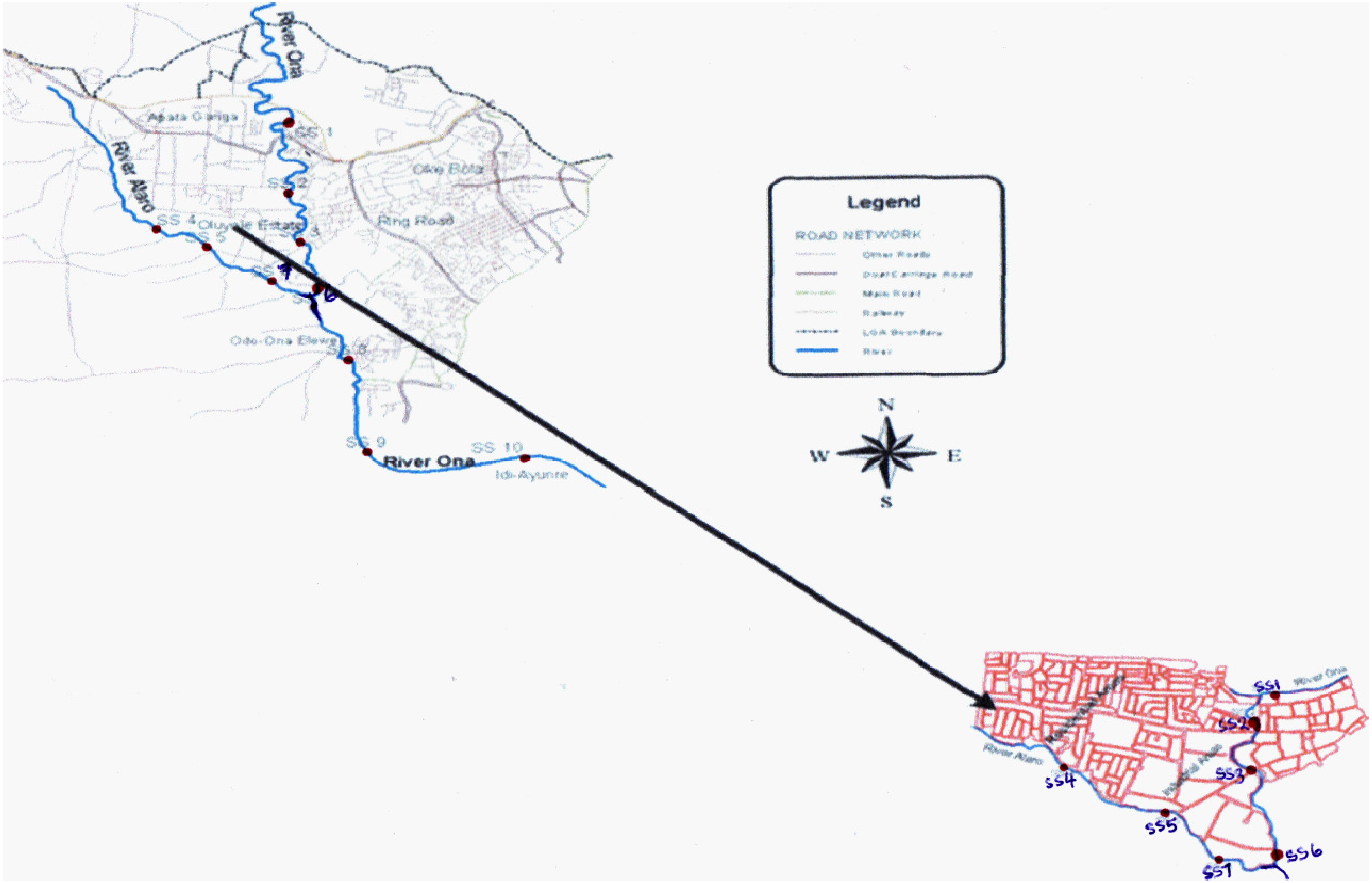

Figure 1. Maps of the study area showing the sampling sites.

Table 1. Physicochemical parameters, inorganic and organic contents of water samples collected from Rivers Ona and Alaro in Oluyole Industrial Estate, Ibadan, Nigeria.

Parameter/sampling site	Upstream zone				Industrial zone			Downstream zone		
	River Ona		River Alaro		River Ona		River Alaro	River Ona + River Alaro		
	SS1	SS2	SS4	SS5	SS3	SS6	SS7	SS8	SS9	SS10
pH	7.59	7.53	7.59	7.50	7.54	7.60	7.40	7.43	7.45	6.88
Temperature (^{0}C)	28	28	26	26	28	27	27	26	26	26
Total solids (mg/L)	360	380	300	280	520	320	260	620	340	640
Suspended solids (mg/L)	260	240	260	240	200	260	240	140	120	160
Dissolved solids (mg/L)	100	140	40	40	320	60	20	480	220	480
Acidity (mg $CaCO_3$)	34.20	24.70	36.10	35.15	31.35	31.35	29.45	36.10	35.15	43.75
Alkalinity (mg $CaCO_3$)	119.20	104.30	111.75	111.75	104.30	111.75	96.85	119.20	126.65	141.55
Total hardness (mg $CaCO_3$)	90	94	102	114	90	114	94	106	98	122
Sulphate (mg/L)	8.08	2.94	7.35	5.88	2.21	4.41	3.68	4.41	5.15	7.35
Total phosphorus (mg/L)	0.71	1.43	1.43	2.86	2.14	3.57	2.86	2.86	3.57	5.71
Chloride (mg/L)	11.78	11.78	7.48	7.70	11.78	7.48	9.52	9.52	12.69	11.33
Nitrate (mg/L)	4.33	3.16	8.04	4.47	3.00	3.63	8.55	4.86	4.88	31.49
Dissolved oxygen (mg DO/L)	5.17	4.98	6.27	7.46	5.17	6.37	5.47	5.17	5.28	4.88
COD (mg O_2/L)	102.00	81.60	61.20	20.40	102.00	40.80	81.60	102.00	122.40	142.80
Oil and grease (mg/L)	19.60	375.20	402.40	410.80	414.80	381.20	430.80	414.80	373.60	384.80

SS 1 – 10: sampling site 1 to 10 (sampling site reference points: SS1- Aseoluwa bakery; SS2- behind Adunola Int'l school; SS3- behind Niger Hygiene Ltd (7up Road); SS4- Steel works Ltd; SS5- Steel works Ltd (Elebu Road); SS6- Odo-ona Elewe axis; SS7- Zartech farms (Adeyemo bus/stop); SS8- Odo-ona Elewe(behind Agba nile panu); SS9- Odo-ona Kekere (Lagos-Ibadan Expressway); SS10- Idi-Ayunre (under bridge). COD – chemical oxygen demand.

Industrial Estate, Ibadan are presented in Table 1. The degree of contamination of both rivers as a result of indiscriminate discharges of municipal and industrial wastes was also evaluated. This is given as the accumulation factor (AF), the ratio of the average level of a given parameter downstream after the point of discharge to the corresponding average level upstream. The accumulation factors of some selected parameters are presented in Table 2.

The temperatures of the upstream and downstream water in both rivers were similar to those reported in similar tropical environment (Jaji et al., 2007). However, the average temperature of 28°C obtained upstream of River Ona was slightly higher than that obtained at the upstream of River Alaro (26°C). This may be due to the difference in time of sample collection and reduced vegetation cover observed along the drainage basin of the river.

Values of pH upstream of both rivers were identical and ranged from 7.50 and 7.59. These values were not significantly affected particularly in the industrial zones of both rivers. However, a slight drop in pH value (6.88) was observed at the sampling site 10 further downstream. This may be attributed to the influx of acidic wastes entering the river from other streams and rivers that empty their contents into these rivers along the drainage basin of the investigated rivers. pH has profound effects on water quality affecting the solubility of metals, alkalinity and hardness of water. The survival of aquatic organisms is also greatly influenced by the pH of water bodies in which they are found. This is because most of their metabolic activities are pH-dependent (Chen and Lin, 1995; Wang et al., 2002).

The mean total solids (370 mg/l) and dissolved solids (120 mg/l) obtained at the upstream of River Ona were higher than those in the same region in River Alaro with corresponding values of 290 and 40 mg/l. The same mean suspended

Table 2. Accumulation factors of some selected parameters monitored in both rivers.

Parameter	Accumulation factor, AF	
	River Ona	River Alaro
Total solids	1.44	1.84
Sulphate	1.02	0.85
Total phosphorus	3.78	1.88
Chloride	0.95	1.47
Nitrate	3.66	2.19

solid values (250 mg/l) found at the upstream of both rivers indicated turbulence, while the higher values of total and dissolved solids in the industrial zone of River Ona were indicative of industrial pollution. At certain locations, it was observed that the dissolved solid contents were found to be greater than the suspended solid levels which were expected. In other cases, suspended solid contents are greater than the dissolved solids which indicate turbulence in the water bodies during sampling and probably because the suspe-nded solids are largely non-settleable.

The slight decrease in the values of these solids downstream may be attributed to the prolonged deposition of solids in industrial effluents along the river course. This may retard the velocity of river flow with consequent rapid deposition of these solids (Fakayode, 2005). Continued deposition of solids may result in serious ecological problems such as flooding, particularly during heavy rainfall with its devastating economic conse-quences (Omoleke, 2004).

The levels of acidity upstream of Rivers Ona and Alaro ranged between 24.70 - 34.20 and 35.15 – 36.10 mg $CaCO_3$/l, respectively. The mean value obtained in the industrial zone of River Ona (31.35 mg $CaCO_3$/l) was higher than that upstream, suggesting the possibility of industrial discharges contributing to the elevated levels. However, the reduction in the mean acidity value of River Alaro with a corresponding decrease in the mean alkalinity value in the industrial zone revealed that some of the acidity in the river might have been neutralised by the alkalinity present in the river. The higher mean value of acidity found further downstream also confirmed the possibility of industrial discharges via other smaller streams along the drainage basin of the investigated rivers.

Water samples from both rivers did not show a positive test to phenolphthalein alkalinity determination. The mean levels of alkalinity of 111.75 mg $CaCO_3$/l recorded upstream of both rivers were the same. However, slight decrease in alkalinity value was observed in the industrial zone of River Ona (108.03 mg $CaCO_3$/l) while River Alaro had a significant decrease in alkalinity (96.85 mg $CaCO_3$/l). The mean total hardness found upstream of River Alaro (108 mg $CaCO_3$/l) was higher than that obtained in River Ona (92 mg $CaCO_3$/l). A comparison of the results of total hardness and alkalinity revealed that the alkalinity values in most of the sampling locations were higher than the corresponding total hardness values. This implied that the presence of basic salts (such as sodium and potassium salts) other than calcium and magnesium salts is likely to be prevalent in the river water (John De Zuane, 1990). There was a slight increase in the mean total hardness (102 mg $CaCO_3$/l) in the industrial zone of River Ona. In contrast, the values decreased in River Alaro's (94 mg $CaCO_3$/l) industrial zone. Although, the observed levels were generally lower than the 500 mg $CaCO_3$/l benchmark established by the WHO for drinking water. This might be due to the diluting effect of storm water on industrial discharges which is an important factor for consideration when assessing river water quality during the rainy season.

Sulphate levels upstream of Rivers Ona and Alaro ranged between 2.94 – 8.08 and 5.88 – 7.35 mg/l with mean values of 5.15 and 6.62 mg/l, respectively. These levels were higher than the natural background sulphate levels of 1.0 – 3.0 mg/l reported for unpolluted rivers in similar studies (Offiong and Edet, 1998; Kudryavtseva, 1999). The elevated levels of sulphate upstream of both rivers may be attributed to increased utilisation of cement for building and construction purposes in these areas. The mean sulphate levels obtained in the industrial zones of both rivers were lower than those found at the upstream regions, suggesting the possibility of sulphur removal from subaqueous biogeochemical cycle.

These removal mechanisms may include formation of iron (or other metal) sulphides, precipitation of sulphate (particularly gypsum and anhydrite) out of solution, removal of organic debris and other sulphur-containing suspended particulates and the exchange of sulphur across the air-water interface (Barton, 1978). The mean sulphate level of 5.64 mg/l downstream was accumulated by a factor of 1.02 in River Ona and 0.85 in River Alaro. In comparison with other studies (Riv'er and Litvinov, 1997; Selezneva and Selezneva, 1999; Stamatis, 1999) with sulphate levels ranging from 59 – 662 mg/l, the levels found in this study were considerably low.

The mean level of total phosphorus (2.15 mg/l) of upstream of River Alaro was twice that found in River Ona. The total phosphorus levels in both rivers, which ranged from 0.71 to 5.71 mg/l was similar to those found in the assessment of the pollution status of some Nigerian rivers (Ajayi and Osibanjo, 1981). The mean total phosphorus levels found in the industrial zones of both rivers were higher than those obtained in the upstream regions. Discharges of industrial effluents with high phosphate content might be responsible for the increased levels observed. Total phosphorus is the second most accumulated nutrient in both rivers with an accumulation factor of 3.78 and 1.88 in Rivers Ona and Alaro, respectively. High levels of total phosphorus and other nutrients have been reported to encourage eutrophication which could further deplete the dissolved oxygen levels of the rivers (Fakayode, 2005; Minareci et al., 2009). Possible sources of phosphate might involve the use of phosphoric acid and phosphate salts as industrial raw materials. In addition, the extensive uses of phosphate-based detergents for washing purposes in industries as well as land application of phosphorus-containing fertilisers can be other possible sources.

The mean chloride levels upstream of Rivers Ona and Alaro were 11.78 and 7.59 mg/l, respectively. The levels downstream were slightly higher than those obtained upstream and in industrial zones of both rivers. Similar trend was observed in effluent receiving rivers of Upper Volga and Danube (Chernyavskaya et al., 1993; Riv'er and Litvinov, 1997). The major sources of chloride in these rivers were likely to be from industrial wastewater contai-ning hydrochloric acid, common salt and other chloride containing compounds used as industrial raw materials, particularly in food industries.

The mean level of nitrate upstream of River Alaro (6.26 mg/l) was higher than that obtained in River Ona (3.75 mg/l). This trend is expected since River Alaro is bound to some commercial farms and agro-allied industries. The increased usage of nitrogen-based fertilisers as well as the poultry and other agricultural wastes from these farms seems to have significantly contributed to the elevated nitrate levels in the river. Leachate from dumpsites within the study area are characterised by high volume of domestic wastes. These are usually drawn into these rivers through urban runoff thereby increasing the levels of nutrients in these rivers (Adeyemo, 2003). Nitrate is the most accumulated nutrient in River Alaro and second most accumulated in River Ona with accumulation factors of 2.19 and 3.66, respectively. The high nitrate level obtained at sampling site 10 was due to the influx of industrial effluents and urban runoff into the river via smaller streams that empties into the river downstream.

The effect of the industrial discharges on dissolved oxygen (DO) content was not particularly significant in both rivers. This is because of the high volume of water that greatly diluted the effluents making its impacts on dissolved oxygen levels less significant. However, a reduction in the DO value (5.47 mg DO/l) in the industrial zone of River Alaro when compared with the mean obtained upstream (6.87 mg DO/l) is indicative of enormous amount of organic loads which required high level of oxygen for chemical oxidation and decomposition. A similar trend was observed further downstream with a drastic decrease in the mean DO level (5.11 mg DO/l). Evaluation of DO is crucial to the survival of aquatic organisms and ultimately in establishing the degree of freshness of a river (Fakayode, 2005).

The mean COD value upstream of River Ona (91.80 mg O_2/l) was greater than twice the value obtained in River Alaro (40.80 mg O_2/l). Both rivers had appreciable increases in COD values in the industrial zone, confirming the impact of industrial discharges on the original quality of the rivers. The COD value (81.60 mg O_2/l) obtained in the industrial zone of River Alaro by implication, suggests that most industries probably have inefficient wastewater treatment plants. There is also the possibility of decreased production rates during the period of sample collection. The dilution of the industrial effluents by the large volumes of river water at the peak of the rainy season could also be responsible for the lower COD values.

COD, oil and grease analyses revealed that River Alaro was more polluted than River Ona, particularly in the industrial zones. A higher COD value obtained downstream with a mean value of 122.40 mg O_2/l suggests that other sources might be responsible for the gross organic pollution of the river which may include escape of leachate from dumpsites, agricultural and urban runoffs, etc. Based on the classification of surface waters by Prati et al. (1971), River Alaro with a COD value of 81.60 mg O_2/l in the industrial zone may be categorised as being heavily polluted, while River Ona with a mean COD value of 71.40 mg O_2/l in the same zone may be seen as being polluted.

Oil and grease determination revealed a high level of oil pollution in most sampling sites. The mean oil and grease level (406.60 mg/l) recorded upstream of River Alaro was considerably higher than that of River Ona (197.40 mg/l). This is due to the urban runoff which conveys great amount of oil and grease from various auto-repair workshops and particularly from oil depot sited further upstream of the river. These levels became slightly elevated in the industrial zone of both rivers suggesting possible contribution from industrial processes, while the values were gradually decreasing further downstream.

Conclusion

The assessment of the quality of river water revealed that both rivers were affected by industrial discharges. The levels of most parameters monitored were generally higher in the industrial zones of both rivers and further downstream than the levels obtained in the upstream of these rivers. This study also established that the surface water quality of both rivers was significantly affected by industrial discharges as indicated by the accumulation factors of some parameters monitored. It will be unsafe to exploit water from these rivers for domestic and agricultural purposes without some forms of physical and chemical treatments.

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