Response of Roof Materials to Acidified Precipitation in a Rural Community in Rivers State, Nigeria.

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Abstract

This study determined the response of roof materials to acidified precipitation in Odagwa, a rural community hosting a crude oil flow station. Rainwater samples were collected from ambient and various roofs within 1000m- 2000m from the flow station's gas flare point. Samples were tested for Turbidity, Colour, pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Magnesium, Sulphate, Nitrate, Chloride, Aluminium, Iron and Zinc using standard methods. Result of the rainwater pH collected in the ambient environment showed a range of values 6-5.5(acid precipitation) between October to April and 6.5-6.9 between May and September. Correlation between pH and amount of rainfall was r2 = 0.86. The intercepted rainwater laboratory results at study location and control location respectively were: Galvanized Iron Roof; turbidity(60,3), colour(16,6), pH(8,6.9), TSS(61,32), TDS(30,28), Mg(0.15,0.05), sulphate(100,52), nitrate(40,20), chloride(50.14), iron(0.4,0.05),zinc(10,1.5), Al(0). Aluminium Roof results; turbidity(62,2), colour(16,5), pH(5.8,6.9), TSS(58,28), TDS(25,23), Mg(0.3,0.05), sulphate(96, 45), nitrate(42,25), chloride(45,12), iron(0.05,0.02),zinc(0.05, 0.04), Al(0.1-0.01). Asbestos Roof results; turbidity(60,4), colour(17,10), pH(6,6.9), TSS(60,30), TDS(30,26), Mg(0.3,0.1), sulphate(120,54), nitrate(60,28), chloride(45,15), iron(0.04,0.01),zinc(0.05, 0.04), Al(0,0). It was recommended that gas flaring be reduced or stopped in the community and in the mean time, rainwater should be treated before use and corrosion resistant roof materials should be used.

Keywords: *acidified; precipitation; roofs; quality.*

INTRODUCTION

Rain according to metrological consideration is water droplets that vary in size from 0.5mm to about 7mm, which are visible to the eyes (Anyadike and Obeta, 2012). We have three major types of rainfall, they include, convectional or convective storm, orographic or relief and frontal or cyclonic rain fall.

The rain water is a natural source of water and in its pure state possesses the Physico-chemical and Biological characteristics of pure water (Akhionbare, 2009). Rainwater, like other waters is a very good solvent especially for ionic or polar compounds hence the popular phrase "water a universal solvent". It is a good solvent for acids, bases, salts and a wide range of gases example CO_2, SO_2, NO_x, NH_3(g).

The water molecule is made up of 2 atoms of Hydrogen and one atom of Oxygen bonded at an angle of 105^0 making it behave like a body having opposite charges called dipole. The chemical formula is simply H_2O but its behaviour is rather complex (Ellen et al, 2004).

Rainwater while falling through the atmosphere dissolves, dilutes and hydrolyses other pollutants in the space ranging from gases, particulates to vapours. This leads to the contamination of rain. Although this singular act may cleanse the atmosphere of pollutants yet the earth's natural and
built environment, hydrosphere and lithosphere cannot be spared.

Depending on the activities going on in an area, rainwater can become turbid, coloured, acidic, alkaline, hardened, contaminated by trace elements, chlorides, sulphates, Nitrates, suspended solids, organic carbon, phosphates, Dissolved solids and carbonates.

Acid rain is primarily formed as a result of emissions of SO_2 and NO_x which combine with atmospheric moisture to form acid (H_2SO_4) and nitric acid (HNO_3) respectively (USEPA, 2011).

The United States Environmental Protection Agency confirmed that acid rain acidifies lakes and streams, damages vegetation, accelerates the decay and corrosion of building materials, paints and metallic structures.

According to Noyes (2005), other acidifying gases that contribute to acid rain include; CO_2 and
Chlorides.

Precipitation in the form of rain, snow, ice or fog causes about half of the atmospheric acids formed to fall to the ground as acid rain while about half fall as dry particles and gases (Mokhatab et al, 2006).

Dara (2006) noted that with reactions of rainwater and sulphur (IV) oxide leads to formation of H_2SO_4 referred to as acid rain, the acid droplets is being neutralized and solubility of SO_2 in droplets increases thereby enhancing the Oxidation process. Both the acid droplet and sulphate particles are removed from the atmosphere by wet precipitation.

MATERIALS AND METHODS

Description of study area

Odagwa the study site and Obite the control site are communities in Etche Local Government Area of Rivers State of Nigeria. Obite community is about 15km from Odagwa. Etche L.G.A. is located at North-Eastern part of Rivers State, Nigeria. It lies within latitude $4^0$45'N to $5^0$17'N and longitude
$6^0$55' E to $7^0$17'E and covers about 641.28km^2 of land area (Nwankwoala and Nworgu, 2009).

Etche is one of the 24 Local Government Areas of Rivers State. It has a population of 295,200 people (NPC, 2006). It has 19 electoral wards including Akwa/Odagwa, Ulakwo and Obite. The L. G. A. has five clans and about 35 communities. Odagwa, Ulakwo and Akwa belong to the Ulakwo / Umuselem clan while Obite belong to the Mba clan.

Etche has its L.G.A. headquarters at Okehi. It is bounded in the North by Imo State, East by Imo River
and Omuma L.G.A., South by Obiakpo and Oyibo L.G.A.'s and West by Ikwerre L.G.A.
Agriculture is the economic mainstay practiced as farming, fishing, lumbering and hunting. Other economic activities

include petty trading, sand mining, transportation, agro-processing, construction and educational activities.

Oil and Gas exploration and exploitation have been going on in Etche since the inception of oil exploitation in Nigeria dating back to 1958.

The area is characterized by the tropical rain forest vegetation (Nworgu, 2001). The Popular trees in the area include Iroko, Obeche and Mahogany. Plant species are scattered, heterogeneous and exist in different heights. The vegetation supports tree crops (citrus, rubber, cocoa, oil palm), arable crops and vegetables.

The area has gently rolling topography below 200m above sea level, it belongs to the Niger
Delta Coastal Plain and classified as low land.

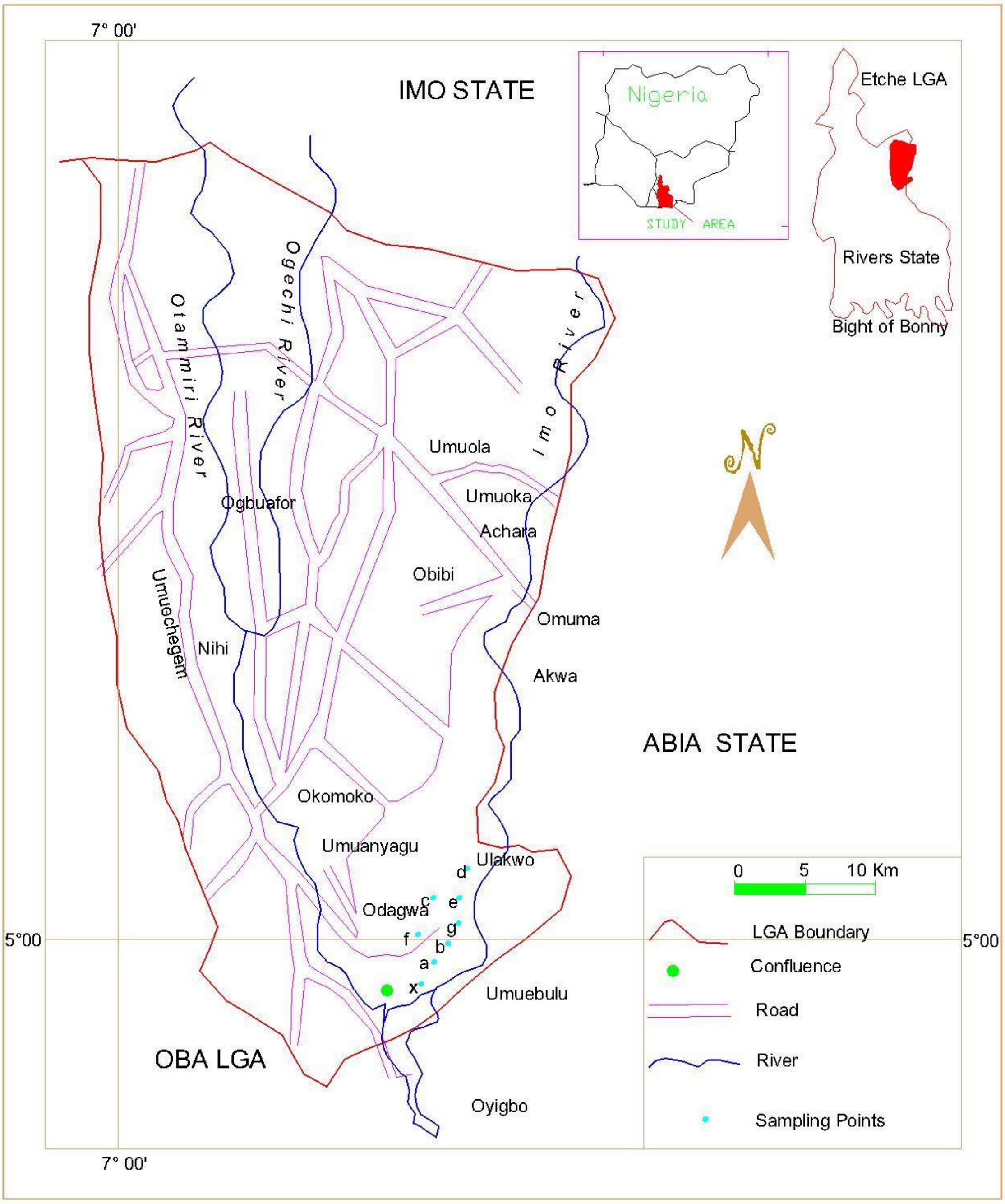
The Etche area is drained by the Otammiri, Ogochie and Imo Rivers. These rivers flow south- wards to join the River Niger and subsequently the Atlantic Ocean.

The area is characterized by sedimentary rock formation and the alluvian deposits comprising of tertiary and quaternary marine or continental deposits.

Extensive petroleum deposits mask the underlying geological structure (Nworgu, 2001). The soil type prevalent in the area can be classified as coarse, loamy, highly weathered, less water logged, moderately acidic and low soluble salt content (Obinna, 2010).

The climate of the area is characteristic of the tropical equatorial climate. Amount of rainfall in the area is between 2000mm to 4000mm annually with two peaks in June / July and September (Nwankwoala and Nworgu, 2009). It has two major seasons, the long rainy season (March to July) and the long dry season (November to February) as well as two minor seasons the short rainy season (September to October) and short dry season (August). Humidity of the area ranges from 40% in dry season to 90% in rainy season. It has two distinct air masses, the tropical continental and tropical marine.

Mean monthly wind speed is between 22.77 to 66.12 Knots, wind direction is dominated by the South Westerly wind throughout the year. Mean monthly minimum temperature is 21.1^{o}C to 24^{o}C while mean maximum monthly temperature is between 29.3^{o}C and 34.2^{o}C (NIMET, 2013).



FED SURVEY MAPS, RIVERS STATE.
SOURCE:

FIG 1.0; MAP OF ETCHE LGA SHOWING THE SAMPLING POINTS.

Sampling Method

Plastic buckets cleaned by rinsing with tap water, chromic acid, 1:1 Nitric acid and finally with distilled water were used to collect rainwater samples on a stand of about 1.5m from the ground to avoid splash water contamination. Samples were divided into two parts for heavy metal analysis and the other part for other parameters. Composite samples of first flush and after first flush were made at various sampling points. The frequency of sampling was monthly in the year 2013. The roofs sampled were 0-5 years old within 1000m – 2000m from gas flare point and at the control location in Obite. Standard methods as outlined in APHA (2012) was used in analysing the samples.

Weather Data

Merlin digital anemometer, hand held digital compass and portable rain guage were used to obtain data on temperature, wind speed and direction, frequency of rainfall and amount of rainfall

RESULTS AND DISCUSSION

Variation of Physicochemical properties of

Rainwater in ambient environment and those Intercepted by Various Roofs:

The results were presented in tables 1.0-1.1 and figures 1.1-1.7.

Table 1.0 Monthly Variation of Rainwater pH, Amount of Rainfall and Wind Speed.

S/N	MONTH	PH	RAINFALL		TEMPERATURE		WIND	
			AMOUNT(MM)	FREQ.	MIN (0^0C)	MAX (0^0C)	SPEED (Knots)	DIRECTION
1.	JANUARY	5.5	23.4	2	21.1	34.2	66.12	SW
2.	FEBRUARY	5.6	10.4	9	22.9	32.6	56.80	SW
3.	MARCH	5.6	92.7	6	24	34.6	50.96	SW
4.	APRIL	5.9	244.7	14	23.6	32.9	50.32	SW
5.	MAY	6.5	194.9	9	23.1	32.4	43.24	S
6.	JUNE	6.8	317.8	16	22.8	30.2	40.33	SW
7.	JULY	6.8	313.0	22	23.0	29.3	42.18	SW
8.	AUGUST	6.7	248.6	19	22.6	29.9	54.89	W
9.	SEPTEMBER	6.9	409.4	22	22.9	29.5	33.67	SW
10.	OCTOBER	6	207.6	18	22.2	30.4	31.79	W
11.	NOVEMBER	6	79.0	5	23.2	31.7	22.77	SW
12.	DECEMBER	5.8	0.00	0	21.7	32.7	35.29	N

SOURCE: FIELD WORK.

Table 1.1; Variation of physicochemical Properties of Rainwater Intercepted by Various Roofs.

S/N			STUDY LOCATION (ODAGWA)			CONTROL LOCATION (OBITE)		
	PARAMETER	UNITS	G.I.Rs	Al.Rs	As.Rs	G.I.Rc	Al.Rc	As.Rc
1.	Turbidity	NTU	60	62	60	3	2	4
2.	Colour	TCU	16	16	17	6	5	10
3.	PH		8	5.8	6	6.9	6.8	6.9
4.	Total Suspended Solids (TSS)	mg/dm^3	61	58	60	32	28	30
5.	Total Dissolved Solids (TDS)	mg/dm^3	30	25	30	28	23	26
6.	Magnesium	mg/dm^3	0.15	0.17	0.3	0.05	0.05	0.1
7.	Sulphate	mg/dm^3	100	96	120	52	45	54
8.	Nitrate	mg/dm^3	40	42	60	20	25	28
9.	Chloride	mg/dm^3	50	45	45	14	12	15
10.	Iron	mg/dm^3	0.4	0.05	0.04	0.05	0.02	0.01
11.	Zinc	mg/dm^3	10	0.05	0.05	1.5	0.04	0.04
12.	Aluminum	mg/dm^3	0.00	0.1	0.00	0.00	0.01	0.00

SOURCE: FIELD WORK

G.I.R = GALVANIZED IRON ROOF. Al.R = ALUMINIUM ROOF. As.R = ASBESTOS ROOF S - represent study location. c – represent control location.

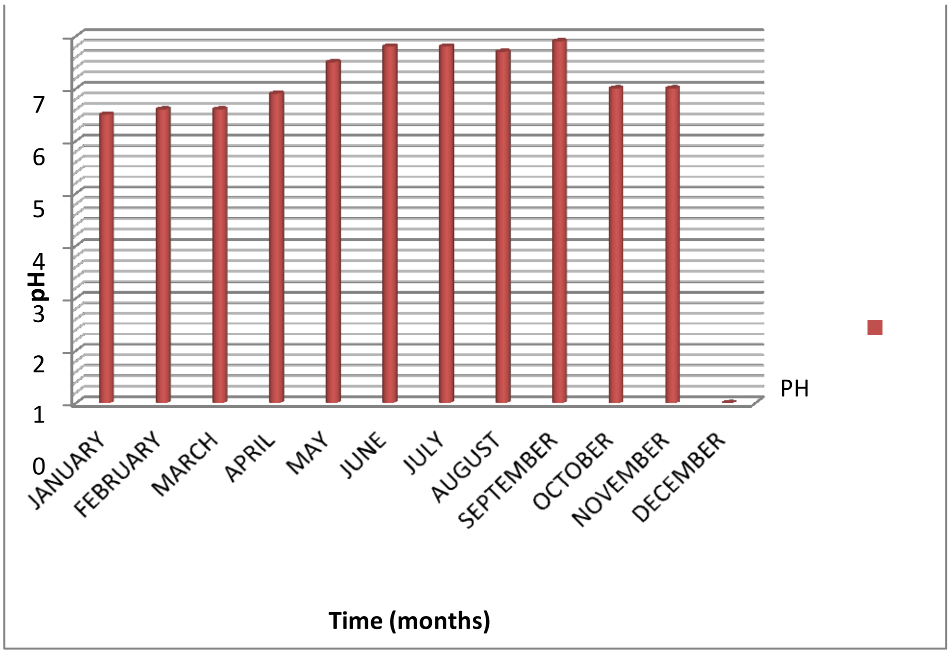


Fig 1.0; Monthly Variation of Rainwater pH.

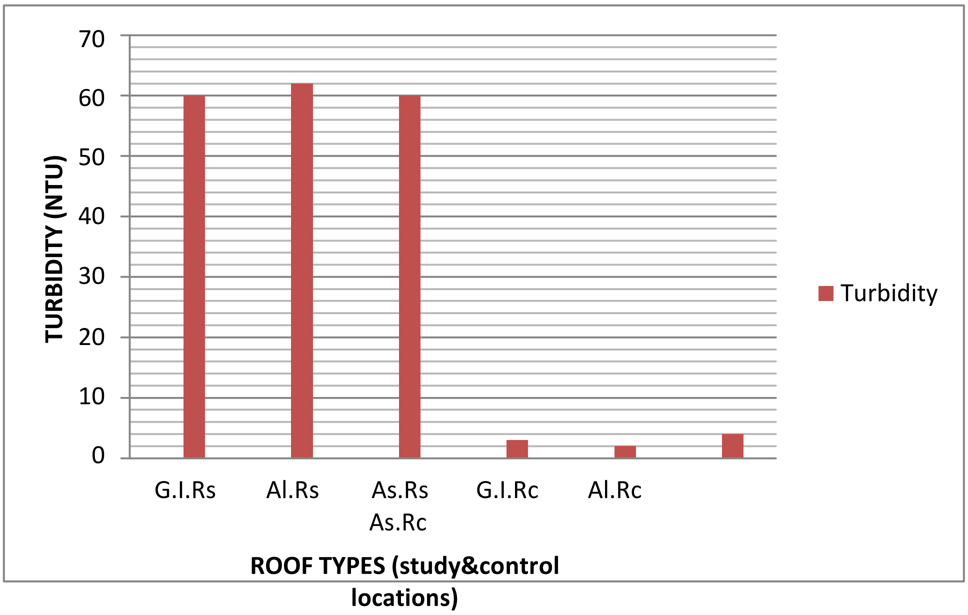


Fig 1.1; Variation of Rainwater Turbidity from roofs in study and control locations.

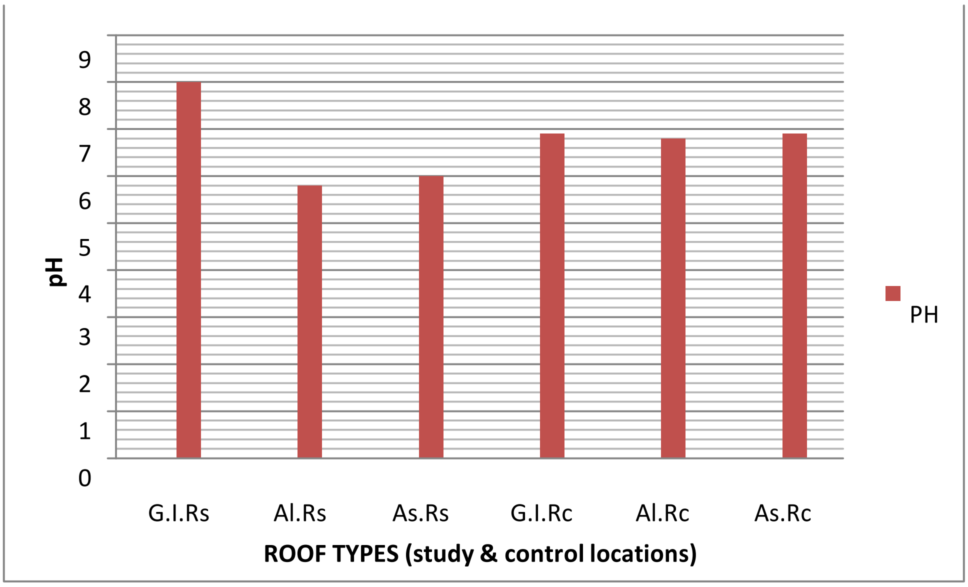


Fig 1.2; Variation of Rainwater pH from roofs in study and control locations.

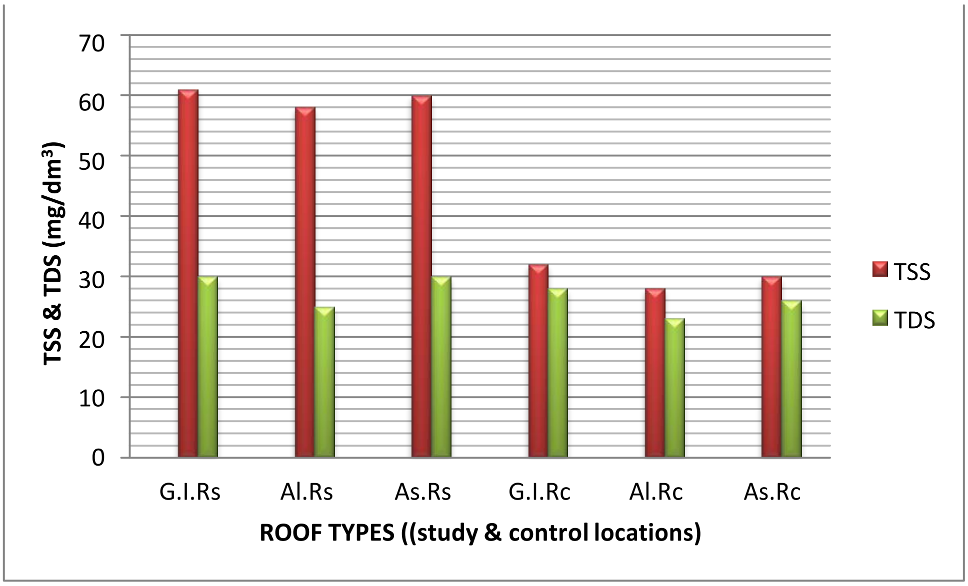


Fig 1.3; Variation of Rainwater TSS and TDS from roofs in study and control locations.

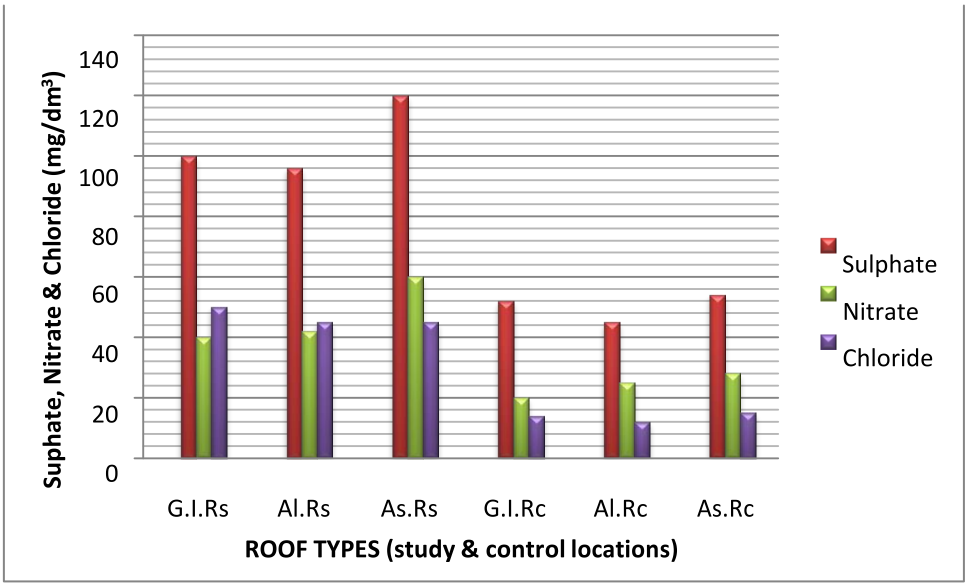


Fig 1.4; Variation of Rainwater sulphate, Nitrate and Chloride in study & control locations.

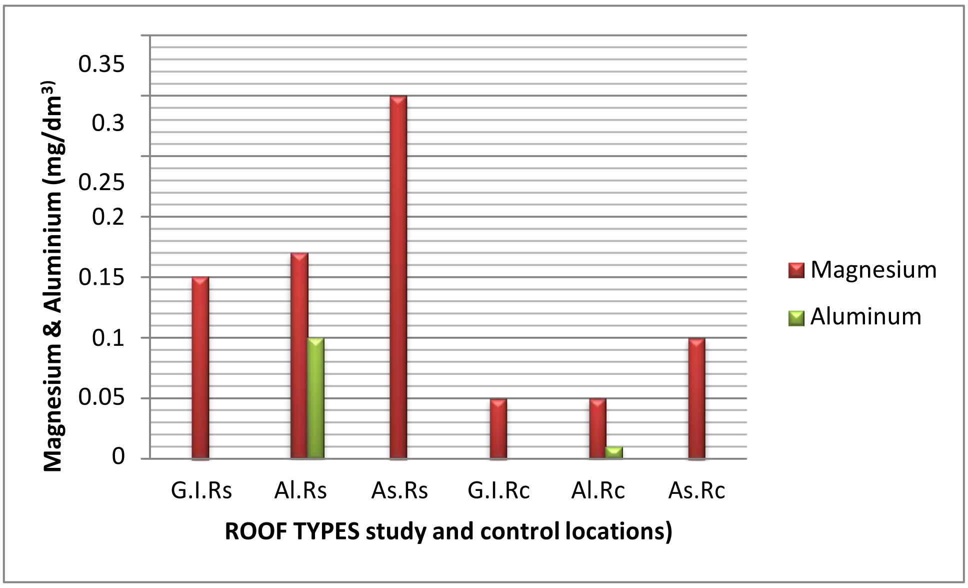


Fig 1.5; Variation of Rainwater Magnesium and Aluminium in study & control locations.

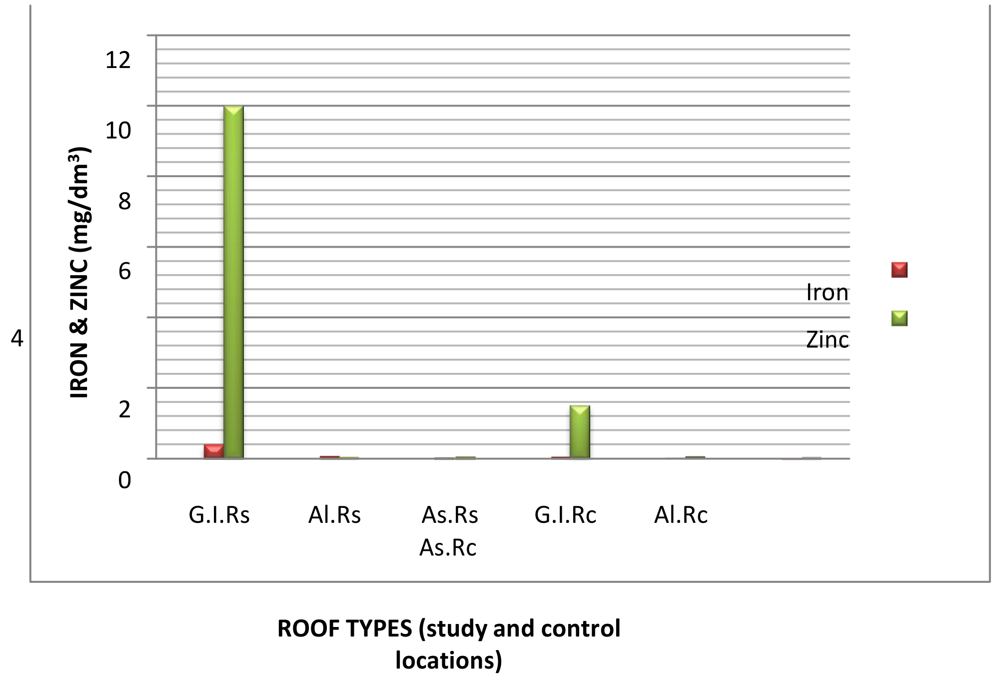


Fig 1.6; Variation of Rainwater Iron and Zinc in study & control locations

Result of the rainwater pH collected in the ambient environment showed a range of values 6-5.5(acid precipitation) between October to April and 6.5-6.9 between May and September. Correlation between pH and amount of rainfall was $r^2 = 0.86$. The intercepted rainwater laboratory results at study location and control location respectively were: Galvanized Iron Roof; turbidity(60,3), colour(16,6), pH(8,6.9), TSS(61,32), TDS(30,28), Mg(0.15,0.05), sulphate(100,52), nitrate(40,20), chloride(50.14), iron(0.4,0.05),zinc(10,1.5), Al(0). Aluminium Roof results; turbidity(62,2), colour(16,5), pH(5.8,6.9), TSS(58,28), TDS(25,23), Mg(0.3,0.05), sulphate(96, 45), nitrate(42,25), chloride(45,12), iron(0.05,0.02),zinc(0.05, 0.04), Al(0.1-0.01). Asbestos Roof results; turbidity(60,4), colour(17,10), pH(6,6.9), TSS(60,30), TDS(30,26), Mg(0.3,0.1), sulphate(120,54), nitrate(60,28), chloride(45,15), iron(0.04,0.01),zinc(0.05, 0.04), Al(0,0).

The results show that unintercepted rainwater in Odagwa is acidic except for the months of June, July, August and September (pH 5.5-6.9). From the intercepted rainwater, the turbidity was highest with Aluminium roof and colour was highest in galvanized iron roof (Turbidity 60-62NTU, Colour 16-17Pt/Co unit, TSS 58-61mg/dm^3)

pH was highest with zinc roof and lowest with Aluminium roof (pH5.8-8). Sulphate and nitrate was highest with asbestos roof and lowest in Aluminium while chloride was highest in zinc roofs. (Sulphate 96-120mg/dm^3, Nitrate 40-60mg/dm^3, Chloride 45-50mg/dm^3). Zinc and Iron recorded highest values in galvanized Iron Roof (zinc 0.05-10mg/dm^3, iron 0.04-0.4mg/dm^3). Magnesium was highest in Asbestos roof while Aluminium was found only in aluminium roofs. (Magnesium 0.15-0.3, Aluminium 0.00-0.1mg/dm^3)

DISCUSSION

The rainwater collected from roofs in control location at Obite recorded low values for all the parameters while from the study location, galvanized iron roofing sheets (zinc roof) had high and unacceptable values of most parameters (see Appendix I & SII) turbidity, colour, TSS, Iron and Zinc (Table 1.1, figures 1.1- 1.6). Turbidity and TSS can be attributed to suspended particulates induced by gas flaring, zinc and iron are likely to have been elevated as a result of products of corrosion. The continued process of gas flaring has not only meant that a potential energy source and source of revenue has gone up in smoke in the study location but the USEIA (2011) identified gas flaring as a major contributor to air pollution and acid rain.

Acidic precipitation acts as corrosive agent exerting high oxidative stress on the metallic surface (Lawton 1997 and Bhatia, 2009). Acidic solution accelerates the corrosion of iron, steel and zinc (Akhionbare, 2009). Okere (2006) in his work agreed that acid rain causes corrosion of roofing zinc sheets. Corrosion of the zinc roof follows a reaction of acid rain and a layer of zinc oxide which usually covers the zinc roof (Akpan, 2003). Madden et al (2007) found out that the corrosive effects of acidic gases and particulates such as SO_2, NO_X, Sulphates and Nitrates are observed on metallic structures and equipment.

Nkwocha (2010) pointed out that the corrosion occurs more during months of scanty rain say December to April than May to July and September. Okereke (2006) concluded that acid rain causes corrosion of roofing zinc sheets, other metal structures and concrete.

The rainwater collected from Aluminium roof had closer properties to the intercepted rainwater from control location except for traces of Aluminium discovered. Potera (2009) stated that corrosion is more effective in Aluminium sheets of less than 0.50mm thickness. Ovri and Iroh (2003) concluded in their work that corrosion of Aluminium is not as rapid as the zinc roof. Akpan (2003) pointed out that aluminium oxide reacts sparingly with dilute acid. This accounted for the similarity of results obtained from Aluminium rainwater in study and control locations. Generally corrosion is less in Aluminum roof compared to the Galvanized Iron roof.

Rainwater intercepted by Asbestos roof had high turbidity, colour, TSS, Magnesium, Sulphate and Nitrate. It is possible that asbestos offer better adsorption surface for particulates. The Centre for Disease Control Canada (2007) reported that asbestos based roofs materials have stronger resistance to acid rain deterioration and corrosion but contributes more to high health risks due to its fine fibres that can penetrate the lungs and are persistent in the environment. The magnesium high value is likely to come from the composition of asbestos.

While galvanized iron roof corrodes faster, Aluminum roof has more acidic rainwater and asbestos roof makes rainwater a higher health risk.

Ejeleonu et al (2011) stated that in Utorogu gas flaring Community, rainwater contains acid radicals like Sulphate (SO_4^{2-}) and Nitrate (NO_3^-). Sulphate and nitrate concentration was highest in the asbestos rainwater (120 and 60mg/dm^3 respectively) this could be as a result of particulate deposition and formation of magnesium sulphate induced by gas flaring.

CONCLUSION

Rainwater in Odagwa is used extensively for drinking and other domestic activities. The World Health Organization and Nigeria Industrial Standards stipulated that water for drinking should be free from contamination, (NIS, 2007). The quality of rainwater intercepted by roofs in the control location was of drinking standard.

Unintercepted rainwater in Odagwa was acidic for most part of the year. Odagwa is a rural community with similar geo-environment with Obite. Her acidic precipitation could be attributed to over 30 years of gas flaring in the community.

Acidified rainwater serves as oxidative agent inducing rapid corrosion of metallic roofs especially the galvanized iron roof. Aluminium roofs' rainwater is the most acidic while the asbestos roof rainwater has more health implications due to respirable fibre content.

If rainwater must continue to be used as source of domestic water supply, efforts should be made to treat it first. Use of Galvanized iron roofing sheets should be discouraged in the community in favour of the Aluminium roof with corrosion resistant material coating.

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APPENDIX I

Nigerian Standards for Drinking Water Quality.

S/N	PARAMETER	UNIT	MAX. PERMITED LEVELS
1	TEMPERATURE	^{o}C	Ambient
2	TURBIDITY	NTU	5
3	COLOUR	TCU/Pt/Co	15
4	ELECTRICAL CONDUCTIVITY	µS/cm	1000
5	PH	-	6.5-8.5
6	TOTAL SUSPENDED SOLIDS	mg/l	50
7	TOTAL DISSOLVED SOLIDS	mg/l	500
8	TOTAL HARDNESS AS CaCO3	mg/l	150
9	SODIUM	mg/l	200
10	MAGNESIUM	mg/l	0.2
11	CALCIUM	mg/l	-
12	SULPHATE	mg/l	100
13	NITRATE	mg/l	50
14	CHLORIDE	mg/l	250
15	CADMIUM	mg/l	0.003
16	IRON	mg/l	0.3
17	LEAD	mg/l	0.01
18	MANGANESE	mg/l	0.2
19	NICKEL	mg/l	0.02
20	ZINC	mg/l	3
21	ALUMINIUM	mg/l	0.2

Source: Nigeria Industrial Standards (Standards Organization of Nigeria) (NIS, 2007)

APPENDIX II

Guidelines for Drinking Water Quality.

S/N	PARAMETER	UNIT	MAX. PERMITED LEVELS
1	TEMPERATURE	^oC	-
2	TURBIDITY	NTU	5
3	COLOUR	TCU/Pt/Co	15
4	ELECTRICAL CONDUCTIVITY	µS/cm	-
5	PH	-	6.5-8.5
6	TOTAL SUSPENDED SOLIDS	mg/l	50
7	TOTAL DISSOLVED SOLIDS	mg/l	600
8	TOTAL HARDNESS AS CaCO3	mg/l	200
9	SODIUM	mg/l	200
10	MAGNESIUM	mg/l	0.5
11	CALCIUM	mg/l	75
12	SULPHATE	mg/l	250
13	NITRATE	mg/l	50
14	CHLORIDE	mg/l	250
15	CADMIUM	mg/l	0.003
16	IRON	mg/l	0.3
17	LEAD	mg/l	0.01
18	MANGANESE	mg/l	0.4
19	NICKEL	mg/l	0.07
20	ZINC	mg/l	5
21	ALUMINIUM	mg/l	0.2

Source: World Health Organization (WHO, 2008)