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Chemical and Physical Properties of Harvested Rainwater from Different Roofing Sheets in Abeokuta, Ogun State

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Abstract
Access to a regular supply of safe water is a basic human right but many people are denied. Rainwater is available for everybody use. This study investigated the physical and chemical properties of rainwater harvested from different catchment roofs in Abeokuta, Ogun Sate. Sterilized buckets were used to collect runoff from five (5) different roofing materials (metal sheets(pan), painted metal sheets, galvanized metal sheets, asbestos(slate) and anodized alluminium) and direct source (control) from June to October, 2010. Sample collection was replicated three times. The runoffs were analyzed for pH, temperature, Electrical Conductivity (EC), Total Dissolved Solid (TDS), chromium (Cr), lead (Pb) and zinc (Zn). pH, temperature, EC, TDS were determined immediately in the sample. Analysis of the heavy metals was done using Flame Atomic Absorption Spectrophotometer. Data obtained were subjected to descriptive statistics, analysis of variance and means were separated using Least Significant Difference (LSD). All the physical and chemical properties investigated except pH, Cr and Pb decreased from the month of June to October. Cr and Pb were not detected in all the roofing sheets throughout the five months. Control had the least concentration of Zn throughout the months while galvanized metal sheets had the highest concentration. Zn concentration in the month of June ranged from 0.09 – 3.39 mg/l with coated pan having significantly ($p < 0.05$) higher Zn concentration. Provision of potable water to the entire population is necessary to avoid taken water contaminated with metals.

Key words: Quality assessment; Rainwater; Roofing sheets

Introduction
Water is essential to all forms of life. It is second in ranking, next to air in the list of human daily needs (NEST, 1991). Without water, humans cannot live for more than a few days. Water is in great demand (Aderogba, 2005) as it represents a unique feature in every settlement: for drinking, sanitation, washing, fishing, recreation and industrial processes. Assess to clean and regular water supply is a basic human right as is access to unadulterated food. A lot of people especially the less affluent however miss out on this as with other human rights.

Rainwater harvesting is a technology used to collect and store rain water from relatively clean surfaces such as roofs, land or rock catchments. The harvested water is usually stored in tanks or channeled to recharge underground water. Rain water harvesting is one of the most promising alternatives for supplying water in the face of increasing scarcity and escalating demand.

Roof-top harvesting systems are most commonly used as the quality of harvested water is reasonably good if the harvesting procedure is coupled with proper installation and maintenance. The quantity and quality of rainwater harvested depends on the rain intensity, the roof's surface area, the type of roofing material and the surrounding environment. It is generally believed that roof runoffs are significantly cleaner than other storm water sources.

This may not be generally true as roofs have a potential to release dissolved and particulate metals such as lead, copper, zinc and total metals generally into collected water (Forster, 1996).

Roofs are made of a variety of materials which can be potential sources of dissolved ions, alkalinity and trace metals. Asbestos sheets (Slates), painted or coated galvanized iron (Pan) and anodized aluminum are most commonly used as roofing sheets in Nigeria. With the health risks associated with asbestos as well as the possibility of leaching from roofing sheets, there is need to investigate physical and chemical properties of water harvested from the various roofing sheets commonly used in Nigeria.

Materials and Methods

Study Area

The study area, Abeokuta is a town on longitude 3^0 26' – 3^0 40'and latitude 7^0 9' – 7^0 14' in Ogun State, South-western Nigeria. Figure 1 shows the map of the study area. The geology of the town is essentially basement rock and it enjoys a favorable climate. The climate of Abeokuta follows a tropical pattern with the rainy season lasting for between seven and eight months between April and October with an interruption in August and the dry season running through November till February. The total rainfall distribution for the months of June, July, August, September and October 2010 were 100.8 mm, 322.9mm, 266.6 mm, 257.6 mm and 172.3 mm respectively (FUNAAB Meteorological Station, 2010)

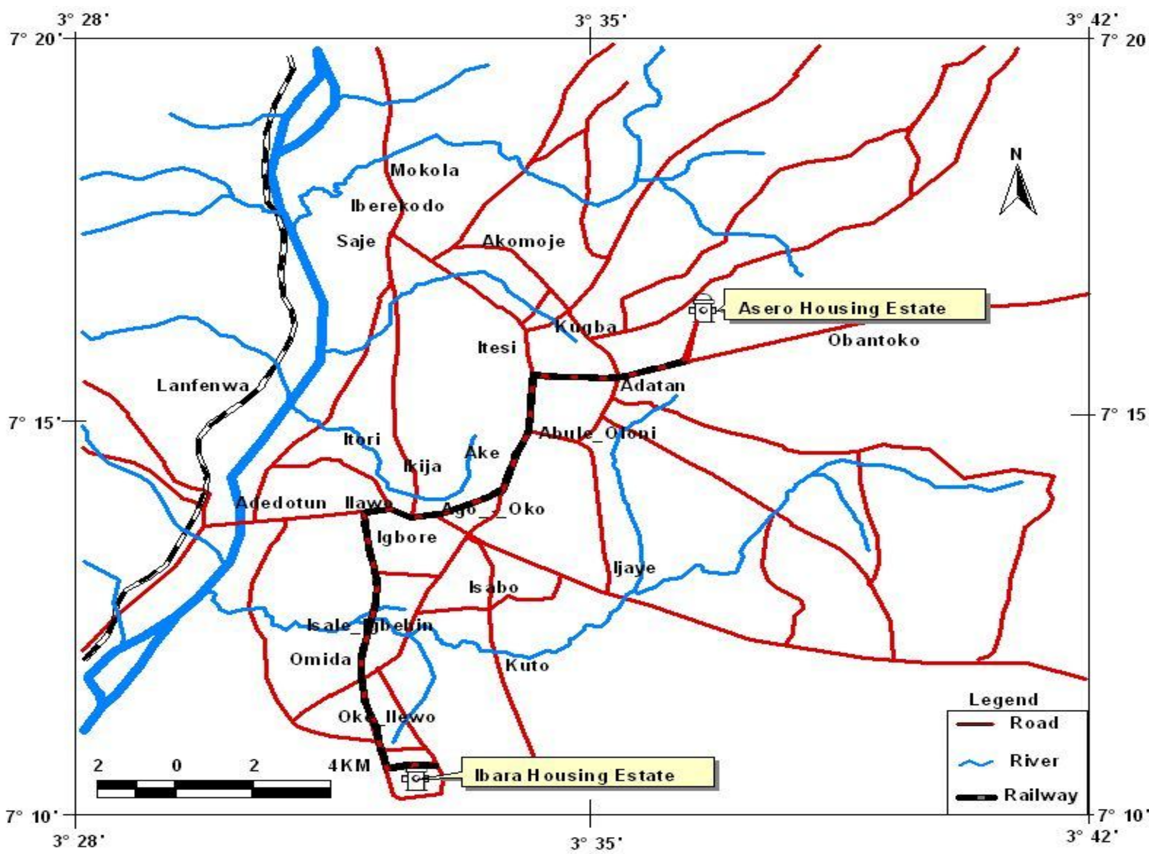

Figure 1: Map of the study area

Sample Collection and Analysis

Rainwater was harvested from seventy five (75) sampling sites consisting of five different roofing materials between June and October 2010 from the densely populated areas of Abeokuta, Ogun state Nigeria. The samples were collected after several rainfalls to minimize pollution due to atmospheric sources. Fifteen (15) samples were also collected directly from the sky to serve as control.

The samples were directly collected from the roof tops in 1L acid leached polythene containers for the determination of total metal concentrations of three selected metals. The pH, temperature, electrical conductivity (EC) and total dissolved solids (TDS) were determined in the samples immediately after collection. One hundred milliliters (100 ml) of the sample was digested with 20 ml of Conc. HNO_3 at 100^0C for 6 hrs to almost dryness in a Teflon beaker. The metals were recovered with 20 ml of 1% HNO_3, centrifuged and decanted. The blank was taken on the reagents through the complete procedure except that the sample was omitted. Replicate analysis was made on the samples.

The concentrations of Cr, Zn and Pb were determined in the samples and the blank with a computerized Buck Scientific model 210 VGP atomic absorption spectrophotometer. Standard solutions of the respective metals were used for instrument calibration. All chemicals were of analytical grade.

Results and Discussion

The physical and chemical properties of harvested water samples for the months June, July, August, September and October were presented in Tables 1 to 5. Values obtained in this study were compared with the World Health organization standard.

Table 1: Physical and chemical properties of harvested water in June

Roofing Sheet	pH	Temp. (^0C)	EC (µScm-1)	TDS (mg/L)	Cr (mg/L)	Zn (mg/L)	Pb (mg/L)
Metal Sheet (Pan)	6.20	27.17	77.33	38.67	nd	1.26	Nd
Asbestos (Slate)	6.45	27.10	141.70	71.00	nd	0.14	Nd
Painted Metal Sheet	6.27	27.13	69.67	34.67	nd	1.43	Nd
Galvanized Metal Sheet	6.18	27.07	50.33	24.33	nd	3.39	Nd
Anodized Aluminum	5.75	27.07	27.33	13.33	nd	0.37	Nd
Control	6.11	26.33	16.00	8.00	nd	0.09	Nd
LSD	0.23	0.14	7.10	3.61	nd	2.51	Nd
WHO	6.5-8.5	25	-	1000	-	3.00	0.01

Table 2: Physical and chemical properties of harvested water in July

Roofing Sheet	pH	Temp. (⁰C)	EC (µScm-1)	TDS (ppm)	Cr (mg/L)	Zn (mg/L)	Pb (mg/L)
Metal Sheet (Pan)	6.21	27.13	34.00	17.00	nd	1.57	Nd
Asbestos (Slate)	6.03	27.03	43.33	19.67	nd	0.11	Nd
Painted Metal Sheet	5.84	27.03	28.67	14.00	nd	1.94	Nd
Galvanized Metal Sheet	5.81	27.00	21.67	11.00	nd	3.26	Nd
Anodized Aluminum	5.87	27.07	28.00	14.00	nd	0.25	Nd
Control	5.75	27.07	11.00	5.67	nd	0.02	Nd
LSD	0.23	0.14	7.10	3.61	nd	2.51	Nd
WHO	6.5-8.5	25	-	1000	-	3.00	0.01

Table 3: Physical and chemical properties of harvested water in August

Roofing Sheet	pH	Temp. (⁰C)	EC (µScm-1)	TDS (ppm)	Cr (mg/L)	Zn (mg/L)	Pb (mg/L)
Metal Sheet (Pan)	7.55	25.70	19.33	9.67	nd	0.77	Nd
Asbestos (Slate)	7.48	25.70	30.67	15.33	nd	0.14	Nd
Painted Metal Sheet	7.32	25.63	12.67	6.00	nd	0.92	Nd
Galvanized Metal Sheet	7.73	25.70	11.67	5.33	nd	1.79	Nd
Anodized Aluminum	7.48	25.63	11.00	5.00	nd	0.30	Nd
Control	7.49	25.47	8.00	4.33	nd	0.10	Nd
LSD	0.23	0.14	7.10	3.61	nd	2.51	Nd
WHO	6.5-8.5	25	-	1000	-	3.00	0.01

Table 4: Physical and chemical properties of harvested water in September

Roofing Sheet	pH	Temp. (⁰C)	EC (µScm-1)	TDS (ppm)	Cr (mg/L)	Zn (mg/L)	Pb (mg/L)
Metal Sheet (Pan)	7.46	26.37	12.33	6.00	nd	1.67	Nd
Asbestos (Slate)	7.34	26.43	22.33	11.00	nd	0.18	Nd
Painted Metal Sheet	7.58	26.43	11.33	5.67	nd	1.97	Nd
Galvanized Metal Sheet	7.39	26.47	11.33	5.67	nd	2.27	Nd
Anodized Aluminum	7.54	26.40	10.33	4.67	nd	0.38	Nd
Control	7.24	26.20	8.00	3.67	nd	0.12	Nd
LSD	0.23	0.14	7.10	3.61	nd	2.51	Nd
WHO	6.5-8.5	25	-	1000	-	3.00	0.01

Table 5: Physical and chemical properties of harvested water in October

Roofing Sheet	pH	Temp. (^{0}C)	EC (µScm-1)	TDS (ppm)	Cr (mg/L)	Zn (mg/L)	Pb (mg/L)
Metal Sheet (Pan)	7.13	27.17	12.67	6.33	nd	0.97	Nd
Asbestos (Slate)	7.35	27.00	19.33	9.67	nd	0.11	Nd
Painted Metal Sheet	7.50	27.01	11.67	5.33	nd	0.53	Nd
Galvanized Metal Sheet	7.42	27.10	10.17	5.30	nd	1.01	Nd
Anodized Aluminum	7.30	27.03	9.00	4.00	nd	0.25	Nd
Control	7.18	27.10	7.33	3.67	nd	0.06	Nd
LSD	0.23		7.10		nd		Nd
WHO	6.5-8.5	25	-	1000	-	3.00	0.01

The results of the analysis of the blank solution indicate no contamination from the reagents used as all the metals were below their detection limits. Results showed that all parameters except temperature in the harvested water were significantly different from that of the control. Roof tops could contain droplets from birds, leaves, atmospheric deposition and other assorted materials which could account for these differences.

Temperature of harvested water did not follow a distinct pattern reflecting the variability of the atmospheric temperature. The pH of harvested water varied considerably from that of the control and did not follow any pattern. While some of the values fell within the range (6.5 – 8.5) stipulated by the WHO for water quality of rain water systems, others did not. These were however still accepted as they did not fall below 5.7, the pH of water in the environment due to the presence of atmospheric CO_2. No significant difference exists between the temperatures of the water samples.

According to the results, harvested water for the months of June and July appear to be relatively acidic with pH ranging from 5.75 – 6.45 and 5.75 – 6.21 respectively. However, from August when rainfall was at its peak, harvested water tended towards slight alkalinity. pH values of 7.32 – 7,73, 7.24 – 7.58 and 7.13 – 7.50 were obtained for August, September and October respectively.

Electrical conductivity (EC) values of harvested water from asbestos sheets were significantly higher than that obtained for other roofing sheets. A value of 141.7 μScm^{-1} was obtained for asbestos compared to 16 μScm^{-1} in the control in the month of June. The roofing sheets with respect to EC can be arranged in the order: asbestos > metal sheet > painted metal sheet > galvanized metal sheet > anodized aluminum. This might be due to the type of roofing material which could have an impact on the chemical properties of harvested water. EC values were observed to reduce as the months went by for all the roofing sheets. By October, a range of 12.67 μScm^{-1} – 19.33 μScm^{-1} was obtained compared to 7.33 μScm^{-1} in the control, the highest being that of water harvested from asbestos sheets. The electrical conductivity of water samples collected from the different roofing sheets were significantly ($p < 0.05$, LSD = 7.10) different from that of the control. This indicates that the type of roofing material can have an impact on the chemical properties of harvested water.

The total dissolved solids (TDS) also recorded high values in water from asbestos roofing sheets than others. In June, a range of 13.33 mg/L – 71 mg/L was recorded compared to 8.00 mg/L in the control. The TDS of water samples collected from the different roofing sheets were significantly ($p < 0.05$, LSD = 3.61) different from that of the control. Components of asbestos might dissolve in water during harvesting accounting for the higher TDS. Aluminum and metal sheets have smooth surfaces and high heat capacity which ensures that depositions on the sheets dry off quickly and swept off the surfaces by rain or wind. Asbestos surfaces however have the potential to retain most contaminants (Ayenimo *et al*., 2006). These in turn may alter the quality of harvested water from these surfaces.

The TDS content of water can be a good indication of contamination or low quality of water. According to most authors, metals are strongly associated with particles in runoffs (Dannecker and Stechman, 1990). As expected, the TDS of harvested water from all the roofing sheets reduced as the months went by.

The EC, which is the property of a substance which enables it to serve as a channel or medium for electricity and the TDS, which measures the amount of dissolved salts in the water are both measures of the dissolved salts in the water (Salinity). Pure rain water is estimated to have an EC < 15 μScm^{-1} and a TDS < 10 mg/L (Deas and Orlob, 1999)

Cr and Pb content of harvested water were less than the detection limits of the spectrophotometer used (0.005 mg/ L and 0.08 mg/ L respectively). Zn was however observed to be present in all samples. In June, Zn concentrations ranged between 0.365 mg/L – 3.385 mg/L compared to a concentration of 0.088 mg/L in the control. The highest concentration was observed in galvanized metal sheets.

Zn is an essential metal required by the body for a lot of physiological functions. However at concentrations greater than required, it becomes toxic. Overdose on Zn can depress the immune system, cause anaemia, and copper deficiency, and decrease high density lipoprotein cholesterol in blood (Akhter *et al*., 2002). From results, only harvested water from galvanized metal sheets in the months of June and July exceeded that standard of 3 mg/L set by the WHO. The higher Zn content of water from metal sheets (painted, unpainted or galvanized) indicates that they could be potential sources of metals than other roof types. This observation agrees with the reports of Gadd and Kennedy (2001) that galvanized metal sheets contribute more to Zn in roof runoffs.

Conclusion

A preliminary assessment of harvested water is essential before use as they could contain substance that may be harmful. In this study, asbestos roofing sheets were observed to impact more on the EC and TDS content of water, while metal sheets impacted on the Zn content. The effect of metallic sheets may become aggravated in the incidence of acid rain as enhanced corrosion and leaching may occur from the surfaces.

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