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Physicochemical Parameters and Heavy Metals in Ground Water Around Dangote Cement Factory Obajana Kogi State Nigeria

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ABSTRACT

The physicochemical characteristics of ground water (well) located at Obajana in Kogi Local Government Area (LGA) of Kogi State were investigated using standard methods. This study was conducted with the aim to determine the impacts of Dangote Cement factory activities located in the area. A total of four (4) ground water samples from different points and the physicochemical parameters and heavy metals were analysed. The pH value ranges from 6.62 – 7.97, total dissolved solids (TDS) values ranges from 320 – 890 mg/L, electrical conductivity (EC) values ranges from 581 – 850 mg/L, Phosphate ranges from 0.68 – 1.05 mg/L, Nitrate ranges from 5.94 – 6.49 mg/L. Turbidity ranges from 7.87 – 8.24 NTU, alkalinity ranges from 0.1 – 0.4 mg/L, dissolved oxygen ranges from 4.2 – 5.2 mg/L, total hardness ranges from 179 – 476.2 mg/L, CT ranges from 29.89 to 73.74 mg/L and temperature ranges from 27°C to 31°C. Metals like Arsenic ranges from 0.027 – 0.029 ppm, Lead ranges from 0.029 to 0.40 ppm, Zinc ranges from 0.002 to 0.006 ppm, Cadmium ranges from 0.061 to 0.074 ppm, Copper ranges from 0.002 to 0.006 ppm, while Iron ranges from 0.015 to 0.069 ppm, and Nickel ranges from 0.002 to 0.006 ppm. These results obtained fell within the maximum allowable limit set by the Nigerian Standard for Drinking Water Quality and World Health Organization for drinking water except for turbidity, dissolved oxygen, phosphate and electrical conductivity and also suggested the need to take adequate and necessary steps in regulating and monitoring of drinking water in settlement around industrial areas.

Keywords: *Well water, physicochemical parameters, heavy metals, Obajana, cement*

1.0. Introduction

Water is fundamental to life on our planet, but this precious resource is increasingly in demand and under threat. The earth's surface is made up of 70% water including rivers, lakes, streams, seas, oceans, ground water and all these forms are very important in life cycle (Arimieari, Sangodoyin, *et al.*, 2014). Of the waters occupying 70% of the earth's surface, only 3% is considered fresh water. (Aniyikaiye, Oluseyi. *et al.*, 2019). Among the freshwater, approximately 5% of them or 0.15% of the entire global water is readily accessible for beneficial purposes. (Usharani, Umarani *et al.*, 2010). Safe and clean water is essential for humankind and nature alike. The increased use of metal-based fertilizer in agricultural revolution of the government could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Also faecal pollution of drinking water causes water borne disease which has led to the death of millions of people. (Adefemi and Awokunmi, 2010). However, surface waters are subjected to enormous pressures, in developing countries surface water may be affected by severe pollution due to its easy accessibility for disposal of wastewater (UN environment, 2019). Once water is contaminated, it's very difficult, costly, and often impossible to remove the pollutants. Globally, about 80 percent of wastewater is currently discharge into water bodies without treatment (UN environment 2019).

Ground water is an important source of water supply in the world which is needed for human survival and industrial development. The ground water chemistry is controlled by the composition of its recharge components as well as geological and hydrological variations within the aquifers (Shahnawaz and Singh, 2009). Polluted groundwater and surface water sources are the cause for the spread of epidemic and chronic disease among human beings. Industrialization and increase in population are responsible for depletion of our groundwater sources (Khodapanah *et al.,* 2009). Improved knowledge is required for understanding and evaluating the suitability of groundwater for different purposes. The knowledge of water-rock interaction as well anthropogenic influence is necessary for eventual utilization and management. Surface water quality comprises physical, chemical and biological qualities of groundwater (Oluseyi *et al*., 2011). Temperature, turbidity, colour, taste and odour make up the list of physical water quality parameters. Since most groundwater are colourless, odourless and without specific taste, the concern is the chemical qualities. Naturally, groundwater contains mineral ions and these ions slowly dissolve from soil particles, sediments and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer. However, human activities can alter the natural composition of groundwater through mining activities, disposal or dissemination of chemicals and microbial matter at the land surface and into soils or through injection of wastes directly into groundwater. Cement industries are generally associated with high dust emissions into atmosphere. Emitted dusts are naturally eliminated as deposits to the earth surface through dry or wet deposition in rainfall (Olaleye, 2005; Asubiojo *et al.,* 1991).

Pollution of freshwater ecosystems can impact the habitat and quality of life of fish and other wildlife. The quality of water varies from sources to sources, place to place and in addition natural and anthropogenic activities are responsible for the enrichment of contaminants (microorganisms, heavy metals and their corresponding salts) in the environment. (Martin, Arana, *et al.,* 2015). Due to the geographical structure and climatic conditions naturally the contamination of metals and various chemicals can exist in the ground water and available natural rocks can be the source for the contamination and augmented concentration. (Dkhar *et al.,* 2014). The concentrations of heavy metals have an important role in life, but if their level becomes higher, they tends to initiate the perilous effects. For example if it crosses the national and international maximum contaminant levels (MCLs); it will result in the metallic poisoning and mortality (in some cases).

The water quality parameters were analyzed and reported in various parts of the globe, the heavy metal concentration was found to be the essential factor to decide the quality of river and ground water. (Durowoju, Odiyo *et al.,* 2016). These industries are providing employment, increasing local incomes and earning foreign exchange for the country. However, these industries discharge their waste directly into the water body, adversely affecting the livelihoods and the day to day life of the whole community of the area. Most industries do not have an effluent treatment plant while those that do have a plant, they have not started operation due to the enormous cost associated with the operation (Emenike, Neris, *et al.,* 2020). Industrial effluents containing chemicals and other harmful products affect the aquatic ecosystem. (Emenike Tenebe, et *al*., 2019). Water intended for human consumption must conform to standard magnitude of physicochemical parameters such as pH, hardness, conductivity and turbidity. It must also abide to certain permissible levels of heavy metals (*Maigari et al., 2014*).

2.0. Materials and Methods

Obajana lies within longitude 6°24'E to 6°27'E and latitude 7°54'N to 7°56'N. It has an undulating surface which gently slopes downward southwest–northeast trend. The study area lies within the Benin-Nigeria shield, situated in the Pan-African mobile zone extending between the ancient Basements of West African and Congo Cratons in the region of Late Precambrian to Early Palaeozoicorogenies (Ekwueme, 2003). Obajana is Located about 45 km away from Lokoja, the facility is accessible via Lokoja-Okene Road. The Dangote Cement Obajana plant is the largest cement plant in Africa with 13.25Mta of capacity across four lines. The plant is equipped with captive power plant, coal mill for power back up and dam for sustainable water supply.

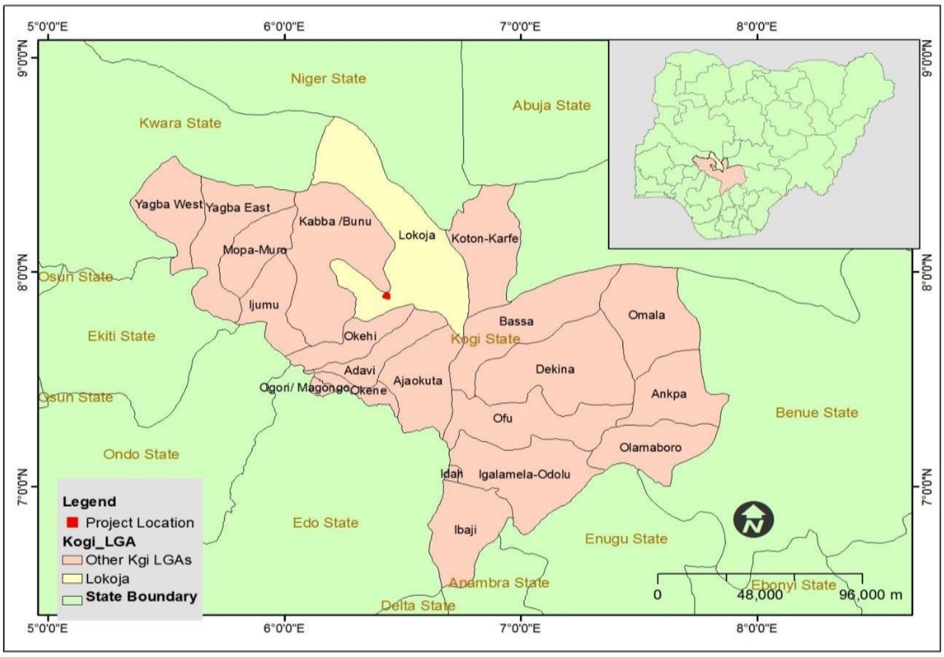

Figure 1 Map of the location of the Obajana cement factory in Kogi state of Nigeria showing the project location

2.2. Sampling

The groundwater was sampled from four (4) different locations around Dangote Cement Factory, Obajana, Kogi State, three (3) of which was sampled from the site of the consumers, while the fourth (4^{th}) was sampled from Mining site in March, 2020. Plastic bottles were used in the collection of each sample and stored in a cool place for laboratory analysis. Parameters such as pH, Electrical Conductivity (EC), Total dissolved solid (TDS) was measured immediately after the samples were collected. Two liters (one liter for the determination of physicochemical analysis and one liter for heavy metal determination) of each water sample was taken in duplicate. The analysis was carried out within one week after sampling. All the chemicals and standard used for the preparation of reagents and solutions were of high purity analytical reagent grade available. A Triple distilled water/ionized water was used throughout the analysis.

Determination of Alkalinity (TA): Alkalinity of water sample was determined by Titrimetric Method. Three (3) drops of Methyl red indicator was added to 25 mL of each sample collected in a washed conical flask and titrated with 0.01 mL of Hcl, total alkalinity was estimated. Methyl red indicator change the color from yellow to pink. Blank titration was done by taking 25 mL of distilled water instead of the sample and precedes the aforementioned procedure.

Total Hardness Determination (TH): Total hardness was determined by Titrimetric Method. To determine the total hardness of water samples, 25 mL of each sample was pipette out in a wash conical flask, 5 mL of ammonia buffer solution and three (3) drop of Eriochrome Black T indicator were added, and the color of the solution turns wine red. This solution was titrated against standardized EDTA solution taken in the burette until the color change from wine red to sky blue which indicates the end point. Blank titration was done by taking 25 mL of distilled water instead of the sample and precedes the aforementioned procedure.

Chloride Determination: Chloride was determined by using Mecurious Nitrate Method. 25 mL of each water sample was placed in conical flask and pH was measured and adjusted 7-8, after that 5 mL Diphenyl-carbazide indicator was added to and titrated with standardized Mecurious Nitrate solution until color change to purple. Similarly blank titration was done by taking 25 mL of distilled water instead of the sample and precedes the aforementioned procedure.

Nitrate determination (NO_3^-): Brucine Colorimetric Method was used for $NO4^{-2}$. to determine nitrate, 1mL of each sample was pipette into washed test-tube with the aid of micro-pipette, 2% of CuSO4 and 1mL of sulfylamide was added to each samples, after which being agitated, 0.05 mL of NED was added, then the sample was proceed to UV-visible spectrometer. Blank titration was done by taking 25mL of distilled water instead of the sample and precedes the aforementioned procedure.

Phosphate determination (PO_4^{3-}): Photometric Method was used for $PO4^{3-}$. To determine phosphate, 1 mL of each was pipette into washed test-tube, 0.1 mL of Hydrazine Sulphate and 0.5mL Ammonium Molybdate was added to the samples. The samples were then agitated, followed by addition of 0.9mL of distilled water. The samples were heated in a water-bath for 30min at 60ºC, then cool for 5min, and then the UV spectrometer was used to determine the phosphate in the samples.

Dissolved Oxygen Determination (DO): Dissolved oxygen was determined by using calibrated dissolved oxygen meter EXTECH (Model 407510_A), the DO was calibrated by switching the DO button in air on the dissolved meter until approximately 21ºC is attained, then the DO button was immediately turned to water and the probe was dipped inside the 50mL of water sample inside the beaker. Then, the DO value was recorded for each sample. Distilled water was used to rinse the probe after each measurement.

Parameters like pH, Temperature, Electrical Conductivity (EC), Total Dissolved Solid (TDS) were measured using Jenway pH-conductivity-TDS meter (Model 3540), before measurement, the probes was calibrated with 0.1M standard phosphate buffer solution, then the probe was immersed in the beaker containing 50ml of water sample, moved up and down and taped on the beaker to free the electrodes from any bubbles. Then data was recorded for each sample. Distilled water was used to rinse the probe after each measurement. Trace heavy metals like As, Cd, Ni, Pb, Fe, Cu, and Zn contents were determined by standard methods prescribed by AOAC using Atomic Absorption Spectrometer (Model AA990).

3.0. Results and Discussion

The physicochemical parameters and heavy metals obtained from the analysis of the water samples from wells in Obajana cement factory are presented in Table 1 and 2. These values were compared with the drinking water quality standards WHO and Nigerian Standard for Drinking Water Quality (NSDWQ).

The average water temperature is 29.3°C which is within the acceptable limit of reasonable water temperature for human use. However, the temperatures of the water samples in mines area and Fisayo area which are close to the mining sites seems to be higher. This could be due to the increase in chemicals in the area as a result of the mining activities and the resultant effect.

pH variable has a major effects on the chemistry of the constituents in water and on treatment process performance. It is therefore imperative that the pH of the source is monitored routinely and that the pH profile is controlled. Dissolved gases and industrial wastes affect the pH value of water and in which changes the test of drinking water. In this study, pH varies from 6.62 - 7.97, which is within the acceptable limits of 6.5 to 8.5.

Dissolved oxygen (DO) is an important regulator of the oxidation-reduction condition that determines the chemical speciation of a number of constituents in water. Oxidizing conditions are produced even when oxygen is present at low concentration. In this study, DO range from 4.2 to 5.4 mg/L, the minimum tolerance for drinking water is 4.0 mg/L. Averagely the DO value is within the acceptable limit for drinking water.

Table 1 Physicochemical Parameters of Well Water Samples.

Physical Parameters	Dangote Area **A**	Fisayo Area **B**	Market Area **C**	Mines Area **D**	NSDWQ	Maximum Limit	WHO
pH	6.62	6.84	7.37	7.97	6.5-8.5	6.5-9.2	6.5-8.5
TDS	347	807	892	512	500	1000	300-600
EC	581	1320	1491	850	1000	1000	500
TA	0.025	0.115	0.345	0.31	200	600	200
TH	179	391	475	269	150	600	500
Cl^-	31.89	63.78	73.74	47.83	250	100	250
PO_4^{3-}	0.69	0.76	0.86	1.05	0.3	0.024	0.1
NO_3	6.49	5.93	6.17	6.42	50	100	45
DO	4.8	5.3	4.4	5.4	5	-	4.0
TD	7	8	8	8	5	5	5
T	29	30	27	31	ambient	-	-

The values are the average standard deviation in three independent analysis. All values are in mg/L except pH and EC (μS/cm) and temperature (T) in °C and TD in NTU

Turbidity is the measure of the particulate matter in water. It affects the choice of clarification methods and can detect whether or not there is need for treatment of water. In this research work, turbidity of the sample varies from 7.87 - 8.24 NTU, the tolerance range for turbidity is 5 NTU according to WHO and NSDWQ (2007) guidelines, so the sample showed higher NTU values than the prescribed range. The value underscores the need for the water to undergo some form of treatment to make it fit for human consumption.

The electrical conductivity of water is due to dissolved mineral ions, the ability of a solution to conduct an electrical current is governed by the migration of solutions and is dependent on the nature and numbers of the ionic species in that solution. This property is called electrical conductivity. It is a useful tool to assess the purity of water. The permissible limit for electrical conductivity (EC) is 300 - 600 μS cm-L, under this analysis, the result of electrical conductivity for all the samples range from 581 - 850 mg/L which measures above WHO limit and this may be as a result of high dissolved mineral ions. This value is within the maximum limit set by the Nigerian standard for drinking water quality (NSDWQ)

Total dissolved solids (TDS) is an important parameter that determines the quality of drinking water. This measure of salt and mineral contentment can affect treatment needs as well as the acceptability of a source of supply. Various types of water soluble mineral and organic matters donate total dissolved solids TDS and can be taken as an indicator for the general water quality because it directly affects the aesthetic value of the water by increasing turbidity. High concentrations of TDS limit the suitability of water as a drinking source and irrigation supply. The acceptable range of TDS is 300 - 600 mg/L and maximum range is 1000 mg/L. The analytical values for the water sample in this research work range from 320 - 890 mg/L, which is within the range of WHO and NSDWQ standard quality for drinking water (500-1000 mg/L).

Alkalinity is the measure of the acid neutralizing capacity of water. The alkalinity of groundwater is mainly due to carbonates and bicarbonates. The acceptable limit of alkalinity is 200 mg/L and in the absence of alternate water source, alkalinity up to 600 mg/L is acceptable for drinking, the result of alkalinity in this study range from 0.1 to 0.4 mg/L which is far below the WHO/NSDWQ standards.

The result of phosphate in this research work range from 0.68 -1.05 mg/L which is far lower than the tolerance range prescribed value. The cause of phosphate in drinking water is mainly due to the use of fertilizer and pesticides, which may be washed into the river or leached down to ground water. Therefore this result shows low level of fertilizer and pesticides use by the resident. Also in this research work, the nitrate content ranges from 5.94 to 6.49 mg/L which is below the tolerance range of 45 mg/L.

The level of total hardness can detect treatment concepts that should be applied. A high level of hardness tends to favour softening. In groundwater hardness is mainly contributed by bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium. So, the principal hardness causing ions are calcium and magnesium. The acceptable limit of total hardness is 300 mg/L whereas the maximum limit is 600 mg/L. The total hardness of analysed water samples in this research work varied from 179.6 to 476.2 mg/L.

Chloride is one of the major inorganic anion in water. In table water the salty taste is produced by the chloride concentration. Chlorides are generally limited to 250 mg/L as prescribed by WHO. The result of chloride analysis in this research work range from 29.89 to 73.74 mg/L which is within the acceptable limit of 200 mg/L set by NSDWQ.

From the result in Table 2, heavy metals were detected in all the four areas sampled except for copper that was not detected in dangote area.

Table 2. Heavy Metals Concentration in Well Water samples.

Heavy metals parameters	Dangote Area (A)	Fisayo Area (B)	Market Area (C)	Mines Area (D)	NSDWQ	WHO
As	0.03 mg/L	0.03 mg/L	0.03 mg/L	0.03 mg/L	0.01 mg/L	0.01 mg/L
Pb	0.03 mg/L	0.03 mg/L	0.04 mg/L	0.04 mg/L	0.01 mg/L	0.01 mg/L
Zn	0.02 mg/L	0.03 mg/L	0.01 mg/L	0.01 mg/L	3.00 mg/L	3.00 mg/L
Ni	0.12 mg/L	0.15 mg/L	0.14 mg/L	0.13 mg/L	0.02 mg/L	0.02 mg/L
Cd	0.07 mg/L	0.06 mg/L	0.06 mg/L	0.06 mg/L	0.003 mg/L	1.00 mg/L
Fe	0.02 mg/L	0.03 mg/L	0.07 mg/L	0.06 mg/L	0.30 mg/L	0.30 mg/L
Cu	ND	0.01 mg/L	0.003 ppm	0.01 mg/L	1.00 mg/L	2.00 mg/L

The values are the average standard deviation in triplicate analysis.

From the result in Table 2, all the heavy metals under consideration (arsenic, lead, zinc, nickel, cadmium, iron and copper) were all detected in all areas except for copper that was not detected in dangote area. Also the concentrations of heavy metals detected were within the allowable limit set by regulatory bodies. In the analysis of water samples around the world, heavy metal concentration was found to be the essential factor to decide the quality of river and ground water (Durowoju, Odiyo, *et al.*, 2016). On the average, the concentrations of arsenic (0.003 mg/L), lead (0.04 mg/L), nickel (0.14 mg/L) and cadmium (0.06 mg/L) and other heavy metals detected vary from one location to another. This could be attributed to distribution of minerals and underlying rock formations that is different from one location to the next. This result is in agreement with the study conducted by Adefemi et al. (2007).

Table 3. Detection limit of heavy metals for perkin model 306AA

Metals	Detection Limit
Zn	0.006
Ar	0.001
Pb	0.004
Cd	0.004
Cu	0.001
Ni	0.005
Fe	0.003

4.0. Conclusions

In this study, the ground water quality in terms of its physical and chemical characteristics were investigated. Results obtained for temperature, pH, total hardness, dissolved oxygen total dissolved solids, sulphate, nitrate, alkalinity, total hardness, chloride and phosphate ions were within the recommended values of Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO). In addition to this it was found that Electrical conductivity (EC) was beyond tolerance limit, Phosphate (PO_4^{3-}) in all sample sites was higher than standard value, turbidity was also found to be higher than the tolerance range in all sampling sites. The concentration of Dissolved oxygen (DO) in all sampling sites was also found to be higher than standard value. These high concentrations suggested that proper treatment and regulation of human and industrial activities is highly required for drinking water in the community.

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