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Examining the Effects of Cement Dust on Surface and Harvested Rainwater in Elebute Community, Southwestern, Nigeria

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Abstract- Cement manufacturing processes produces a significant amount of dust which pollute water sources. Amidst various receptacles for cement dust, roof material employed for rainwater harvesting and exposed surface water bodies are the principal media for cement dust accumulation. In this study, triplicate water samples each from Elebute River and harvested rainwater (from galvanized zinc roof, corrugated aluminum roof, asbestos roof and directly from the sky) were collected from Elebute community (nearest community to Ewekoro cement factory) in sterile, well labelled and air-tight bottles for physico-chemical and heavy metal/ metalloid characterization according to APHA standard. Results obtained revealed that most of the selected physico-chemical parameters fell within the permissible level recommended by the WHO and NIS water quality standard, except concentrations of TDS, TS and total hardness of rainwater samples harvested from aluminum roof. Metal concentrations (iron, zinc and lead) were higher than the WHO permissible limits. High concentration of the toxic metals was associated with the activities of cement production, particulate emissions as well as pollutants from heavy vehicular movement in and out of the factory. Water collected from Elebute River and harvested rainwater within Elebute community requires treatment for potable and domestic usage.

Keywords*- Elebute Community, Cement Dust, Surface Water, Rainwater*

I. INTRODUCTION

Cement industries are generally associated with high dust emissions into the atmosphere [1, 2]. Cement dust originates from the mixing of calcium carbonate, aluminum, silicate, silica oxide and iron oxide as raw materials for cement production in a rotary kiln. These dusts are naturally deposited through precipitation to the earth surface [3, 4]. Rain and wind among other natural phenomena are responsible for large area spread of the dust during and after production of cement in the cement industry.

Cement dusts have adverse effects on the ecosystem when they accumulate overtime on water, plants, animals and soils. Study [5] had showed that the adverse effect of cement dust is as a result of the heavy metals in the dust, though presence of some of these metals are macro-nutrients for humans but poses a toxicological risk at high level [6,7] to man and the environment. The first receptacle for the cement dust is the roof employed for rainwater harvesting and then the earth surface, part of which water occupies as surface water resource.

In developing nations, critical problem has arose owing to unavailability of potable water, which has posed great risk to personal, community and environmental sanitation [8]. Increase in population owing to several factors poses a great stress on the available pipe-borne water and on provision of potable water [9]. Major available sources of water for consumption are groundwater, spring water, surface water and rainwater [10, 11, 12]. Regardless of the source, the water is usually susceptible to pollution from cement dust accumulation, improper sewage and industrial discharge, agricultural runoff, oil spillage, underground tank leakages, un-regulated dredging, indiscriminate organic and inorganic waste disposal amidst others. These pollutants are either washed off the roof or land into surface and groundwater resources [13].

Pollutants in form of solids, liquid or gaseous substances discharged into the environment, adversely affect quality of the ecosystem and usefulness of its resources (aquatic and terrestrial ecosystem) [14]. Among these pollutants, air pollution from undesirable contamination of gas, smoke, dust, fume, mist, odour, and chemical particulates result in significant health risk [15]. These air pollutants include carbon oxides, nitrogen oxides, sulphur oxides, hydrocarbons and particulate matter, which account for about 90% of global air pollution and are emitted directly from either natural events or from human activities like cement production.

Particulate matter deposition [16], fugitive emission [17] and exhaust fumes from vehicles and machines are identified as the major atmospheric pollution problem from Ewekoro cement production plant. Surface water, rainwater harvested from roofs of building and the environments are affected by contaminations from cement dust deposition. Water supply from these sources are the main source of drinking water and other domestic uses for inhabitants of the communities surrounding the cement factory eliciting a great concern because it often give the water a cloudy appearance and low degree of acceptability due to cement dust accumulation. Report from the Nation newspaper [18] revealed that 12 communities affected by the cement dust intrusion are Lapeleke, Akinbo, Oke – Oko, Egbado, Sekoni, Olujobi, Papalanto, Ewekoro, Egba -Ajegunle, Elebute, Alagunto and Itori. According to the report, the first eight communities are situated on areas referred to as 'limestone belt,' while the four others, Elebute inclusive, though have limestone, but quarrying of it can't take place there as they are homes only for the dust accumulation, discharged from the cement factory on regular bases.

Previous studies on the effect of cement dust had focus on its impact on soil and selective green plants [19], on air, water and planktonic quality [20], on groundwater [21], on surface and underground water [22], on water quality of rivers [23]. Report had shown that cement dust intrusion changes water' salt content causing disruption of aquatic communities and reduced water quality [24] for consumption. Regular physical, biological and chemical composition of water resources are very important for public health issues [25]. Therefore, this study assessed the impact of cement dust on the quality of surface and harvested rainwater in Elebute community near Ewekoro cement factory, because rainwater serves as the main source of water supply in the raining season for the community.

II. MATERIAL AND METHODS

A. *Study Area*

The cement factory is located in Ogun State, Nigeria, within the tropical lowland rain forest region of Nigeria. The Local Government area is bounded in the North by Abeokuta, in the East by Obafemi Owode, in the West by Yewa South and Ifo Local government areas. The cement factory (Ewekoro) is on the latitude 6^0 55' N and longitude $3^0$12' E which is about 64 kilometers North of Lagos and 42 kilometers South of Abeokuta. Elebute community is about a km to the cement factory and it is the closest community to the factory, hence the water sampling point.

B. *Materials and Equipment*

Materials and equipment used include tape rule, bowl, bottle, funnel, weighing scale, thermometer, pH meter, conical flask, burette, beakers, measuring cylinder, Atomic Absorption Spectrometer (AAS) amidst others. The reagents used were of analytical grade. The equipment and instruments used were all calibrated to check their status before and in the middle of the experiments.

C. *Water Sampling*

Triplicate water samples each from Elebute River and rainwater samples from galvanized zinc roof, corrugated aluminum roof, asbestos roof and directly from the sky were collected from Elebute community in sterile, well labelled bottles for identification. The roof catchments (zinc, aluminium and asbestos) within the community were selected based on close proximity to each other and cement dust accumulation per time. Rainwater samples were collected directly from the sky by installing three sterilized rainwater collector in each of the designated sampling points. The rain samplers were mounted 1.5 m above the ground to avoid rainwater splashing back into the collector. The pH of samples was determined using a pH meter (HANNA, model 96107) and temperature with thermometer. Gravimetric method was used to determine total dissolved solids (TDS), suspended solids (SS) and total solid (TS) while total alkalinity, total hardness, calcium and magnesium were determined by titrimetric method. Sulphate, nitrate and nitrite were determined by colorimetric method while the metal ions (iron, zinc and lead) were analyzed using atomic absorption spectrometer (AAS). Collected samples were analyzed in accordance with standard methods recommended by the American Public Health Association, APHA [26].

III. RESULTS AND DISCUSSION

A. *Physico-chemical Characterization of collected water samples*

The mean value obtained for the concentration of selected parameters (physico-chemicals, metals and metalloid ion) tested are shown in Table 1.

Water samples were slightly acidic to neutral. Average pH value at 25°C ranged between 6.81 and 7.6 across all sampling points and are all within acceptable WHO and NIS limits of 6.5 - 8.5 and 7.0 – 8.5, respectively. The average pH values (less than 8.3) obtained indicates that the majority of the alkalinity is due to the presence of bicarbonate. The pH is a significant operational water quality parameter because it indicates the hydrogen ion concentration in the water. Water pH concentration fluctuates continuously in response to various factors and inflow parameters. Effluents from cement plant were more often reported to be alkaline in nature, intrusion of pollutants or particulate matter/ emmissions could result to acidic concentration. Water pH values lower than 6.5 are considered acidic for human consumption and can cause health problems [27]. Oluseyi [21] observed acidic pH concentration below the permissible threshold from groundwater samples collected from Ewekoro environs during the dry season of the year unlike the wet season. However, similar results with the present study were obtained from Lafarge cement environ by the same author.

TABLE I. MEAN CONCENTRATION OF SELECTED PHYSICO-CHEMICAL, METAL AND METALLOID IONS IN WATER SAMPLES

	Water Samples from					Water Standard	
Parameters	From zinc roof	From aluminum roof	From asbestos roof	Directly from the sky	From Elebute river	WHO Standard	NIS Standard
pH at 25°C	7.01	7.6	7	7.12	6.81	6.5-8.0	6.5 - 8.5
TDS	394	730	294	100	240	<600	500
Suspend solid	16	30	12	14	10	-	-
Total solid	384	760	306	114	250	500	-
Free carbon dioxide	12.7(28)	6.8(9.68)	4.2(39)	1.7(4.4)	10.1(31)	-	-
Total alkalinity ($mgCaCo_3/L$)	142.9	193.6	199.6	22.6	98	-	20-200
Phenolphthalein Alkalinity	0	0	0	0	0		
Methyl orange Alkalinity	142.9	193.6	199.6	22.6	98		
Chloride ,Cl^-	16.4	70	14	9.4	42	250	200
Sulphate,SO_4	0	70	0	0	0	500	100/250
Nitrate,NO_3	< 10	< 10	< 10	< 10	< 10	50	50
Nitrite,NO_2	0.02	0.02	0.02	1.32	0.013	3	0.2
Total hardness $mgCaCo_3/L$	136	346	104	18	96	500	150
Calcium Hardness	112	276	90	12	54	-	-
Magnesium Hardness	24	70	14	6	42	-	-
Iron, Fe	0.09	0.5	0.3	0.36	0.3	0.1	0.3
Zinc, Zn	0.23	0.2	0.26	0.06	0.13	0.1	3
Lead, Pb	0.015	0.011	0.02	0.012	0.016	0.01	0.01
Silica	48.4	87	57.1	4.3	5.1	100	-

All values in mg/L except pH

The mean value for total dissolved solid (TDS) of most of the water samples except those collected from aluminum roof (730 mg/L) were within the limits set by NIS and WHO standard of 500 and <600 mg/L, respectively. Values obtained from the water samples were relatively high, between 100 – 730 mg/L indicating the intrusion of cement dust, because groundwater samples within the study environ and Lafarge cement industry gave a much lower TDS values ranging between 1 – 65 and 6 – 35 mg/L respectively. By implication soil layers had play a role in the reduction of the TDS concentration. The average high TDS value of water samples collected from aluminum roof (730 mg/L) could be attributed to high deposit of the cement dust on the aluminum roofing material. Water with high TDS value often has low acceptability [28, 29]. EPA [30] associated TDS in water with dissolved solids from natural sources and chemicals from industrial processes like cement production. TDS concentration between 151.3 – 229.5 mg/L was obtained from groundwater collected from a cement production environment [19], these are in agreement with some of the values obtained in the present study. The palatability of water with a TDS level of less than about 600 mg/L is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 700 or 1000 mg/L. The high levels of TDS in water may affect acceptability and may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances [31].

Suspended solid (SS), reflect the concentration of suspended matter in the water samples and as a measure of the physical dirt or impurity in water. For the surface water, it is a function of the upstream and downstream erosion. From Table 1, average concentration of SS obtained ranged from 10 – 30 mg/L, similar results was obtained by Olaleye [20]. Water samples collected from all the sampling points were within the acceptable limit of EPA [30]. The low value of SS for samples collected in River Elebute is an indication that most of the pollutants were washed off almost immediately.

Average total solids (TS) in the water samples ranged from 114 – 760 mg/L. This indicates that cement production releases significant amount of dust not only to the atmosphere, but to surface water as well. All the water samples had TS concentration within the recommended standard of 500 mg/L except for samples collected from aluminum roof which were above the acceptable limit of WHO standard. This was as a result of the proximity of the roof to dust deposition and accumulation.

The average carbon dioxide (CO_2) concentration obtained varied from 1.7-12.7 mg/L and 4.4 – 39 mg/L. Rainwater is naturally acidic because of exposure to atmospheric carbon dioxide. As rain falls to the earth, each droplet becomes saturated with CO_2; and pH is lowered. As surface and rainwater flow over and percolate through surfaces with particulate or rock formations containing calcitic limestone ($CaCO_3$), the acidity produced by CO_2 will dissolve limestone and form calcium and magnesium bicarbonate salts, resulting to increased pH and alkalinity. Alkalinity in natural surface water originates from dissolution of carbonate minerals and from CO_2 in the air. The presence of CO_2 in water adds to the total bicarbonate concentration in the water.

The mean concentration of total alkalinity and methyl orange alkalinity expressed as calcium carbonate, ($CaCO_2$)

were the same for all the samples while the phenolphthalein alkalinity were zero. The mean concentration of total alkalinity from rainwater collected from zinc, aluminum and asbestos roof material were 142.9, 193.6, and 199.6 mg/L while that directly from the sky and Elebute river were 22.6 and 98 mg/L respectively. Alkalinity in water is caused primarily by dissolved minerals [30]. Alkalinity in most natural surface and groundwater is mainly derived from the dissolution of carbonate minerals, and from CO_2 present in the atmosphere. The carbonate species (HCO_3^- and CO_3^{2-}) contribute to total alkalinity. Surface water with relatively high alkalinities has a greater ability to neutralize acidic pollution from rainfall or wastewater, and is able to resist major changes in pH level. Water with low alkalinity is very susceptible to changes in pH. The buffering species that constitute alkalinity are primarily the base anions bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}). Since average pH value obtained was below 8.3, by implication, bicarbonate are the major alkalinity species. Observed phenolphthalein alkalinity was zero, hence, bicarbonate equals methyl orange alkalinity while carbonate and hydroxide were zero mg/L respectively.

Sulphate and chloride content of the water samples were within the acceptable WHO and NIS limit with water source from aluminum roof having the highest value for chloride concentration. The work of Oluseyi [21] showed that groundwater within Ewekoro and Lafarge cement factory had higher concentration of sulphate than the recommended WHO standard in the dry season with a sulphate concentration of 623 and 542 mg/L, respectively, while chloride concentration were within the threshold. High sulphate and chloride content can affect acceptability of drinking water. High concentrations of chloride often give a salty taste to water and the presence of sulphate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste thresholds for sulphate and chloride are in the range of 250 mg/L and 200–300 mg/L, respectively. Sulphate are deposited into waters from industrial wastes and through atmospheric deposition. The ratio of the chloride and sulfate concentrations to the bicarbonate concentration has been shown to be helpful in assessing the corrosiveness of water [31].

The average concentration of nitrate and nitrite in all the water samples were within the WHO permissible threshold of 50 and 3.0 and mg/L, respectively. Similar results had been reported [32].

The mean value obtained for total hardness ranged from 18-346 mg/L. Rainwater samples harvested from roof catchment had higher total hardness value (104 – 346 mg/L) compared to those obtained directly from the sky (18 mg/L). Previous research on quality of rainwater from different roof material [32] obtained lower total hardness value ranging between 29 – 50 mg/L in a non-cement production environment. This construe that cement dust on the roof material play a vital role in the quality of the harvested rainwater. Average value obtained from Elebute River was 96 mg/L. It is imperative to note that anthropogenic activities are most often responsible for contamination of water samples collected from surface water. Hardness is usually not of great health concern at levels found in drinking-water, though it often affect acceptability of drinking water if level is high (degree of acceptability of water hardness may vary for each individual). Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. The taste threshold for calcium ion is in the range of 100 – 300 mg/L with extreme values at 500 mg/L while the taste threshold for magnesium is usually lower than that for calcium [31]. Rainwater harvested directly from the sky and Elebute River was soft. Hardness value less than 100 mg/L is indicative of water softness. Low values of water hardness from Elebute River could be attributed to cement dust on the river or effluent from cement plant [23]. Total hardness level in groundwater samples obtained from Ewekoro and Lafarge cement environs were in the range of 56 – 270 and 20 – 240 mg/L respectively. Mean values obtained from surface and harvested rainwater in this study were slightly higher than that observed from groundwater.

Mean calcium hardness level were between 12 – 276 mg/L while that of magnesium hardness were 6 - 70 mg/L. Calcium and magnesium are directly related to water hardness. The principal sources of calcium and magnesium in most of the water samples are detrital minerals such as plagioclase feldspar, pyroxene, amphibole and garnet [33]. High calcium and magnesium content in water collected from Elebute River, aluminum and zinc roof as compared to samples collected from the sky are probably due to dissolved solids and chemical reaction. Concentrations obtained were within the threshold.

B. Heavy Metals and Metalloid ion Characterization

Average concentration of iron in the water samples were 0.09, 0.5, and 0.3 mg/L for zinc, aluminum and asbestos roofs, respectively while 0.36 and 0.3 mg/L were obtained for those harvested directly from the sky and Elebute River respectively. Samples from aluminum roof and those directly from the sky were above the recommended value of 0.3 mg/L. Previous study in a non-cement environ [32] observed that iron content in harvested rainwater were nil, this is contrary to the average results obtained in the present study. Results obtained in this study revealed a link to cement dust intrusion into the water samples analyzed. Assessment of iron concentration is significance because of its effects on acceptability. High level of iron in water could impact colour to water, hence, should be taken into consideration as part of water monitoring parameter. At levels above 0.3 mg/L, iron stains laundry and plumbing fixtures. When consumed in excess, its damages vital organs in the body. There is usually no noticeable taste at iron concentrations below 0.3 mg/L [31]. NIS standard [34] specified that concentration of iron should not exceed 0.1 mg/L, values obtained were above the NIS standard except those obtained from zinc roof.

Zinc is present in water inform of salts and organic complexes. Mean concentration of zinc in all the water samples ranged from 0.06 – 0.26 mg/L. Drinking water often do not have zinc concentration above 0.1 mg/L. Concentration of zinc in surface water and groundwater often do not exceed 0.01 and 0.05 mg/l, respectively. Higher than 0.1 mg/L zinc concentration in water samples from zinc, aluminum, asbestos and Elebute surface water are indicative of cement dust contamination. All samples had zinc concentration above 0.01 mg/L, indicative of atmospheric cement dust pollution. Zinc imparts an undesirable astringent taste to water at a taste threshold concentration of about 4 mg/L. Water containing zinc at concentrations in excess of 3–5 mg/L may appear opalescent and develop a greasy film on boiling [31].

Mean lead concentration in all the water samples were between 0.011 – 0.02 mg/L, these values were higher than the recommended value of 0.01 mg/L. Similar results were obtained from surface and groundwater samples around a cement factory in Calaber, Nigeria [22]. Groundwater samples from Ewekoro environs were reported to have lower concentrations than the recommended values for iron and zinc while lead had higher concentrations than the permissible limits [21]. High level of lead causes cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems [34]. Heavy metal emissions to the environment among other pollutants have been associated with the activities of cement factories in the course of cement production and high levels of heavy metals have been reported around cement factories compared to unpolluted areas by several studies [35, 36]

Observed silica level in the water samples varied between 4.3 – 87 mg/L. Silica (silicon dioxide) is a compound of silicon and oxygen ($Si0_2$) which occurs in a variety of forms, such as sand, quartz, sandstone, and granite. Studies in humans have shown that breathing certain forms of silica dust (for example, when working in a factory like cement factory) can cause lung damage. Rivers generally contain 4 mg/L silicon. Silicon is generally harmless when present in water, because it is naturally present in large amounts, however, abnormally high concentrations could limit algal growth.

IV. CONCLUSION

In this study, selected physico-chemical characteristics and metal/metalloid ions concentration in rainwater harvested from three different roof media (galvanized zinc, corrugated aluminum and asbestos), harvested directly from the sky and collected from Elebute River (surface water) were examined in Elebute community near Ewekoro cement production industry to assess the impact of cement dust on the quality of the collected water samples. Results obtained shows that most of the physico-chemical parameters fell within the permissible level recommended by the WHO and NIS, except for the concentration of TDS, TS and total hardness of rainwater harvested from aluminum roof. Most of the water samples from the different sampling points had high level of metal ion concentration. High concentration of the toxic metals (iron, zinc and lead) were associated with the activities of cement production, particulate emissions as well as pollutants from heavy vehicular movement in and out of the factory. Hence, cement manufacturing activities produces a significant amount of dust which pollutes water sources. Amidst various receptacles for the cement dust, roof material employed for rainwater harvesting and exposed surface water bodies are the principal media for the dust accumulation. Cement dust on the roof material play a vital role in the poor quality of the harvested rainwater. Attention is required by households utilizing aluminum roof material for harvesting rainwater for domestic uses. More importantly, water from Elebute River and harvested rainwater within Elebute community requires treatment for potable usage.

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