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Evaluation of the Spatial Variation of Rainwater Quality in Parts of Akwa Ibom State of Nigeria Using Chloropleth Map

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Abstract

Studies on the effects of oil exploration activities in Akwa Ibom State of Nigeria have shown that the air quality has been negatively impacted over the years. The quality of rainwater is a function of the prevailing air quality in any area where it falls. Rainwater is an alternative water supply for most of the local population. This study evaluated the spatial variation of rainwater quality in selected locations in parts of Akwa Ibom State within the months of March, July and November using temperature, pH, colour, NO3, Fe, Pb, Cd, and Mn as indices. Control locations in the northern part of the State were also selected. Results showed that rainwater quality in study locations in the south (5.1-5.7) was more acidic than in the north (5.4 – 6.9). Generally, values of quality parameters in the study locations were higher than their values in the control locations and followed the pattern March > November > July values. Critical levels of heavy metals were observed (Fe: 0.21 – 0.62 mg/l; Pb: 0.12 – 0.90 mg/l; Cd: 0.01 – 0.05 mg/l; Mn: 0.02 – 0.07 mg/l in study locations) and Fe: 0.1 – 0.90 mg/l; Pb: 0.01 – 0.60 mg/l; Cd: 0.00 – 0.003 mg/l and Mn: 0.01 – 2.10 mg/l in control locations). It was also established that rainwater contaminant levels are a function of the frequency and intensity of the rainfall; the levels in this study expectedly reduced with an increased rainwater intensity. Wind action and lithogenic effects played a role in the dry periods.

Keywords: Variation, Precipitation, Scavenging, Frequency, Intensity, Chloropleth maps, Lithogenic, Wind.

Introduction

The earth's atmosphere is an envelope of gases extending to a height of about 2000km (Egereonu, 2006). The properties of these gases have some effects on the air pollution chemistry (Ubuoh et al., 2010). Anthropogenic sources of materials in the atmosphere include combustion of fuels for energy generation, transport, heating and industrial needs, wind-blown soils from arid and agricultural regions, volatilization from agriculture, waste disposal and previously polluted sites (Meybeck and Helmer, 1996 and Akhionbare, 2009a). Such sources could be point, non-point or mixed in nature. Spatial patterns of contaminants in the atmosphere have been studied (Ferron and Gille, 1995; Sanusi, 1996; and Sanusi *et al*., 1999). Pollutants in the atmosphere may come from both local and distant areas following different pathways (Carole *et al.,* 2002). Certain air pollutants, including a variety of dust particles and acid droplets droplets can influence the development of clouds and precipitation within an area (Odu, 1994). Substances may be removed from the atmosphere through such significant mechanisms as dispersion, rainout and scavenging leading to rainwater contamination (Golomb *et al*.,1997; Migon *et al*., 1997; Vukmirovic et al., 1997; Injuk *et al*., 1998; Garnaud *et al*., 1999; Efe, 2006; Kanellopoulou, 2001 and Akhionbare, 2009a). This results in the dissolution of gases and particles, or impaction into a pre-existing liquid droplet (Carole *et al*., 2002). These two processes can occur in a cloud or below it during rain, thus increasing the levels of these gases or particles in rainwater. As rain falls from the clouds to the ground, it washes pollutants from the air, and in the process, take up pollutants. Rainfall is normally slightly acid because it dissolves atmospheric carbon dioxide, which produces weak carbonic acid

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(H_2CO_3). However in regions polluted with oxides of sulphur and oxides of nitrogen, rainfall produces relatively strong sulphuric acid (H_2SO_4) and nitric acid (HNO_3). Akwa Ibom State of Nigeria houses a range of industrial, exploratory, agricultural, transportation and commercial activities which are expected to impact on the air quality and hence on the rainwater quality. Rainwater is an alternative source of drinking water for a good percentage of the populace. The aim of the study was therefore to determine the composition of rainwater in various parts of the State.

Materials and Methods

Study Area

Akwa Ibom State is located between latitude 4032' and 505' North and longitude 702'and 8025'. It has total population of 2,395,756 (87.89% rural and urban 12.11%), spread across landmass of 8,412 km^2. The rainfall varies from more than 3000 mm along the coast to about 2000 mm inland, and the mean temperature varies between 25-28°C. The State holds some of the largest reserves of oil and gas, both on and offshore and this account for 28 percent of Nigeria's total crude oil export (Akwa Ibom State, 2006).

Sampling

Rainwater was collected from 10 locations in Akwa Ibom State between 2008 – 2010 during the month of March, July and November. The choice of these months was to also capture the effect of the major seasons on the rainwater quality in the study area. March represents the period of the early rain, July is the peak when the rain has achieved some degree of frequency or regularity and November is the end of the rainy season when rainfall becomes very infrequent and intensity gradually reducing. Eket, Ikot Abasi, Onna, Ibeno, Eastern Obolo, and Mbo (coded SRWH 1-6) were the study locations chosen at the windward side of the gas flaring along the coastline of Akwa Ibom State. Four locations (Essien-Udim, Ini and Uruan and coded CRWH 1 - 4) were used as control. These are locations where gas flare has little or no influence on rainwater (Ubuoh *et al*., 2010).To be able to determine the true quality of rainwater, samples were collected in plastic basins located at least one metre above the ground in the study locations. The collection of rainwater was on an event basis. Soon after the rain had fallen, the water in the plastic basins were transferred to 2L plastic polyethylene bottles, filled to the brim and cocked to avoid any air column. Samples were then sent to the laboratory for analysis.

Sample analysis

Temperature was measured insitu using a mercury-in-glass thermometer, the HACH MODEL l 48600 digital pH meter was used for measurement of pH. Colour was measured using the Lovibond colour comparator. Nitrate ion was determined by the phenol disulphonic acid technique, and Fe, Pb, Cd and Mn were determined by spectrophotometric method.

Data analysis

The choropleth map is a standard mapping technique for the visualization of the spatial distribution of data values associated with geographically aggregated units (Kumar, 2004) ARCVIEW Version 9 was used as a tool for designing maps in G.I.S. To construct the choropleth maps for the ten study locations rainwater physico-chemical characteristics were aggregated into classes of equal intervals (Carter, 2002).

Results and Discussion

Rainwater quality Variations at the Stations

Table. 1 shows the rainwater qualities in the study locations (RWH1-6) while Table. 2 show values at the control locations (CRWH1-4) in the months of March, July and November. The results show that most of the rainwater samples were acidic (pH range: 5.1-5.7) when judged from the pH scale where a pH of 7 is neutral while a pH above 7 is alkaline and that below 7 is acidic. When pH of rainwater falls below 5.7, it is said to be acid rain. The reduction in pH from 7 in most of the samples is attributed to the high level of nitrates (15.6-48.9 mg/l) in the rainwater obtained by the

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Table.1: Variations in rainwater quality in the study locations

Quality Parametrs	Study Location																	
	Eket (RWH1)			Ikot Abasi (RWH2)			Onna (RWH3)			Ibeno (RWH4)			Easternobolo (RWH5)			MBO (RWH6)		
	Mar	July	Nov	Mar	July	Nov	Mar	Jul	Nov	Mar	July	Nov	Mar	July	Nov	Mar	July	Nov
Temp (c)	35	26	28	31	26	27	36	29	32	38	29	32	35	27	30	38	27	29
Color Pt / Co Scale	18	9	11	17	8	11	21	13	14	22	9	16	19	11	13	19	12	13
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
NO_3 mg/l	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
Fe mg/l	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
Pb mg/l	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
Cd mg/l	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 mg/l	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: Variations in rainwater quality in the control locations

Quality Parameters	Control Locations											
	Etinan (CRWH1)			Essienudim (CRWH2)			INI (CRWH3)			URUAN (CRWH4)		
	Mar	July	Nov	Mar	July	Nov	Mar	July	Nov	Mar	July	Nov
Temp^{o}C	27	23	24	24	22	24	25	23	24	25	22	23
Colour Pt/Co Scale	17	8	15	8	4	5	6	4	5	15	11	13
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
NO_3 mg/l	5.2	2.6	4.1	0.8	0.5	0.7	0.3	0.1	0.2	3.8	2.1	2.8
Fe mg/l	0.9	0.6	0.7	0.4	0.1	0.3	0.4	0.2	0.3	0.6	0.4	0.5
Pb mg/l	0.6	0.2	0.4	0.04	0.01	0.02	0.03	0.01	0.03	0.3	0.1	0.2
Cd mg/l	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 mg/l	2.1	1.3	1.5.	0.02	0.01	0.02	0.02	0.01	0.03	0.5	0.3	0.4

dissolution of oxides of nitrogen (NOx) released from the gas flares in the vicinity by falling rainwater (Odu, 1994). This differs considerably from the higher pH values (5.4-6.9) and lower nitrate values (0.1-5.2 mg/l) obtained in the control stations.

Rainwater Quality Variations in March

Figs. 1-8 shows chloropleth maps indicating spatial variations of rainwater quality at the control and study locations in the month of March. Generally, values of the quality parameters in the study locations, which are in the southern part of the study area, were higher than their values in the control locations. These higher concentrations are attributed mainly to gas flare effects. This is consistent with the findings of Efe (2006) in Delta state, and Ubuoh et al (2010) in Akwa Ibom State.

Rainwater Quality Variations in July

Figs. 9–16 show the variations of rainwater quality in the month of July when rainfall intensity was high indicating peak rainy season period. As was observed in March, the results show that concentrations of parameters in rainwater were higher in the study locations than the control locations, a scenario which was attributed to the effects of gas flaring. They were, however, lower

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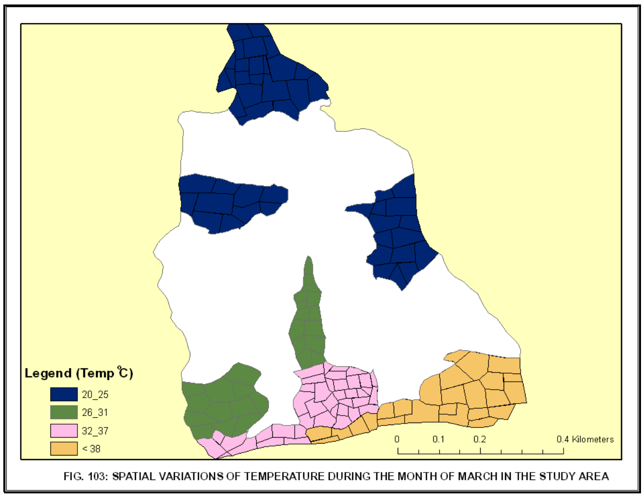

Fig. 1: Spatial Variations of temperature of rainwater in the study area in March

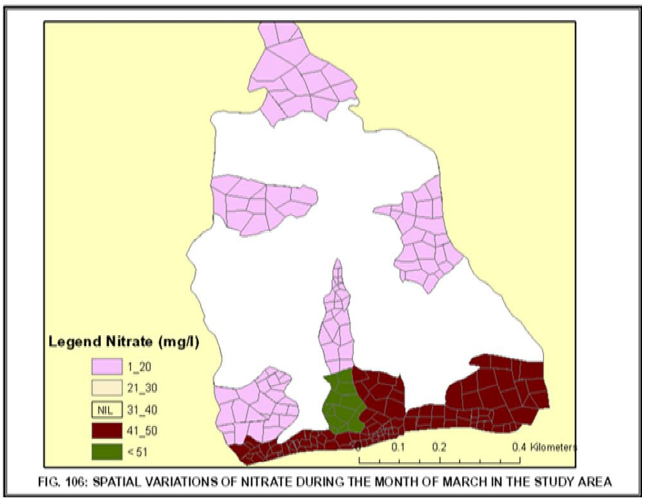

Fig. 4: Spatial variations of nitrate in rainwater in the study area in March

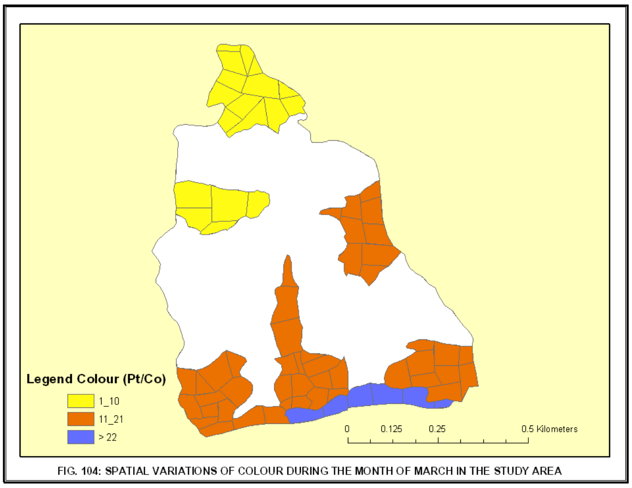

Fig. 2: Spatial Variations of color of rainwater in the study area in March

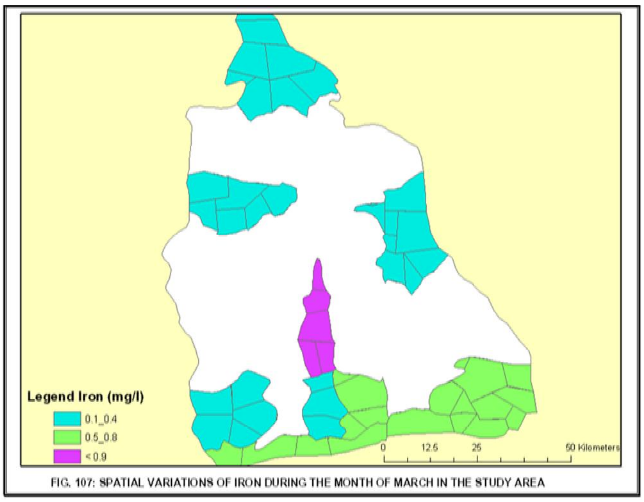

Fig. 5: Spatial variations of Iron in rainwater in the study area in March

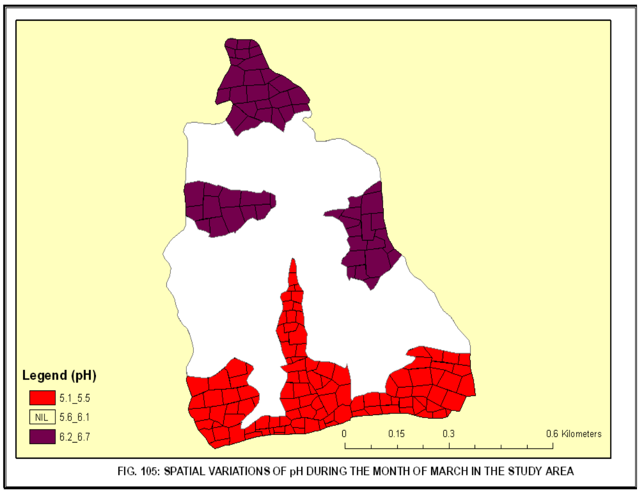

Fig. 3: Spatial variations of pH of rainwater in the study area in March

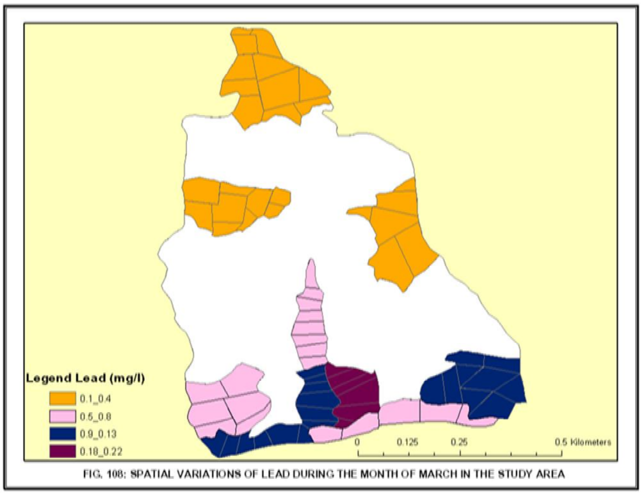

Fig. 6: Spatial variations of Lead in rainwater in the study area in March

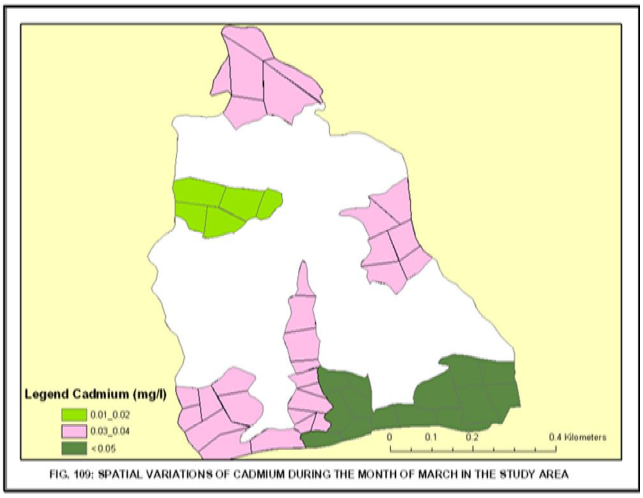

Fig. 7: Spatial variations of cadmium in rainwater in the study area in March

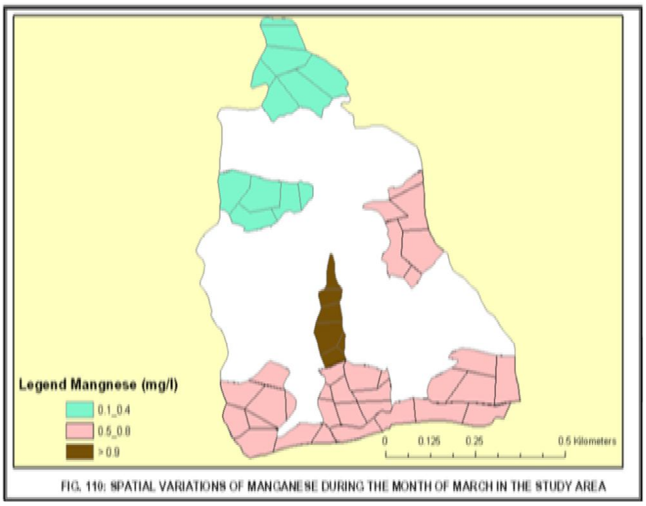

Fig. 8: Spatial variations of Magnesium in rainwater in the study area in March

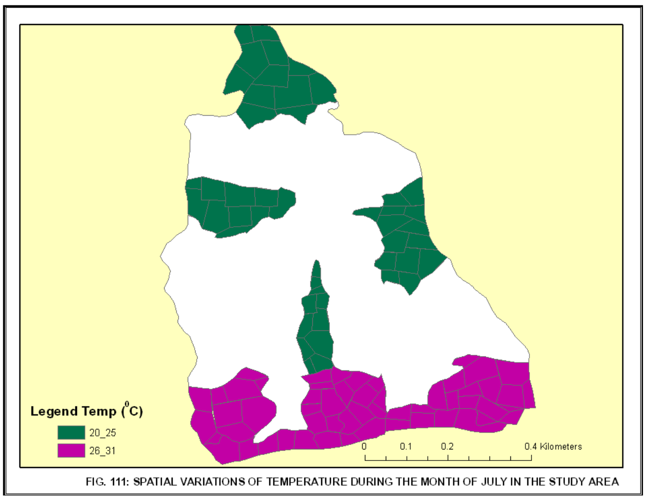

Fig. 9: Spatial variations of temperature of rainwater in the study area in July

than March values. pH values were higher in July probably due to dilution effects (Odu, 1994 and Akhionbare, 2004; Akhionbare and Akhionbare, 2004, 2005). Rainwater contaminant levels are a function of the frequency and intensity of the rainfall; the levels in this study expectedly reduced with an increased rainwater intensity.

Rainwater Quality Variations in November

Figs.17-24 show chloropleth maps indicating spatial variations of rainwater quality at the study and control locations in the month of November. As in March and July, rainwater quality had higher levels of the various parameters in the study locations than in the control locations in November when rainfall intensity decreased. pH also decreased (from a range of 5.5-5.6 in July to 5.4-5.6) in November with the decrease in rainfall intensity. There was a buildup of concentrations of contaminants in November (than in July) when the rainfall frequency and intensity had reduced being close to the end of the rainy season and the onset of the dry season. These results are also consistent with the findings in Ebocha Area of Delta State of Nigeria who observed that contaminant concentrations in rainwater were higher if the interval between one rainfall and the other is longer (Odu, 1994).

Variation of Heavy Metal Concentrations in Rainwater

Critical levels of heavy metals were observed in rainwater samples in both study and control samples. The following ranges were observed in the study locations: Fe, 0.21-0.62 mg/l; Pb, 0.12-0.90 mg/l; Cd, 0.01-0.05 mg/l; Mn, 0.02-0.07 mg/l. In the control locations: Fe, 0.1-0.90 mg/l; Pb, 0.01-0.60 mg/l; Cd, 0.00-0.003 mg/l; Mn, 0.01-2.10 mg/l. Control locations had higher values of Fe and Mn and are attributed to lithogenic sources (Akhionbare, 2011). The action of wind in entraining particulates into the atmosphere could lead to high levels of heavy metals in rainwater; while dry deposition could occur during the dry season (Odu, 1994; Meybeck and Helmer, 1996; Akhionbare, 2009b, 2011).

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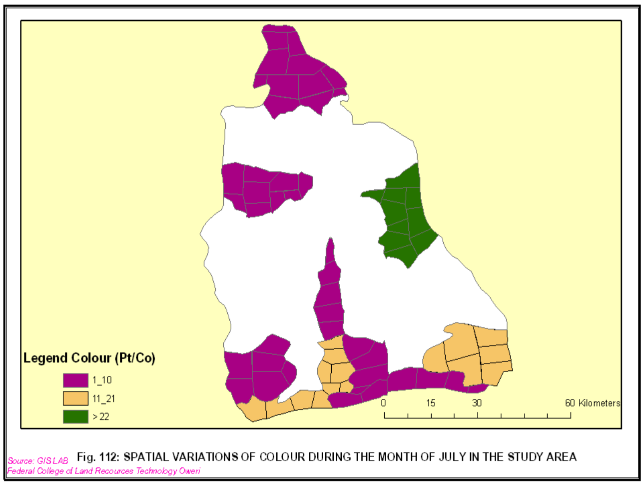

Fig. 10: Spatial variations of color of rainwater in the study area in July

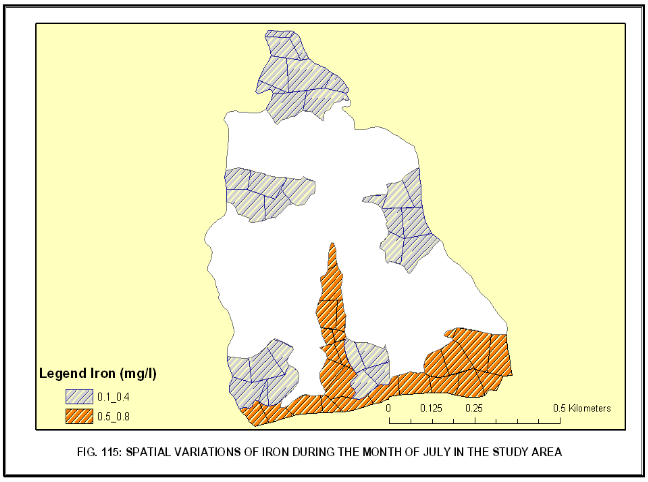

Fig. 13: Spatial variations of Iron in rainwater in the study area in July

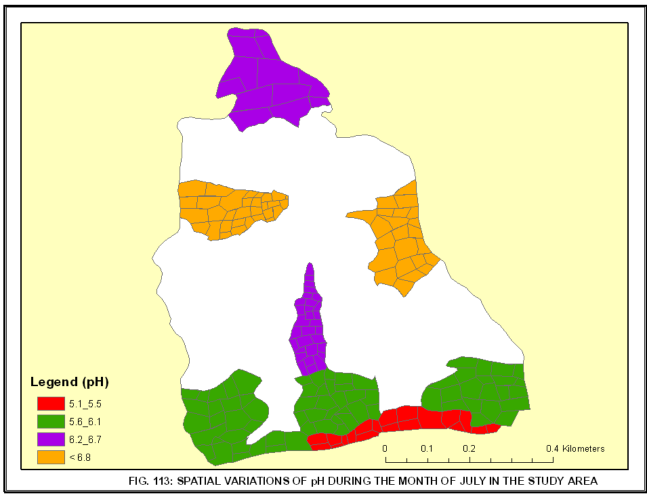

Fig. 11: Spatial variations of pH of rainwater in the study area in July

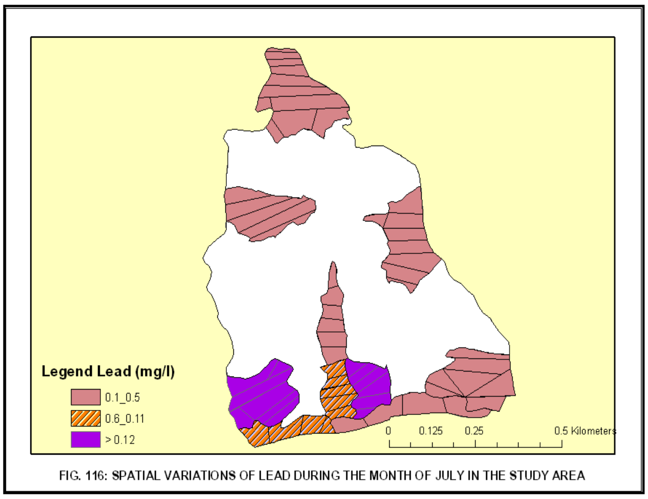

Fig. 14: Spatial variations of Lead in rainwater in the study area in July

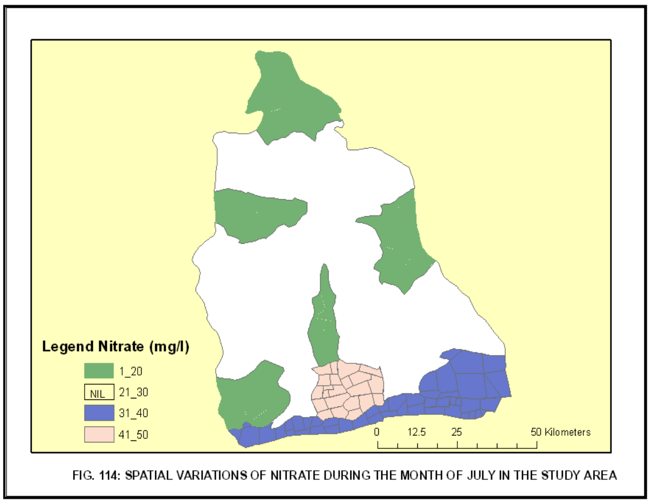

Fig. 12: Spatial variations of Nitrate rainwater in the study area in July

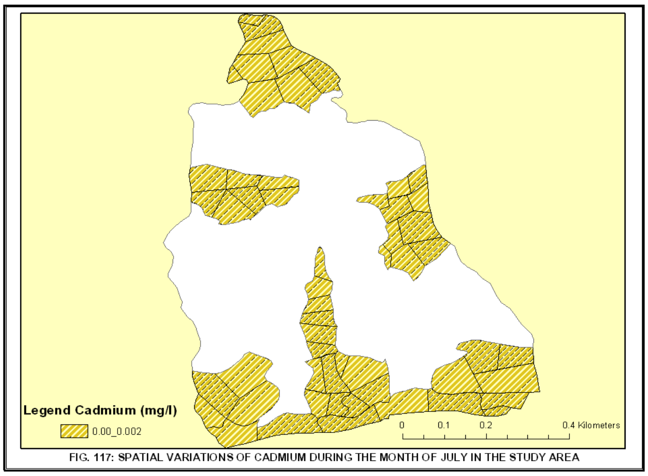

Fig. 15: Spatial variations of Cadmium in rainwater in the study area in July

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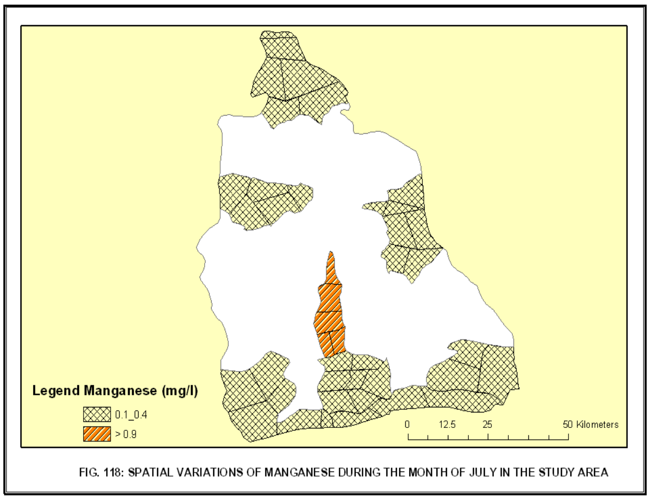

Fig. 16: Spatial variations of Magnesium in rainwater in the study area in July

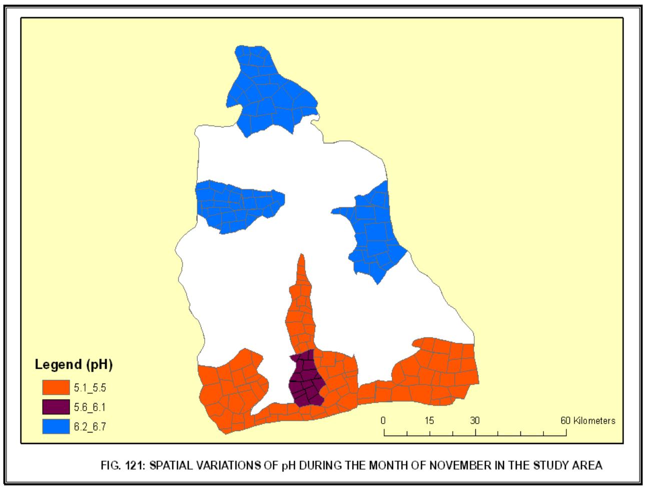

Fig. 19: Spatial variations of pH of rainwater in the study area in November

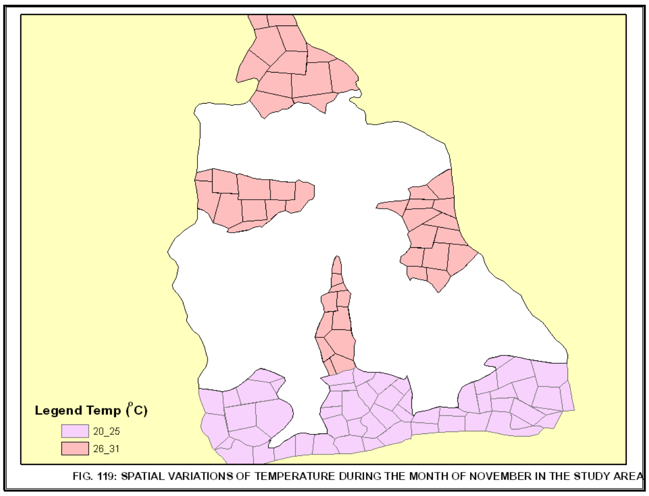

Fig. 17: Spatial variations of temperature of rainwater in the study area in November

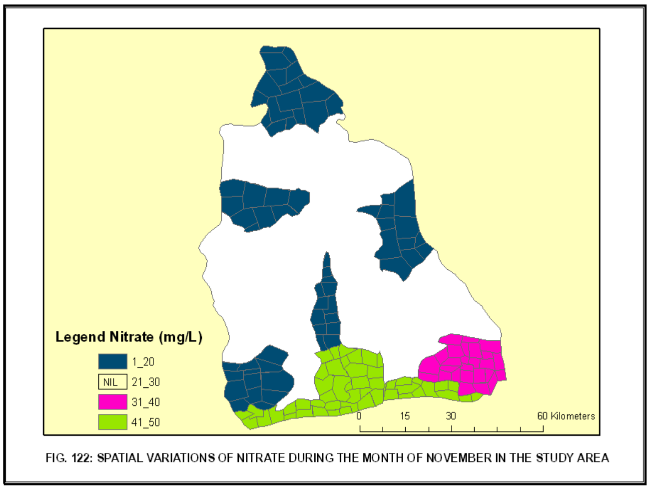

Fig. 20: Spatial variations of nitrate in rainwater in the study area in November

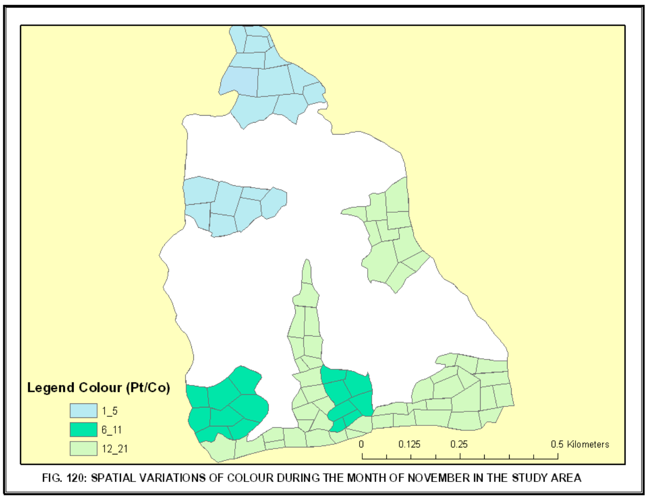

Fig. 18: Spatial variations of color of rainwater in the study area in November

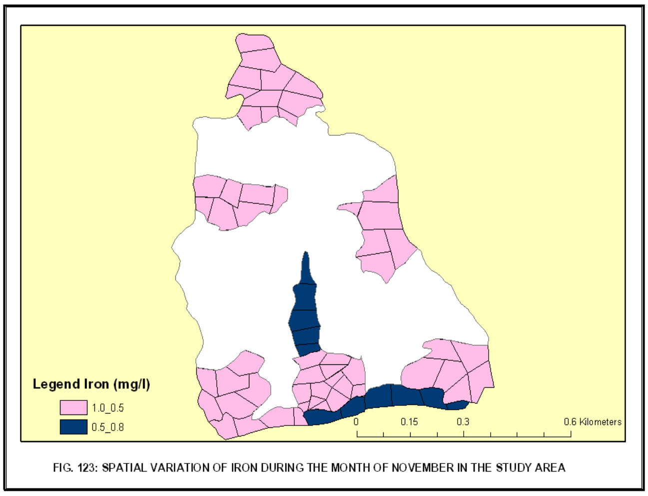

Fig. 21: Spatial variations of Iron in rainwater in the study area in November

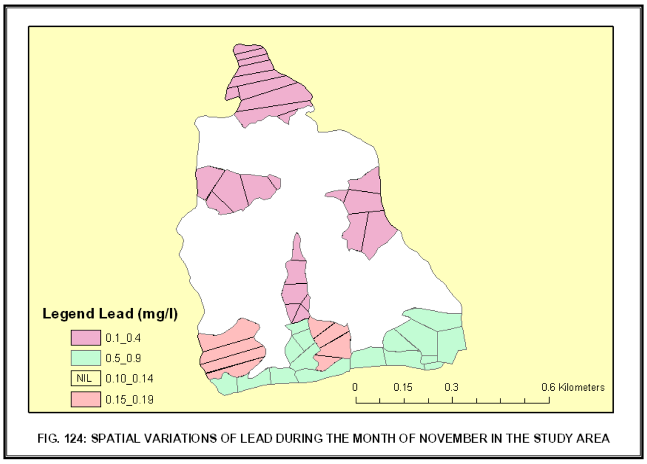

Fig. 22: Spatial variations of Lead in rainwater in the study area in November

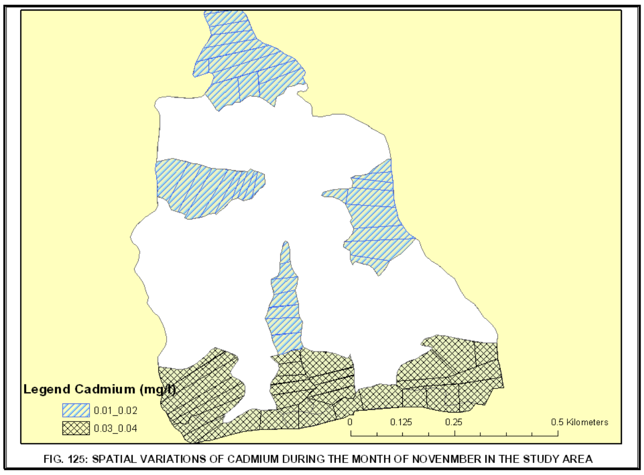

Fig.23: Spatial variations of Cadmium in rainwater in the study area in November

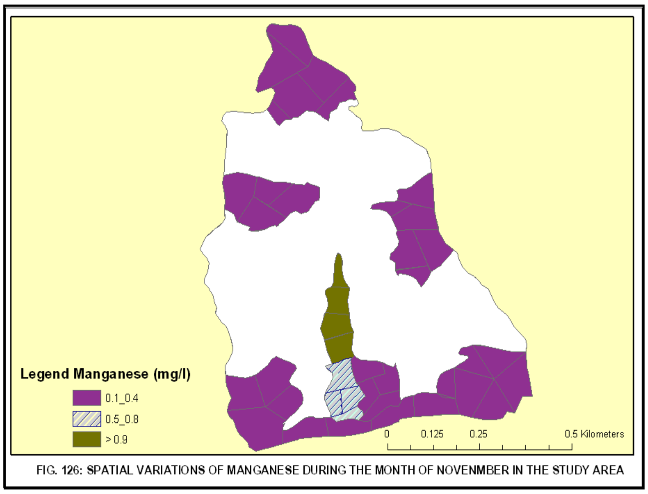

Fig. 24: Spatial variations of Magnesium in rainwater in the study area in November

This is in addition to disturbances arising from oil exploration activities within the study area especially in the dry periods of March and November. The levels of these metals also followed the observed trend, i.e. values were highest in March, followed by November, while July recorded the least values.

Conclusion

The study has shown that rainwater in the southern part of Akwa Ibom State was more acidic than that from the north. The highest level of contaminants was observed in the month of March, followed by November while July recorded the least. There was a gradual build up of pollutants in the atmosphere in the month of November due to rain cessation. This build-up of pollutant is regulated by rainfall frequency and intensity in the locality while the source is mostly from the various activities of the Oil Company in the locations which include gas flaring among others. This situation is aided by the South West Trade Wind (SWTW) across the Atlantic Ocean which distributes the gas plume all around the flare and towards the hinterland.

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