Physico-Chemical Characteristics of Rainwater in a Nigerian Rural Community Experiencing Gas Flaring.

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Abstract
This study determined the rainwater quality of Odagwa, a rural community hosting a crude oil flow station. Rainwater samples were collected at various distances from the gas flare point in ambient air. Samples were tested for Temperature, Turbidity, Colour, pH, Electrical Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Sodium, Magnesium, Calcium, Total Hardness (TH), Sulphate, Nitrate, Chloride, Aluminium, Iron, Zinc, Lead, Cadmium, Nickel and Manganese using standard methods. Tables, Bar charts and Correlation were used to present and analyze the data. Results showed the following range of values: Temperature (30^oC-34^oC), Colour (12 – 18TCU) Turbidity (45-64 NTU), EC (16-20.5µS/cm), TDS (16-20mg/L), pH (5.1 – 6.5), T S S (42 – 65mg/ L), Sodium (100-140mg/ L), Mg (0.1-0.18mg/ L), TH (50mg/ L) Sulphate (20-50mg/ L), Nitrate (5-6mg/ L), Chloride (5.5-5.7mg/ L), Mn (0.05 – 0.3 mg/ L), Pb (0.04 – 0.08mg/ L), Cd (0.01– 0.24mg/ L) and Ni (0.001 – 0.05mg/ L) within 500m- 5000m distance from gas flare point. Generally results indicated that the rainwater and air quality of Odagwa are negatively impacted by gas flaring within the community. It was recommended that the flaring of associated gas in the community take into consideration necessary environmental mitigation and rainwater treated adequately before utilization.
Keywords: Rainwater, Gas Flaring, Physico-Chemical, Quality.

INTRODUCTION

Rainwater, like other waters is a very good solvent especially for ionic or polar compounds hence the popular phrase “water a universal solvent”. It is a good solvent for acids, bases, salts and a wide range of gases example CO_2, SO_2, NO_x and NH_3(g).

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

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

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

The Niger Delta environment have become the sink for over 1.8 billion cubic feet of associated gas flared on daily bases from over 123 flaring sites releasing over 45.8 billion kilowatt of heat (Aniefiok et al, 2013).

Can the Niger Delta environment of Nigeria remain the same over forty years of incessant and ever increasing oil and gas exploitation? Closer study on Odagwa a community in Etche Local Government Area of Rivers State will go a long way in answering the above question.

The associated gas is released as a waste product from the petroleum extraction industry, due to complexities in the management of the gas, it is simply burnt off in Gas flares. The associated gas is composed of 81% methane (CH_4), 5% Ethane (C_2H_6), 6% Propane (C_3H_8), 4% Butane (C_4H_{10}), 1% Nitrogen (N_2), > 0.15%CO_2. (Gazprom, 2010). Flaring of gas being typical fossil fuel combustion has notable products such as carbon dioxide CO_2, Carbon Monoxide CO, Sulphur Dioxide SO_2, Nitrogen Oxides NO_X, Methane CH_4, Carbon Disulphate CS_2, Carbonyl Sulphide COS, Benzene, Toluene, Xylene, Benzo($\propto$)Pyrene, Hydrogen Sulphide H_2S, Metals like Arsenic, Chromium, cadmium, Nickel, Cobalt lead, Zinc, Iron, Dioxines and Particulate matter (USEPA, 2014, USEPA & GRI 1995). The presence of pollutant compounds in the atmosphere is of great environmental concern (Mokhatab *et al*, 2006).

Atmospheric conditions offer some removal mechanisms for pollutants emitted into the atmosphere. Akhionbare (2009) identified dispersion, gravitational settling, flocculation, absorption, rain out and adsorption as some of the removal mechanisms. Dispersion is the process by which contaminants move through air spreading a plume over a large area, it could be vertical or and horizontal (Dara, 2006).

Rainwater in gas flaring vicinity is relatively acidic, rich in micro nutrients and heavy metals (Ejeleonu *et al*, 2011). Aririatu (2006) pointed out that, total suspended solids, colour and turbidity are important water quality concerns. Air pollutants like SO_2, NO_x, sulphates, nitrates may fall down on land either as dust, droplets or with precipitation as acid rain (Garg, 2008). Such rainwater could accelerate metallic corrosion (Ovri and Iroh, 2013), poor crop yield (Okereke, 2006), fading of materials (Bhatia, 2009) and retardation of plant growth (Narayanan, 2009). Bhatia (2009) stated that urban centres will have more polluted surface waters than the rural areas due to atmospheric contamination with CO_2, CO, SO_2, NH_3, NO_X, H_2S, smoke, vehicular emission, waste water and solid waste dumps. He found out that in polluted surface waters ions like Na^+, K^+, $Mg^{2+,}$ SO_4^{2-}, $H_2PO^-_4$ and $H_4P_2O_7^{2-}$ interact to form a variety of complex compounds thereby influencing the water quality. The study area as a rural Nigerian community is expected to have a good rainwater quality but the practice of associated gas flaring in the vicinity prompted this study aimed at determining the physico- chemical properties of rainwater in Odagwa, Rivers State, Nigeria.

MATERIALS AND METHODS

Description of study Area

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

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

Etche has its L.G.A. headquarters at Okehi. It is bounded in the North by Imo State, East by Imo River and Omuma L.G.A., South by Obiakpo and Oyibo L.G.A.'s and West by Ikwerre L.G.A.

Agriculture is the economic mainstay practiced as farming, fishing, lumbering and hunting. Other economic activities include petty trading, sand mining, transportation, agro-processing, construction and educational activities.

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

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

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

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

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

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

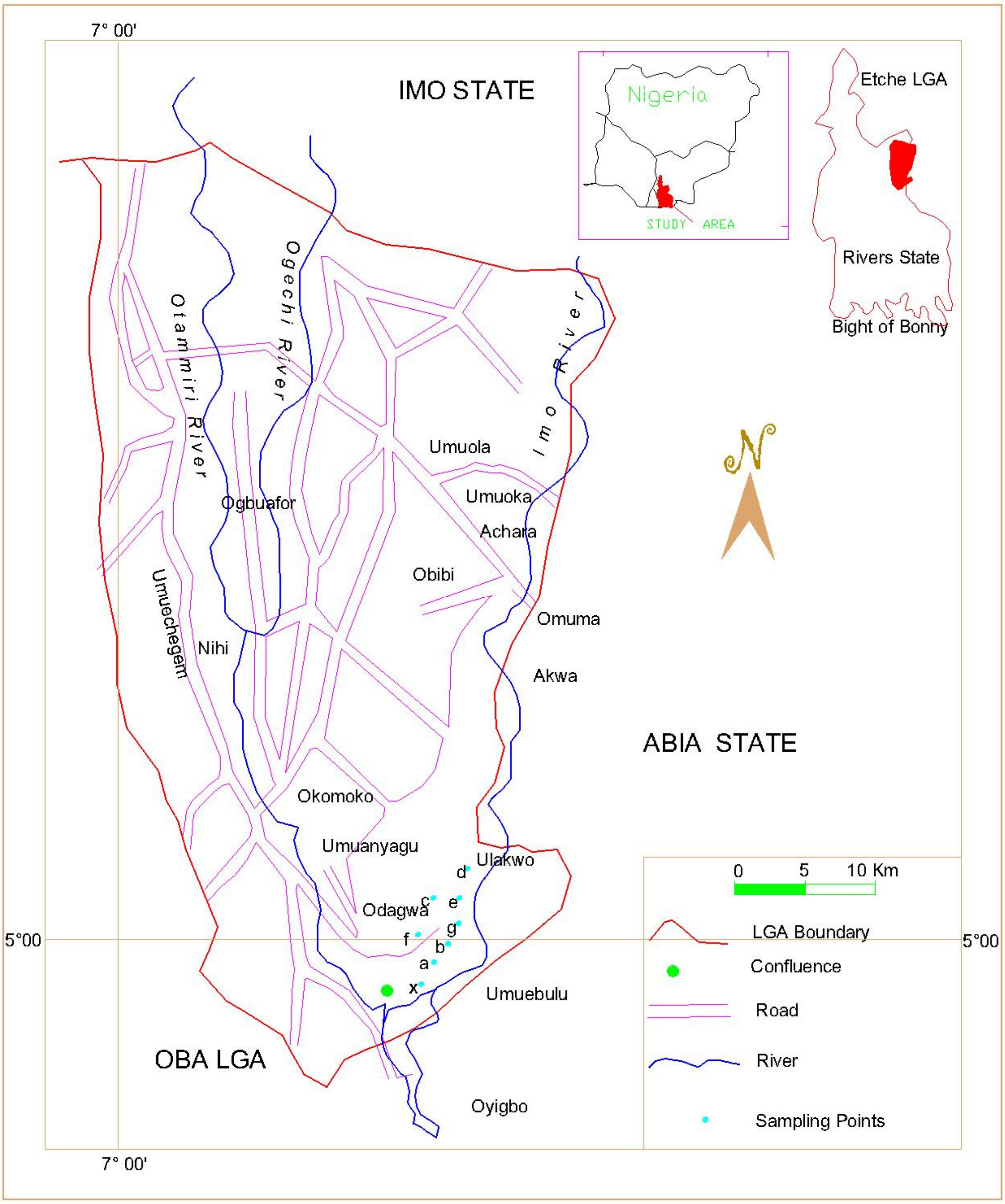
The weather and climate of the area is characteristic of the tropical equatorial climate.

Amount of rainfall in the area is between 2000mm to 4000mm annually with two peaks in June / July and September (Nwankwoala and Nworgu, 2009). It has two major seasons, the long rainy season (March to July) and the long dry season (November to February) as well as two minor seasons the short rainy season (September to October) and short dry season (August).

Humidity of the area ranges from 40% in dry season to 90% in rainy season. It has two distinct air masses, the tropical continental and tropical marine.

Mean monthly wind speed is between 22.77 to 66.12 Knots, wind direction is dominated by the South Westerly wind throughout the year.

Mean monthly minimum temperature is 21.1^{0}C to 24^{0}C while mean maximum monthly temperature is between 29.3^{0}C and 34.2^{0}C (NIMET, 2013).



SOURCE: FED SURVEY MAPS, RIVERS STATE.

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

Geographical Coordinates

The table below shows the geographic Coordinates of sampling points in Odagwa and the control site at Ulakwo using Garmin Global Positioning System, model etrexH.

Table 1.0; geographical coordinates of sampling points

Sampling Points	Northing(°&’)	Easting(°&’)	Elevation(ft)
Flare Area X	04°59.720’	07 ° 11.490’	54.12
A	04°59.560’	07 ° 11.165’	82.71
B	04°59.280’	07 ° 10.695’	98.56
C	05 ° 05.162’	07 ° 07.415’	131.43
D	05 ° 06.290’	07 ° 06.316’	98.85
E	05 ° 04.380’	07 ° 07.623’	97.62
F	05 ° 04.192’	07 ° 07.455’	97.31
G	05 ° 04.161’	07 ° 07.172’	97.56
H	05 ° 04.462’	07 ° 05.115’	96.78

Table 1.1; Physico – Chemical Analytical Methods.

S/N	PARAMETER	UNIT	METHOD
1	Temperature	°C	Insitu measurement with celsius thermometer
2	Turbidity	NTU	Measurement taken insitu with Hatch portable Turbidometer model 2100Qis
3	Colour	TCU	Measurement was taken insitu with lovibond System 2000+ colorimeter model LO142000-G
4	Total Suspended Solid	mg/L	Evaporation of 100ml sample on weighed evaporation dishes
5	Total Dissolved Solid	mg/L	Evaporation of 100 ml sample filtered through less than 2µ optical glass filter on weighed evaporation dishes
6	Electrical conductivity	µS/cm	Measured insitu with Hatch electrical conductivity meter model HQ4OD
7	Ph		Measured insitu with Hatch portable pH meter MODEL HQ4OD
8	Sodium	mg/L	Flame photometry with the Sherwood Flame photometer model 360
9	Magnesium	mg/L	Flame photometry with the Sherwood Flame photometer model 360
10	Calcium	mg/L	Flame photometry with the Sherwood Flame photometer model 360
11	Total Hardness ($CaCO_3$)	mg/L	Titration of sample against EDTA standard solution
12	Nitrate	mg/L	Labomed Ultraviolet Spectrophotometer model UV-2505 with absorbance and transmittance read off at 220nm and 225nm.
13	Chloride	mg/L	Titration of sample against standard Silver Nitrate with Potassium Chromate as indicator.
14	Sulphate	mg/L	Labomed Ultraviolet Spectrophotometer model UV-2505 with absorbance read off at 420nm
15	Metals (Zn, Pb, Ni, Mn, Fe & Cd)	mg/L	Toposun Atomic Absorption Spectrophotometer (AAS) model TPS-AA320N.

Sampling Method

Plastic buckets cleaned by rinsing with tap water, chromic acid, 1:1 Nitric acid and finally with distilled water was used to collect rainwater samples on a stand of about 1.5m to avoid splash water contamination(Ejeleonu *et al*, 2011).

Samples were divided into two parts for heavy metal analysis and the other part for other parameters. Composite samples of first flush and after first flush were made at various sampling locations. The frequency of sampling was monthly in the year 2013.

The samples collected were stored in 2 litre plastic bottles properly rinsed and labeled.
The samples for calcium, magnesium, sodium, chloride, sulphate, nitrate, hardness, TSS and TDS were preserved at temperature of 4^0c using the Rubbermaid model FG2A0904MODBL-5 QUART Personal ice chest cooler for a maximum holding time of 24 hours.
The samples for heavy metal analysis were preserved by adding 2ml conc. HNO_3I^{-1} solution to the sampling bottle before storing the sample to ensure that all composites were well preserved. Samples were tested for Temperature, Turbidity, Colour, pH, Electrical Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Sodium, Magnesium, Calcium, Total Hardness (TH), Sulphate, Nitrate, Chloride, Aluminium, Iron, Zinc, Lead, Cadmium, Nickel and Manganese using standard methods (APHA, 2012).

Results and Discussion

Variation of Physicochemical Properties for Un-intercepted Rainwater at Various Distances from the Flare Point;

The results were presented in table 1.2

Table 1.2; Variation of Physicochemical Properties of Rainwater at Various Distances, from Gas Flare Point.

S/N	PARAMETER	UNITS	500m	1000m	2000m	CONTROL (ULAKWO) 5000m
1.	Temperature	^OC	34	32	32	30
2.	Turbidity	NTU	60	64	62	45
3.	Colour	TCU	16	18	15	12
4.	Electrical Conductivity	µS/cm	20.5	18.5	17.0	16.0
5.	pH		5.1	5.4	5.8	6.5
6.	Total Suspended Solids (TSS)	mg/L	65	60	58	42
7.	Total Dissolved Solids (TDS)	mg/L	20	18	16.8	16.0
8.	Manganese	mg/L	0.2	0.3	0.3	0.05
9.	Sodium	mg/L	100	120	140	140
10.	Magnesium	mg/L	0.1	0.15	0.18	0.15
11.	Calcium	mg/L	1.3	1.28	1.25	1.05
12.	Sulphate	mg/L	20	50	50	20
13.	Nitrate	mg/L	5	6	8	5
14.	Chloride	mg/L	5.5	5.7	5.6	5.7
15.	Total Hardness as CaCO3	mg/L	50	50	50	50
16.	Lead	mg/L	0.08	0.06	0.058	0.04
17.	Cadmium	mg/L	0.2	0.24	0.15	0.01
18.	Nickel	mg/L	0.01	0.05	0.02	0.001
19.	Zinc	mg/L	0.05	0.04	0.06	0.06
20.	Iron	mg/L	0.06	0.05	0.04	0.05

SOURCE: FIELD WORK

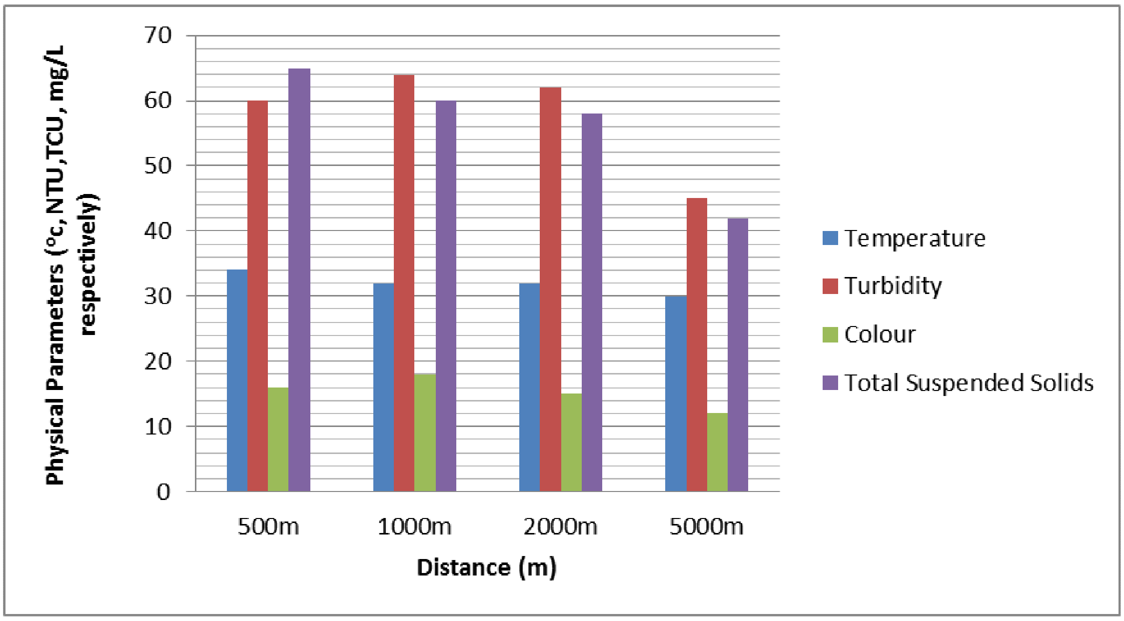


Fig 1.1; Variation of Temperature, Turbidity, Colour and TSS with Distance from Flare Point.

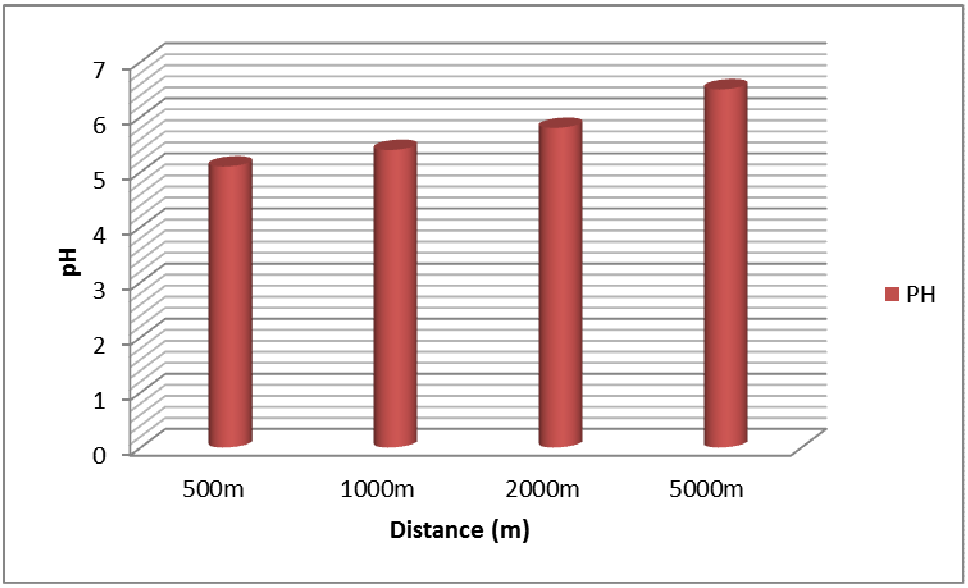


Fig 1.2a; Variation of Rainwater pH with Distance from Flare point.

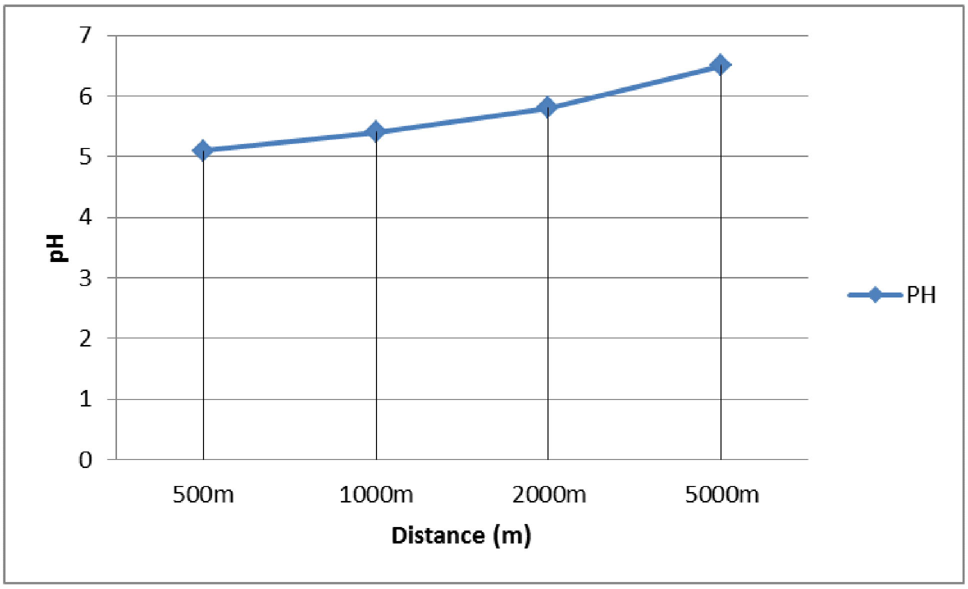


Fig 1.2b; Variation of Rainwater pH with Distance from Flare point.

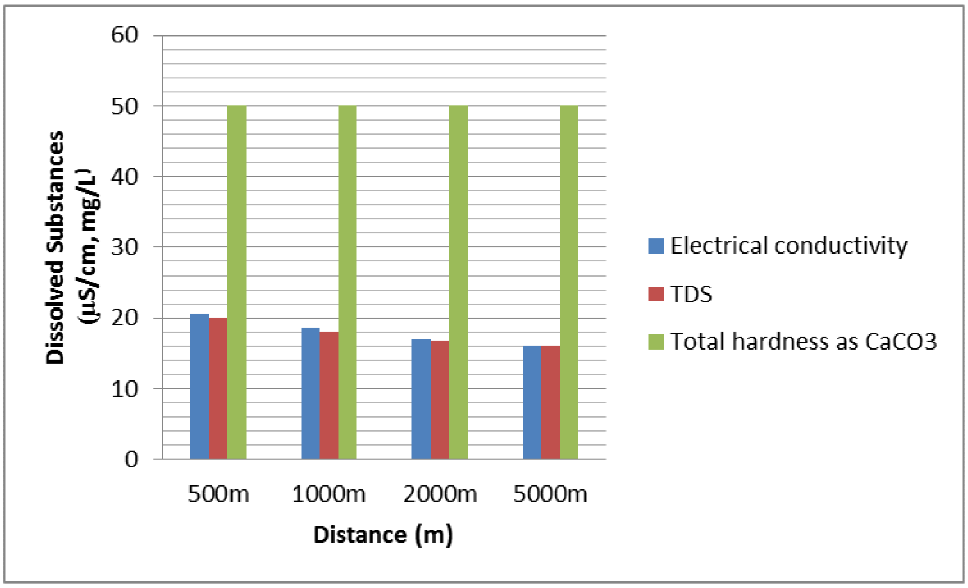


Fig 1.3; Variation of EC, TDS and TH with Distance from flare point.

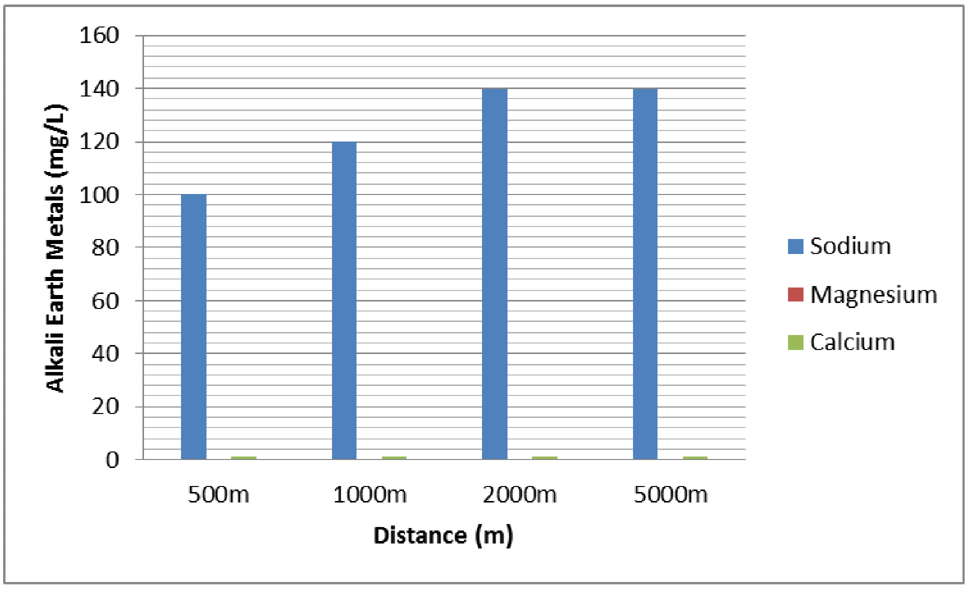


Fig 1.4a; Variations of Sodium, Magnesium and Calcium with Distance from flare point.

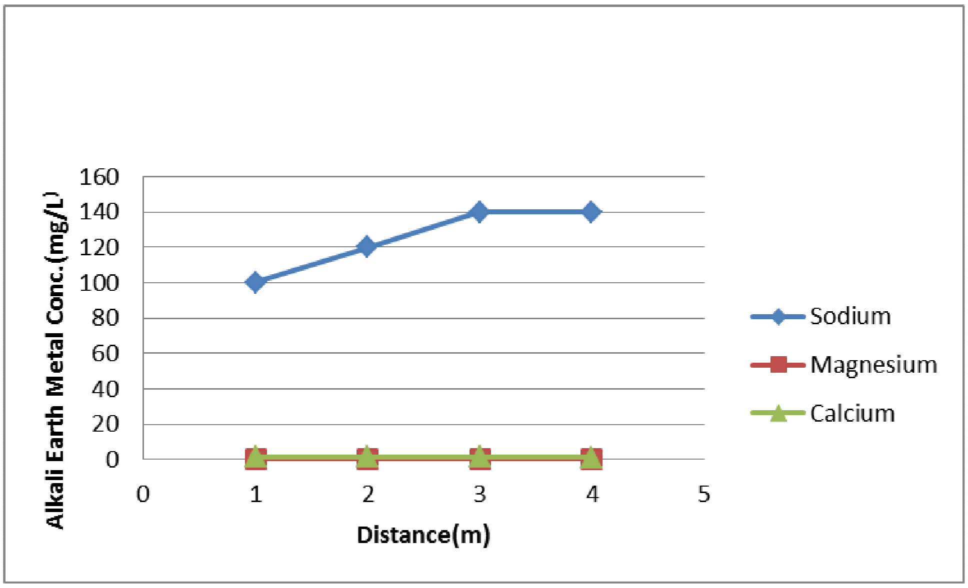


Fig 1.4b; Variation of Sodium, Magnesium and Calcium with
Distance from Gas Flare Point.

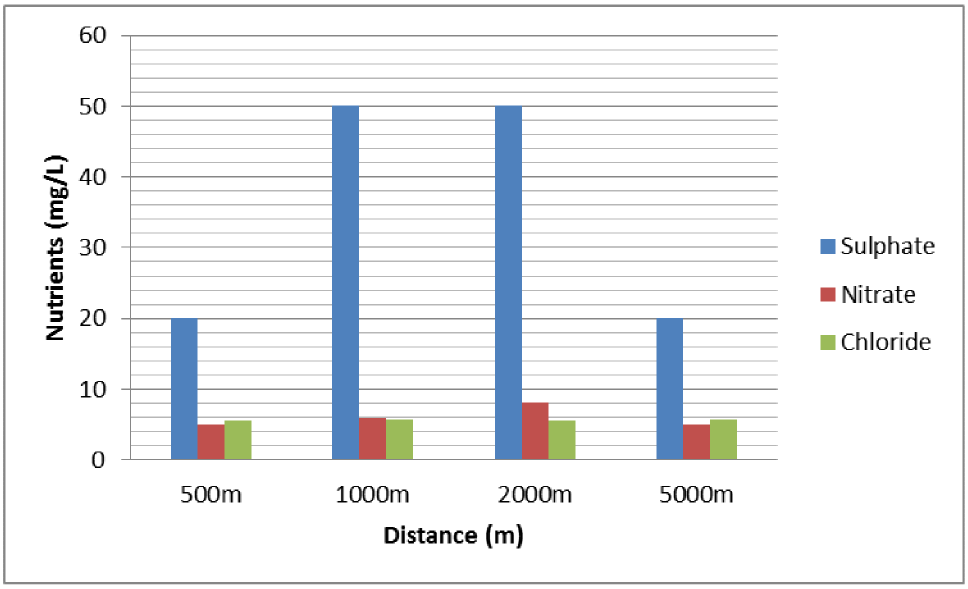


Fig 1.5a; Variation of Sulphate, Nitrate and Chloride with Distance from Flare Point.

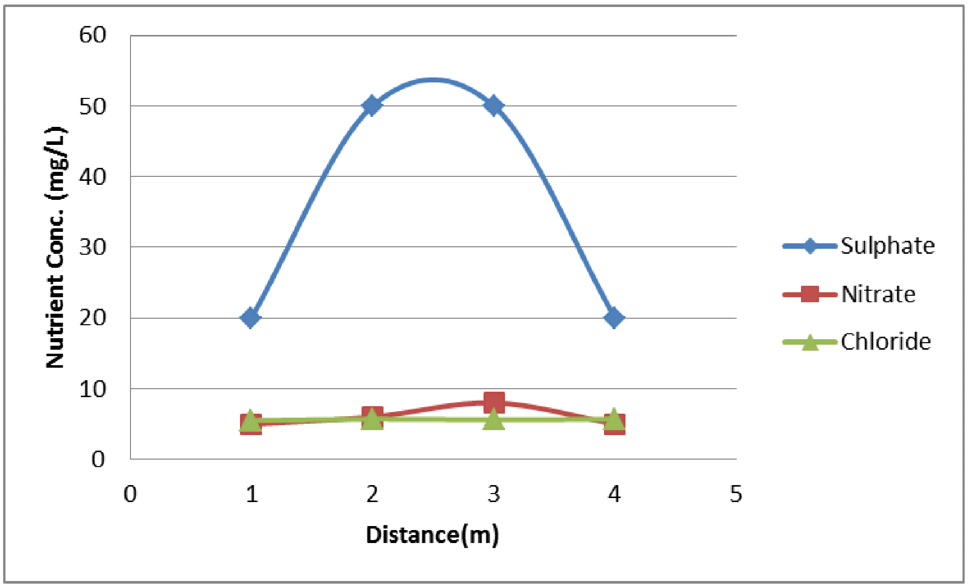


Fig 1.5b; Variation of Sulphate, Nitrate and Chloride with Distance from flare point.

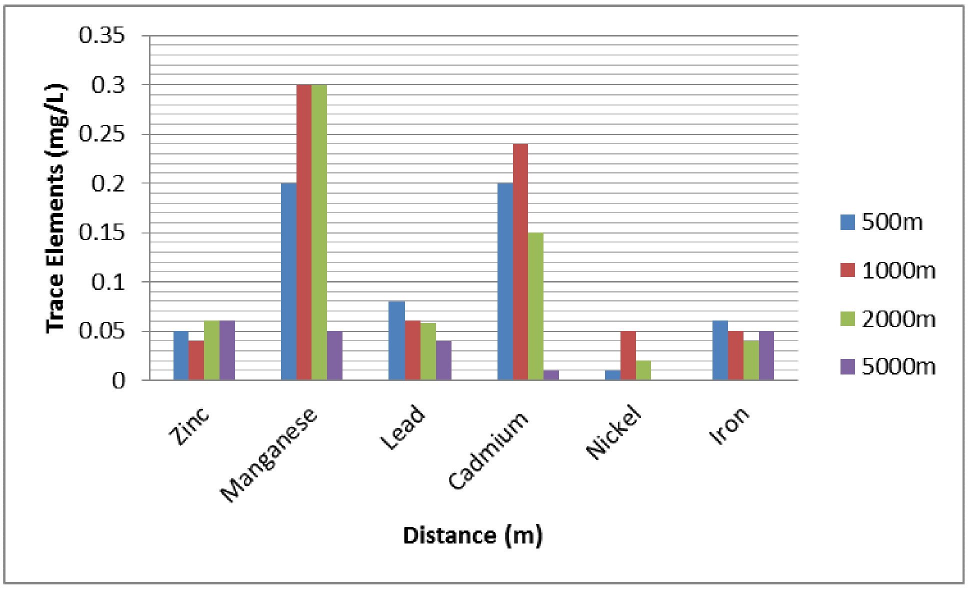


Fig 1.6; Variations of Heavy metals with Distance from flare point.

The results show that physical properties decreased with increase in distance from flare point. (Temperature 30°C-34°C, Turbidity 45-64NTU, Colour 12-18TCU units and TSS 42-65mg/dm^3). pH increased with increased distance from the flare point (pH 5.1-6.5). Electrical Conductivity and TDS decreased slightly but were low while Total Hardness remained constant (EC 16-20.5µS/cm, TDS 16-20mg/dm^3, TH 50mg/dm^3). Alkali earth metals increased with distance from flare point but magnesium and calcium were low (Sodium 100-140mg/dm^3, magnesium 0.1-0.18mg/dm^3, calcium 1.05-1.3mg/dm^3) the nutrients increased, peaked and then decreased with distance from flare point (Sulphate 20-50mg/dm^3, Nitrate 5-8mg/dm^3, Chloride 5.5-5.7mg/dm^3). For the heavy metals, lead decreased with distance, zinc and iron decreased and increased while manganese, cadmium and nickel increased and then decreased with increase in distance from the flare point (Lead 0.04-0.08mg/dm^3, Zinc 0.04-0.06mg/dm^3, Iron 0.04-0.06mg/dm^3, manganese 0.05-0.3mg/dm^3, Cadmium 0.01-0.24mg/dm^3 and Nickel 0.001-0.05mg/dm^3). From correlation analysis; temperature had high correlation with turbidity, colour, electrical conductivity, pH, TSS, TDS, Mn, Na, Mg, Ca, Cl, Pb, Cd and Fe. The correlation between temperature and SO_4, NO_3, Ni, and Zinc was low. Turbidity recorded high correlation with colour, EC, pH, TSS,TDS, Mn, Ca, SO_4, NO_3, Pb, Cd,Ni and Zinc while the correlation with Na, Mg, Cl and Fe was low. There was high correlation between colour and EC, pH, TSS, TDS, Mn, Na, Ca, SO_4, Pb, Cd, Ni and Zn while correlation between colour and Mg, NO_3, Cl and Fe was low. Electrical Conductivity had high correlation with pH,TSS,TDS,Na, Mg, Ca, Pb, Cd, Zn and Fe with low correlation with Mn, SO_4, NO_3 and Ni. pH recorded high correlation with TSS,TDS, Mn, Na, Ca, Cl, Pb, Cd and Zn with low correlation between pH and SO_4, NO_3, Cl, Ni and Fe. TSS recorded high correlation with TDS, Mn, Na, Ca, Cl, Pb, Cd, Zn and Fe. Correlation between TSS and Mg, So_4, No_3, Ni and Fe were low. (See appendix II).
The correlation analysis revealed strong relationships between parameters at distances 500m to 5000m from the gas flare point

Discussion

Variation of Rainwater Quality at Various Distances from Gas Flare Point

Results showed that rainwater quality parameters recorded increased and unacceptable levels within 500m - 2000m from gas flare point, see appendix I. The rainwater temperature, colour, turbidity, pH, total suspended Solids (TSS), Manganese, Lead, Cadmium and Nickel were high (Table 1.2, Fig 1.1- 1.6). The high values are due to dissolution and deposition of pollutants in the Rainwater. At Ulakwo, the control location, the physico-chemical parameters of rainwater were low and acceptable. There were strong relationships between most of the parameters studied, see appendix II. Ejelonu *et al* (2011) found out that in Utorogu gas flaring Community the rainwater within 1500m radius had pH less than 6.5. It was similar to results obtained by Ubuoh (2012) in Akwa Ibom communities experiencing gas flaring. In his study Akpan (2003) discovered that rainwater in gas flaring Communities of Eket in Akwa Ibom State has high values of colour, turbidity, lead, nickel and TSS. Akhionbare (2009) confirmed that at the instant of formation, rainwater is pure but gets contaminated as it dissolves pollutant gases in the atmosphere.

The rainwater in Odagwa has pH levels from 5.1 to 5.8 within 2000m from the gas flaring point, Avwiri and Ebeniro(1995) concluded in their study that rainwater having pH less than 6 can lead to corrosion of metals, fading of paints, fabrics and other materials, acidification of surface water, groundwater and soil. It can also lead to destabilization of aquatic ecosystem. Okereke (2006) added that rainwater in gas flare areas induces soil acidity and accumulation of heavy metals such as lead which can cause poor crop yield and poisoning of living organisms. The high temperature can deplete dissolved Oxygen in the rainwater and nearby surface waters such as Imo, Otamiri and Ogochie rivers. The high TSS, turbidity and Colour will make the rainwater lose its aesthetics and acceptability for domestic utilization.

Conclusion

Gas flaring is the major source of emission into the ambient air within the vicinity of the rural community of Odagwa. The study successfully determined the physico- chemical properties of rainwater in Odagwa at various distances from gas flare point. The results reveal that between 500m-2000m (inhabited area) from flare point, the rainwater quality was poor compared to the result at 5000m (Ulakwo community) which served as the control.

The degraded rainwater quality can be attributed to gas flaring in the area which is consequently a major contributor to poor crop yield, corrosion of roofs and other metallic structures, fading of paints and materials, pollution of runoff, surface and ground water, gastro intestinal problems in animals and humans, leaching of nutrients, bioaccumulation and demobilization of heavy metals and so many other chain effects.

The Government, oil and gas operators, environmental and civil right organizations should intensify efforts at stopping or reducing the practice of gas flaring in Nigeria. In the immediate, it was recommended that the flaring of associated gas in the community take into consideration necessary environmental mitigation and rainwater treated adequately before utilization.

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APPENDIX I
Nigerian Standards for Drinking Water Quality.

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

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

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APPENDIXES

Appendix II

Correlation Matrix of Rainwater Properties Between 500m-5000m from Gas Flare Point

	Temp	Turbidity	Colour	EC	pH	TSS	TDS	Mn	Na	Mg	Ca	SO_4	NO_3	Cl^-	TH	Pb	Cd	Ni	Zn	Fe
Temp	1																			
Turbidity	0.70749995	1																		
Colour	0.65319726	0.91272063	1																	
EC	0.93831486	0.59009575	0.6810052	1																
pH	-0.9438798	-0.8267937	-0.8587517	-0.941889	1															
TSS	0.94409886	0.89931225	0.8412358	0.8644644	-0.97414	1														
TDS	0.93864651	0.55119665	0.6361134	0.9981788	-0.92394	0.845719	1													
Mn	0.51832106	0.96567525	0.8323078	0.360258	-0.65231	0.762387	0.316238162	1												
Na	-0.8528029	-0.4324066	-0.591864	-0.978019	0.86244	-0.74387	-0.98058853	-0.1842	1											
Mg	-0.6154575	0.01741744	-0.1809068	-0.795657	0.54772	-0.389053	-0.820329728	0.27647	0.89227	1										
Ca	0.88610151	0.95291349	0.8913506	0.7981845	-0.95108	0.989332	0.771851087	0.84508	- 0.66499	-0.2705	1									
SO_4	0	0.70038921	0.5773503	-0.147442	-0.19069	0.319277	-0.199116993	0.85519	0.30151	0.69631	0.451129	1								
NO_3	0	0.51740203	0.1885618	-0.300965	0	0.213291	-0.325156689	0.69826	0.49237	0.78174	0.306955	0.816497	1							
Cl-	-0.8528029	-0.3519588	-0.1740777	-0.711287	0	-0.673859	-0.7404444	-0.1842	0.63636	0.57735	-0.57431	0.301511	-2.18654E-15	1						
TH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1					
Pb	0.99813026	0.68616875	0.9573729	0.9573729	-0.94884	0.935164	0.95797154	0.48717	- 0.88313	- 0.65731	0.873831	-0.035289	-0.057627077	-0.8405682	##	1				
Cd	0.77309904	0.94423868	0.9833941	0.7635898	-0.92723	0.925297	0.725666711	0.84361	-0.6593	- 0.25043	0.95762	0.517892	0.211428444	-0.3470006		0.771654	1			
Ni	0.17251956	0.73641406	0.8561257	0.2238308	-0.47042	0.465415	0.164633797	0.77332	- 0.15121	0.23831	0.574791	0.799711	0.320946912	0.3392053		0.172675	0.75813	1		
Zn	-0.4264014	-0.593302	-0.8703883	-0.622376	0.68995	-0.568842	-0.580348314	-0.4789	0.63636	0.3674	-0.60454	-0.301511	0.246182982	-0.0909091		-0.457524	-0.7981	-0.8051	1	
Fe	0.5	-0.0943333	0.1632993	0.7298004	-0.47194	0.287334	0.750917207	-0.3455	-0.8528	- 0.98473	0.17722	-0.707107	-0.866025404	-0.4264014		0.548972	0.20345	-0.1917	- 0.4264	1