COMPARATIVE ASSESSMENT OF HARVESTED RAINWATER QUALITY FROM DIFFERENT ROOFING MATERIALS IN PETROLEUM PRODUCING COMMUNITY, EGBEMA, RIVERS STATE, NIGERIA

[1]gwuorah, A.U.; [2]Egbu, A.U.; [3]Eze, M.U. and [4]Nwaugo, V.C.

[1]*Dept of Urban and Regional Planning, College of Arts and Science, Port Harcourt*

[2]*Dept of Urban and Regional Planning, Abia State University, Uturu*

[3]*Dept of Estate Management, Abia State University, Utnru.*

[4]*Dept of Microbiology, ABia State University, Uturu*

08063494654

Abstract: A comparative study of the quality of rain water from different roofing materials was carried out in Egbema, an oil producing community in Rivers State. While SO4, P04, NO3, turbidity and hardness of the rain water samples were more in asbestos and concrete roofs, the metallic ions, Zn, Fe, Al. Mn and Pb were statistically (p=0.05) more in corrugated iron and aluminum roofs which also had higher conductivity. Higher acidity was observed in the gas flaring area (Ebocha) compared to Okwuzi, 3-4km away. This resulted in greater cation and anions in the rain water from Ebocha compared to Okwuzi (P = 0.05). Seasonal effects showed that higher values where obtained from the occasional rains of the dry season, followed by the early rainy season rain water samples while the least were in the mid rainy season rain water. Values from the late rains of rainy season were not statistically (P = 0.05) higher than the mid rainy season ones, though they were slightly higher. More fungal count, were recorded during the dry periods, followed by the heterotrophic bacteria with the least being the coliforms. Higher microbial counts were found in the asbestos, followed by the concrete roofs before the corrugated iron roofs and then the aluminum roofs. The above observations were attributed to the acid rain formation due to the gas flaring activities at Ebocha. Rainwater from the Egbema communities was therefore not potable and safe for drinking purposes.

Keywords: Oil production, roof materials, gas flaring, dry and rain seasons

Introduction

Water is a very important and indispensable natural and environmental resource. Adequate and safe water supply is very central in the development and sustenance of any nation (Babalola, 1997). The supply of potable water to the human settlement requires very careful planning and implementation.

*Corresponding author:
VO Nwaugo;vonwaugo@yahoo.com.
[1]**Ugwuorah, A.U**

It is therefore very paramount to assess the quality before supply or use (Babalola, 1990;Nwaugo *et al.*, 2009a).

There are three major sources of domestic water supply to a community which include - atmospheric water (rain water), ground water (borehole or spring water) and surface water (rivers, streams, ponds) (Nwaugo *et al.*, 2008, 2009a). In the case of atmospheric water, the water passes through the air, dissolving soluble substances along its trail before landing on roofs to run down the grills or directly on the earth's surface. The contents of the roofs therefore determine the contents of the harvested rain water in addition to the air quality (Nwaugo *et al.*, 2009b).

The Nigerian environment has been extensively inudated by the oil exploration and exploitation activities (Ojeh, 2011; Ubouh, 2012). One of the major issues in oil production is gas flaring, which has characterized the Nigerian oil industry since the discovering of oil in the late 1950s and 1960s. Several authors have stated that gas flaring results in acid rain formation in the affected areas (Ubuoh, 2002; Obia *et al.*, 2011; Nwankwo and Ogagarue, 2011). The acid rain therefore determines the quality of the rain water in addition to its effects on roofing materials.

In the catchment or harvesting of rain water the roofing materials play very vital roles in the quality of the rain water. The acid rain in gas flaring area affects the roofing materials (Obia *et al.*, 2011; Campopiano *et al.*, 2009, 2010) hence various substances will contaminate the water. Various materials have been used in the roofing of buildings following the rapid advancement of science and technology. Such materials used include corrugated iron sheets (commonly referred to as zinc), asbestos sheets, aluminum sheets, plastics and concrete. These materials have their advantages and disadvantages which in the process affect the comfort, esthetics and general disposition of the building involved.

The quality of the domestic water its availability and quality play significant roles as determinant of environmental health. The management and supply of good domestic water also play primary role in the epidemiology of both communicable and non communicable diseases. It is therefore on this note that this study was designed to assess the quality of harvested rainwater from various types of roofing materials in gas flaring area of Egbema, Rivers State, Nigeria. In doing this, the effect of seasonal changes was taken into consideration too.

Materials and Methods

- The Study Area

The study area was Egbema, a well known oil producing community in the Niger Delta area of Nigeria. Since the discovery of oil in 1960s in the area, the associated gas has been flared unabated till date, resulting in air quality modification. Egbema lies at the northern apex of Rivers State at the boundary with Imo State while the exact location of the flare area is Ebocha which lies at $5^{o}41^{l}$ and $6^{o}4^{l}$.

The study area has typical rainforest climate and has two major seasons - dry and rainy season, though occasional rains can equally be experienced at anytime of the year even at the peak of dry season.

Collection of Rainwater Samples

A random sampling technique was employed in choosing the buildings whose roofs were to be used in the study. Four roofing materials were selected. These were asbestos, corrugated iron sheet (zinc), aluminum sheets and concrete roofs. The roofs of the buildings were properly cleaned to remove all debris and particles before the study began. Care was taken to avoid any accidental contamination of the expected rainwater during and after collection. The water was collected as it came off the roofs in very clean and sterile plastic containers without allowing it to touch any other material. Samples were collected directly from the rains by placing the containers on 2mm stools and allowing the water to drop directly from the sky into the containers as controls at both Ebocha and Okwuzi.

Analysis of the Rainwater Samples

Using HANA 1990 and HANA HI 9835 multipurpose testers the pH, temperature, turbidity and conductivity of the collected rain water samples were determined *in-situ*. The total hardness, phosphate (PO_4), sulphate (SO_4), nitrate (NO_3), and total suspended solids were determined according to UNEP (2004) procedures. Using various techniques ranging from titrimetric, flame photometric to atomic absorption spectrophotometric methods, the concentrations of several metallic ions in the water were also determined (UNEP, 2004).

Furthermore the biological loads (bioloads) of some microbial groups were assessed to determine the microbiological quality of the water. These groups were total heterotrophic bacteria (THB), total coliform (TC) and total fungi (TF). Their numbers were determined using culture technique involving different media. Nutrient agar was used for THB, McConkey Agar for TC and Sabouround dextrose agar for TF using spread plate technique after ten-fold seria dilution as described by Chessbrough (2005).

Results

Fig 1 shows the physicochemical parameters measured and their values in the dry season. Temperature of the rain water was higher at Ebocha (30.6 – 32.1°C) than Okwuzi (27.0 – 28.6°C) with the clean catch rain water (controls) having the lowest values. There was no statistical differences based on roofing materials ($P = 0.05$). Water from Ebocha had lower pH values than Okwuzi with Al and Zn roofs having pH values of 5.2 while asbestos and concrete had 5.7 at Ebocha. Values at Okwuzi were nearly uniform 5.7 – 5.8 except the control with 5.9.

The roofing material types had significant influence on conductivity hardness, TDS, PO_4 and NO_3 values of the rain water samples with values from Ebocha being higher than those from Okwuzi ($P = 0.05$). The values of SO_4 were not significant except in asbestos roof at Ebocha (6.7mg/l) while others had a range of 6.2 – 6.4mg/L. At Okwuzi SO_4 had a value of 6.0mg/l and the roofing material types except asbestos which had 6.4mg/L.

Fig 2 shows that the pattern observed in the dry season values (Table 1) remained in the early rainy season. However, while the pH and NO_3 content remained significantly unchanged ($P = 0.05$), other parameters decreased slightly in values.

All the parameters measured showed significant changes in Fig 3 (mid rainy season) compared to Fig 1 (dry season), except pH values that increased ($P = 0.05$). However, the same trend was maintained in every parameter. Values of the control 2 (Okwuzi) were different from those of control 1 (Ebocha) just like in the roofing materials types too. Values obtained in Table 4 were not statistical different from those in Table 3 though marginal increase was observed ($P = 0.05$). The concentrations of the metallic ions observed in the various rain water samples from different roof types are shown in Figures 1-4 according to the various periods of sampling.

Figure 5 shows that the most important metallic ions with concentrations above WHO limits was Pb, with value range of 0.08 – 0.09 at 0.03 – 0.05 at Okwuzi. However, Fe and Mn showed values that were considerable near the upper limits following WHO (2007) standards. Observations showed that higher metallic contents were observed at Ebocha than Okwuzi with corrugated iron roofs having higher values, followed by AL roofs before asbestos and concrete roofs (P = 0.05). The concentration of Al was highest in AL roofs while Zn showed the same in Zn roofs.

Figure 6 shows the absence of Cr and Cd in the rain water from roofs at Okwuzi with only traces at Ebocha during the early rains. Figure 7 shows that the water samples had lower metallic concentrations than Figures 1 and 2. Cu, Cr and Cd were not observed in roofs water and control in Okwuzi but traces were seen at Ebocha. Lower metallic concentration were observed in mid rainy season rain water samples. Values from Figure 8 were similar to those in Figure 7.

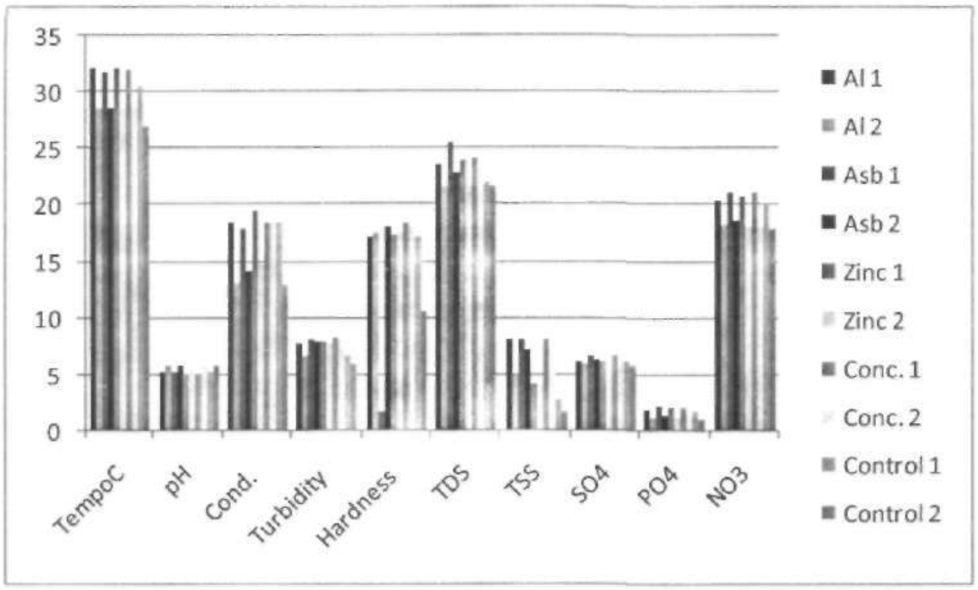
Generally, higher metallic ions concentrations were observed in Al and Zn roofing materials. Again values from Ebocha (gas flaring spot) were generally higher than those from Okwuzi (3km distance way) in all seasons examined.

Microbiological assessment of the rain water samples showed very significant difference (P = 0.05). Asbestos and concrete roofs had higher microbial counts than zinc (corrugated iron sheets) roof while Al roofs had the least. The same trends were observed both at Ebocha and Okwuzi. However, TFC counts were significantly higher than the THBC and TCC was the least with higher counts at Okwuzi than Ebocha (Table 5). Seasonal influence showed that highest counts were recorded in the early rain season water, followed by the dry season (occasional rain) water while the least were observed in the mid rainy season water (P = 0.05).

Discussion

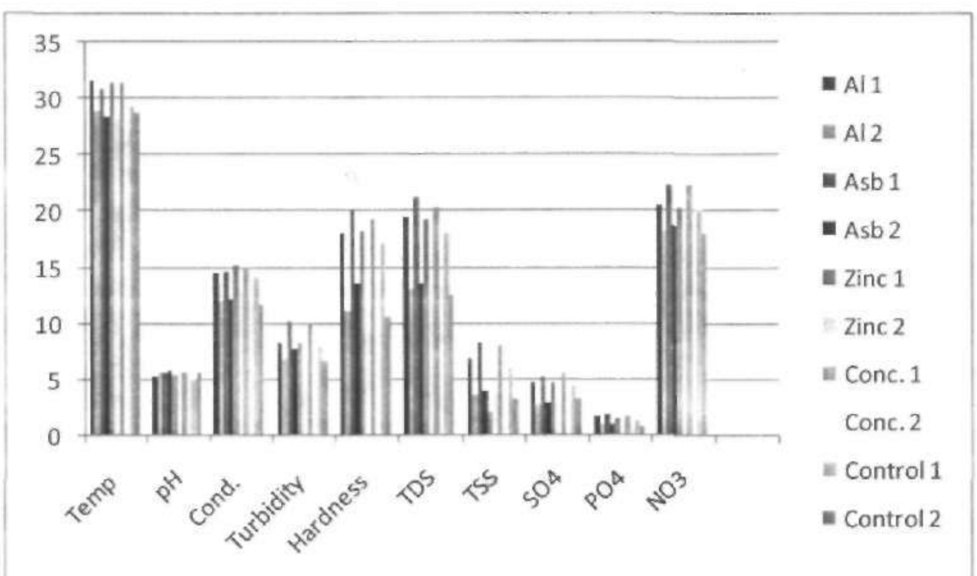
Oil production with its associated flaring of associated gas have been going on in Egbema since 1960s when oil was first discovered in commercial quantities in the area. Assessment of the rain water from Egbema showed variations based on location and the activities taking place. The physicochemical parameters assessed showed that NO_3, was high at both the gas flaring area (Ebocha) and the community tested – Okwuzi. In addition, the hardness of the rain water followed the same pattern with the rain water being acidic. The acidity was higher at Ebocha than Okwuzi.

The various types of roofing materials showed variations in the water quality at both sampling stations. NO_3, SO_4, PO_4 and hardness including TDS and TSS were higher in the asbestos roofing material followed by the water from concrete roof. Similarly, rain water from corrugated iron sheets had similar higher concentration than aluminum roofs. These observations are similar to the results reported by Olaoye and Olaniyan (2012) and Van-metre and Mahler (2007), Obia and Obot (2010), Campopiano *et al* (2009). Obia *et al.*, (2011) reported that acid rains cause the decay of asbestos roofing sheets and corrugated iron roofing metals. Asbestos and concrete roofs contain higher percentages of SO_4, NO_3 and PO_4 including carbonates which could be found in rain water harvested from such roofs.



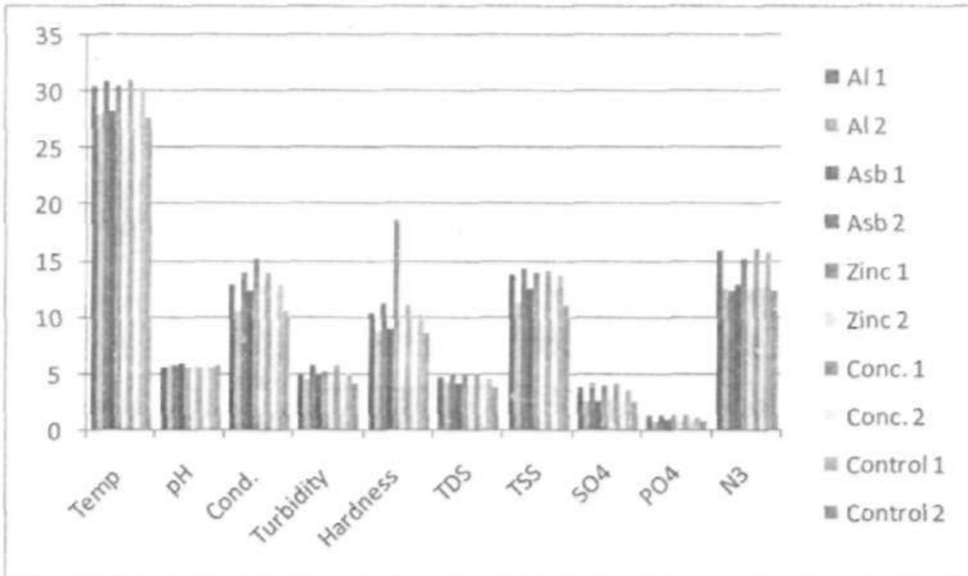
Key; 1=Ebocha 2= Okwuzi

Fig 1: Physicochemical properties of rainwater harvested from different roofing materials (Dry season).



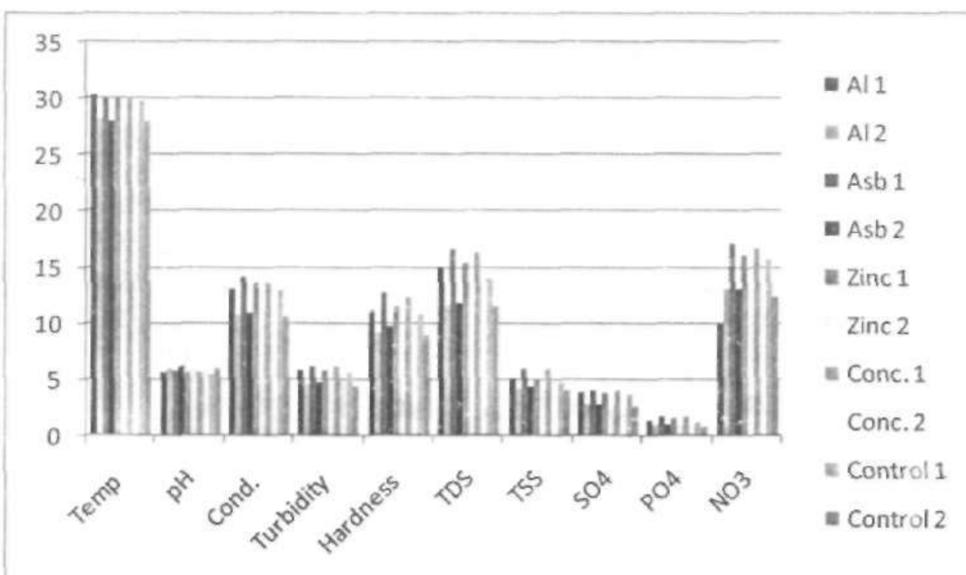
Key; 1=Ebocha 2= Okwuzi

Fig 2: Physicochemical properties of rainwater harvested from different roofing materials (early rainy season).



Key; 1=Ebocha 2= Okwuzi

Fig 3: Physicochemical properties of rainwater harvested from different roofing materials (mid rainy season).



Key; 1=Ebocha 2= Okwuzi

Fig 4: Physicochemical properties of rainwater harvested from different Roofing materials (late rainy season).

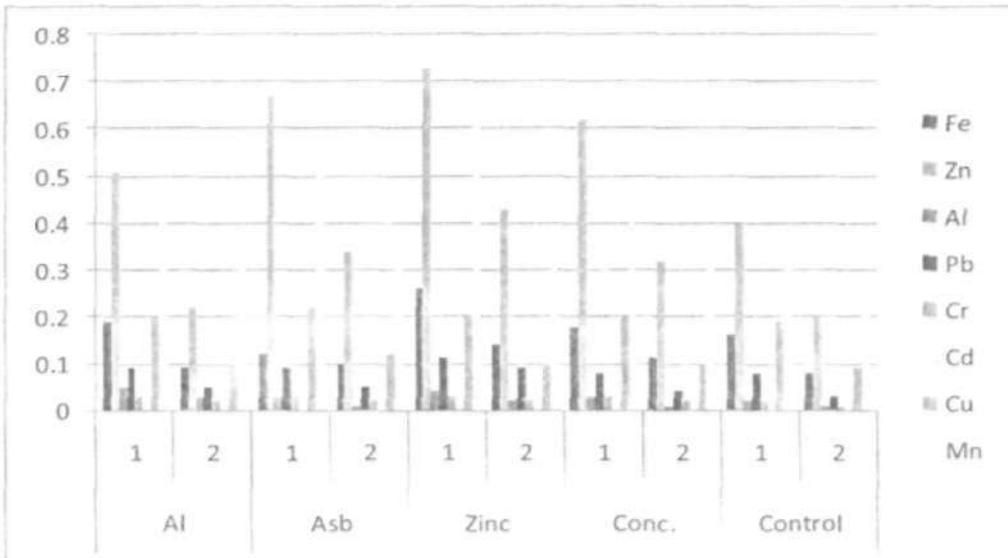


Fig 5; Metallic ions concentrations in the harvested rainwater (Dry season)

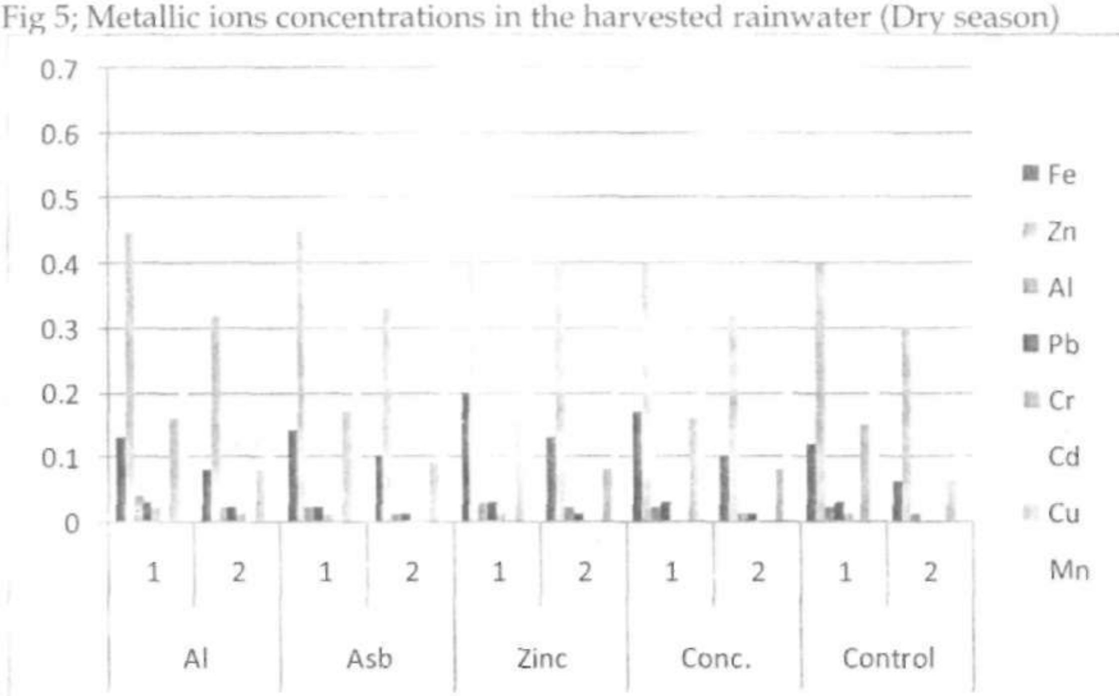


Fig 6; Metallic ions concentrations in the harvested rainwater (Early rainy season)

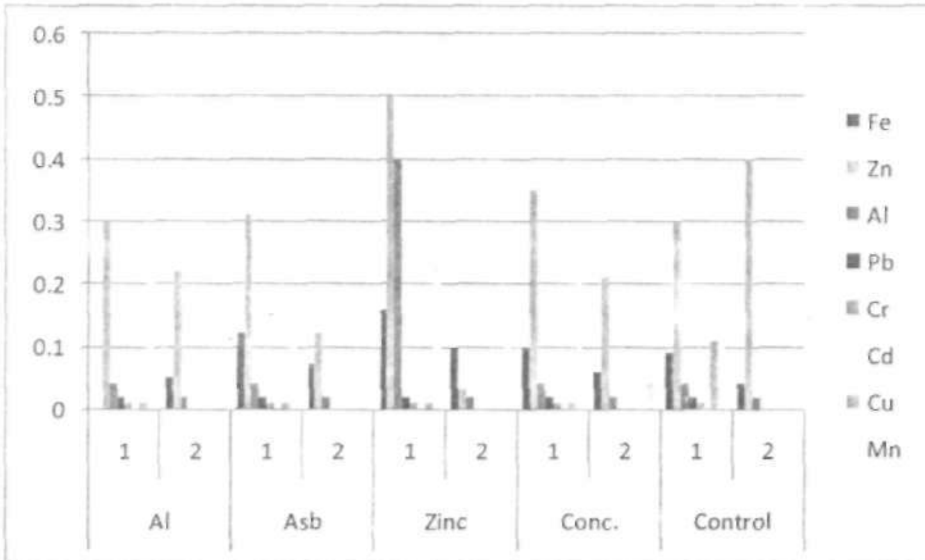


Fig 7; Metallic ion concentrations in harvested rainwater (mid rainy season)

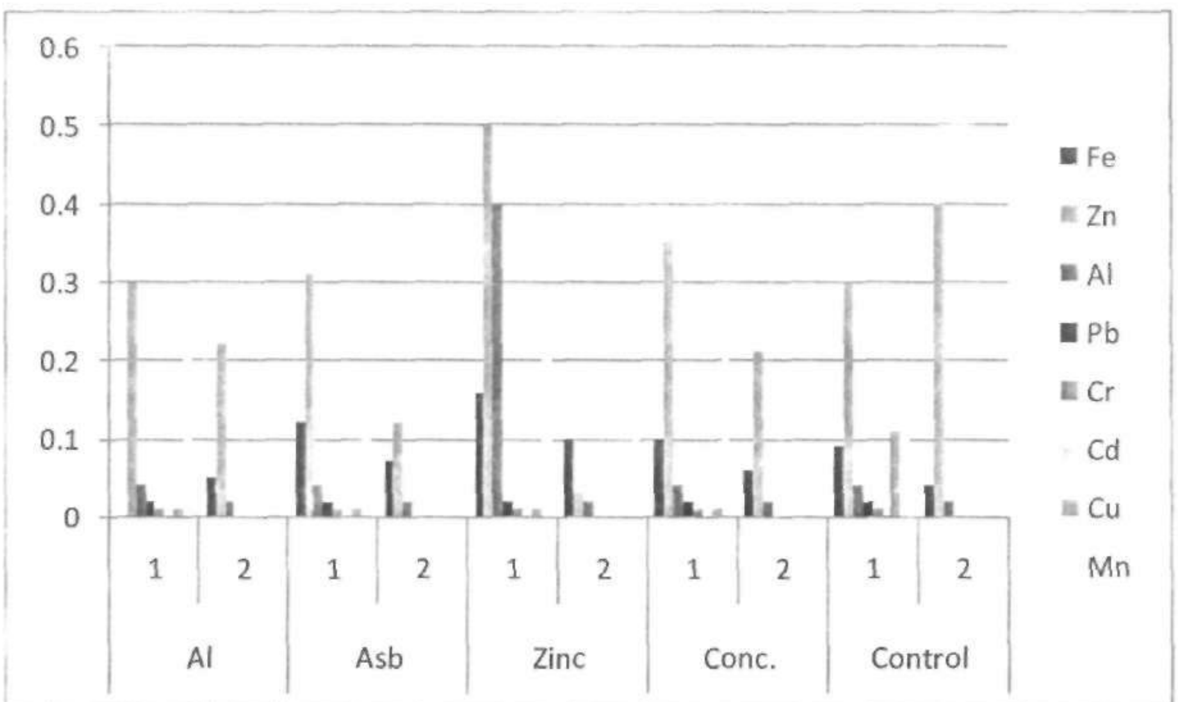


Fig. 8; Metallic ion concentrations in harvested rainwater (late rainy season).

Table 1 Microbiological loads of the various rainwater samples.

	Al		*Asb*		*Zinc*		*Conc.*		*Control*	
	1	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
Mid dry season										
THBC	$1.0 X 10^4$	$2.1 x 10^4$	$3.1 x 10^4$	$3.4 x 10^4$	$1.4 x 10^4$	$2.3 x 10^4$	$3.4 x 10^4$	$3.9 x 10^4$	$2.4 x 10^3$	$1.2 x 10^4$
TCC	$0.4 X 10^1$	$0.5 x 10^1$	$0.6 x 10^1$	$0.8 x 10^1$	$0.5 x 10^1$	$0.8 x 10^1$	$1.0 x 10^1$	$0.9 x 10^1$	$0.2 x 10^1$	$0.8 x 10^1$
TFC	$1.9 X 10^4$	$1.9 x 10^4$	$1.9 x 10^4$	$2.6 x 10^4$	$1.6 x 10^4$	$2.1 x 10^4$	$12.1 x 10^4$	$2.3 x 10^4$	$1.1 x 10^3$	$1.4 x 10^3$
Early rainy season										
THBC	$1.2 X 10^4$	$1.9 x 10^4$	$2.0 x 10^4$	$3.0 x 10^4$	$1.4 x 10^4$	$2.5 x 10^4$	$1.9 x 10^4$	$2.6 x 10^4$	$1.1 x 10^2$	$1.3 x 10^2$
TCC	$0.5 X 10^1$	$0.8 x 10^1$	$0.9 x 10^1$	$1.1 x 10^1$	$0.5 x 10^1$	$0.9 x 10^1$	$0.8 x 10^1$	$1.0 x 10^1$	$0.2 x 10^1$	$0.4 x 10^1$
TFC	$1.6 X 10^4$	$2.4 x 10^4$	$1.9 x 10^4$	$3.2 x 10^4$	$1.8 x 10^4$	$2.9 x 10^4$	$2.0 x 10^4$	$3.0 x 10^4$	$1.3 x 10^2$	$1.6 x 10^2$
Mid rainy season										
THBC	$1.4 X 10^2$	$1.6 x 10^2$	$1.9 x 10^2$	$2.1 x 10^2$	$2.1 x 10^2$	$1.4 x 10^2$	$1.8 x 10^2$	$1.3 x 10^2$	$1.2 x 10^1$	$1.4 x 10^1$
TCC	$0.3 X 10^1$	$0.5 x 10^1$	$0.6 x 10^1$	$0.8 x 10^1$	$0.8 x 10^1$	$0.3 x 10^1$	$0.5 x 10^1$	$0.3 x 10^1$	$0.2 x 10^1$	$0.2 x 10^1$
TFC	$1.4 X 10^2$	$1.6 x 10^2$	$1.9 x 10^2$	$2.4 x 10^2$	$2.4 x 10^2$	$1.5 x 10^2$	$2.9 x 10^2$	$1.8 x 10^2$	$1.6 x 10^1$	$1.9 x 10^1$
Early dry season										
THBC	$1.1 X 10^3$	$1.8 x 10^2$	$1.9 x 10^2$	$2.2 x 10^2$	$1.6 x 10^2$	$2.0 x 10^2$	$1.4 x 10^2$	$1.6 x 10^2$	$1.2 x 10^2$	$1.0 x 10^1$
TCC	$0.2 X 10^1$	$0.5 x 10^1$	$0.5 x 10^1$	$0.6 x 10^1$	$0.4 x 10^1$	$0.5 x 10^1$	$0.5 x 10^1$	$0.5 x 10^1$	$0.3 x 10^1$	$0.3 x 10^1$
TFC	$1.5 X 10^3$	$2.0 x 10^2$	$2.0 x 10^2$	$2.2 x 10^2$	$1.9 x 10^2$	$1.9 x 10^2$	$1.4 x 10^2$	$2.3 x 10^2$	$1.5 x 10^2$	$1.6 x 10^2$

The presence of these saltts in rain water from asbestos and concrete roofs could have caused the high turbidity and hardness in water from the gas flaring area and the community close to it.

The metallic ion concentrations were higher in the metallic roofing sheets – corrugated iron and aluminum sheets. This observation tallies with the reports of Obia and Obot (2010), Obia *et al.*, (2011), Lien *et al.*, (2007) and Tidblad *et al.*, (20000). The general consensus among these researchers is that metals dissolve under acidic conditions and the rain water from these areas are acidic. It was therefore possible for the metallic roofing sheets to dissolve under acid rain releasing more of these metallic ions. This assertion could be said to be true as corrugated iron sheets had higher Zn and Fe concentration which are its components while aluminum roofs had higher Al ions too. The presence of the other metallic ions in rain water form Ebocha could be attributed to contaminants in working materials, as much metallic work takes place at Ebocha than Okwuzi. Guthrie *et* al., (2002) and Natesan *et al.*, (2008) stated that the higher the acidity of the solution, the higher its corrosive effects. Dissolution (ionization) of metals was higher in acidic water Thus, the higher conductivity observed in rain water from corrugated iron sheets followed by aluminum could be due to such effects. This is buttressed as higher conductivity was observed at Ebocha with higher acidity than Okwuzi with low pH. Nwaugo *et al.*, (2009b) working in Isihagu reported higher metallic ions in the mine effluent and pit water with higher acidic pH.

Observations in the microbiological analysis showed that TFC were higher in both sampling situations (Ebocha and Okwuzi) than THBC with TCC being the lowest. Fungi are spore formers whose spores resist harsh environmental conditions and are easily dispersed by winds (Schimidt, 2004). Only few heterotrophic bacterial species produce spores (eg *Bacillus* species) while coliforms do not produce any spores. Prescott *et al.*, (2005) and Pelezar *et al.*, (2005) agree that coliforms will easily die off under increased environmental temperature and low pH at the point where spores will still survive. Similarly, Nwaugo *et al.*, (2009b) working in Isihagu domestic water supply stated that TCC was also the lowest in rain water from that area.

There was a clear-cut seasonal influence on the results obtained. Higher values of physicochemical parameters were observed in the occasional dry season and early rainy season rainwater than the mid rainy season and late rainy season rainwater samples. This could be attributed to accumulation of particles in the air. The rains of the early rainy season had washed the suspended or particulate materials down, making the air cleaner in the rainy season. Kuruvillo (1999) and Graedel (1994) had earlier stated similar observations. Tawari and Abowei (2012) stated that the dry season air is dirty while the rainy season air is clean in the Niger Delta area of Nigeria and the study area (Egbema) is also in the same Niger Delta area. This is easily attributed to the 'cleansing' by heavy downpours during the rainy season period. Thus the occasional rains of the dry season and early rainy season rains contained more substances and were equally more acidic than other samples.

Microbiological analysis showed slightly different trend. The microorganisms were more in the early rainy season rainwater than the dry season occasional rains. The occasional rains were light and only drizzled in most cases, hence were not strong enough to wash down much microbial progagules. As the intensity of the rains increased in the early rainy season, these organisms were removed making the mid rainy seasons water the cleanest. This suggestion was buttressed further as the counts slightly increased during the late rains. This is due to the infrequent rains, which caused a light accumulation of particles again in the air. This observation suggests that microbial progagules accumulate in the air with time and will decrease with the advent of rains.

Analysis of the results obtained showed that asbestos and concrete roofs had higher microbial counts than corrugated iron and aluminum sheets in that order. The various depressions in asbestos and concrete roofs acted as stores or collection point for these microorganisms. With the accumulation and availability of NO_3, PO_4 and carbonates, microbial growths on such asbestos and concrete roofs became possible. Graedel (1994) and Haneef *et al.*, (1999) attributed the erosion of cultural artifacts and buildings materials to such situation. Similarly, Norvaisiene *et al.*, (2003) and Nduka *et al.*, (2008) attributed the gradual deterioration of building and plastered facades in acid rain region to the same scenario. Favero-longo *et al* (2006) had earlier reported the growth of fungi of ascomycetes family on sterile asbestos fibres, which agrees with the high fungal counts and colonization of asbestos roof in this study.

Results obtained in the study showed that buildings at Ebocha suffered higher corrosive effect than those at Okwuzi indicating acid rain as the cause. This is because of the higher acidity of Ebocha than Okwuzi rain water samples.

From the above explanations, gas flaring affected roofs of building adversely, which in turn affected the rain water harvested from such roofs adversely too. It also revealed that the least contaminated rain water was that from aluminum roofs, in the mid raining season though no harvested rainwater was good enough for drinking purposes.

References

Babolola, J.O. (1990). Coping with water supply demands and growth in the 1990s. *Water Res. J. Nig. Assoc. Hydrogeol 2(1)*:26-30.

Babalolo, J.O. (1997). Rural water supply: Issues, problems and prospects. *Water Res. J. Nig. Assoc. Hydrogeol 8(1)*:19-25.

Beddoe, R.F. and Dorner, H.U. (2005) Modeling acid attack on concrete. Part I. The essential mechanisms *Cement Concrete Res* 35; 2333-2339.

Campapiano, A.; Ranies, D.; Zakrzewska, M.A.; Ferri, R.; D'annibale, and Pizzutelli, G. (2009). Risk assessment of the decay of Asbestos cement roofs. *Am. Occup. Hyg. 53 (6)* 627-238.

Cheesbrough, M. (2005). District Laboratory Practice in Tropical Countries, Low Price Ed. Cambridge University Press, United Kingdom

Efe, S.I. (2006) Quality of rain water harvesting for rural communities of Delta State, Nigeria. *The Environ* 26(3) 175-181

Favero-Longo, S.E.; Siniscalo, C.; Piervittori, R. (2006). Interactions of sterile-cultured Lichen-forming ascomyaetes with asbestos fibre. *Mycol Res. 111*:473-481

Graedel, T.E. (1994). Effets of emissions to the atmosphere on materials and cultural artifacts. In. V. Galvert (Ed). The chemistry of the atmosphere: Its impacts on Global Change, Blackwell, Oxford. 42-65

Guthrie, J.; Battat, B. and Grethlein, C. (2002). Accelerated corrosion testing. *AMPTIAC. Quarterly* 6(3) 11-15.

Haneef, S.; Dickinson, C. and Johnson, J. (1999) Effects of air pollution on historic buildings and monuments and the scientific basis for conservation, Corrosion and Protection Center, University of Manchester Report on a Research Project Support by the Commission of the European Community

Kuruvillo, A.K. (1999) Life prediction and performance assurance of structural materials in corrosive Environments – A State of the Arts-Report".Advanced materials and Processes Technology Information Analysis Centre, Falls Chruch 1999

Lien, L.T.; Sam, P.T. and Hong, H.L. (2007) Results of studying atmospheric corrosion in Vietnam 1995-2005 *Sc. Technol Advanced Materials* 8(788):552-558.

Nduka, J.; Orisakwe, O.; Ezenweke, L.; Ezenwa, T.; Chendo, M. and Ezeabasili, N. (2008) Acid rain phenomenon in Niger Delta region of Nigeria: Economic, Biodiversity and Public Health Concern. *The Sci., World J. 8*:811-818.

Narvaisiene, R.; Miniotaite, R. and Stankevicius, V. (2003).Climate and air pollution effects on building facades.*Mat. Sci. 9* (1):931-8

Natesan, M.S.; Selvaraj, T.; Manickam and Venkatachari (2008). Corrosion behaviour of metals and alloys in marine industrial environment. *Sci. Technol Advanced Materials 9*(4):615-626.

Nwaichi, E.O and Uzazobona, M.A. (2011). Estimation of the CO_2 level due to gas flaring in Nigeria Delta. *Res. J. Environ. Sci. 5*:565-572.

Nwankwo, C.N. and Ogagarue, D.O. (2011). Effects of Gas flaring on surface and ground waters in Delta State, Nigeria *J. Geo Min. Res. 3*(5): 131-136

Nwaugo, V.O.; Onyeagba, R.A. and Nwachukwu, N.C. (2006) Effect of gas flaring on soil Microbial spectrum in parts of Niger Delta area of Southern,Nigeria. *Afr J Biotech* 5 (19) 1824-182

Nwaugo, V.O., Chima, G.N., Elekwa, I. and Inyang, C. U (2009) Evaluation of surface water quality in heavy metal mining area of Ishiagu, South Eastern Nigeria.*J Sci Eng Technol* 16(2); 8781 – 8794

Nwaugo,V.O., Chima,, G.N.,Elekwa, I. and I.S. Onwuchekwa (2009a)Comparative assessment of domestic water supply sources in Ishiagu, a heavy metal mining community in Ebonyi State, Nigeria. *J Appl Sci12* (2):8473 – 8486

Nwaugo, V.O Chima, G.N. Elekwa, I and Inyang C.U (2009b) Evaluation of surface water supply in Heavy Metal Mining area of Ishiagu, South eastern Nigeria..*J.Eng. Sci Tech 16(2)*;8187-8190

Nwaugo, V.O.; Egbu, A.U.; Odu, N.N. and Ogbonna, C.E. (2011)Impact of Metal Mining on Domestic Water Quality in Ishiagu and its Environs, Ebonyi State, Nigeria *ABSU JEST.1(1); 62 - 71,*

Obia, A.E. and Obot, I.O. (2010). Atmospheric corrosion of metallic roofing sheet in building construction in the Niger Delta Region of Nigeria. *J. Environ. Issues Agric Dev. Countries 2(283)* 117-124.

Obia, A.E.; Okon, H.E.; Ekum, S.A. and Eyo-Ita, E.E. (2011) The influence of gas flare particulates and rainfall on the corrosion of galvanized steel roofs in the Niger Delta, Nigeria. *J. Environ. Protect* 2:1341-1546.

Ojeh, V.N. (2012). Sustainable development and gas flaring activities: A case study of Ebedei area of Ukwuani LGA, Delta State. Res. Environ, 2(4):169-174.

Olaoye, R.A. and Olaniyan, O.S. (2012). Quality of rain water from different roof materials *Int. J. Eng. Technol.* 2 (8) 1413-1421

Pelczar, M.,Chan E.I S. and Kriegi N.R (2003) *Microbiology of the soil and atmosphere: Concept and application in Microbiology* McGraw-Hills. Inc U.S.A.

Prescott, L.M, Harley, J.P and Klein, D A (2003) *Microbiology* 6a edition, McGraw-Hill Education. United States

Schmidt, O. (2006) Wood and Tree fungi Biology, Damage, Protection and Use Springer Berlain Heidelberg Verlag

Tawari, C.C. and Abowei J.F.N. (2012). Air pollution in the Niger Delta area of Nigeria. *Int. J. Fish Aquat. Sci. 1(2)*:94-117.

Tridblad, A.; Mikhilor, A.; and Kucera, V. (2000). Acid deposition effect on materials in subtropical countries: Data compilation and temperate climate comparison. Sec report 2000: 8E. Swedish Corrosion Institute, Stockholm, 2000

Ubouh, U.E. (2002). Spatial and temporal variations of acid rain formations in selected oil producing communities in Akwa Ibom State, Nigeria. *Cand. J. Sci. Indust. Res 3(4):* 193-206

UNEP (2004) United Nation Environmental programme., Analytical methods for Environmental Water Supply. Global Environmental Monitoring System with international Atomic Energy Agency, Canada

Van-Metre, P.C and Mahler, B.J. (2003). The contributions of particles washed from rooftops to contaminant loading to urban streams, *Chemosphere* 52(10):1727-1741.

Watanabe, T (2002) *Pictorial Atlas of Soil and Seed fungi; morphologies of cultured fungi and key to species* 2nd edition Boca Raton, CRC Press.

Webster, J and Weber, R (2007) *Introduction to fungi* 3rd edition. New York, Cambridge University Press.

Weiner, E R (2007) *Applications of Environmental Aquatic Chemistry.* A practical guide.
Boca Raton, USA CRC Press

WHO (2007) World Health Oganisation. *International drinking water standards,* 3rd edition. Geneva