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Characterization by Principal Component Analysis (PCA) of the Chemistry of Atmospheric Precipitation in Oil and Non-Oil Producing Communities of Akwa Ibom State, Nigeria

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ABSTRACT

This paper examines the character of atmospheric precipitation from oil and non-oil producing communities of Akwa Ibom State, Nigeria, due to incidence of rainwater pollution and its effects on man and his environment. This was accomplished through the use of principal component analysis (PCA) for data interpretation and grouping of atmospheric precipitation for rainwater quality sustainability for human consumption .Twenty seven (27) samples of atmospheric rainwater from oil producing and non- oil producing communities were tested. From the use of PCA, four underlying components were extracted from study locations: Component I with high positive loadings includes: (temperature, TDS, Turbidity, EC, NO_3, Pb),Component II (pH, Cl, Zn), Component IV ($CaCO_3$, NH_4Fe) all emanated from gas flared region leading to acid rain formation within oil producing communities. Results from non-oil producing communities shown high positives loadings in Component 1 (temperature, Cl, SO_4, $CaCO_3$,NH_3, Fe, Cd and Mn).Component II : (Colour, pH, Zn), component III (NO_3), and Component IV (turbidity, Pb) suspected to be caused by vehicular flows, agriculture and other activities outside gas flaring. Ultimately, the results of PCA reflect a good look on the water quality monitoring and interpretation of the atmospheric rainwater in oil producing and non-oil producing communities of Akwa Ibom State. This then calls for enforcement of the enabling environmental rules and regulations to mitigate environmental pollution caused by incessant gas flaring in the region.

Keywords: Principal Component Analysis, Atmosphere, Chemistry, Precipitation, Gas flaring

INTRODUCTION

Water is one of the essential inputs for sustenance of all living being. The need of water for various purposes is increasing at a fast rate due to the continual increase in population, rapid urbanization with change in life style and growing industrialization (Gajbhiye *et al.*, 2014b; Sharma *et al.*, 2014b). Rainwater plays an important role in scavenging atmospheric soluble and insoluble components, making the chemical investigation of rainwater compositions a useful tool to trace different sources of atmospheric pollutants (Özsoy andÖrnektekin, 2009). Obaidy and Joshi (2006) reported that chemical composition of rain water signifies the quantity and quality of air emissions supplied to the atmosphere from natural and anthropogenic sources. Pollutants released to the atmosphere as gases and aerosols from human activities are transported and deposited several kilometres away from their source; being removed by dry or wet deposition, with its consequences over living organisms in the ecosystems (Steinnea, 1990; Berner and Berner, 1996; N'egrel and Roy, 1998; Molinaroli et al., 1999). Within the last decade, an intensive effort has been made to determine the atmospheric physicochemical compositions in both urban and rural areas (Migon and Nicolas, 1997; Vukmirovic et al, 1997; Injuk *et al*, 1998; Garnaud *et al*, 1999) . Those previous works have highlighted that the atmosphere is: an important pathway for transport of heavy metals and the major external input of bio-available heavy metals to the environment and human health (Jacjs, 1990; Bilos *et al*, 2001; Keith 2013). Atmospheric deposition has largely been neglected in considering the effect of air pollutants on human health yet can be a major environmental problem (Keith, 2013).

According to Jolliffe (2002), principal component analysis (PCA) is a useful statistical tool for the analysis of large multivariate data.

Analysis via this technique produce easily interpretable results, and have been used successfully in water quality assessment (Praus, 2005; Anyadike, 2009; Peixun *et al* , 2001; Kanellopoulou , 2001 ;Olobaniyi and Owoyeni, 2006).The application of principal component analysis has helped identify important components or factors accounting for most of the variances of a system (Ouyang et al. 2006; Shrestha and Kazama 2007). They are designed to reduce the number of variables to a small number of indices while attempting to preserve the relationships present in the original data (Mazlum *et al.*, 1996; Jayakumar and Siraz, 1997; Salman and Abu Ruka'h, 1998; Praus, 2005; Olobaniyi and Owoyeni, 2006).

Iyer *et al.* (2003) constructed a statistical, model which based on the PCA for coastal water quality data from the Cochin coast in south west India, which explain the relationships between the various physicochemical variables that have been monitored and environmental conditions effect on the coastal water quality.

Recently, Ndehedehe et al (2016) employed PCA to analyze terrestrial water storage and precipitation in West Africa. The application of PCA in the assessment of the atmospheric precipitation in Akwa Ibom is first of its kind for the grouping and separation of rainwater quality in Akwa Ibom State.

Therefore, the main objective of this study is to apply principal components analysis (PCA) in order to interpret and grouping the atmospheric rainwater quality characteristics within the coastal and urban environment of Akwa Ibom State in order to ensure rainwater quality sustainability.

MATERIALS AND METHODS

Study Area

Akwa Ibom State is located in the South eastern part of Nigeria. It is located between latitude 4° 32′ and 5° 5′ North and longitude 7° 2′ and 8° 25′ East (Fig. 1). The rainfall varies from more than 3000 mm long the coast to about 2000 mm inland, with temperature that varies between about 25–28°C. The state holds some of the largest reserves of oil and gas in the country both onshore - offshore and account for about 28% of the total and crude oil export (Akwa Ibom, 2006) . It is the operating base of the American oil giant Exxon-Mobil, while Shell, Chevron and Total (Elf) are also actively engaged in the area. The operational base of the company is located in Qua Iboe Terminal (QIT) and it has several production platforms spread along continent shelf of the Atlantic coast of Akwa Ibom (Ekop and Udotong, 2004).

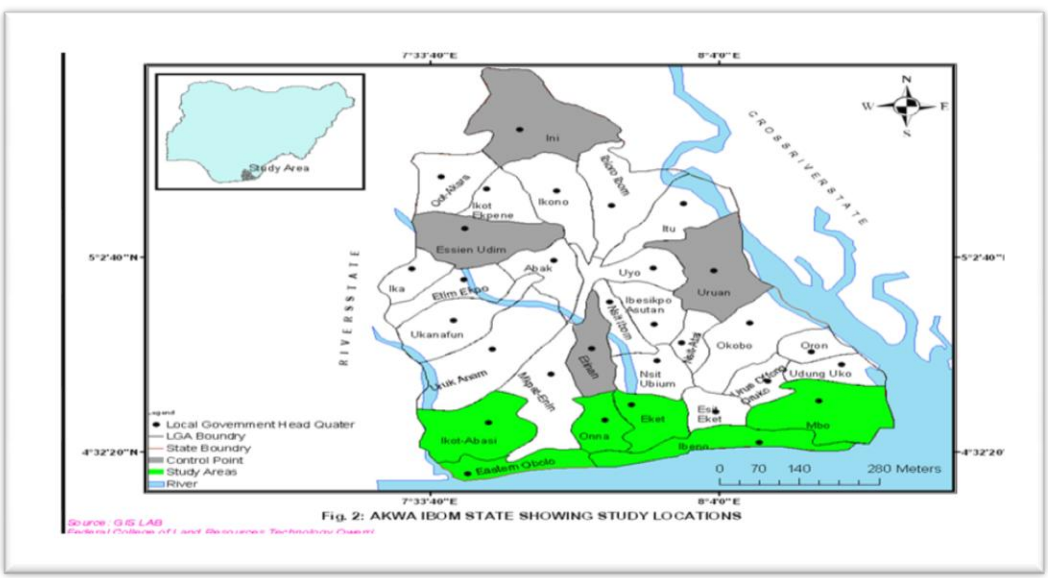

Fig. 1: Map of Akwa Ibom State showing study locations

Atmospheric precipitation sampling and analysis

Six Local Government Areas were chosen as oil producing communities to include Eket, Ikot-Abasi, Onna, Ibeno, Eastern-Obolo and Mbo where incessant gas flaring is observed. Non-oil producing communities to include include: Etinan, Essien-Udim, Ini and Uruan Local Government Areas that fall outside gas flare region. Rainwater samples were harvested directly from the atmosphere as ambient rainwater during the months of March, July and November. Harvested rainwater from atmosphere involved placing basins on the rooftops to avoid splashing. After each rain events, polyethylene bottles and funnels, previously rinsed with rainwater were used for rainwater storage by trained ten (10) field assistants/overseers at different locations. And the corked rainwater samples were frozen in coolers that contained ice blocks and sent to Environmental Laboratory in Federal College of Land Resources Technology, Owerri, Nigeria.

Principle Component Analysis

Statistical computations were made using SPSS version 7 (2004) software package (StatSoft). Principal component analysis (PCA) is a powerful tool that attempts to explain the variance of a large dataset of intercorrelated variables with a smaller set of independent variables (Simeonov *et al.* 2003). PCA technique extracts the Eigen values and eigenvectors from the covariance matrix of original variables. The Principal Components (PCA) are the uncorrelated (orthogonal) variables obtained by multiplying the original correlated variables with the eigenvector, which is a list of coefficients (loadings or weightings). Thus, the PCA is weighted linear combinations of the original variables. PCA provide information on the most meaningful parameters, which describe the whole data set while affording data reduction with a minimum loss of original information (Hair *et al.* 1995; Sharma 1996; Vega *et al.* 1998). The first principal component is that linear combination of the original variables which contributes a maximum to their total variance; the second principal component, uncorrelated with the first, contributes a maximum to the residual variance, and so on until the total variance is analyzed. Since the method is so dependent on the total variance of the original variables, it is most suitable when all the variables are measured in the same units (Sharma *et al.*, 2013, 2014a). Principal component analysis used is based on the correlation matrix since the units of my data are different.

Determination of atmospheric rainwater quality

For atmospheric precipitation sampling 19 parameters as variables were chosen to including: temperature, taste, odour, colour, total dissolve solids (TDS), total suspended solids (TSS),turbidity, chloride (Cl), Sulphate (SO_4^{2}), Nitrate (NO^{-}_3), $CaCO_3$ as hardness, Ammonium (NH_3^{+}), Copper (Cu^{+}), Iron (Fe^{+2}), Zinc (Zn^{+2}), Lead, aluminum, cadmium, and manganese. Principal component analysis was applied on these data for separation and grouping.

RESULTS AND DISCUSSION

Analysis of the atmospheric water samples are shown in Tables 1 and 4.These tables indicate the physical and chemical compositions of atmospheric rainwater that varied in concentrations at the different locations in the oil and non-oil producing communities . Tables 2 and 5 shown correlation matrix of atmospheric Rainwater in the study area while Tables 3 and 6 indicate rotated component matrix of atmospheric rainwater quality in Oil and non-oil producing communities.

Table 1: Mean values of Physical and chemical Characteristics in Atmospheric Precipitation in Oil –Producing Communities.

Physical Parameters	Selected Oil producing communities																	
	EKET (RWH1)			IKOT ABASI (RWH2)			ONNA(RWH3)			IBENO(RWH4)			EASTERNOBOLO(RWH5)			MBO(RWH6)		
	Mar	July	Nov.	Mar.	July	Nov.	Mar.	July	Nov.	Mar.	July	Nov	Mar	July	Nov.	Mar.	July	**Nov.**
Taste	Obj.	Unobj.	Obj.	Obj.	Unobj.	Obj.	Obj.	Unobj.	Obj.	Obj.	Unobj.	Obj.	Obj.	Unobj.	Obj.	Obj.	Unobj	**Obj**
Odour	Obj.	Unobj	Obj.	Obj.	Unobj.	Obj.	Obj.	Unobj.	Obj	Obj.	Unobj.	Obj.	Obj.	Unobj.	Obj.	Obj.	Unobj	**Obj**
Temp.	35	26	28	31	26	27	36	29	32	38	29	32	35	27	30	38	27	**29**
Colour	18	9	11	17	8	11	21	13	14	22	9	16	19	11	13	19	12	**13**
Appear	Obj	Unobj.	Unobj	Obj	Unobj.	Unbj	Obj.	Unobj.	Unobj.	Obj.	Unobj.	Obj.	Obj.	Unobj	Unoj	Obj	Unobj	**Obj**
TDS	16.5	7.01	8.2	11.7	4.8	6.8	9.4	4.5	5.7	19.8	8.5	11.5	15.2	9.9	12.3	15.9	6.8	**7.1**
TSS	8.2	2.9	4.8	2.8	0.6	0.9	9.2	6.1	6.9	11.7	2.6	5.8	8.9	3.6	6.5	12.1	4.2	**6.3**
Turbid	35.1	19.3	21.3	25.7	17.6	23.5	40.7	2i.6	29.9	45.1	30.4	37.5	28.9	18.9	22.4	37.5	26.9	**28.9**
Ph	5.4	5.6	5.5	5.5	5.7	5.5	5.5	5.7	5.6	5.1	5.5	5.4	5.4	5.6	5.5	5.4	5.6	**5.5**
EC.	45.2	26.1	28.3	38.3	26.6	29.6	46.5	27.3	31.1	49.8	28.9	30.7	43.2	27.7	33.4	47.2	28.7	**31.3**
Cl	28.1	17.0	19.7	21.9	15.0	17.5	19.6	13.0	16.0	34.1	21.8	28.9	31.8	23.6	29.3	34.9	25.7	**28.6**
SO_4	4.62	1.54	2.54	4.09	0.01	1.09	14.01	11.8	12.11	36.5	31.5	34.2	29.2	23.8	25.6	28.7	24.2	**26.3**
NO_3	48.9	45.6	46.7	20.8	15.6	18.6	51.8	43.5	45.5	48.9	33.6	42.5	46.9	40.1	43.3	46.3	32.4	**35.6**
$CaCO_3$	35.7	20.3	24.7	18.7	6.9	9.12	26.9	17.58	19.8	37.2	19.7	29.5	35.6	21.3	29.1	32.2	24.4	**24.9**
NH_4	0.41	0.23	0.29	0.09	0.05	0.07	0.07	0.03	0.06	0.03	0.01	0.02	0.04	0.01	0.03	2.02	0.02	**1.03**
Cu	**0.9**	**0.04**	**0.06**	**0.06**	**0.02**	**0.03**	**0.09**	**0.05**	**0.07**	**0.9**	**0.5**	**0.7**	**0.06**	**0.02**	**0.03**	**0.08**	**0.03**	**0.05**
Fe	**0.51**	**0.37**	**0.41**	**0.35**	**0.21**	**0.28**	**0.43**	**0.21**	**0.32**	**0.62**	**0.41**	**0.51**	**0.53**	**0.31**	**0.42**	**0.51**	**0.33**	**0.43**
Zn	**0.9**	**0.12**	**0.16**	**0.19**	**0.13**	**0.16**	**0.92**	**0.62**	**0.66**	**0.63**	**0.23**	**0.36**	**0.35**	**0.28**	**0.33**	**0.09**	**0.04**	**0.07**
Pb	**0.21**	**0.12**	**0.16**	**0.6**	**0.12**	**0.17**	**0.9**	**0.6**	**0.7**	**0.7**	**0.5**	**0.7**	**0.9**	**0.6**	**0.8**	**0.9**	**0.5**	**0.7**
Al	**0.02**	**0.001**	**0.01**	**0.03**	**0.01**	**0.02**	**0.03**	**0.01**	**0.02**	**0.02**	**0.001**	**0.01**	**0.04**	**0.002**	**0.02**	**0.03**	**0.001**	**0.02**
Cd	**0.05**	**0.02**	**0.03**	**0.04**	**0.02**	**0.03**	**0.04**	**0.02**	**0.03**	**0.05**	**0.02**	**0.03**	**0.04**	**0.01**	**0.03**	**0.05**	**0.02**	**0.03**
Mn	**0.06**	**0.02**	**0.03**	**0.05**	**0.02**	**0.03**	**0.07**	**0.03**	**0.05**	**0.06**	**0.02**	**0.04**	**0.06**	**0.03**	**0.04**	**0.07**	**0.03**	**0.05**

Table 2 Correlation Matrix of Atmospheric Rainwater in oil Producing Communities

Significant at $p < 0.05$.

Variables	Temp	Col	TDS	TSS	Turbid	pH	EC	Cl.	SO_4.	NO_3	$CaCO_3$	NH_3	Cu	Fe	Zn	Pb.	Al.	Cd	Mn
Temp.	1																		
Colour	0.39	1																	
TDS	0.55	0.39	1																
TSS	0.58	0.97	0.44	1															
Turbid.	0.82	0.35	0.48	0.53	1														
pH	0.72	0.85	0.57	0.93	0.65	1													
Elec.	0.44	-0.18	-0.05	-0.06	0.34	0.21	1												
Cl	0.86	0.53	0.70	0.70	0.77	0.81	0.31	1											
SO_4	0.88	0.31	0.33	0.51	0.64	0.6	0.44	0.88	1										
No_3	0.06	-0.27	0.53	-0.25	-0.02	-0.23	-0.49	0.02	-0.07	1									
$CaCO_3$	0.87	0.74	0.47	0.88	0.70	0.90	0.27	0.91	0.85	-0.21	1								
NH_3	0.96	0.57	0.55	0.73	0.72	0.83	0.35	0.93	0.93	-0.01	0.96	1							
Cu	-0.91	-0.15	-0.59	-0.34	-0.61	-0.54	-0.5	0.82	-0.88	-0.23	-0.71	-0.90	1						
Fe	0.94	0.61	0.57	0.77	0.73	0.84	0.27	0.91	0.87	0.04	0.95	0.99	-0.84	1					
Zn	0.09	0.89	0.27	0.78	-0.09	0.65	-0.31	0.33	0.11	-0.22	0.51	0.34	0.01	0.38	1				
Pb	0.3	-0.49	0.08	-0.34	0.59	-0.2	0.32	0.04	0.12	0.20	-0.1	0.03	-0.23	0.01	-0.83	1			
Al	0.34	0.73	0.59	0.65	0.02	0.62	-0.23	0.53	0.33	0.24	0.56	0.55	-0.39	0.60	0.80	-0.65	1		
Cd	0.82	0.21	0.80	0.35	0.78	0.58	0.46	0.75	0.58	0.22	0.59	0.71	-0.80	0.68	-0.08	0.48	0.22	1	
Mn	0.68	0.50	0.55	0.53	0.61	0.78	0.71	0.75	0.58	0.2	0.70	0.71	-0.67	0.68	0.25	0.05	0.36	0.73	1

Atmospheric Rainwater Quality in Oil Producing Communities

Compositional relations in atmospheric rainwater shown in (Table 2), indicated strong correlations $p < 0.05$. Exist between temperature and turbidity, pH, Cl, SO_4, $CaCO_3$, Cd and strongly correlated with NH_4, Fe and but negative correlation between temperature and copper $p < 0.05$. Strong correlation exist between colour and TSS, and good with pH, $CaCO_3$, Zn, Al; TDS with Cl, Cd; TSS strongly correlated with pH, good with Cl, $CaCO_3$, Fe, Zn; Turbidity with Cl, $CaCO_3$, NH_3, Fe,Cd; pH with NH_4, Fe, Mn and strongly correlated with $CaCO_3$; EC with Mn; good correlation exist between Cl and SO_4, Cu, Mn and strong with $CaCO_3$, NH_3 , Fe respectively; good correlation exist between SO_4 and $CaCO_3$, Fe , negative correlated with Cu and strongly correlated with NH_3; $CaCO_3$ strongly correlated with NH_3 and Fe, negatively correlated Cu and good with Mn; NH_3 strongly correlated with Cu, Fe and good with Cd , Mn respectively; Cu with Fe; Zn negatively correlated with Pb and positive with Al; and Cd with Mn. It is very difficult at this stage to group the parameters into components and attach any physical significance. Hence, in the next step, the principal component analysis has been applied. The correlation matrix is subjected to the principal component analysis.

Strongly correlated physicochemical parameters include temperature, total dissolved solids (TDS), total suspended solids (TSS), Turbidity, pH, electrical conductivity (EC), chloride (Cl), Sulphate (SO_4), nitrate (NO_3), total hardness ($CaCO_3$), ammonium (NH_3), Copper (Cu), Iron (Fe), Zinc (Zn), Lead (Pb) and aluminum (Al). These may probably come from the same source which is gas flaring. Beside colour, cadmium and manganese coming from natural source, (is mainly associated with the natural composition of the rest of the physicochemical parameters. The positive and strong correlations of these parameters in rainwater can work together to alter rainwater quality in the study area. For example, NO_3^- and SO_4^{2-} show good correlation during early March periods in rainwater samples indicating their origin from similar sources (mostly combustion and formation in atmosphere) (Ubuoh et al, 2017). Total hardness which is expressed as $CaCO_3$ in water is correlated with chloride and sulphate with the values of 0.65 and 0.79. This then implies that the association of hardness with chloride will cause water to be very hard for human consumption. Ammonium is positively correlated with temperature, TSS, turbidity, electrical conductivity, sulphate and nitrate. It is worthy to note that, ammonium is water charges with an increased temperature (0.55), also ammonium in rainwater can act as neutralizer leading to an increase in pH with the value (-0.016). Origin of NH_4^+ from the soil is ruled out and it can be concluded that NH_4^+ is being contributed by other sources. In the atmosphere, ammonia generally occurs as $(NH_4)_2SO_4$ and NH_4NO_3 suggesting association of NH_4^+ with SO_4^{2-} and NO_3^- after the neutralization process. This is supported by the fact that NH_4^+ has good correlation with NO_3^- (r = 0.68 as well as with SO_4^{2-} r = 0.55). Above all, the high and low correlations of physical and chemical in atmospheric rainwater do not present a precise interference into the role played by these variables in atmospheric pollution which is a non-point source. The nature of the correlations among these variables may lead to variance generation that the correlations matrix cannot explain. Additionally, the strong inter-correlation between the assumed independent variables would account for some weak association/correlation as observed in the Table 2.

In order to eliminate the effect of the strong inter-correlations, and to include the contribution of weak variables, the extractions are made by transforming the 19 variables into orthogonal varimax values by principal component analysis (PCA). In order to remove doubt of efficacy of the variables, factor loadings after varimax rotation was applied to the eigen vectors, and 4 components (factors) out of the 19 predictor variables for the analysis of atmospheric rainwater pollutants in the study locations as shown in Tables 3 and 6 below:

Table 3: Rotated Component Matrix of Atmospheric Rainwater Quality in Oil Producing Communities

S/N	Variables	COMPONENTS			
		I	II	III	IV
1	Temp.	**0.93**	**-0.70**	0.08	0.04
2	Colour	0.41	0.02	-0.68	0.19
3	TDS	**0.87**	0.47	-0.04	-0.05
4	TSS	0.35	0.55	-0.37	0.60
5	Turb.	**0.83**	0.36	0.17	0.31
6	pH	0.05	**0.90**	0.32	0.05
7	Elec. Con.	**0.86**	0.41	0.08	0.20
8	Cl	0.43	**0.70**	0.01	0.51
9	SO_4	0.42	0.55	0.07	0.63
10	NO_3	**0.92**	0.15	0.06	0.32

11	$CaCo_3$	0.15	0.25	0.31	**0.73**
12	NH_3	0.51	-0.12	-0.01	**0.77**
13	Cu	-0.44	**-0.79**	0.01	-0.26
14	Fe	-0.01	0.32	-0.14	**0.85**
15	Zn	0.53	**0.71**	-0.07	0.29
16	Pb	**0.81**	0.41	0.12	0.35
17	Al	0.68	0.34	0.04	0.58
18	Cd	0.57	0.52	0.23	0.37
19	Mn	0.48	0.24	**0.81**	0.08
	Eigenvalue	**11.733**	**2.075**	**1.824**	**1.211**
	Variability (%)	**61.751**	**10.921**	**9.602**	**6.372**
	Cumulative %	**61.751**	**72.672**	**82.274**	**88.646**

Atmospheric rainwater quality in non-oil producing communities

The principal component analyses for atmospheric rainwater sample in oil producing settlement shown in Table 3. It includes loading for the rotated component matrix, Eigen values for each component, per cent and cumulative per cent of variance explained by each component. As shown in Table 3 principal component analysis (PCA) has helped to identify four underlying component that explains 88.646% of the common variance with component I having variability of 61.751%, component II 10.921%, component III 9.602% and component IV 6.372% respectively. For accuracy and efficacy of interpretation, it is stated that an Eigen value must not be less than 1.00 (Anyadike, 2009).The Eigen values of the first four principal components (>1) can be used to assess the dominant atmospheric rainwater quality in the oil producing settlement. The concentrations temperature, From component 1, temperature, TDS, EC, NO_3, Pb shown high positive loadings ranging between 0.83-0.93, with moderate positive loadings of NH_3, Zn, Al and Cd ranging between 0.51-0.68 , and rest being low negative and positive loadings (Component 1).Component 11 recorded high positive loadings of pH, Cl and Zn ranging between 0.70-90, with high negative loadings of temperature and Cu(-0.70-0.79), with moderate positive loadings of TSS, SO_4 and Cd ranging between 52-5, and the rest being negative and positive low loadings (Comp11), component 111, Mn recorded high positive loading (0.81), with colour showing moderate negative loading (-0.68), with the rest being negative and positive loadings (Comp111).Component 1V recorded high positive loadings of $CaCO_3$, NH_3, and Fe ranging between 0.73-0.95, with moderate positive loadings of Cl, SO_4, TSS and Al ranging between 0.51-0.63 and others recorded negative and positive low loadings (Component 1V).

Table 4: Mean Concentrations of the Physical Characteristics in Atmospheric Rainwater from Non-oil producing Communities

Parameters	Non-oil producing Communities											
	ETINAN			ESSIENUDIM			INI			URUAN		
	Mar.	July	Nov.	Mar.	July	Nov.	Mar.	July.	Nov.	Mar.	July	Nov.
Taste	Un	Un	Un	Un	Un	Un	Un	Un	Un	Un	Un	Un
Odour	Un	Un	Un	Un	Un	Un	Un	Un	Un	Un	Un	Un
Temp.	27	23	24	24	22	24	25	23	24	25	22	23
Colour	17	8	15	8	4	5	6	4	5	15	11	13
Appearance	Obj.	Un	Obj	Un	Un	Un	Un	Un	Un	Un	Un	Un
TDS	4.1	2.3	2.8	1.8	1.2	1.4	1.1	0.6	0.7	12	7	10
TSS	0.8	0.4	0.6	0.5	0.2	0.4	0.5	0.3	0.4	0.5	0.3	0.4
Turbidity	4	1	3	2	0	1	2	0	1	3	0	1
pH	5.4	6.4	5.5	6.6	6.8	6.7	6.5	6.7	6.6	6.5	6.9	6.6
EC.	7.8	4.3	5.6	7.3	5.2	5.8	1.3	0.9	1.1	1.9	1.3	1.4
Cl^-	7.0	3.09	4.01	1.4	0.7	0.9	0.3	0.1	0.2	10	6	8
SO_4^{2}	4.8	1.2	3.0	0.08	0.05	0.07	0.4	0.1	0.3	2.5	1.2	1.7
NO_3^-	5.2	2.6	4.1	0.8	0.5	0.7	0.3	0.1	0.2	3.8	2.1	2.8
$CaCO_3$	2.9	1.3	2.6	0.9	0.6	0.8	0.3	0.1	0.2	6.3	3.5	5.7
NH_4^{+2}	0.98	0.12	0.14	0.08	0.03	0.05	1.93	1.35	1.57	0.56	0.23	0.42
Cu	0.4	0.1	0.2	0.2	0.01	0.02	0.01	0.0	0.01	0.4	0.2	0.3
Fe	0.9	0.6	0.7	0.4	0.1	0.3	0.4	0.2	0.3	0.6	0.4	0.5
Zn	1.6	0.5	0.9	1.3	0.2	0.8	0.4	0.1	0.3	0.9	0.6	0.8
Pb	0.6	0.2	0.4	0.04	0.01	0.02	0.03	0.01	0.03	0.3	0.1	0.2
Al	0.4	0.1	0.2	0.01	0.0	0.01	0.01	0.0	0.01	0.2	0.01	0.01
Cd	0.003	0.001	0.002	0.002	0.0	0.001	0.003	0.001	0.002	0.003	0.001	0.002
Mn	2.1	1.3	1.5.	0.02	0.01	0.02	0.02	0.01	0.03	0.5	0.3	0.4

Variables	Temp	Col	TDS	TSS	Turbi	pH	Elec.	Cl.	SO4.	NO3	CaCO3	NH3	Cu	Fe	Zn	Pb.
Temp.	1															
Colour	0.39	1														
TDS	0.55	0.39	1													
TSS	0.58	**0.97**	0.44	1												
Turbid.	**0.82**	0.36	0.48	0.54	1											
pH	**0.72**	**0.85**	0.57	**0.93**	0.65	1										
Elec.	0.44	-0.18	-0.05	-0.06	0.34	0.21	1									
Cl	**0.86**	0.53	0.67	0.69	**0.71**	**0.88**	0.31	1								
SO4	**0.88**	0.31	0.33	0.51	0.64	0.6	0.44	**0.88**	1							
No3	0.06	-0.27	0.53	-0.25	-0.02	-0.23	-0.49	0.02	-0.07	1						
CaCo3	**0.87**	**0.74**	0.47	**0.88**	**0.70**	**0.92**	0.27	**0.91**	**0.85**	-0.21	1					
NH4	**0.96**	0.57	0.55	**0.73**	**0.72**	**0.83**	0.35	**0.93**	**0.92**	-0.01	**0.96**	1				
Cu	**-0.91**	-0.15	-0.59	-0.34	-0.61	-0.54	-0.5	-0.8	**-0.88**	-0.23	**-0.71**	**-0.92**	1			
Fe	**0.94**	0.61	0.57	**0.77**	**0.73**	**0.84**	0.27	**0.93**	**0.87**	0.03	**0.95**	**0.99**	**-0.84**	1		
Zn	0.09	**0.89**	0.27	**0.79**	-0.09	0.65	-0.31	0.33	0.11	-0.21	0.51	0.34	0.01	0.38	1	
Pb	0.3	-0.49	0.08	-0.34	0.59	-0.2	0.32	0.04	0.12	0.19	-0.1	0.03	-0.23	0.01	-0.82	1
Al	0.34	0.68	0.59	0.65	0.02	0.62	-0.23	0.53	0.33	0.24	0.56	0.55	-0.40	0.60	0.80	-0.65
Cd	**0.81**	0.21	**0.80**	0.36	**0.78**	0.58	0.46	**0.75**	0.58	0.22	0.59	**0.71**	**-0.79**	0.68	-0.08	0.48
Mn	0.68	0.42	0.55	0.53	0.61	0.78	0.67	**0.75**	0.58	0.2	0.69	**0.71**	-0.67	0.68	0.25	0.05

Table 5: Correlation Matrix of the physical and chemical concentrations in Atmospheric rainwater Quality in non-oil Producing Communities.
Significant at $p < 0.05$.

Compositional relations in atmospheric rainwater qualities in non-oil producing communities are shown in (Table 6) indicate strong correlations $p < 0.05$, temperature is strongly correlated with turbidity, pH, Cl, SO_4, $CaCO_3$, NH_3, Fe, Cd and strongly uncorrelated with Cu; colour with TSS,pH, $CaCO_3$, Zn; TDS with Cd, TSS with pH, $CaCO_3$, Fe, Zn, turbidity with Cl, $CaCO_3$, NH_3, Fe, Cd ; pH with Cl, $CaCO_3$, NH_3, Fe, Mn, ;Cl with SO_4, NH_3, Fe, Cd, Mn; $CaCO_3$ with NH_3, Fe and strongly uncorrelated with Cu; NH_3 uncorrelated with Cu and strongly correlated with Fe, Cd, Mn; Cu strongly uncorrelated with Fe, Cd, Zn strongly uncorrelated with Pb and strongly correlated with Al, Cd with Mn respectively.

Table 6 :Varimax Rotated Components Matrix of the Variables in the Control Locations

S/N	Variables	COMPONENT			
		I	II	III	IV
1	Temp.	**0.90**	0.26	0.06	0.27
2	Colour	0.18	**0.98**	-0.02	-0.09
3	TDS	0.60	0.33	**0.66**	0.14
4	TSS	0.37	**0.92**	-0.04	-0.01
5	Turbid.	0.61	0.40	0.01	**0.70**
6	pH	0.60	**0.78**	-0.06	0.06
7	Elec.Cond.	0.63	-0.32	**-0.62**	0.12
8	Cl	**0.86**	0.41	0.10	0.07
9	SO_4	**0.90**	0.16	-0.09	0.02
10	No_3	0.05	-0.26	**0.95**	0.01
11	$CaCo_3$	**0.76**	0.63	-0.09	0.05
12	NH_3	**0.88**	0.42	0.04	0.05
13	Cu	**-0.98**	0.03	-0.17	-0.36
14	Fe	**0.84**	0.48	0.10	0.05
15	Zn	0.02	**0.85**	0.02	-0.52
16	Pb	0.19	-0.46	0.06	**0.87**
17	Al	0.37	0.58	0.40	-0.57
18	Cd	**0.78**	0.08	0.25	0.45
19	Mn	**0.77**	0.30	-0.22	0.09
	Eigen value	**10.686**	**3.925**	**2.049**	**1.055**
	Variability (%)	**56.242**	**20.657**	**10.786**	**5.555**
	Cumulative %	**56.242**	**76.899**	**87.685**	**93.239**

As shown in Table 6, principal component analysis (PCA) has helped to identify four underlying component that explains 88.646% of the common variance with component I having variability of 56.242%, component II 20.657%, component III 10.786% and component IV 5.555%.respectively. From Table 7,the concentrations of temperature, Cl, SO_4, $CaCO_3$, Fe, Cd, and Mn show high positive loadings ranging between (0.77-0.90),Cu with high negative loading (-0.98) and moderate loadings of TDS, turbidity, pH and EC ranging between 60-63 in component 1.Component II recorded high positive loadings of colour, TSS, pH and Zn ranging between 0.78-0.98 with $CaCO_3$, Al show moderate loadings of 0.58- 0.64.Component III recorded high positive loading of NO_3 (0.95), moderate positive loading of TDS(0.66) and moderate negative loading of EC 0.62. Component iv recorded high positive loadings of turbidity and Pb ranging between 0.70-0.87, with Zn, Al showing negative moderate loadings between -0.52 -0.57. The results also indicate that Components I-IV recorded negative and positive low loadings .

CONCLUSION

1. From oil producing communities (Eket, Ikot-Abasi, Onna, Ibeno, Eastern-Obolo and Mbo), the high positive loadings are important parameters in atmospheric precipitation to include temperature, TDS, Turbidity, EC, NO_3,Pb in component I, pH, Cl, Zn in component II as high positive loadings and component IV having high positive loadings of $CaCO_3$, NH_3 and Fe, with III having no higher positive loading.
2. From non-oil producing communities, the high positive loadings in the atmospheric precipitation are (temperature, Cl, SO_4, $CaCO_3$,NH_3, Fe, Cd and Mn in component I, Colour, pH, Zn in component I, NO_3in component III, and Component IV turbidity and Pb. From the results, it is concluded that pollutants in atmospheric rainwater harvested from the southern parts of Akwa Ibom State originate from oil exploitation due to incessant gas flaring by Mobil Oil Nigeria , because there is little or no industry existing in the region except oil industries and allied inductries. While, in the non –oil producing communities, locations like Etinan and Uruan and environs that are closed to oil producing locations are affected by incessant gas flaring blown by south east trade windis suspected to be responsible for

the pollution of atmospheric rainwater (Ubuoh, 2012). This then calls for total implementation of the enabling rules and regulations that could mitigate negative human actions on environment, especially gas flaring which is the major problem in oil producing communities and Akwa Ibom State in general.

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