Asian Journal of Chemical Sciences

4(1): 1-6, 2018; Article no.AJOCS.35442
ISSN: 2456-7795

Determination of Heavy Metal Concentrations of Rain Water Harvested from Different Roofing Sheets in Outskirt of Makurdi, Benue State, Nigeria

B. L. Gav[1*], R. N. Vesuwe[1], A. O. Ijeomah[1], E. E. Okoko[1], P. N. Tor[1] and J. N. Tsaviv[1]

[1]Department of Chemistry, Federal University of Agriculture Makurdi, PMB 2373, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOCS/2018/35442
Editor(s):
(1) Dilip Kumar Maiti, Professor, Department of Chemistry, University of Calcutta, India.
Reviewers:
(1) Abida Begum, P. E. S. School of Engineering, India.
(2) U. A. Birnin-Yauri, Usmanu Danfodiyo University, Nigeria.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/23533

Original Research Article

Received 23rd June 2017
Accepted 28th August 2017
Published 10th March 2018

ABSTRACT

Roofing sheets (coloured, colorless and rusted) in Sochia and Demekpe areas of Makurdi Benue state, Nigeria were analyzed to determine the level of heavy metals (Fe Zn, Cu, Pb and Cd) using Atomic Absorption Spectrophotometeric method (AAS). The result ranged from 1.58 mgL – 3.00 mg/L (Zn), 2.15 m/gL - 3.80 mg/L (Fe), 0.04 mg/L – 0.06 mg/L (Cu), 0.02 mg/L – 0.09 mg/L (Pb) and 0.02 mg/L – 0.08 mg/L (Cd). For Zn, Fe, Cu and Cd in coloured, colourless and rusted roofing sheets respectively. There was significant difference ($P \leq 0.05$) between water from coloured, colourless and rusted roofing sheets. The concentration of Zn, Fe, Cu and Cd in the rain from rusted roofing sheets were higher, followed by that from the coloured roofing sheets while that from the colourless roofing sheets have the least concentration. All the parameters examined in the rain water samples have values that are below or within the maximum permissible limits of WHO [8] standard for drinking water quality except in rusted roofing sheets where the rain water have values above the maximum permissible limits of WHO standard for drinking water. Therefore rain water harvested from rusted roofing sheets is not safe for human consumption.

**Corresponding author: E-mail: benedictgav@gmail.com;*

Keywords: Heavy metals; roofing sheets; rain water harvesting; AAS.

1. INTRODUCTION

Water is an essential indispensable natural resource for the survival and sustainability of life and for many industrial processes. Pure water is an odourless, tasteless, colourless and transparent liquid (although may appear to have a blue coloration in larger volumes like in seas and oceans). Its major chemical components include; hydrogen and oxygen in the ratio of 2:1 combined in the atmosphere according to the equation;

$$H_{2\,(g)} + ½O_{2(g)} \rightarrow H_2O_{\,(g)}$$

Water is largely conserved in various natural and/or artificial ways such as lakes, rivers, seas, oceans and in underground. (i.e. wells and bore-holes) from rains or sometimes rocks. Pure, clean and safe water exists most times temporarily in nature only to be contaminated by the influence of human and/or industrial activities. Water supply for human consumption should be adequate and free from foreign matters (chemical or biological) that is capable of threatening human health. Poor water quality and bad sanitation are hazardous; about five million deaths a year are said to accrue from polluted/contaminated drinking water [1]. The World Health Organization (WHO) estimated that safe water could prevent 1.4 million children death from diarrhea each year [2]. Water finds it's applications in agriculture, transportation, in manufacturing industries and domestically to say the least.

Rain as a major source of water is a condensed vapour (humidity) in the atmosphere which precipitates and falls to the earth in form of droplets due to gravity which can be harvested from roof run offs or directly received into basins like rivers, seas, oceans, and eventually underground. Rain is a major component of the water cycle. The major cause of rain production is moisture moving along three dimensional zones of temperature and moisture contrast known as weather-fonts. If sufficient moisture and upward motion is present, precipitation falls from connective clouds such as thunder clouds which can organize into narrow bands. In mountainous areas like Mambilla hills in Gembu local government area of Taraba State, heavy precipitation is possible where up-slope flow is maximized within windward side of the terrain at elevation which forces moist air to condense and fall out as rain- fall along the sides of mountains. The only possible time when rain water might be considered to be almost pure (in case of dissolved gases and dust) is when the water is harvested directly from the rain without any form of interception. However material mediums are required in order to harvest a large volume for drinking and other purposes, hence the need to use run offs with properly designed gutters like corrugated roofing sheets, Ordinary zinc-coated roofing sheets, and rusted roofing sheets as the case may be, because of these medium of collection, the rain water can become contaminated with heavy metals [3].

Heavy metals are those chemical elements that have specific densities above 5g/cm^3 and have the ability to threaten human health upon consumption. They may occur in rain water naturally when the water comes in contact with rocks or by means of contamination from roof runoffs. The extent of contamination depends on the nature of the collection medium (roofing sheet). Heavy metals have been excessively released into the environment due to increased industrial processes from manufacturers of fertilizers to high production of industrial wastes, which may become deposited on roof sheets [4].

Trace metals are common in water and these are normally not harmful to human health, example of such metals include calcium, magnesium, potassium and sodium which are essential for normal body functions. However, other metal like iron, manganese and zinc are only needed at low levels in the body to serve as catalysts for enzyme activities. The major threat to human health occurs mainly in cadmium, lead, and arsenic. Other water-contaminant heavy metals include nickel, platinum, vanadium, cerium, copper, chromium e.tc. Long-term exposure to heavy metals may result into slowly progressing physical, muscular and neurological degenerative processes that manifests Alzheimer's disease, Parkinson's disease, muscular dystrophy, multiple sclerosis [5], diabetes mellitus, hypertension and ischemic heart disease. Repeated long term contact with some heavy metals or their compounds may cause cancer [2].

Even though rain water may be good enough for drinking and may require little or no further artificial treatment, it may not be completely healthy for direct consumption due to contaminations by some environmental factors

like air-bone debris, droppings from climbing animals or flying birds on roof tops and runoff components (heavy metals). The communities depend on rain water collected from these roofs during raining season. Most of these roofs are rusted and it is possible that water collected from them could be polluted by zinc and iron as a result of the rust.

Battling with the scarcity of water may leads to develop some of the newer frontiers for rain water harvesting techniques, which will enhance the management of water pollution in such areas where portable water is lack due to increased level of pollution by heavy metal contamination from roof sheets. This particular study is aimed to monitor the level of pollution occurs at the base line level of water harvesting system rather will provide future references to manage problems of severe water scarcity.

2. MATERIALS AND METHODS

2.1 Study Area

Benue State is one of 36 States of the Federal Republic of Nigeria located in the north-central region. The state is made up 23 local government areas and it lies within the lower river Benue trough in the middle-belt region of Nigeria. Its geographical coordinates are longitude 7° 47′ and 10° 0′ east. Latitude 6° 2.5′ and 8° 8′ north and shares boundaries with five other states namely: Nasarawa state to the north, Taraba state to the east, Cross-River state to the south, Enugu state to the south-west and Kogi state to the west. The state also shares a common boundary with the Republic of Cameroun on the south-sast. Benue state occupies a landmass of 34,059 km^2. According to the 2006 national census [6], the

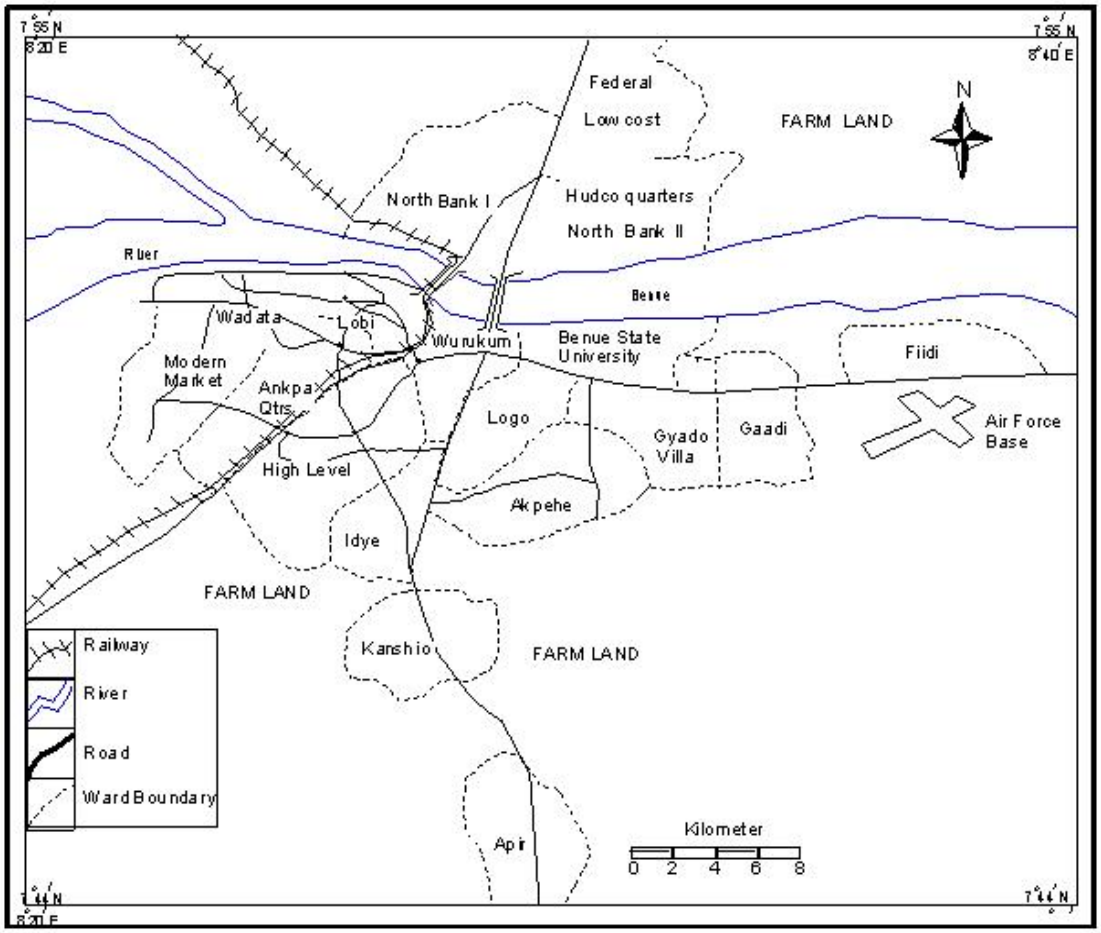

Fig. 1. Map of Makurdi showing location of study areas
Source: Benue State Urban Development Board Makurdi (2010)

State has a population of about 4.25 million people. It is inhabited predominantly by the Tiv and the Idoma peoples. There are other ethnic groups including Igede, Etulo and Abakwa, Jukun, Hausa, Akweya and Nyifon. With the capital at Makurdi, Benue is a rich agricultural region. Some of the crops grown are cassava, potatoes, guinea corn, yam, soya beans, rice, ground-nuts etc. The physical features of the area are generally low lying (100 m -250 m) and gently undulating with occasional inselbergs, knoll, laterite etc. The state has the typical climate of the tropical zone because of its location. Its climate is quiet pleasant with average maximum and minimum temperatures of 35°c and 21°c in summer and 37°c and 16°c in winter respectively. The climate is characterized by two distinct seasons i.e the dry and wet. The dry season spans from October to march while the wet season is from April to September. The months of December, January, February are cold due to harmattan wind blowing across the local government areas from the north-east. The sediments are generally sandy-loam shelf basement complex and alluvial plain. The vegetation of the state consists of rain forests which have tall trees, tall grasses and oil palm trees. More than 80% of the inhabitants are predominantly farmers [6].

2.2 Collection of Samples

A total of nine samples of rain water were collected from different rains over different roofing sheets (corrugated, ordinary and rusty roofing sheets) in containers between July and November 2015 from two different locations (Sochia and Demekpe) in Makurdi local government of Benue state and stored in a refrigerator at temperature of 4°c prior to analysis.

Figs. 2, 3, 4 shows the different roofing sheets in the communities in the study locations;

Fig. 2. Ordinary (colourless) roofing sheet

Fig. 3. Corrugated (coloured) roofing sheet (zinc)

Fig. 4. Rusted roofing sheet

2.3 Sample Preparation

All rain water samples collected were taken into plastic containers, corked and stored in a refrigerator at temperature of 4°c prior to analysis. 100 cm^3 of each water samples was pipette into 250 cm^3 beaker and 15 cm^3 on concentrated HNO_3 and 5cm^3 concentrated HCl were added. The solution was meant to digest the particulate matter by heating the solution in a bath, until the solution was evaporated to about 20 cm^3. It was cooled, filtered and transferred into 100 cm^3 volumetric flask. The solution was diluted up to the mark with distilled water [7].

2.4 Method of Analysis

Copper, iron, lead, zinc, and cadmium concentration were determined using the Atomic Absorption Spectroscopy (AAS) 300 as described by [1].

2.5 Statistical Analysis

All data generated were analyzed statistically using ANOVA method.

3. RESULTS AND DISCUSSION

3.1 Results

Table 1. Heavy metal content (mg/L) in rain water harvested from different roofing sheets

Metals	Sample A	Sample B	Sample C	*WHO(1996)
Zn	2.40± 0.2	1.58± 0.12	3.00± 0.25	5.00
Fe	2.74± 0.5	2.15± 0.20	3.80± 0.33	0.03
Cu	0.05± 0.01	0.04± 0.01	0.06± 0.02	1.00
Pb	0.07± 0.02	0.02± 0.004	0.09± 0.03	0.05
Cd	0.05± 0.01	0.02± 0.004	0.08± 0.03	0.005

**Source: Ehi- Eromosele et al., 2012 [10]*

3.2 Discussion

Zinc: The concentration of Zn (2.40±0.2 mg/L) in coloured sheets, (1.58±0.12 mg/L) in colourless roofing sheets and (3.00±0.25 mg/L) in rusted roofing sheet fall below the maximum acceptable concentration of 5.00 mg/L as recommended by WHO [8]. Rusted roofing sheet has the highest concentration (3.00±? mg/L) and the least was colourless roofing sheets. This may be attributed to the washing of rusted roof sheet as it is getting old due to high temperature variation, this is an indication that impinging of rain drops on the coloured-paint and rusted roof sheets gradually erodes the paint and rusted materials. Once the coating zinc is peeled off the exposed iron in the presence of rain water rusts as follows $4Fe(s) + 3O_2(g) + 2nH_2O \rightarrow 2(Fe_2O_3.nH_2O(s)$. The order of variability is rusted sheets> coloured sheet> colourless sheet.

Iron: The concentration of Fe (2.74±0.50 mg/L) in coloured sheet, (2.15±0.20 mg/L) in colourless and (3.80±0.33 mg/L) in rusted sheets are all above the recommended maximum allowable concentration of 0.03 mg/L by WHO. The concentration was highest in rusted roofing sheet followed by coloured sheet and least in colourless sheet.

Copper: Copper is an essential element that promote the activity of certain enzyme system in the human body. The concentration of Cu (0.05±0.01 mg/L), (0.04±0.01 mg/L) and (0.06±0.02 mg/L) in coloured sheet, colourless sheet and rusted sheets respectively. The results obtained from this research are below the WHO maximum allowable concentration of 1.00 mg/L even though the concentration was highest in rusted sheet. High doses of Copper can cause anaemia, liver and kidney damage, and stomach and intestine irritation [5].

Lead: Lead is a well known toxicant that has several deleterious effects on human health even at low concentration. The concentration of Pb (0.07±0.02 mg/L), (0.02±0.004 mg/L) and (0.09±0.03 mg/L) in coloured sheets, colourless sheets and rusted sheets respectively is above the maximum acceptable concentration of 0.05 mg/L as recommended by WHO. Pb concentration in the runoff from coloured, colourless and rusted roofing sheets may be due to exhaust from vehicles, generator sets and gasoline combustion which cause air pollution with lead particles reaching roof sheets through deposition [9].

Cadmium: The concentrations of Cd in the three samples were higher than the maximum acceptable limit by WHO. The highest concentration of Cd was found in rusted sheets (0.08±0.03 mgL) and least in colourless sheet (0.02±0.004 mgL). Long term exposure to cadmium is associated with renal dysfunction. Cadmium is bio-persistent and once absorbed remains resident for many years. High exposure can lead to obstructive lung diseases and has been linked to lung cancer. Cadmium may also cause bone defects in humans and animals. The average daily intake for humans is estimated at 0.15 from air and 1 from water [2].

Analysis of variance (ANOVA) showed no significant variation ($P \leq 0.05$) between water samples for the heavy metals determined in coloured-painted, colourless and rusted roof sheets. The concentration of heavy metals Zn, Fe, Cu, Pb, Cd of rusted roof sheets were significantly different from that of coloured-painted and colourless roof sheets ($P \leq 0.05$) in all the sampled areas. The difference is significant at 0.05 level calls for cautions as trace amount of heavy metals such as Cd and Pb could be

harmful to human after prolong exposure to these pollutants.

4. CONCLUSION

The study presented data on the concentrations of rain water harvested from different roofing sheets in outskirt of Makurdi, Benue State, Nigeria. The result showed that the rusted roofing sheet has the highest level of heavy metals content (3.0, 3.80, 0.06, 0.09 and 0.08 for Zn, Fe, Cu, Pb, and Cd respectively) followed by the colored roofing sheet (2.40, 2.74, 0.05, 0.07and 0.05) and then the colourless roofing sheet has the least content (1.58, 2.15, 0.04, 0.02 and 0.02) for the metals being considered. As revealed from the analysis, most of the samples require at least some level of treatment particularly those from rusted and colored roofing sheets. However, all water samples were quite safe for all other domestic uses such as; laundry, bathing, toilet flushing and other cleaning works. Though most of the parameters examined in the water samples have values that are below or within the maximum allowable limits of WHO, FAO [11] standards for drinking water quality but there is calls for cautions as trace amount of heavy metals such as Cd and Pb could be harmful to human after prolong exposure to these pollutants even at low concentration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Etonihu AC, Lawal K. Physicochemical and heavy metals analysis of water, sediment and fish samples from River Kaduna, Nigeria. Journal of Water, Air and Soil Pollution. 2013;4(1):1-7.
2. Garty J, Kauppi M, Kauppi A. Accumulation of air born elements from vehicles in transplanted lichens in urban sites. J. Environ, Qual. 1996;25:269-272.
3. Thomas PR, Greene GR. Rain water from different roof catchments. Wat. Sci. Tech. 1993;28:291-299.
4. Raphael O, Goodwill JG. The spatial effect of rusty roof on water quality in Otukpo Local Government Area of Benue State, Nigeria. Int. J. Marine Atmos. Earth Sci. 2013;1:27-37.
5. Jones DC, Miller GW. The effects of environmental neuro-toxicants on the dopaminergic system: A possible role in drug addiction. Scientific Journal of Science and Technology. 2008;4(9):345-349.
6. Ajaero C. A brand new image for Benue, Newswatch magazine (Newswatch Communications); 2007.
7. Egwaikhide PA, Salihu L, Lawal U. Physico-chemical characteristics and trace metal analysis of water samples from selected hand dug wells in an industrial layout. Int. J. Chem. Sci. 2006;5(2):200-203.
8. WHO. World Health Organisation, International Standards for Drinking Water, World Health Organization, Geneva, Switzerland; 1992.
9. Quck U, Forster J. Trace metals in roof run off. Water, Air and Soil Pollut. 1998;69: 373-389.
10. Ehi-Eromosele CO, Okiei WO. Resources and Environment. 2012,2(3):82-86. DOI: 10.5923/j.re.20120203.01
11. FAO. United Nations Food and Agricultural Organisation, Water Quality for Agriculture, Paper No.29 (Rev.1), UNESCO, Rome; 1985.

Peer-review history:
The peer review history for this paper can be accessed here:
http://prh.sdiarticle3.com/review-history/23533