Iranian (Iranica) Journal of Energy & Environment
Journal Homepage: www.ijee.net
IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

Research Note

A Comparative Evaluation of Rain Water Obtained from Corrugated Roofing Sheets within Awka Metropolis, Anambra State

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PAPER INFO

Paper history:
Received 13 December 2021
Accepted in revised form 08 March 2022

Keywords:
Alkalinity
Chloride
Corrugated roofing sheet
Nitrate
Rain water
Total solid

ABSTRACT

The objective of this study was to evaluate comparatively the effects of different brands of corrugated roofing sheets on rainwater utilized within Awka metropolis. Different physicochemical parameters were assessed in the rain water harvested using established standard laboratory procedures. The rain water was harvested directly (control) and also collected after passing through the different brands of corrugated roofing sheets (samples). The results showed no appreciable effects on the physical appearance, observable odour, or taste of the water samples compared to the control sample. However, at 30 °C, there were minor changes in the pH. The amount of suspended solids (SS) in mg/100ml, total solids (TS), and total dissolved solids (TDS) found in each of the samples, including the control sample, did not vary. This showed that the corrugated roofing sheet has no significant effect on the SS, TS, and TDS of the rain water harvested within the study area. Iron, zinc, and chloride ions followed a similar trend as SS, with Fe and Zn occurring at non-detectable limits of the instrumentation, while the levels of Cl- ion (3mg/100ml) did not vary in all the samples, including the control sample. The results revealed that corrugated roofing sheets affect the total alkalinity and methyl orange alkalinity of the harvested rain water in the study area greatly but had no impact on their physical appearance.

***doi**: 10.5829/ijee.2022.13.02.04*

INTRODUCTION

Environmental pollution and contamination are two of the most negative repercussions of humanity's recent technological and innovative advances [1-3]. Water quality and waste management are two of contemporary society's most fundamental tenets [4-9]. Agricultural, household, and industrial activities consume more than one-third of the world's available fresh water sources [10-13]. Due to population growth, water availability was reduced to 3300 cubic meters in 1960 and to 1250 cubic meters in 1995. This trend is anticipated to continue, with a worldwide decline to 650 cubic meters possible by 2025 [14]. A global freshwater crisis may occur in the far future as a result of the continually growing demand for household consumption, which grows with population growth and industrial usage, particularly with the creation of new industries [15-17]. According to Boretti and Rosa [18], by 2050, around 57 percent of the world's population would live in water-scarce locations (at least one month out of the year).

There is a great disparity in the availability of safe drinking water between the rural and urban dwellers of every society [19]. According to Efe [20], about 70% of urban dwellers and 20% of rural dwellers worldwide have access to safe drinking water. This great disparity is the brainchild that necessitated the need for other sources of "portable water." One of such solutions is Rainwater Harvesting. One such solution is rainwater harvesting. Nigeria is the largest country in West Africa, with a population of over 200 million people and an annual growth rate of 2.5 percent, and approximately 48 percent of its population lives in rural areas [21]. Rainwater harvesting is one option for Nigeria to achieve the Sustainable Development Goals of providing clean and cheap water to all of its citizens by 2030 (SDG 6 goal)

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Please cite this article as: P. E. Omuku, C. C. Odidika, A. E. Ozukwe, K. O. Iwuozor, A Comparative Evaluation of Rain Water Obtained from Corrugated Roofing Sheets within Awka Metropolis, Anambra State, 2022. Iranian (Iranica) Journal of Energy and Environment, 13(2), pp.134-140. Doi: 10.5829/ijee.2022.13.02.04

[22, 23]. Rainwater harvesting is the small-scale concentration, collection, storage, and utilization of runoff from rain for productive purposes [24, 25]. Most rural residents in this region of the globe see rainfall as the most drinkable source of water if properly harvested [26]. As a result, most rural Nigerians drink rainwater that has not been purified. The majority of these people collect rainwater directly from building roofs into basins, as well as via ridges connected to manually dug wells [27]. Roof catchment appears to be the most prevalent type of catchment for rainwater harvesting. This is because the residents use their existing roofs, incurring no new expenses, and the amount and quality of rainwater collected depends on the location and kind of roofing material [28]. Concrete, corrugated plastic, galvanized, corrugated iron sheets, thatch, tile, asbestos cement sheets, or clay are examples of roofing materials [29]. As a result, the majority of rural residents drink rai-nwater from these sources without paying attention to the quality of the water. This has necessitated the growing body of literature in recent years within the Nigerian sphere that seeks to determine the portability level of rainwater as well as the effect roofing sheets have on it.

Tenebe, Emenike [30] examined the bacteriological quality of rainfall (RW) obtained from storage facilities in Ekpoma, a rural town in South-South Nigeria. Tobin, Ediagbonya [31] observed high concentration of total coliform as well as *Escherichia coli* in the rainwater collected from Usugbenu, in Edo state. Nnaji and Nnam [32] evaluated eighteen physicochemical and two microbial properties of twenty-five rainwater harvesting tanks in Enugu-Ezike in Enugu state. Dinrifo, Babatunde [33] determined the physico-chemical properties of rain water collected from some Industrial areas of Lagos state. Igbinosa and Aighewi [34] assessed the heavy metal concentration as well as physicochemical quality of corrugated iron sheets in Oluku communities in Benin city. Igbinosa and Aighewi [35] determined the physicochemical quality and heavy metal concentration of harvested rainwater from Ugbihoko village in Benin city. Igbinosa and Osemwengie [36] assessed the environmental and sanitary quality of rainwater collected from corrugated iron sheets in a rural community in Benin city. Olaoye and Olaniyan [37] studied the physicochemical properties of rainwater obtained from four different roofing sheets within Ogbomosho, Oyo state. Adeyeye, Akintan [38] determined the physicochemical properties of rainwater collected from four different roofing sheets in Ikole Local Government in Ekiti State. Omokpariola, Nduka [39] determined the ionic composition of rainwater obtained from roofing surfaces across Rivers state. Ibikunle, Ajayi [40] explored the activity concentrations of some natural radionuclides in rainwater samples collected from different rooftops and sources in Akure, Ondo state. Rainwater captured from rooftops in Esan-West Local Government Area of Edo State, Nigeria, was studied for its physicochemical and bacteriological properties [41].

Within the last decade, several key papers have studied the quality of rain water as well as that obtained from roofing materials within the Nigeria sphere. The massive amount of literature present in this field necessitated this study as there is little information about rain water from Awka, the capital city of Anambra state. The only related study regarding this was carried out by Nduka and Orisakwe [42], but the study was limited as it studied only the concentration of lead present in rainwater obtained from Awka. In addition, even though a great deal of literature has been churned out in this field, none of them studied the physicochemical properties of rain water as well as rain water obtained from roofing sheets while also taking into consideration the age of the roofing sheet. This is an important novelty in the study. This work was aimed at determining the physicochemical properties of rain water as well as evaluating the effects of roofing materials on the quality of harvested rain water that is generally utilized within Awka metropolis.

MATERIAL AND METHODS

Study site

This research was carried out in Awka, the state capital of Anambra. Awka is located between 6°11'N and 6°15'N, and 7°04'E and 7°09'E.

The Onitsha-Enugu dual-carriageway runs through the town. It is bordered to the north-west by Okpuno, to the north-east by Amansea, to the south-west by Amawbia, and to the east by Nibo as shown in Figure 1. Awka is bordered to the north by Ugwuoba in Enugu State, and its built-up area is around seven kilometers from the Amawbia junction. It has low-lying terrain due to its location on the Mamu River plain, with all areas being less than 333 m above sea level. There are two distinct seasons in the town's climate: rainy and dry. The

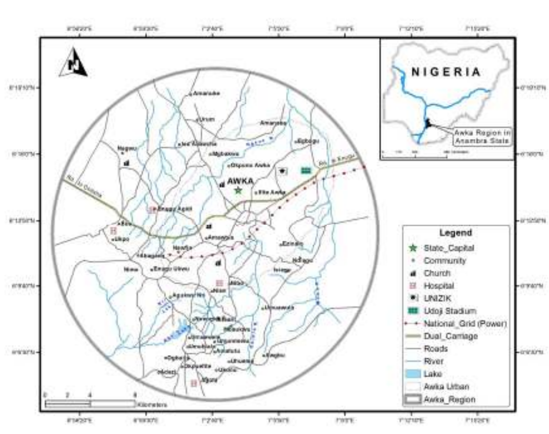

Figure 1. Map of Awka Metropolis [43]

rainy season lasts for eight months and the dry season for four. The yearly rainfall is around 1850 mm, and the average temperature is around 28 °C all around the year [44].

Sample collection

Rainwater samples were collected from the rainwater harvesting system. Five different houses of various roofing sheet material brands located within Awka metropolis were utilized for the study. The roofing sheet material were identified by the Building Engineers on sites and labelled accordingly as shown in Table 1. The control rain water sample was rainwater harvested directly in a pre-cleaned plastic basin without it having contact with any surface or object. The control sample was obtained to help in the determination of the properties of the rain before it came into contact with the roofing sheets. From this, deductions can then be made on the effect of the roofing sheets on the properties of the rain water. The rain water samples were harvested from the five different roofing sheets into pre-cleaned polyethylene container (1-L capacity) and labelled appropriately as shown in Table 1. Therefore, a total of five samples were obtained together with the control sample.

Physicochemical analysis

The water samples were analyzed using standard methods as stated by Nnaji and Nnam [32] and Dinrifo, Babatunde [33]. The parameters tested for were substances which dissolve in rain water, of which some are beneficial to humans, but in excess they are threats to the well-being of the individual that consumed them. The harvested rain water samples were tested organoleptically, quantitatively, and qualitatively for appearance, odour, taste, conductivity, pH, total solid (TS), total dissolved solid (TDS), total alkalinity (TA), total hardness, chloride, sulphate, nitrate, potassium, calcium, iron, zinc, and copper. The nitrate, sulphate, copper, and alkalinity were examined using their test tablets and the smart spectrophotometer. The carbon dioxide, total hardness, and chloride were analysed using the LaMotte kit from the USA. All the analyses were conducted in triplicates and the mean value was obtained.

Table 1. Roofing sheet materials used for the study

S/N	Sample Labels	Roofing Sheet Brands	Duration of Use (Years)
1	A	Swan midigal corrugated iron roofing sheet	10 - 20
2	B	Swan Kam corrugated iron roofing sheet	7 - 20
3	C	Swan surn corrugated iron roofing sheet	12 - 30
4	D	Aluminum roofing sheet	12 - 30
5	E	Corrugated rusted iron roofing sheet	10 -20

Several stainless-steel baffles were used on the absorber surface to produce a serpentine air passageway and improve the convective heat transfer mechanism. A 10 mm thick glass plate was installed 40 mm above the absorber to protect it and decrease convective/radiant heat losses to ambient environments. The critical experimental setup component and their technical specifications are given in Table 1. A convergent duct at the exhaust opening helps the airflow leave the SAH uniformly. A centrifugal air blower sucks cold air into the collector and exhausts hot air to the ambient, and all voids and seams were sealed with silicone sealants to avoid air leakage.

RESULTS AND DISCUSSION

The results of the harvested rain water analyses are presented in Table 2. The six samples, including the control with respect to organoleptics, met the required standard by the World Health Organization. They were clear as to sight, tasteless as to taste, and odorless as to smell. Hence, since the WHO standard requires that drinking water be tasteless, odorless, and colorless, they were within the WHO standard.

The accepted WHO pH 6.5-8.5 for the five corrugated roofing sheets with the control all having varying pH with the swan sumo corrugated roofing sheet having the least acidic value with a pH of 6.86 at 30°C, but within the WHO accepted range, while the swan midigal corrugated value of 6.61 at 30°C is within the WHO accepted range. With the decreased pH of swan sumo, it was clear when compared with the control that some alkaline substance was washed into the water sample of about 0.21 (6.86–6.65). Both values were within the ranges obtained by Olaoye and Olaniyan [37] for asbestos roofs, which ranged from 6.58 to 6.94, and above the ranges obtained for aluminum roofs, which ranged from 6.13 to 6.31. The accepted WHO total dissolved solid (TDS) for drinking water is 500 mg/l. The water samples, including the control, had a recurring maximum total dissolved solid content of 40 mg/l each. This is within the accepted WHO standard. The maximum accepted world health organization standard of carbon dioxide content for drinking water is 50 mg/l. In the parametric analyses carried out, the control had the highest carbon dioxide content of 5 mg, while the Swan Kam corrugated iron roofing sheet and the rusted corrugated iron roofing sheet had the lowest, at 3 mg/l for both. Both the control and Swan Kam corrugated iron roofing sheets and the rusted corrugated iron roofing sheets were very low within the maximum objectionable carbon dioxide content of drinking water. Some of the carbon dioxide content of the harvested water may be lost to the atmosphere or to the corrugated roofing sheet. Control (5 mg/l)-the content of

Table 2. Results of the harvested rain water analyses

S/N	Test	WHO Standards	Control	Sample A	Sample B	Sample C	Sample D	Sample E
1	Appearance	-	Clear	Clear	Clear	Clear	Clear	Clear
2	Odour	-	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
3	Taste	-	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
4	pH @ 30 °C	6.5-8.5	6.65	6.61	6.20	6.86	6.78	6.68
5	TS (mg/l)	500 max	40.0	40.0	40.0	40.0	40.0	40.0
6	TDS (mg/l)	500 max	40.0	40.0	40.0	40.0	40.0	40.0
7	SS (mg/100ml)	-	BDL	BDL	BDL	BDL	BDL	BDL
8	CO_2 (mg/l)	50 max	5.00	4.50	3.00	3.50	4.00	3.00
9	MOA (mg/l)	100 max	26.0	113	Out of range	Out of range	122	121
10	TA (mg/l)	100 max	26.0	113	Out of range	Out of range	122	121
11	TH (mg/l)	100 max	3.00	4.00	4.00	4.00	4.00	3.00
12	Chloride (mg/l)	200 max	3.00	3.00	3.00	3.00	3.00	3.00
13	Sulphate (mg/l)	200 max	9.00	6.00	8.00	5.00	6.00	9.00
14	Nitrate (mg/l)	50 max	4.00	3.00	6.00	7.00	5.00	2.00
15	Potassium (mg/l)	10 max	0.70	9.00	7.00	2.00	0.70	0.80
16	Calcium (mg/l)	75 max	2.00	2.70	2.35	2.70	2.70	2.00
17	Magnesium (mg/l)	30 max	1.00	1.35	1.35	1.35	135	1.00
18	Iron (mg/l)	0.3 max	BDL	BDL	BDL	BDL	BDL	BDL
19	Zinc (mg/l)	5.0 max	BDL	BDL	BDL	BDL	BDL	BDL
20	Copper (mg/l)	1 max	0.46	1.42	1.40	0.85	0.28	1.82

TS =Total Solid; TDS=Total Dissolved Solids; SS =Suspended Solid; CO_2 = Carbon Dioxide; MOA = Methyl Orange Alkalinity; TA = Total alkalinity; TH = Total Hardness; BDL = Below Detectable Limit; WHO = World Health Organization [45, 46].

rusted roofing sheets (2-3 mg/l) was the largest amount of carbon dioxide lost.

The WHO standard for total alkalinity content of drinking water is 100 mg/l with the exception of the control, which was 26 mg/l within the acceptable maximum limit. Swan midigal, aluminum, and rusted corrugated sheets were above the maximum WHO standards, which were 122 and 121, respectively, while Swan Kam and Swan Sumo were both out of range and, judging by the control, should have been above 100 mg/l. The value obtained by Olaoye and Olaniyan [37] was far below what was obtained. The lowest dissolution was from swan midigal at 87 mg/l (133-26) and the highest was from aluminum roofing sheet at 96 mg/l (122-26) above the control. The standard WHO total hardness content for drinking water acceptable to WHO is 100 mg/l, but 3 mg/l was the value obtained for the control and the rusted corrugated iron sheet. In the total hardness (parametric) test, 4 mg/l was the total hardness content for the rest of the samples. Olaoye and Olaniyan [37] obtained 31–39 mg/l for aluminum and 29–31 mg/1 for the concrete roof.

The maximum chloride content of drinking water acceptable to the WHO is 200 mg/l. All of the samples used in the chloride parametric analyses had a chloride content of 3 mg/l, which is extremely low. The analysis by Olaoye and Olaniyan [37] had a chloride content of 90 mg/l for asbestos, concrete roof and corrugated plastic roofs. While the value obtained for the aluminum roof was 8 mg/l, which was very much above the obtained value. The maximum sulphate content of drinking water acceptable to the WHO is 200 mg/l. The control and the rusted corrugated iron sheet had a sulphate content of 9 mg/l which is the maximum obtained. Swan sumo corrugated iron roofing sheet had the least sulphate content at 5 mg/l. The maximum nitrate content of drinking water acceptable to WHO is 50 mg/l. The control had a nitrate content of 4 mg/l while the maximum nitrate content contained by a swan sumo corrugated iron roofing sheet was 7 mg/l, while 2 mg/l was implicated in the nitrate content of the rusted corrugated iron roofing sheet. The maximum potassium content of drinking water acceptable by the WHO standard is 10 mg/l. The control had a potassium content of 0.7 mg/l, while swan sumo had a minimum potassium content of 0.2 mg/l, with swan midigal recording a value of 0.9 mg/l.

Figure 2 shows the variation in the harvested rainwater parameters. It was observed that CO_2 levels decreased to varying degrees with the different roofing sheets, indicative that the roofing sheets act as absorbents, thereby reducing the amount of CO_2 as rainwater passes through them. This may be attributed to the presence of micro pores in the roofing sheet materials where the CO_2 is adsorbed. A similar trend was observed in the SO_4^{2-} ions levels, with the exception being noticed in sample E. The total hardness levels increased as the rainwater was harvested from the different roofing sheets compared to the value obtained from the control sample. There was also a significant increase in the levels of copper and nitrate ions as the rainwater was harvested from the different roofing sheet materials.

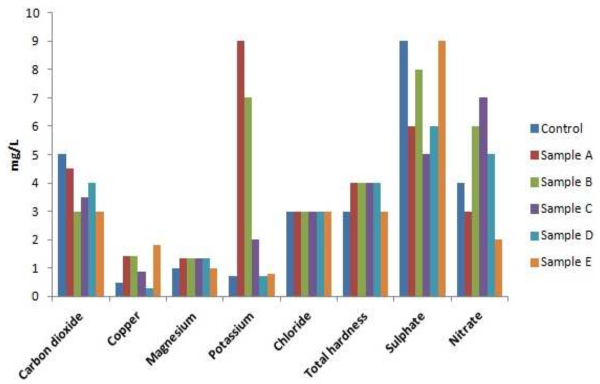

Figure 2. Variation in the rainwater parameters

CONCLUSION

Several key conclusions were derived from this study. Based on the observation of the study, the research methodology implemented was successfully able to comparatively evaluate the physicochemical characteristics of the rainwater samples. The results showed no appreciable effects on the physical appearance, observable odor, or taste of the water samples compared to the control sample. However, at 30 °C, there were minor changes in the pH of the test samples. The amount of suspended solids (SS) in mg/100ml, total solids (TS), and total dissolved solids (TDS) found in each of the samples, including the control sample, did not vary. There was no significant change in the values of Potassium for samples A (0.9 mg/l), B (0.7 mg/l), C (0.2 mg/l), D (0.7mg/l) and E (0.8 mg/l). Copper content was 0.46 mg in the control, while 1.82 mg was found in sample E. There was an appreciable effect of the corrugated roofing sheet on the total alkalinity of the water samples as the value increased from 26mg/l (control), 113 mg/l (sample A), 121mg/l (sample E), and 122 mg/l (sample D). The values obtained in samples B and C were so high as to be out of range limit of the instrumentation. A similar trend as for total alkalinity was observed for the methyl orange alkalinity.

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Persian Abstract

چکیده

هدف از این مطالعه بررسی مقایسه‌ای اثرات مارک‌های مختلف ورق‌های سقف راه‌راه بر روی آب باران مورد استفاده در کلان‌شهر آوکا بود. پارامترهای فیزیکوشیمیایی مختلف در آب باران برداشت شده با استفاده از روش‌های آزمایشگاهی استاندارد ارزیابی شد. آب باران مستقیماً (شاهد) برداشت و پس از عبور از برندهای مختلف ورق سقف راه‌راه (نمونه) نیز جمع آوری شد. نتایج هیچ اثر قابل ملاحظه‌ای بر ظاهر فیزیکی، بو یا طعم نمونه‌های آب در مقایسه با نمونه شاهد نشان نداد. با این حال، در ۳۰ درجه سانتی‌گراد، تغییرات جزئی در pH وجود دارد. مقدار جامدات معلق (SS) در ۱۰۰ میلی‌گرم بر میلی‌لیتر، کل جامدات (TS) و کل جامدات محلول (TDS) یافت شده در هر یک از نمونه‌ها، از جمله نمونه شاهد، تفاوتی نداشت. این نشان داد که ورق سقف راه‌راه هیچ تاثیر قابل توجهی بر SS، TS، و TDS آب باران برداشت شده در منطقه مورد مطالعه ندارد. یون‌های آهن، روی و کلرید از روندی مشابه با SS پیروی کردند، با آهن و روی در محدوده‌های غیرقابل تشخیص ابزار دقیق، در حالی که سطح یون کلر (۳ میلی‌گرم در ۱۰۰ میلی‌لیتر) در همه نمونه‌ها، از جمله نمونه‌ها، متفاوت نبود. نمونه کنترل. نتایج نشان داد که ورق های سقف راه‌راه بر روی قلیائیت کل و قلیائیت متیل اورانژ آب باران برداشت شده در منطقه مورد مطالعه تأثیر زیادی دارد، اما تأثیری بر ظاهر فیزیکی آنها ندارد.