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Assessment of Impact of Industrial Discharge on the Quality of Water around Lafarge Cement WAPCO, Ewekoro, Nigeria.

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Abstract
The negative impact of industrial discharges into freshwater on wellbeing of man and environment prompted the assessment of the quality of water around Lafarge Cement WAPCO, Ewekoro, Ogun State. The water samples were analysed for water quality parameters using standard methods for its pH, temperature (°C), electrical conductivity (μS/cm), turbidity, alkalinity (Alk), total hardness (TH) and concentrations of sulphate (SO_4^{2-}), nitrate (NO_3^-), phosphate (PO_4^{3-}), chloride (Cl^-), total suspended solids(TSS), total dissolved solids (TDS), total solids (TS), heavy metals (Pb, Cr, Cd, Mn, Ni, Fe). Results showed that TSS, TDS, TS,SO_4^{2-}, Turbidity, Fe, Cr, Cd, Mn, Ni and Pb concentrations were above the maximum permissible limits of National Agency for Food and Drug Administration and Control (NAFDAC), Standard Organization of Nigeria (SON), Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO, 2006) for drinking water during some months of the study period. However, the water temperature, pH, conductivity, NO_3^-, PO_4^{3-}, Cl^- and Alk levels were within the permissible limits of all the standards. In conclusion, the water is unfit for domestic uses, drinking and aqua cultural purposes since most of the parameters measured were above the maximum permissible limits of the national and international standards. Regular water quality monitoring to determine the status of the study area is recommended for human safety and environmental sustainability.

Keywords: Industrial discharge, Environment, Pollution, Water quality, Freshwater

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Introduction

The presence of industrial pollutants in the surrounding environment tampers with the natural quality of the environmental media which has detrimental effects on plants, animals and human beings. Life without cement in this 21st century is inconceivable because cement is the basic ingredient of concrete used in constructing modern edifices and structures. Cement, however, generates dust during its production (Meo, 2004). Cement dust contains heavy metals like chromium, nickel, cobalt, lead and mercury pollutants which are hazardous to the biotic environment with negative impact on vegetation, human health, animal health and ecosystem (Baby *et al*., 2008).The primary component of cement is limestone and other clay-like materials which are heated in a kiln at 1400°C and then mixed with gypsum to form cement (Huntzinger and Eatmon, 2009). Calcination of these constituents is responsible for about 50% pollutants emissions from cement industry while indirect emissions are produced by burning fossil fuels to heat the kiln. The fuel may be derived from coal, natural gas or oil.

The world production of cement was put at 2.55 billion tons in 2006 and the production is growing by 2.5% annually. It has been projected that the value will rise to 3.7 – 4.4 billion tons by 2050 (Rubensten, 2012).

As at 2015, 71% of the world population used a safely managed drinking-water service located within their premises while 89% of the global population and 69% Nigerians depend on basic service of an improved drinking-water supply within 30 min round trip from their premises (The World Bank Group, 2017). About 27% of global population uses a drinking water source contaminated while over 40 % live in sub-Saharan Africa (UNO, 2010). As such, developing countries are confronted with the great challenge of controlling water pollution especially in industrial areas which may have an adverse effect on the health of the population. Therefore, there is urgent need to protect the available water resources with stringent measures and prevention techniques. A full understanding of the extent of pollution in a water body is indispensable in order to preserve the water for present and future uses (Mahananda *et al*., 2010).

The management of the anthropogenic discharges and the natural physico-chemical characteristics has a great effect on both surface and underground water qualities of any water regime (Efe *et al*., 2005; Ajai *et al*., 2011). The goal of this study is however, to assess the influence of anthropogenic activities (cement production) on the quality of surface water in river Akinbo. This study is significant considering the recommendation of a previous work (Ibitoye and Ajibade, 2008) on a continuous assessment of the impact of cement production in the study area. Hence, inquiry into the status of water at the study area is of economical, environmental and scientific importance.

Materials and Methods

Study Area and Sampling Points

The study site is River Akinbo at Akinbo Community in Ewekoro, Ogun state (Fig 1). The river flows through the West African Portland Cement Company (WAPCO), dust and waste water from the factory are directly discharged into the river. The Ewekoro plant of WAPCO is located in Ewekoro local government area of Ogun State. Ewekoro cement factory it is on a latitude 5°.50'N and longitude 3°.17 ' E. Also it is approximately 64 kilometers north of Lagos and 42 kilometers south of Abeokuta. The area is largely rural and characterized by two distinct seasons: the dry season occurring between December and March; and rainy season occurring between April and November. The inhabitants are predominantly farmers who engaged in the planting of sugar cane, cassava, maize and vegetable. Cash crops such as cocoa, kolanut and oil palm are also cultivated. The water sampling points were geo-referenced with Global Positioning System (GPS) and summarised in Table 1.

Water Samples Collection and Parameters Analysed

Water samples were taken at distances as shown (Fig 1) along river Akinbo that flows through the Lafarge Cement factory and points of collection were labelled A (637.5 m), B (650 m), C (962.5 m) and D (2325 m) respectively in relation to the factory. The geo-referencing of the sampling points is as presented in Table 1. Water samples were collected at these points along Akinbo River for a consecutive period of 9 months from October, 2015 to June, 2016. All bottles were marked individually with waterproof marker to show location, date, and sample type. Water samples were collected in polyethylene bottles that were pre-treated as previously described by Abdus-Salam and Oyede (2013).

Water samples were taken beyond the bank of the river but not deeper than 100 cm below the water surface. Sampling bottles were filled to the brim of the containers before capping to prevent loss of dissolved oxygen. The samples for heavy metal analysis were collected in separate containers and they were preserved with 2 mL conc. HCl per litre of sample (Abdus-Salam *et al.,* 2010). This is to reduce adsorption and precipitation of metals on the walls of containers. Prior to metal analysis, the raw samples were digested to solubilize metals in water. A 100 mL of well-mixed water sample was measured into 250 mL conical flask, and then 2 mL of conc. HNO_3 and 10 mL conc. HCl were added and heated on a steam bath. The heating continued until there was volume reduction to near 25 mL, while ensuring that sample does not boil. The sample flask was cool down and then filtered the content into 100 mL volumetric flask to remove insoluble material. Distilled water was added to make up the volume. These samples were analysed for Cr, Fe, Pb, Mn, Ni and Cd concentrations using Atomic absorption spectrometer (AAS).

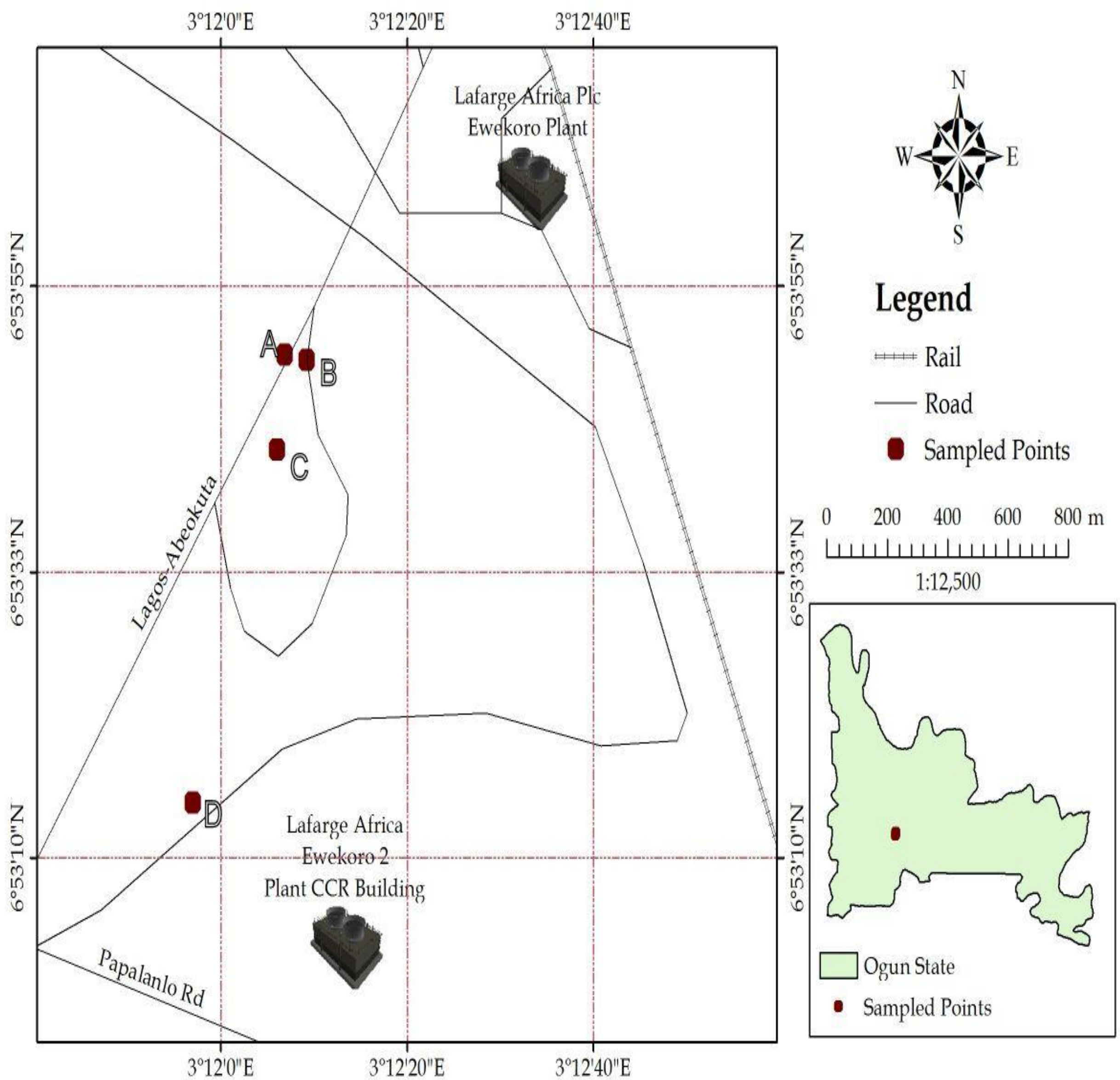

Fig 1. Sampling points

Table 1: Water sampling points for the study

Sampling Code	Latitude	Longitude
A	6°53'49.4"N	3° 12'09.2"E
B	6°53'49.4"N	3° 12'08.2"E
C	6°53'42.4"N	3° 12'06.0"E
D	6°53'14.7"N	3° 11'57.0"E

Readings for pH, temperature (°C), electrical conductivity (μS/cm), turbidity were conducted *in-situ* with the use of pH meter, Mercury-in-glass thermometer and EC multi meter Hi 98129 respectively. Other parameters were determined *ex-situ* using standard methods. The sulphate (mg/L), nitrate (mg/L), phosphate (mg/L) and chloride (mg/L) were analysed by spectrophotometric methods. The chloride, nitrate, sulphate, phosphate were determined by Mohr's, sodium salicylate (colorimetric), turbidometric and ascorbic acid methods respectively (Ademoroti, 1996b). The total suspended solid (mg/L), total dissolved solids (mg/L), total solid (mg/L), alkalinity (mg/L), heavy metals (Pb, Cr, Cd, Mn, Ni, Fe) and hardness (mg/L) were determined using standard methods.

Standards for Calibration

Standard for calibration of AAS were prepared from Analytical grade reagent. Five sets of working standard solutions were prepared from Analar grade reagent by serial dilution of stock solution. The working standards were as follows: 5, 10, 15, 20 and 25 ppm. Standard hollow cathode lamps were used for each element.

Data Analysis

Descriptive statistics were computed for every physico-chemical parameter for each water sampling location. The parameters computed include mean, minimum and maximum values and standard deviation from mean. Finally, mean values of the parameters obtained from the various sampling locations were compared with SON, FEPA, WHO and NAFDAC permissible limits in order to establish the water quality of River Akinbo.

Results and Discussions

The Table 2 contained water quality analyses involving 19 parameters, with mean values, maximum and minimum, and standard deviation values, for all the four sample points. The pH ranged between 6.8 and 9.5 across all the sample locations with highest value recorded at point A. This range of values is in agreement with similar analytical reports (Ujoh and Alhassan, 2014; Ibitoye and Ajibade, 2008; Salami *et al*., 2002) and is within the permissible limits of WHO, SON, FEPA and NAFDAC. The water temperature ranged between 17°C to 27°C and it is within the permissible limits of WHO, SON, EPA and NAFDAC standard values. The survival and varieties of aquatic animals are dependent on water temperature which controls their metabolic processes. Electrical conductivity values ranged between 208 to 582 μS/cm across the sampling points. These values are within the permissible limits of WHO, SON, FEPA and NAFDAC standards. The TDS, TSS and TS ranged between 20 to 1320, 10 to 9860 and 70 to 10430 mg/L respectively. These values are higher than the permissible limits of WHO, FEPA, SON and NAFDAC. Ordinary visual observation of the area shows that there is lots of dust in the atmosphere which eventually settled in the water body. Total alkalinity ranged between 8 to 76 mg/L and Total hardness ranged between 8 to 260 mg/L across the sampling locations which fell within the permissible limits of WHO, SON, EPA and NAFDAC. The phosphate, nitrate and chloride ranged between 8.05 to 104.45, 0.40 to 1.55 and 8-56.99 mg/L respectively and are within the permissible limit of WHO, EPA, NAFDAC and SON. These parameters have zero percent violation of the standards. Sulphate ranged is between 221.33 to 3650 mg/L with 100 % violation of WHO, SON, NAFDAC and EPA for most part of the sampling period.

From Table 2, the concentration range for Iron (Fe) is between 0.12-27.27 mg/L which is above permissible limit of WHO, EPA, NAFDAC and SON. The concentration range for Lead (Pb) is between 0.00 to 0.02

mg/L. Although the highest value of 0.02 mg/L is above WHO permissible limit of 0.01 mg/l but in most of the sampling points, Lead concentration recorded was below the permissible limit of WHO. A range between 0.001-0.33 and 0.003 to 2.72 mg/L were recorded for Cd and Mn respectively which are above the permissible limit of WHO for drinking water. Similar values have been reported (Ibitoye and Ajibade, 2008). The Cr concentration ranged between 0.04 to 1.44 mg/L, a value higher than WHO, SON and EPA permissible limits for drinking water. Nickel (Ni) concentration ranged between 0.03 to 0.06 mg/L and is within the permissible limit of WHO for drinking water

Table 2: **Physico-chemical parameters of water samples with reference to WHO standards**

Parameters	Point A	Point B	Point C	Point D	Mean	Min.	Max.	StanDv	WHO (STD)	Remarks
pH	7.97	7.92	7.89	7.91	**7.92**	**7.89**	**7.97**	**0.03**	**6.5-9.5**	**BPL**
Temp (°C)	23.11	21.22	21.18	20.22	**21.43**	**20.22**	**23.11**	**1.21**	**25**	**BPL**
TH (mg/L)	142.89	37.78	162.22	166.67	**127.39**	**37.78**	**166.67**	**60.63**	**500**	**BPL**
TSS (mg/L)	1213.33	1194.44	1143.33	1126	**1169.28**	**1126**	**1213.33**	**41.31**	**80**	**APL**
TDS (mg/L)	517.78	460	404.44	440.67	**455.72**	**404.44**	**517.78**	**47.35**	**500**	**APL**
TS (mg/L)	1731.11	1654.44	1647.78	1566.67	**1650**	**1566.67**	**1731.11**	**67.20**	**80**	**APL**
Cl- (mg/L)	31.77	31.7	27.38	28.1	**29.74**	**27.38**	**31.77**	**2.36**	**250**	**BPL**
PO_4^{3-}(mg/L)	34.27	41.41	39.17	40.96	**38.95**	**34.27**	**41.41**	**3.27**	**200**	**BPL**
NO_3^- (mg/L)	0.68	0.51	0.54	0.58	**0.58**	**0.51**	**0.68**	**0.07**	**0.8**	**BPL**
SO_4^{2-} (mg/L)	1742.82	1524.4	1465.48	1619.85	**1588.14**	**1465.48**	**1742.82**	**121.16**	**500**	**APL**
TUR(NTU)	4.01	3.4	2.15	3.33	**3.22**	**2.15**	**4.01**	**0.78**	**5**	**BPL**
ALk (mg/L)	37.33	37.78	30	37.33	**35.61**	**30**	**37.78**	**3.75**	**200**	**BPL**
EC (µS/cm)	416.78	408.33	381.56	419.56	**406.56**	**381.56**	**419.56**	**17.34**	**1200**	**BPL**
Fe (mg/L)	7.22	6.01	1.89	6.4	**5.38**	**1.89**	**7.22**	**2.38**	**3**	**APL**
Pb (mg/L)	0.001	0.0003	0.001	0.002	**0.001**	**0.0003**	**0.002**	**0.001**	**0.01**	**BPL**
Cr (mg/L)	0.32	0.3	0.16	0.37	**0.29**	**0.16**	**0.37**	**0.09**	**0.05**	**APL**
Cd (mg/L)	0.04	0.05	0.03	0.02	**0.04**	**0.02**	**0.05**	**0.01**	**0.001**	**APL**
Mn (mg/L)	0.77	0.84	0.62	0.61	**0.71**	**0.61**	**0.84**	**0.11**	**0.1**	**APL**
Ni (mg/L)	0.04	0.12	0.08	0.004	**0.06**	**0.004**	**0.12**	**0.05**	**0.07**	**APL**

KEY: TUR = Turbidity; TH = Total Hardness

ALK = Alkalinity; TSS = Total Suspended Solids

EC = Electrical Conductivity; TDS = Total Dissolved Solids

APL- Above Permissible Limit BPL- Below Permissible Limit

Table 3 summarized the parameters analysed and described them in terms of violation of WHO standard for drinking water. The values obtained for Total suspended solid (TSS), Total dissolved solid (TDS), Total solid (TS), sulphate, turbidity, Fe, Cr, Cd, Mn, Ni and Pb concentrations were higher than WHO upper permissible limits, therefore violated WHO standard while the water temperature, pH, conductivity, phosphate, nitrate, chloride and alkalinity levels were within the WHO standard values. These results followed similar trends observed by similar researchers on impacts of cement production on the environment (Dimowo, 2013; Ujoh and Alhassan, 2014; Salami *et al*., 2002; Ibitoye and Ajibade, 2008).

Table 3: **Average values of the physico-chemical parameters of water samples (Oct, 2015 to June, 2016).**

Parameters	Point A	Point B	Point C	Point D
pH	7.97±0.72	7.92±0.34	7.89±0.40	7.91±0.37
	(6.8-9.5)	(7.6-8.7)	(7.4-8.7)	(7.3-8.6)
Temp (ºC)	23.11±1.90	21.22±1.79	21.18±1.88	20.22±1.56
	(21-27)	(18-24)	(20-23)	(17-22)
TH (mg/L)	142.89±64.79	37.78±19.86	162.22±37.68	166.67±62.88
	(18-240)	(8-62)	(102-184)	(82-260)
TSS (mg/L)	1213.33±3243.58	1194.44±3184.51	1143.33±3129.26	1126±3114.79
	(20-9860)	(20-9680)	(10-9480)	(10-9430)
TDS (mg/L)	517.78±506.65	460±490.41	404.44±402.74	440.67±419.94
	(60-1320)	(30-1250)	(20-1150)	(20-1040)
TS (mg/L)	1731.11±3296.84	1654.44±3249.49	1647.78±3130.05	1566.67±3060.65
	(180-10430)	(150-1400)	(70-1190)	(60-9650)
Cl^- (mg/L)	31.77±14.84	31.7±14.83	27.38±15.42	28.10±15.09
	(10.99-56.99)	(11-42.99)	(8-40.99)	(8-47.99)
PO_4^{3-}(mg/L)	34.27±32.10	41.41±35.38	39.17±29.96	40.96±36.75
	(10.38-86.44)	(9.75-104.45)	(8.90-79.23)	(8.05-94.92)
NO_3^-(mg/L)	0.68±0.47	0.51±0.37	0.54±0.39	0.58±0.41
	(0.90-1.55)	(0.21-1.31)	(0.40-1.27)	(0.14-1.30)
SO_4^{2-}(mg/L)	1742.82±1189.21	1524.4±1029.68	1465.48±972.24	1619.85±1255.93
	(221.33-2525.33)	(464-3232)	(352-2592)	(360-3650.67)
TUR (NTU)	4.01±4.92	3.40±3.41	2.15±1.42	3.33±4.85
	(0.72-16)	(1-7)	(1-4)	(1-16)
ALK (mg/L)	37.33±15.36	37.78±19.86	30±18.27	37.33±17.78
	(16-70)	(8-62)	(20-54)	(12-76)
COND.	416.78±109.56	408.33±124.23	381.56±122.15	419.56±80.61
(µS/cm)	(305-563)	(279-582)	(208-532)	(340-533)
Fe (mg/L)	7.22±9.91	6.01±7.14	1.89±3.11	6.40±8.49
	(0.49-27.27)	(1.05-18.79)	(0.12-9.65)	(0.59-24.15)
Pb (mg/L)	0.001±0.003	0.0003±0.001	0.001±0.003	0.002±0.004
	(0.01)	(0.02)	(0.001)	(0.01)
Cr (mg/L)	0.32±0.53	0.30±0.38	0.16±0.33	0.37±0.48
	(1.44)	(0.04-1.24)	(1.03)	(1.32)
Cd (mg/L)	0.04±0.02	0.05±0.10	0.03±0.05	0.02±0.02
	(0.001-0.064)	(0.001-0.33)	(0.01-0.15)	(0.07)
Mn (mg/L)	0.77±0.73	0.84±0.86	0.62±0.59	0.61±0.50
	(0.004-2.06)	(0.003-2.72)	(0.003-1.35)	(0.02-1.24)

Note: Values in parenthesis are the range

Conclusion

In general, the environmental consequences of cement production at the study area are glaring even to a passive observer. River Akinbo surface water samples displayed higher values of some physico-chemical parameters and heavy metal contents higher than some selected standards (WHO, EPA, NAFDAC, SON) which were attributed to existence of anthropogenic factors. Results showed Total suspended solid, Total dissolved solid, Total solid, Sulphate, Turbidity, Fe, Cr, Cd, Mn, Ni and Pb concentrations were above the maximum permissible limit of National Administration for Food, Drugs and Control (NAFDAC), Standard Organization of Nigeria(SON), Federal Environmental Protection Agency (FEPA), World Health Organization (WHO) for drinking water during certain months of the study period. Results also showed that water temperature, pH, conductivity, phosphate, nitrate, chloride and alkalinity were within the permissible limits of all the standards. Since most of the parameters measured were above the maximum permissible limits of the national and international standards, it can be concluded that the water is unfit for domestic uses, drinking and aqua cultural purposes and therefore needs to be treated if it is to be used at all.

Therefore this study recommends:

- Treatment of effluents and solid waste before final disposal to reduce contaminant load.
- Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) should be installed at Larfage plant kilns Ewekoro to reduce particulate emission during production;
- Consistent monitoring of water quality at the vicinity of the study area to develop mitigation and ameliorative measures towards controlling pollution levels at the study area.

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