GLOBAL JOURNAL OF ENVIRONMENTAL SCIENCES VOL. 2 NO. 1 2003:47 - 52

ACIDIC PRECIPITATION AND INFRASTRUCTURAL DETERIORATION IN OIL PRODUCING COMMUNITIES OF AKWA IBOM STATE: A CASE STUDY OF EKET, SOUTH EASTERN NIGERIA.

E. R. AKPAN
(Received 11 September 2001; Revision accepted 19 June 2002).

ABSTRACT

To examine the impact of rain on iron roofing in Eket, the quality of direct and roof rainwater collected over a period of two weeks in May, 1999 were compared. Simultaneous study at Uyo, Akwa Ibom State Capital, served as the control. Rainwater parameters considered include: pH, conductivity, total dissolved solids, particulate matter, total hardness, chloride, sulfate, nitrate, iron, and ammonium. Measurements of wind direction and strength were also obtained for every rain event. During the study, an acidic rain of pH 5.4 was measured in a sample from Eket. A comparison of this direct rainfall with the corresponding roof rainfall showed a marked drop in chloride content from 1,050 mg/l in the direct rainwater to 28.4 mg/l in the roof rainwater. This drop is attributed to the reaction between HCl in rain and zinc in roofing material. A similar trend was also found in sulfate concentration, which was attributed to the reaction between H_2SO_4 in rainwater and the protective ZNO layer of zinc plated iron roofs. These reactions are responsible for the accelerated rusting of roofing materials in oil producing communities of Southern Nigeria. The main source of these acids in rainwater at Eket, is the Mobil Producing gas flaring operations at nearby onshore and offshore locations. During the wet season, flare gases are carried inland throughout Eket and environs by South West Trade Winds leading to persistent acidic rain in these communities with attendant infrastructural damages.

Key Words: Acid rain, petroleum gas flaring, air pollution, iron roof corrosion.

INTRODUCTION

Corrosion of iron and its aloys is widespread and occur even in the absence of air. The rate of corrosion depends mainly on the extent of atmospheric pollution and nature of eroded material. Of special concern are constituents which cause or promote acidic precipitation and high ionic concentration of moisture (Elliot & Schwieger, 1984). These include proximity to the seacoast and associated wave mobilization of salt water into the atmosphere which is a major source of chloride ion, and hence, increasing rusting incidence while anthropogenic release of gaseous effluents represents the most dominant cause of corrosion (Heij & Erisman, 1995).

Most of the air pollution events today, is associated with fossil fuel combustion. In the Niger Delta region of Nigeria, petroleum gas flaring is the most prominent type of fossil fuel combustion. NEST (1991) reported that

E. R. AKPAN, Institute of Oceanography, University of Calabar, Calabar, Nigeria

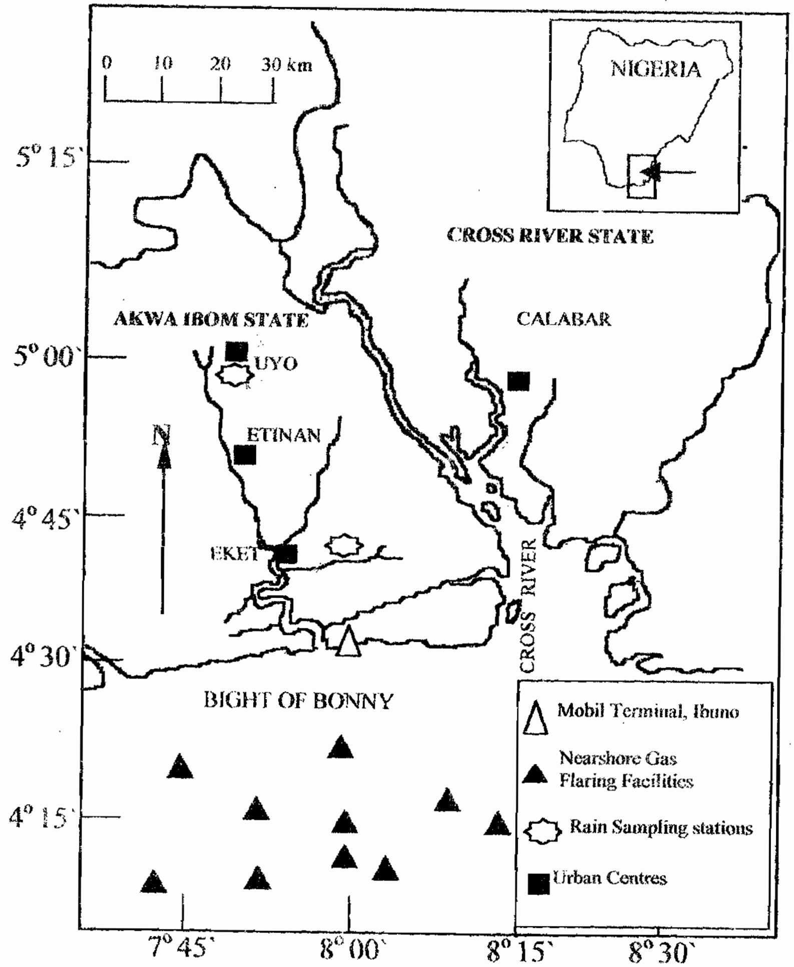

Fig. 1: Map of study area showing rain sampling stations

Nigeria was flaring N2 milllion worth of gas daily. According to the study, gas flaring resulted in both chemical and thermal pollution of the atmosphere in oil producing communities. Both forms of pollution have been implicated in accelerated corrosion of iron and steel materials (Scully, 1975; White, 1988). Several reports of acid rain studies in the Niger Delta, however, seem to suggest that there is no acid rain in the region (Ubong & Gobo, 2001).

Rusting of roofs is perhaps the most dominant feature in Eket community of Akwa Ibom State. The communities have attributed this phenomenon to the gas flaring activities of Mobil Producing Nigeria Unlimited. Mobil's onshore and offshore gas flaring operations take place south of Eket. During the wet season, which usually lasts from April to October, South West Trade Winds blow through the flare facilities and transport the flare gases to downwind inland communities including Eket and environs. The study was undertaken to investigate the impact of gas flaring on rainwater quality and its relationship

Table 1: Physicochemical measurements at Ekpene Obo, Eket rain study location (S.W.= SOUTH WEST, H = HIGH, M = MEDIUM, L = LOW, - = NO WIND)

Parameter	Sample	1-5-99	3-5-99	5-5-99	6-5-99	7-5-99	11-5-99	13-5-99	*Mean
PH	D	5.40	6.40	7.19	6.56	6.58	5.92	5.80	6.41
	R	5.93	6.18	7.20	6.55	6.32	6.14	5.86	6.38
Conductivity (mS/cm)	D	6,380	6.5	51.5	18.9	4.1	3.3	5.3	14.9
	R	24	7.6	90.4	13.7	4	3.2	5.3	14.9
TDS (mg/l)	D	4,374	8	44.1	24.6	5.1	4.1	6.6	15.4
	R	30	9.4	77.5	16.9	4.9	4	7.3	20
PM (mg/l)	D	224	100	400	140	100	70	80	148
	R	840	200	190	100	200	170	100	160
TH (mg/l)	D	67.2	12	68.6	56	16	12	12	29
	R	32	16	24.7	12	16	12	16	16
Cl^- (mg/l)	D	1,050.8	28.4	42.6	28.4	71	28.4	71	37.9
	R	28.4	14.2	14.2	14.2	14.2	28.4	42.6	12.3
SO_4^{2-} (mg/l)	D	5.9	0.4	0.6	0	0.3	0.1	0.4	0.3
	R	2.8	0.7	0.4	0.6	0.2	0.2	0.2	0.4
NO_3^- (mg/l)	D	0.3	0	1.7	0.2	0	0.3	0.6	0.5
	R	0	0	0	0	0	0.1	0.3	0.1
Fe (mg/l)	D	4.4	1.2	1.7	0	0.8	0	3.8	1.3
	R	1.5	0	1.1	0.8	0.8	0.8	0	0.6
$NH4^+$ (mg/l)	D	ND	ND	ND	ND	ND	0.01	0.07	0.04
	R	ND	ND	ND	ND	ND	0.18	0.06	0.04
Wind Direction		-	-	S.W.	S.W.	-	S.W.	S.W.	
Wind Strength		-	-	H	M	-	L	L	

- Average of measurements excluding that of 1st May, 1999; ND = Not determined.

with accelerated roof corrosion in Eket.

MATERIALS AND METHODS

Rainwater samples were collected at Ekpene Obo town Esit Eket Local Government Area and Abak Road, Uyo Metropolis, Akwa Ibom State. Collections at Uyo served as the control. Both direct rain (D) and roof rain (R) were simultaneously collected during every rain event. The samples were collected in medium-sized steel basins which were placed on raised platforms to avoid splash contamination. At the onset of each rain event, the wind direction and relative strength were documented. The study lasted for two weeks from 1st May to 13th May, 1999.

Rainwater pH values were measured in situ using WTW pH 90 meter. Subsamples were collected in pre-cleaned polyethylene bottles and transported to the laboratory for other physicochemical measurements. Electrical conductivity was measured with WTW LF 90 conductivity meter. Total dissolved solids (TDS) was measured gravimetrically. Particulate matter (PM), sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+) and iron (Fe) were determined spectrophotometrically using HACH 3000 direct reading spectrophotometer. Particulate matter was further subjected to ignition at 800°C to facilitate determination of the inorganic matrix. Total hardness (TH) and chloride (Cl^-) were determined by titration.

Data from 1st May was excluded from mean calculations because of the marked difference between it and all other samples.

RESULTS

Results of the study are presented in tables 1

Table 2: Physicochemical measurements at Abak Road, Uyo rain study location (S.W.= SOUTH WEST, H = HIGH, M = MEDIUM, L = LOW, - = NO WIND)

Parameter	Sample	1-5-99	2-5-99	3-5-99	5-5-99	11-5-99	13-5-99	*Mean
pH	D	ND	5.70	6.12	6.11	6.00	ND	5.98
	R	6.33	5.58	6.06	6.10	6.06	6.14	5.99
Conductivity (mS/cm)	D	6.7	11.2	23.7	21.3	ND	15.7	15.7
	R	65.1	7.3	7	19.2	20.5	12.1	13.2
TDS (mg/l)	D	ND	8.3	13.8	29.3	26.3	ND	19.4
	R	55.8	9.0	8.7	23.7	25.3	15	16.4
PM (mg/l)	D	ND	80	40	20	100	ND	60
	R	180	50	70	70	100	100	78
TH (mg/l)	D	ND	20	15	25	20	ND	20
	R	40	20	25	25	24	16	22
Cl^- (mg/l)	D	ND	17.8	17.8	26.6	12.2	ND	18.6
	R	17.8	17.8	17.8	26.6	12.2	42.6	23.4
SO_4^{2-} (mg/l)	D	ND	ND	1.4	1.8	2	0.5	1.4
	R	2.6	2	1.9	1.4	0.7	0.3	1.3
NO_3^- (mg/l)	D	ND	0.8	0.7	2.8	2.4	ND	1.7
	R	5.6	1.2	0.7	2.5	1.2	1.3	1.1
Fe (mg/l)	D	ND	2.6	1.4	4.2	3.7	ND	3
	R	2	1.4	0	3.2	0.7	1	1.3
$NH4^+$ (mg/l)	D	ND	ND	ND	ND	0.86	ND	0.86
	R	ND	ND	ND	ND	1.31	0.58	0.95
Wind Direction		-	-	S.W.	S.W.	S.W.	S.W.	
Wind Strength		-	-	H	M	L	L	

- *Average of measurements excluding that of 1st May, 1999; ND = Not determined.

and 2. Acidic rain with pH 5.4 was encountered only once, in the direct rain at Eket on 1st May, 1999. The levels of conductivity, TDS, Cl^-, PM, and SO_4^{2-} in the sample were markedly higher than the levels in all the other samples both in Eket and Uyo. A marked drop in the concentration of these parameters was also observed in the corresponding roof rain compared to the direct rain samples of the 1st May.

A comparison of the direct rain samples with pH values above 5.6 (normal rain) in Uyo and Eket locations showed that Cl^- was significantly higher in Eket than Uyo. In contrast, Cl^- levels of roof rain were higher in Uyo than Eket ($P<0.05$). At Eket, Cl^- levels were also higher in direct than roof rain samples while the opposite was true at Uyo. Sulfate and nitrate levels in direct and roof rain samples were higher at Uyo than Eket ($P<0.05$). At Eket, direct rain nitrate concentration was higher than roof rain but at Uyo there was no significant difference between direct and roof rain samples. There was no significant difference between Fe concentrations in direct rain in Eket and Uyo but roof rain was significantly higher in Fe at Uyo than Eket. Particulate matter of both direct and roof rain were significantly higher in Eket than Uyo. At both locations, roof rain had higher PM values than direct rain. Examination of the ignition residue of PM from roof rain, revealed that particulate matter at Eket was composed mainly of iron rust while that of Uyo was mainly silt. Compared to Uyo, pH levels at Eket were relatively higher.

DISCUSSION

Under normal circumstances, the atmosphere in Uyo seems to be more polluted than that of

Eket. For instance, rainwater pH values at Uyo are relatively lower than Eket, which indicates relatively higher concentration of acidic gases. Sulfate, nitrate and ammonium levels were found to be higher at Uyo than Eket during the study. This situation is attributed to automobile nd automobile related emissions because of the heavier traffic density at Uyo compared to Esit Eket.

Automobile emissions can contribute significantly to atmospheric levels of nitrogen oxides, sulfure oxides and oxides of carbon (Elliot & Schwieger, 1984). In comparison to the Uyo location, which is at the center of Uyo metropolis (approximately 2 m from the busy Abak Road), Eket location is in a low traffic terrain at Ekpene Obo (about 5 m from Esit Eket- Eket Local Government road, Fig. 1). The rainwater sample of 1st May, indicates a more serious atmospheric pollution at Eket. Concentrations of acidic ions, Cl^- and SO_4^{2-} were significantly higher in this sample than others. If these ions were associated with their neutral salts (i.e. NaCl and Na_2SO_4 etc from sea salt spray) the pH of direct rain would have been higher since according to Freedman (1989) saltwater should actually help to neutralize acidity because of its high pH value. These anions must therefore come from their mineral acids, HCl and H_2SO_4. This is also inferred from the observed drop in their concentrations in roof rain sample compared to direct rain sample, and the corresponding increase in the pH of the roof rain sample (Table 1). The observed drop in concentrations of Cl^- and SO_4^{2-} in roof rain sample is attributed to chemical reactions between the corresponding mineral acids and zinc coating of the corrugated iron roofing material:

$$Zn + 2HCl \rightarrow ZnCl + H_2 \quad \ldots\ldots 1$$

$$ZnCl + ZnO + H_2O \rightarrow 2Zn(OH)Cl \quad \ldots\ldots 2$$

$$H_2SO_4 + ZnO \rightarrow ZnSO_4 + H_2O \quad \ldots\ldots 3$$

These reactions do not take place with the neutral salts of the acidic ions. This, therefore, completely precludes marine aerosols as the source of the high concentration of these ions in the rain sample. The source of these acids can only be traced to fossil fuel combustion. According to Förstner and Witman (1981) acidic precipitation is caused by the release of acidic gases such as SO_2, NO_2, HCl etc into the atmosphere. Stern (1977) names the gases emitted by fossil fuel combustion to include SO_2, SO_3, NO, NO_2 (NOx), CO, hydrocarbons and HCl. In United States and Canada, fossil fuel power plants are the major sources of acidic gases and acid precipitation (Nebel, 1987). In the absence of large fossil fuel power plants and traffic density at Eket, the most important sources of these acids in the atmosphere is the Mobil Producing gas flaring operations. Gas flaring has been implicated in both chemical and thermal pollution of the atmosphere in oil producing communities of Nigeria (NEST, 1991). The attack of the zinc coating of the roofs by these acids (equations 1 to 3 above), exposes the underlying iron material to the full impact of corrosion agents leading to the observed accelerated roof rusting and rotting in the communities. The accelerated rusting is evident in the high Fe content of PM from roof rain samples at Eket. The silty nature of the PM at Uyo is a result of dust arising from high density of automobile traffic on nearby Abak Road. This dust is mainly responsible for the higher content of sulfate, chloride and nitrate in roof rainwater samples from Uyo.

During the wet season, which is dominated by South West Trade Winds, Eket communities are located downwind of Mobil's onshore and offshore gas flaring operations and are thus exposed to the full impact of the associated air pollution.

Uyo is much less affected because of its distance from the flaring operations (≈ 70 km) and direction of prevailing South West Winds (Fig. 1). The higher concentrations of NO_3^- recorded at Uyo compared to Eket is an indication of the difference in sources of pollution at both locations. While automobile emissions are the major source of air pollution at Uyo, petroleum gas flaring is the major source at Eket. Natural gas is known to contain very little or no nitrogen in comparison to other petroleum fuels (Stern, 1977).

For acid rain study to produce reliable results, it must be long term and all possible rain events must be examined since the occurrence and frequency of acidic precipitation at any location cannot be predicted. During the present study, only one rain event was acidic. The frequently reported absence of acid rain in the Niger Delta may be associated with poor sampling design and short duration of study.

ACKNOWLEDGEMENT

I wish to thank Miss Eugenie Dungla and Glory Effiang for sample and data collection at Uyo and Eket locations respectively.

REFERENCES

Elliot, T. C. and Schwieger, R. G., 1984. The acid rain sourcebook. McGraw-Hill Inc., New York.

Förstner, U. and Wittman, G. T. W., 1981, Metal pollution in aquatic environment. Springer Verlag. Berlin. 486pp.

Heij, G. J. and Erisman, J. W., 1995, Acid rain research: Do we have enough answers?. Elservier, New York.

Nebel, B. J., 1987, Environmental Science. 2nd Edition, Prentice Hall Inc. New Jersey. 574pp.

NEST, 1991, Nigerian threatened environment. A national profile. Nigerian Environmental Study Action Team Publication. 288pp.

Stern, A. C., 1977. Air pollution. Academic Press. London 946pp.

Ubong, I. U. and Gobo, A. E., 2001, Fundamentals of environmental chemistry and meteorology. Tom & Harry Publ. Ltd. Port Harcourt. 264pp.

White, J. C., 1988. Acid rain: The relationship between sources and receptors. Elservier, New York.