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Investigating The Influence Of Age And Materials of Roofing Sheets On The Quality Of Harvested Rainwater In Sango Ota, Nigeria.

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Abstract: *This study was carried out to investigate the influence of age and materials of roofing sheets on the quality of harvested rainwater in Sango Ota of Ogun State Nigeria, between the months of June and August 2016. The harvested rainwater samples were stored properly and analyzed for physicochemical properties and metal contents. The physicochemical analysis results showed a temperature range of 27.50^oC - 27.80^oC, pH range of 6.51 - 6.81, Dissolved Oxygen range of 5.36 - 8.37mg/L, conductivity range of 7.55-99.25µS/cm, color of 5.00 TCU, turbidity range of 0.76-2.65mg/L, total solids range of 8.70-102.67mg/L, total suspended solids range of 5.60-53.46mg/L and total dissolved solids range of 3.10-56.28mg/L. All these physical quantities had concentration within the recommended guidelines of the World Health Organization, though pH of all the samples tends towards the lower limit of 6.5 of the WHOguidelines. The chemical qualities of Acidity ranged between 6.46-15.11mg/L, alkalinity 2.32-10.55mg/L, total hardness 10.15-44.45m/L, calcium hardness 6.05-22.23mg/L, magnesium hardness 4.10-22.22mg/L, chloride 16.11-33.11mg/L, nitrate 1.26-6.23mg/L, nitrite 0.003 - 0.045mg/L while sulphate had 1.12-17.33mg/L and phosphate had 1.06 – 1.87mg/L and some are below detection limit.All these chemical quantities had concentration within the recommended guidelines of the World Health Organization.Metal qualities ranged between 0.03mg/L for Chromium and 1.08mg/L for Iron. All these values are seen to conform to limits stipulated by the WHO as a guide for potable water. The values obtained were observed not to follow any regular pattern as values for some aged roofing materials were more than those obtained for new roofing materials and values for some new roofing materials were more than those obtained for aged roofing materials, while those for asbestos were more than those for the corrugated iron sheets. It was found in this investigation that the material from which the roof is made may have effect on the rainwater quality as there was a contrast between the concentrations of the roofing materials samples and the control samples. Also, the age of the roofing materials adversely affects the water quality as there are contrast. This can be attributed to the deterioration of aged sheets leading to the release of the embedded chemicals, metals and contaminants into the water as they fall and strike it.*

Keywords: *harvested rainwater, Metal analysis, physicochemical analysis, roofing sheets,water analysis.*

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I. Introduction

Most rural areas in developing countries like Nigeria, may not have access to portable water due to unevenly spread development in the country, inadequate funding of developmental projects, environmental pollution etc. This leave the locales with surface water and ground water and in situations of no surface water or groundwater caused by hard ground, salty, acidic or any other reasons that make the water unpleasant or unfit to drink, it becomes imperative for another source such as rainwater.

Rainwater could be said to offer the cleanest naturally occurring water,though a product of a natural distillation process,but at risk of contamination by airborne particles, smokes, dust, car and engine exhaust, fossil fuel burningand other industrial processes.Contamination of harvested rainwater by chemical pollutants may arise from a variety of materials or substances which it comes in contact with starting from the atmosphere. Rainwater could dissolve gases and wash off chemicals from contacting dust particles and roof materials. It could also dissolve metals. Separation of chemicals from the walls of storage tanks is also possible.In most urban areas in developing country, modern technologies for obtaining drinking water are related to the exploitation of surface water from rivers, streams and lakes, and groundwater from wells and boreholes. However, these sources account for only 40% of total precipitation [1].

Rainwater can be harvested from almost any type of roof which includes, asbestos sheets, corrugated iron sheets, tiled roofs, corrugated mild steel, palm leafed roofs etc. These type of water can be a valuable resource and can be quite safe for drinking when harvested and stored.

Among the various methods for the harvesting or collection of rainwater, roof seems to be the most common as the inhabitants use existing roofs of their houses to harvest the water so as to avoid incurring additional costs. The quality and amount of these water, depends on the total surface area and type of roofing material used. Roofs offer a possible ideal surface for harvesting rainwater as long as they are clean. The most commonly used roofing materials in Nigeria and in the study areas are galvanized iron, aluminum and asbestos.

The quality of drinking water is a powerful environmental determinant of health. Drinking water quality management has been a key pillar of primary prevention of diseases for over one and a half centuries and it continues to be the foundation for the prevention and control of waterborne diseases[2]. In the past, it was believed that rainwater was pure and could be consumed prior to purification and treatment. This may be true in some areas and location that are unpolluted due to high level of industrialization, urbanization and over population; rainwater collected in many locations however contains large number of chemical and nonchemical impurities [3].

Relatively cheap materials can be used for construction of storage containers and roof surfaces as no other equipment may be necessary after initial construction of the roof. This method is relatively straightforward and low or no maintenance costs are required. Collected rainwater can be consumed without treatment, if a clean collecting surface has been used as it provides a supply of safe water close to homes, schools or clinics, encourages increased consumption, reduces the time women and children spend collecting water, reduces back strain or injuries from carrying heavy water containers [1]

In as much as rainwater harvesting through roof seems good, the water can be contaminated by bird or animal droppings on roof surfaces, quality of roofing materials used and deterioration of roofing materials as they age may also affect the quality of this water. Therefore it is necessary to study the effect of the age of various roofing materials on the physical and chemical qualities of rainwater harvested for domestic uses.

II. Materials And Methods

2.0 Description Of Study Area

The study area of this work is Sango Ota in Ado/Odo-Ota Local Government Area of Ogun State, with an area of about 878 km^2 , located at 6°41′00″N 3°41′00″E and a population of about 526,565 at the 2006 census[4].The residential, clinical, religious and educational areas of the study area was chosen due to its similarity with a study done in Abeokuta [3]but with more population. The heavily industrial areas are neglected.

2.1 Method of Sampling and Collection of Rainwater Samples

This sampling was done in similarity with the study at Abeokuta [3]. A random sampling technique or method was employed in selecting the sampled houses. The first field work was to identify houses with the choice roofing material (new and aged asbestos sheets and new and aged corrugated iron sheets) within the study area and then the houses from whose roofs the rainwater samples will be harvested was chosen randomly. The samples were collected between the months of June and July when the rains were peak. Care was taken to ensure that no accidental contamination occurred during sample collection and storage. The rainwater samples were collected into containers and stored in bottles which were previously washed with liquid soap having no fragrance or scent as this could affect one of the physical properties (odor) of the samples. These containers and bottles were then rinsed with sterile (double distilled-de-ionized) water and left to drain to dryness prior to being used for collection. During collection, first flush from the roofs was avoided and not collected as this could contain extremely high amount of contaminants and dirt deposited from the atmosphere. The control sample was collected directly from the atmosphere avoiding any contact. The temperature and pH of the samples were obtained at the spot of collection before the samples were stored in the refrigerator at a temperature of 4^oC prior to being taken to the laboratory for analysis.

2.2 Physicochemical Analysis

The physicochemical parameters were determined using standard methods of water analysis[5] which included suspended solids, total solids dissolved solids, volatile solids, turbidity, pH, acidity, and alkalinity.

2.3 Instrumental Analysis of the Sample

100ml of each of the sample was measured into a 250ml Erlenmeyer flask and acidified with 2M HNO_3. The mixture was swirl to mix properly, evaporated to dry on a steam bath and cooled. 25ml concentrated HNO_3 was added to the cooled residual bath. The flask was placed in a hot plate and the acid evaporated to small volume taking care that there was no spattering in the process. 25ml concentrated HNO_3 and 10ml H_2O was added repeatedly each time completed by repeating the above procedure, and the residue in the flask was white. The following metals were analyzed using Bulk 110 model of Atomic Absorption Spectrophotometer: Iron, Chromium, Manganese, Copper, Aluminum and Zinc.

III. Results And Discussion

Table 1 shows the results physical analysis conducted on the various harvested rainwater samples while table 2 shows the results of analysis of some chemical properties of these water samples and table 3 shows the results obtained from the elemental analysis carried out on the water samples. Table 1 presents the physical parameters of the water samples. The result showed that the temperature of the samples ranged between 27.50^{o}C and 27.80^{o}C with the temperature of asbestos roofing sheets being more than that of the corrugated iron sheets. Thesetemperatures are similar to the values obtained at Abeokuta [3] but slightly higher and as well fell within the range of 20^{o}C to 32^{o}C as stipulated by the WHO[6]. Colors obtained for all samples are 5.0TCU value which are similar to the values obtained at Abeokuta and corresponds with the limit of 15TCU set by the WHO[6].

Average turbidity values for new and aged asbestos sheets were 1.74NTU and 2.65NTU respectively and 1.33NTU and 1.55NTU for new and aged CIS respectively. That for the control samples was 0.76NTU. These values are similar to the values obtained at Abeokuta but slightly higher for aged asbestos, new and aged CIS and control. However, the average turbidity values conformed to the limit of 5.0NTU stipulated by the WHO[6]. High turbidity can be attributed to the high amount of suspended solids and reduces light penetrating ability in the samples and leads to a higher temperature as particles tend to absorb heat.

Dissolved oxygen values obtained are similar to the values obtained at Abeokuta [3] but with5.65mg/L, 5.85mg/L, 8.37mg/L and 7.32mg/L for new and aged asbestos, new and aged CIS respectively with new and aged CIS being slightly higher.

All the samples and the control exhibit electrical conductivity with New and aged asbestos having values of 72.05µS/cm, 74.14µS/cm respectively while new, aged CIS and the control samples had values of 97.90µS/cm, 99.25µS/cm, 7.55µS/cm respectively showing tendency of high amount of dissolved solids and a good indicator of the presence or absence of conductivity ions. The values are different from those obtained in Abeokuta [3] but similar to the results obtained by Eruola et al [7] in Oke-Lantoro, Abeokuta. However, these conductivity values all fall below the limit of 1000µS/cm set by the WHO [8].

The result obtained for average total dissolved solids in this study are below the limit of 500mg/L set by the WHO [8] but showing the TDS values for CIS 51.15mg/L and 56.28mg/L are higher than that of asbestos 49.11mg/L and 49.21mg/L compared to the study in Abeokuta and a slightly higher control of 3.10mg/L which isalso in correlation with the result of study carried out in Abeokuta having a high range 9.67mg/L to 71.00mg/L for asbestos, this was done by Bada et al. [9]. TDS has a huge effect on other characteristics of water samples such as the temperature, turbidity and electrical conductivity.

The high value of TSS obtained for the control 5.60mg/Lis higher than that obtained in Abeokuta and could be an attribute of suspended particles such as dust in the atmosphere since various activities are carried out this environment compared to the location in Abeokuta. The result also shows that TSS values for asbestos samples 51.42mg/L and 53.46mg/L, are both higher than that for CIS 29.54mg/L and24.12mg/L which is similar to the study in Abeokuta but higher.

The total solids value for asbestos 100.53mg/L and 102.67mg/L were higher than that for CIS 80.69mg/L and 80.40mg/L, while the value for control was 8.70mg/L.This valuesmay account for the significant effect noticed on the turbidity, conductivity and temperature of the samples.

The pH of the samples fell within the range of 6.5 to 8.5 set by the WHO [6] but more acidic, with the control having the lowest value of 6.51, followed by that of new and aged CIS 6.58 and 6.62 respectively.The pH values of 6.75 and 6.81 were obtained for new and aged asbestos

Table 2 presents the chemical parameters. The results of total hardness of control sample was 10.15mg/L and those samples of asbestos sheet 41.31mg/L and 44.45mg/L were higherthan that of CIS 29.45mg/L and 21.63mg/L, these can be attributed to the higher amount of total solids in the asbestos samples. However, these values are considered safe as they fall below the range of 100-300mg/L stipulated by the WHO [6] and are seen to be less than that obtained by Olaoye and Olaniyan[10] in Oyo State and also similar to that of Abeokuta. The hardness values of samples have significant effect on its mineral content and alkalinity.

Calcium hardness of samples are safe as they fall below the limit of 75mg/L set by WHO [8]. The values showed that hardness of asbestos 20.11mg/L and 22.23mg/L are higher than hardness of CIS 15.10mg/L and 11.23mg/L. The control has a values of 6.05mg/L.

Magnesium hardness of samples are safe as they fall below the limit of 50mg/L stipulated by the WHO [5]. The values showed that hardness of asbestos 21.20mg/L and 22.22mg/L are higher than hardness of CIS 14.30mg/L and 10.40mg/L. The control has a values of 4.10mg/L. These values were also less than those obtained by Olaoye and Olaniyan, [10] in their activity in Oyo State and also similar to that of Abeokuta.

The sulfate content of all samples except aged asbestos 17.33mg/L, are below detection limit while that for the control sample was 1.12mg/L which are in contrast to the results obtained in Abeokuta, could still regarded as safe as they are below the limit of 100mg/L set by the WHO [8].

Average chloride values obtained were found to be much less than the 90.0mg/L obtained by Olaoye and Olaniyan, [10] in Oyo state and also similar to that of Abeokuta which is less than the maximum of 250mg/L set by the WHO [8]. 33.11mg/L and 21.21mg/L were obtained for new and aged asbestos while 24.13mg/L and 23.25mg/L were obtained for new and aged CIS and 16.11mg/L was obtained for the control. The significance of average chloride content is its effect on salinity. The higher the chloride content, the higher the salinity of water samples [3].

Nitrate content values obtained were found to be much less than the range of 31.9mg/L to 39mg/L obtained by Olaoye and Olaniyan, [10] and also similar to that of Abeokuta which were below the limit of 50mg/L set by the WHO [6]. 6.23mg/L, 6.19mg/L, 3.35mg/L, 3.67mg/L and 1.26mg/L for new and aged asbestos, new and aged CIS and the control respectively. The significance of nitrate is that it affects the oxygen carrying ability of blood- a high nitrate value results in a reduced carriage of oxygen by the blood [3].

Nitrite, the reduced form of nitrate, had values which are all safe as they fall below the limit of 0.2mg/L set by the WHO [6] and are 0.031mg/L and0.045mg/L for aged asbestos and aged CIS respectively and control as 0.003mg/L. Both new new asbestos and new CIS were below detection limit (BDL).

The phosphate content are similar to the results obtained in Abeokuta but the aged CIS was below detection limitand the values for new and aged asbestos, new CIS and the control are 1.17mg/L, 1.87mg/L, 1.06mg/L and 1.43mg/L respectively. Thoughthere is no known limit set by the WHO for phosphate content, a high amount only has a slight temporal effect (interference with digestion) in the body of humans [3].

There is also no known limit set by the WHO for alkalinity and acidity, 6.23mg/L, 10.55mg/L, 7.54mg/L, 8.74mg/L and 2.32mg/L were alkalinity values obtained for new and aged asbestos, new and aged CIS and the control respectively while 7.79mg/L, 6.73mg/L, 15.11mg/L, 12.34mg/L and 6.46mg/L were acidity values obtained for new and aged asbestos, new and aged CIS and the control respectively.

Table 3 presents the result for Zinc content which showed that new asbestos and new CIS and the control were below detection limit while that for aged asbestos and aged CIS were 0.45mg/L and 0.63mg/L respectively. These results are within the limit of 3.0mg/L stipulated by the WHO [6]. These values are found to be in contrast with the study in Abeokuta [3] but correspond with those obtained by Eletta and Oyeyipo[11] and Joanne [2]. Zinc in water is significant in that it is required for good working of the immune system, diarrhea treatment, common cold treatment and wound healing but extreme amounts have adverse effects on the health [3].

Aluminum content of new, aged asbestos, aged CIS and the control were below detection limits, while new CIS was 0.09mg/L a value similar to that obtained in Abeokuta [3] but slightly higher and also within the limit of 0.1mg/L set by the WHO [12]. Very high values of aluminum are associated with a mental disorder known ad dementia- an inability to think and thus should be avoided [3].

High copper content in drinking water is associated with gastrointestinal diseases and long intakes results in liver or kidney damage. However, the average copper content of these samples fall below the limit of 2.0mg/L set by the WHO [6]. 0.31mg/L, 0.34mg/L, 0.42mg/L, 0.44mg/L and 0.07mg/L were values obtained for new and aged asbestos, new and aged CIS and the control respectively. These values are similar with the study in Abeokuta [3] and Eletta and Oyeyipo, [11] but slightly higher and having a lower control.

The average values for the manganese content of new, aged asbestos and control were below detection limit while new and aged CIS were 0.05mg/L and 0.08mg/L respectively. This is lower than the values obtained in Abeokuta [3] and the investigation carried out by Joanne, [2] in Nairobi, Kenya and also fall within the recommended guidelines of 0.4mg/L by the WHO [6].

Iron content of all the samples were also found to be below detection limit except aged CIS having 1.08mg/L. This is similar to the result obtained in Ilorin, Kwara state by Eletta and Oyeyipo, [11] but much higher than that obtained in the investigationcarried out in Abeokuta, Ogun state [3] and that of WHO [6] with standard of 0.3mg/L. Iron play an important role in aiding the transportation of oxygen in the blood and it has no severe hazard when present in large amounts [3].

The average chromium content of samples were 0.07mg/L, 0.08mg/L, 0.58mg/L, 0.61mg/L and 0.03mg/L for new and aged asbestos, new and aged CIS and the control respectively. These values are similar with the study in Abeokuta [3] and found to be slightlyhigher than the limit of 0.05mg/L set by the WHO [6]. However, high amounts of chromium in drinking water can be attributed to cancer and tumor formation and thus should be avoided [3].

IV. Conclusion

The physical and chemical parameters of all the harvested rainwater samples analyzed in this study conformed to the recommended guidelines stipulated by the WHO. The pH of all the samples, tends towards the stipulated lower limit of 6.5 and some parameters such as total dissolved solids, total suspended solids and total solids of asbestos sheet have values much higher than the values of corrugated iron sheets.

The chemical and the elemental parameters followed no regular patter as the values for CIS was more than the values obtained for asbestos in some parameters while the values for asbestos was more than the values obtained for CIS in other parameters. This is similar to the observation made in the study in Abeokuta.It was also found that some of the parameters of the samples havehigher values in the aged than in the new roofing materials. This can be attributed to the deterioration of aged sheet leading to the release of these chemicals and contaminants into the water as they fall and strike it.

In a comparison of thisstudy to that of Abeokuta and those of the literature review, it can be seen that the rainwater in this study area has higher values to that Abeokuta in most parameters but safer when compared to others in the literature review. All the samples contain one contaminant or the other, though at minimal levels, and must undergo some level of purification before they can be used for any domestic function. Drinking water should undergo filtration and boiling or distillation, as well as any other advantageous purification process before being drunk.

Table 1 - Result for organoleptic and physical analysis of harvested rainwater.

Parameters	**NA**	**AA**	**NCIS**	**ACIS**	**C**	**WHO**
Temperature ^{O}C	27.60±0.05	27.80±0.03	27.50±0.05	27.65±0.05	27.80±0.04	20 – 30
Color TCU	5.00±0.00	5.00±0.00	5.00±0.00	5.00±0.00	5.00±0.00	15.00
Turbidity NTU	1.74±0.03	2.65±0.04	1.33±0.06	1.55±0.07	0.76±0.08	5.00
Dissolved Oxygen	5.65±0.05	5.85±0.06	8.37±0.04	7.32±0.05	5.26±0.01	4.00
Conductivity μS/cm	72.05±0.02	74.14±0.06	97.90±0.03	99.25±0.02	7.55±0.06	1000
Total Dissolved Solids	49.11±0.04	49.21±0.05	51.15±0.04	56.28±0.03	3.10±0.06	500
Total Suspended Solid	51.42±0.03	53.46±0.04	29.54±0.07	24.12±0.08	5.60±0.04	500
Total Solids	100.53±0.06	102.67±0.04	80.69±0.05	80.40±0.06	8.70±0.06	1200
pH	6.75±0.02	6.81±0.02	6.58±0.03	6.62±0.02	6.51±0.03	6.5-8.5

N.B; NA- New Asbestos, AA- Aged Asbestos, NCIS- New Corrugated Iron Sheet, ACIS- Aged Corrugated Iron Sheet, C- Control Experiment, WHO- World Health Organization.
Values are in mg/L except otherwise stated.

Table 2 - Result for chemical analysis of harvested rainwater.

Parameters	**NA**	**AA**	**NCIS**	**ACIS**	**C**	**WHO**
Total Hardness	41.31±0.12	44.45±0.10	29.45±0.13	21.63±0.11	10.15±0.13	100-300
Calcium Hardness	20.11±0.10	22.23±0.11	15.10±0.12	11.23±0.11	6.05±0.11	75
Magnesium Hardness	21.20±0.11	22.22±0.10	14.30±0.11	10.40±0.12	4.10±0.11	50
Sulfate	BDL	17.33±0.07	BDL	BDL	1.12±0.05	100
Chloride	33.11±0.09	21.21±0.06	24.13±0.07	23.25±0.04	16.11±0.05	250
Nitrate	6.23±0.07	6.19±0.05	3.35±0.06	3.67±0.08	1.26±0.05	50
Nitrite	BDL	0.031±0.01	BDL	0.045±0.01	0.003±0.01	0.2
Phosphate	1.17±0.04	1.87±0.03	1.06±0.08	BDL	1.43±0.06	
Alkalinity	6.23±0.05	10.55±0.04	7.54±0.04	8.74±0.07	2.32±0.06	
Acidity	7.79±0.10	6.73±0.09	15.11±0.03	12.34±0.09	6.46±0.08	

N.B; NA- New Asbestos, AA- Aged Asbestos, NCIS- New Corrugated Iron Sheet, ACIS- Aged Corrugated Iron Sheet, C- Control Experiment, WHO- World Health Organization.
Values are in mg/L except otherwise stated.

Table 3 - Result for elemental analysis of harvested rainwater.

Parameters	**NA**	**AA**	**NCIS**	**ACIS**	**C**	**WHO**
Zinc	BDL	0.45±0.02	BDL	0.63±0.03	BDL	3.00
Aluminum	BDL	BDL	0.09±0.07	BDL	BDL	0.10
Copper	0.31±0.01	0.34±0.04	0.42±0.02	0.44±0.04	0.07±0.05	2.00
Manganese	BDL	BDL	0.05±0.01	0.08±0.06	BDL	0.40
Iron	BDL	BDL	BDL	1.08±0.07	BDL	0.30
Chromium	0.07±0.05	0.08±0.07	0.58±0.01	0.61±0.03	0.03±0.01	0.50

N.B; NA- New Asbestos, AA- Aged Asbestos, NCIS- New Corrugated Iron Sheet, ACIS- Aged Corrugated Iron Sheet, C- Control Experiment, WHO- World Health Organization.
Values are in mg/L except otherwise stated.

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