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Assessment of Pollutants in Streams around a Cement Plant in Central Nigeria

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ABSTRACT

The study assessed the chemical and heavy metals content in surface water samples collected at 9 points from 3 different streams within a radius of 5 kilometers to the factory, and an additional control water sample collected from a stream at *Tarhembe*, 12 kilometers from the factory. Laboratory analyses were conducted for 18 parameters, while mean, maximum and minimum values, and standard deviation for all parameters tested were derived using SPSS Version 15. Using the WHO (2011) Guidelines for Drinking Water, the concentration levels of pollutants in water samples were determined for all 18 parameters to establish whether or not they constitute significant health problems. The results for physico-chemical parameters show that pH values range between 6.07 and 8.48 across all sample locations with the highest value recorded in Sample E. Generally, the concentration of these parameters vary across all water samples however, the largest mean value was recorded for the Total Dissolved Solids (TDS) at Sample E which is almost twice the WHO permissible limit. The temperature ranges between 22.4 and 22.9, while Turbidity and Total Hardness range between 6.0 and 232.0 and 10.5 to 66.0, respectively, and are found to be significantly higher than the permissible limit provided by the WHO (2011). All values of physic-chemical parameters recorded from the water sample at the Control Community are found to occur below permissible limit except for turbidity. All heavy metals content in water samples were found occurring above the WHO (2011) permissible limits, except for Potassium which was not detected in any water sample. The study concludes that the quality of surface water at the study area is compromised and polluted at significant proportions. The study recommends reduction in release of pollutants and fugitive dust from the factory, amongst others.

Keywords: *Surface water, physico-chemical parameters, heavy metals, water pollution, cement production, Yandev*

I. INTRODUCTION

Within the last three decades, global concern has accelerated and focused on anthropogenic activities that alter the natural environment during natural resources exploitation and the attendant impact on the physical environment. These concerns have translated into several initiatives at the global level intended for adoption at national and local levels ultimately, with a view to engendering environmental sustainability (1).

In 1992, the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, produced an action document tagged Agenda 21. The document acknowledged the perpetuation and worsening deterioration of ecosystems on which we depend for our well-being, amongst other social-economic disparities between nations. Similarly, the United Nations Framework Convention on Climate Change (UNFCCC) came into force in 1994 (now totaling 194 parties/countries). Further, the Millennium Declaration in 2000 by 189 countries produced the Millennium Development Goals (MDGs) document which broadly seeks to address environmental degradation issues and socio-economic disparities among nations before the year 2015.

In spite of the broad dimensions of the various global instruments generally aimed at sustainability in environmental resources utilization, of specific interest to this study is the MDG No. 7 which states, inter alia: To ensure environmental sustainability, vide:

Target 7A: Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources;....

Target 7C: Halve, by 2015, the proportion of the population without sustainable access to safe drinking water....

This study therefore, intends to verify the level of adoption of (part of) the MDG No. 7 at the Dangote Cement Company, Yandev, a part of rural Nigeria where limestone mining and cement production activities have been on-going over the past 3 decades.

Although the overall global proportion of people using an improved water source rose from 76% in 1990 to 89% in 2010, over 40% of all people without improved drinking water live in sub-Saharan Africa (2). This presents a significant challenge to countries within and peoples living in the Sub-Saharan African region. Therefore, there is every need to protect the available water resources in Sub-Saharan Africa, with specific emphasis on prevention. As rightly indicated by (3), the knowledge of

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extent of pollution and the status of water becomes essential in order to preserve the valuable source of water for present and future generations.

According to (4; 5), the qualities of a water resource (surface and sub-surface) depend on the management of anthropogenic discharges within, as well as the natural physic-chemical characteristics of the catchment areas. The focus in this study is however, on the influence of anthropogenic activities (limestone mining and cement production) on the quality of surface water around the study area. The study is deemed necessary as there was no environmental impact assessment carried out prior to the establishment of the factory. Aside being a major environmental component, water is also invaluable to human, animal and plant populations. Hence, investigation into the status of water quality at the study area, and indeed elsewhere, is of scientific, economic and environmental significance.

II. OBJECTIVES OF THE STUDY

The central objectives of this study are:

- Determine the level of concentration of pollutants in water within the study area;
- Compare the water quality between host communities and a control community to ascertain the degree of variance in amount of water pollutants present between the two; and,
- Compare WHO water quality guidelines with amount of pollutants found in water within the study area to assess water quality status

III. STUDY AREA

The cement factory is located at Yandev, near Gboko town, in Gboko Local Government Area (LGA) of Benue State in Nigeria's north-central region. The central location of the factory is at 7º 24′ 42.45″N and 8º 58′ 31.28″E, at about 532 feet above mean sea level (Figure 1). The study area, is located within a sub-humid tropical region with mean annual temperature ranging from 23ºC to 34ºC, and is characterized by two distinct seasons: the dry season occurring between December and March; and rainy season occurring between April and November. The mean annua1 precipitation is about 1,370mm and is described by (6) as having a bimodal pattern. The average wind speed over the study area is about 1.50 m/s, while the average ambient air temperature is about 30ºC (7).

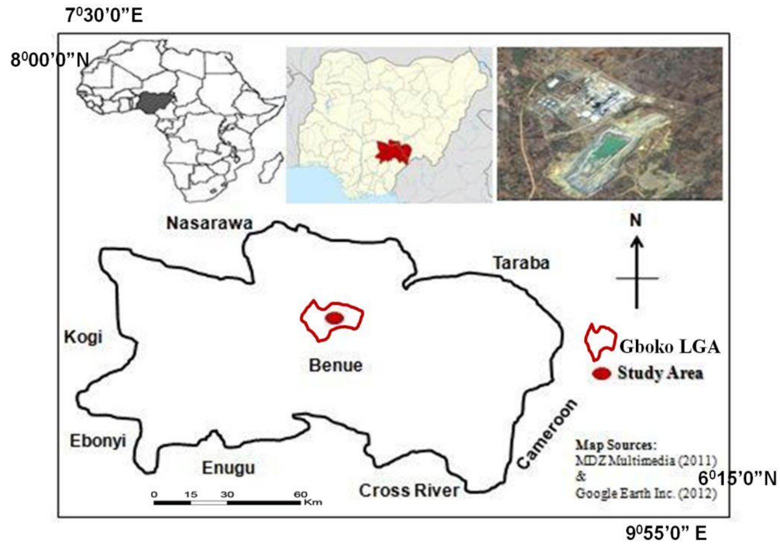

Fig. 1. Location of Study Area

The area is located within the general area of the Benue Trough, which according to (8) is largely covered by Cretaceous continental (to the north) and marine (to the south) sediments. The limestone reserves at the study area are of Cretaceous formation and in excess of 70 million tonnes (9). The River Benue is the second largest river in Nigeria and the most prominent geographical feature in Benue state. Within the study area however, the most significant water bodies to be found are two streams – 'Ahungwa' and 'Oratsor'. During the construction of the cement factory, Ahungwa stream was dammed to impound water for use by the various production processes at the factory. Similarly, the area is characteristically a flat plain without hills or rocky outcrops. The major communities within the 5-kilometre radius (comprising the area of interest to this study) falls within the Mbaiwan, Mbatyula, Mbausu, Mbagar, Mbaataiwa and Mbawav kindreds of Mbatyu in Mbayion, Gboko LGA. The most prominent communities within the study area are Tse-Kucha and Tse-Amua. The inhabitants are largely pre-occupied in traditional subsistence agriculture/land cultivation and wildlife hunting.

IV. METHODOLOGY

a. Water Samples Collection and Parameters Analysed

Water samples were collected at 9 points from 3 different streams within a radius of 5 kilometers around the factory. An additional water sample was collected from a stream at *Tarhembe*, the control community (Table 1). An overall composite water sample total of 10 were thus, collected from streams for the study (Figure 2 and Plate 1). The water samples were tested for 18 parameters (Table 2). Water samples analysis

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was carried out at the Laboratory of the Kaduna State Environmental Protection Agency (KEPA).

Table 1. Water Sampling points for the study

Sample Code	Sample Locations	Lat-Long	
		N	E
A	Factory Dam	7.37184	9.02896
B	Dam Upstream	7^{0}22'06.85''	9^{0}01'29.47''
C	Dam Downstream	7^{0}22'21.79''	9^{0}01'50.06''
D	Amua Stream	7^{0}23'31.54''	9^{0}00'04.33''
E	Water at Quarry behind Factory	7^{0}24'39.59''	8^{0}58'45.04''
F	Ngo Stream I	7.42089	8.96926
G	Ngo Stream II	7.41397	8.97074
H	Ngo Stream III	7^{0}24'02.14''	8^{0}58'12.33''
I	Ngo Stream IV	7.35929	8.97019
J	Stream at Tarhembe (Control Community)	7.50113	8.91446

Plate 1. Water samples collection at a stream in study area

b. Digestion procedure for water samples

At the KEPA Laboratory, 50ml of thoroughly shaken water sample was measured accurately into a beaker and digested 5ml of concentrated HNO_3 for a few hours on a hot plate at $100^{0}C$ till the solution reduced to less than 20ml by volume. The solution was allowed to cool again then filtered with 125mm filter paper into 100ml standard flask and made to the mark with de-ionized water. The 100ml digested sample solution was transferred to 100ml plastic container and taken for heavy metals determination on Atomic Absorption Spectrometer (AAS). A blank of the de-ionized water was prepared using the same procedure and subjected to the same analytical procedure.

Fig. 2. Water Samples Collection Points

Table 2. Parameters Analysed in Water Samples

S/No.	Parameters
1	pH
2	Conductivity
3	Temperature
4	Dissolved Oxygen
5	Total Dissolved Solids
6	Total Suspended Solids
7	Turbidity
8	Total Hardness
9	Calcium (Ca)
10	Sodium (Na)
11	Potassium (K)
12	Magnesium (Mg)
13	Copper (Cu)
14	Chromium (Cr)
15	Manganese (Mn)
16	Lead (Pb)
17	Zinc (Zn)
18	Iron (Fe)

c. Calibration Standards

Calibration standard containing only the elements to be analysed were prepared. 5 sets of standards were prepared in order to obtain a good precision. Working standard solutions were prepared by diluting stock and intermediate standards. The working standards were as follows: 2, 4, 6, 8 and 10 ppm. Standard Pye Unicam hollow cathode lamps are used for each element.

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d. Spectrometer Specification

The spectrometer specification is provided below:

Thermo scientific iCE 3000 series AA spectrometers;
6 lamps Automated carousal;
Coded hollow cathode lamps;
Wavelength range 180nm to 900nm; and,
Absorbance range -0.150A to 3.000A.

e. Flame parameters

Flame type: Air/acetylene
Nebulizer uptake: 4secs
Burner height: 7.00mm
Fuel flow: 1.2L/min

f. Calibration Parameters

Calibration curve: normal
Excess curvature limits: -10% to +40%
Line fit: segmented curve
Rescale limit: 10.0%
Scaling factor: 1.000

g. Data Analysis

Descriptive statistics were computed for every chemical parameter for each water sampling location. The parameters computed include mean, minimum and maximum values, standard deviation and variance. Finally, mean values of the parameters obtained for the various locations were compared with the various permissible limits of the parameters set by WHO (9) in order to identify elements that attained pollution level.

V. RESULTS AND DISCUSSIONS

The results of water analyses conducted in this study are presented on Table 3 (for chemical content) and Table 4 (for heavy metals content) below. The analyses were conducted for 18 parameters, with mean values, maximum and minimum values, and standard deviation values, for all 10 stream sample locations. The WHO (10) did not provide permissible limit for some of the elements analysed. In such cases, the study relied on provisions in the water analyses literature to determine whether or not concentration of such parameters in water constitutes significant health problems. On the whole however, pH values range between 6.07 and 8.48 across all sample locations with the highest value recorded in Sample E. Generally, the concentration of these parameters varies across all parameters on Table 3. Of significance is the large mean value recorded for the Total Dissolved Solids (TDS) which is almost twice the WHO permissible limit. The highest TDS is also recorded at Sample E. The temperature ranges between 22.4 and 22.9, while Turbidity and Total Hardness range between 6.0 and 232.0 and 10.5 to 66.0, respectively. The recorded mean values of TDS and Turbidity are significantly higher than the permissible limit provided by the WHO (10). Finally, all values of chemical contents recorded from the water sample at the Control Community are found to occur below permissible limit except for turbidity.

On Table 4, the values of heavy metals' content in water samples are provided. While Potassium was not detected in all water samples, all other elements were found occurring above the WHO (10) permissible limits. Additionally, some sample locations exhibit values exceedingly above permissible limits. For instance, while Chromium is not detected in some water samples, it was found above the permissible limit in all water samples that it was found occurring in (Samples B, D, E, H and I). Finally, although all values of heavy metals recorded from the water sample at the Control Community are found to occur above the permissible limit, the concentration levels are lesser than those at the immediate vicinity of the factory. There is therefore, a marked difference in the concentration levels of pollutants between water samples around the vicinity of the factory and the water sample from the control community.

VI. CONCLUSION

On a general note, the environmental consequences of cement production at the study area are glaring even to a passive observer. The amount of pollutants in water is generally higher at the host communities than at the control community. The analysis of water samples reveals concentration of chemical elements and heavy metals in water around the vicinity of the factory. The results denote pollutants in stream water which is one of the major sources of water for domestic use at the study communities (except for Potassium which was not detected in any water sample). While the results show variations, the levels of contamination are generally higher at the two host communities than at the control community. The impact of these concentrations on human, plant and animal populations is indeed significant as revealed from various studies elsewhere (10; 11; 12; 13), and at the study area (14). The study recommends:

- Consistent inquiry in the status of the study area is suggested as necessary for sustainable resources exploitation at the study area;
- Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) should be installed at the Dangote Cement kilns to reduce in very drastic

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proportions the amount of plume emissions with poisonous gases such as NOx 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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Table 3. Chemical Content in Water Samples

Parameters	pH	Conductivity	T°C	DO	TDS	TSS	Turbidity (NTU)	Total Hardness
Sample A	7.20	1.43	22.60	5.10	960.00	126.00	182.00	66.00
Sample B	6.17	1.12	22.50	3.60	750.00	45.00	24.00	18.00
Sample C	7.24	1.40	22.40	8.30	960.00	95.00	139.00	44.00
Sample D	6.07	0.86	22.60	7.20	580.00	93.00	87.00	17.50
Sample E	8.48	12.54	22.70	6.30	8400.00	18.00	14.00	57.50
Sample F	6.80	1.28	22.60	7.90	860.00	102.00	145.00	15.00
Sample G	8.07	7.46	22.50	8.40	5000.00	9.00	6.00	25.50
Sample H	7.24	0.97	22.60	7.80	640.00	38.00	50.00	20.50
Sample I	6.32	1.32	22.90	5.50	282.00	232.00	282.00	11.00
Control Sample	6.54	0.84	22.80	8.40	460.00	33.00	32.00	10.50
Mean	***7.01***	***2.92***	***22.62***	***6.85***	***1133.20***	***79.10***	***96.10***	***28.55***
Minimum	***6.07***	***0.84***	***22.40***	***3.60***	***282***	***9.0***	***6.0***	***10.50***
Maximum	***8.48***	***12.54***	***22.90***	***8.40***	***5000.0***	***232.0***	***282.0***	***66.00***
Standard Deviation	***0.79***	***3.92***	***0.15***	***1.66***	***1376.25***	***66.81***	***89.78***	***20.01***
WHO(10) Recommended Values	***6.5-8.5***	***400***	***NP***	***NP***	***600***	***NP***	***5***	***200***
Remarks	***BPL***	***BPL***	***-***	***-***	***APL***	***-***	***APL***	***BPL***

Permissible Limit Values in ppm

*** APL = Above Permissible Limit**
*** BPL = Below Permissible Limit**
*** NP = Not Provided**

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Table 4. Heavy Metals' Content in Water Samples

Parameters	Calcium	Sodium	Potassium	Magnesium	Copper	Chromium	Manganese	Lead	Zinc	Iron
Sample A	64.70	4.43	ND	1.53	0.10	ND	0.26	0.03	0.11	2.20
Sample B	17.10	2.41	ND	0.84	0.23	0.09	1.27	0.05	0.30	5.56
Sample C	42.01	4.83	ND	1.37	0.18	ND	1.19	0.05	0.26	2.14
Sample D	16.05	1.22	ND	0.04	0.50	0.06	0.89	0.10	0.32	8.49
Sample E	53.30	125.42	ND	4.44	0.10	0.06	0.77	0.15	0.48	0.09
Sample F	14.65	5.47	ND	0.44	0.02	ND	ND	0.01	0.29	1.64
Sample G	23.31	41.07	ND	1.71	0.13	ND	ND	0.04	0.32	2.08
Sample H	20.45	31.47	ND	0.05	0.33	0.06	ND	0.06	0.15	0.07
Sample I	10.81	0.48	ND	0.02	0.29	0.06	ND	0.08	0.17	2.07
Control Sample	9.80	3.07	ND	0.19	0.19	ND	0.09	0.10	0.39	1.94
Mean	***27.22***	***21.99***	***0.0***	***1.06***	***0.21***	***0.03***	***0.54***	***0.14***	***0.28***	***2.63***
Minimum	***9.80***	***0.48***	***0.0***	***0.02***	***0.02***	***0.0***	***0.0***	***0.01***	***0.11***	***0.07***
Maximum	***64.70***	***125.42***	***0.0***	***4.44***	***0.50***	***0.09***	***1.27***	***0.82***	***0.48***	***8.49***
Standard Deviation	***19.21***	***38.96***	***0.0***	***1.35***	***0.14***	***0.04***	***0.53***	***0.24***	***0.11***	***2.55***
WHO (10) Permissible Limit	***0.01***	***0.05***	***0.012***	***0.05***	***0.02***	***0.05***	***0.1***	***0.01***	***0.01***	***0.1***
Remarks	***APL***	***APL***	***BPL***	***APL***	***APL***	***APL***	***APL***	***APL***	***APL***	***APL***

Permissible Limit Values in ppm

*** APL = Above Permissible Limit**
*** BPL = Below Permissible Limit**
*** ND = Not Detected**

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