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Gas Flaring and Rainwater Composition - A Negative Synergy: A Case Study of Utorogu Community in Niger-Delta, Nigeria

Research Article

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Abstract

The environment of the Niger Delta has been degraded through oil exploration activities. The soil, ground and surface water have remained the deposit sites for the crude oil/natural gas processing wastes. Although some studies exist on the pollution status of the region, the situation of a number of communities has not been investigated. This study therefore, examined the impacts of gaseous emissions from the flaring of gases at the gas plant located within Utorogu community through rainwater samples collected from the community. The rainwater samples were collected at 500 m, 1000 m and 5000 m away from the flare site of the gas plant (downwind) and analyzed for physico-chemical properties and heavy metals. For a control study, rainwater samples were collected from Okere-a community outside the same local government area with Utorogu. All the parameters were determined in triplicates using standard analytical methods; and the data generated analyzed using correlation test. The rainwater chemistry varied little with time and distance. The findings suggest that rainwater within the Utorogu community are well within acidic pH range (pH < 6.50), contain acidic radicals like PO_4^{3-}, SO_4^{2-}, NO_2^- and HCO_3^-; and are very rich in both micronutrient elements and heavy metals; while that of the control area are less acidic and less rich in heavy metals. Thus, if flaring of gas by the crude oil processing plant is not checked, there is a tendency of increasing acidic and metal polluted rainwater within this community. The reduction of gaseous emissions whitim this community would significantly decrease or slow down the acidification of water bodies and reduce stress to forests. In addition, the lifespan of building materials and structures of cultural importance would be lengthened. Also, the reductions in emissions would help to protect public health. The present study examines a three year profile (1998-2000) of gas flaring activities in Utorogu oil producing community; and its outcome would provide information on the potential environmental impacts of gas flaring within the given oil producing community.

Keywords: Environment; Oil exploration activities; Gaseous emissions; Heavy metals; Public health

Introduction

Anywhere, the petroleum industry is a power-generating entity. When significant deposits of oil were discovered in the 15th century, this fossil fuel appeared to offer limitless source of energy to drive development. While oil and the energy it supplies provide multiple benefits to human society, every stage in the life cycle from exploration to use can have harmful impacts on health and environment [1].

Oil production has been going on in Nigeria for over 45 years together with the flaring of natural gas. Flaring is a means of safely disposing of waste gases through the use of combustion. Data collected

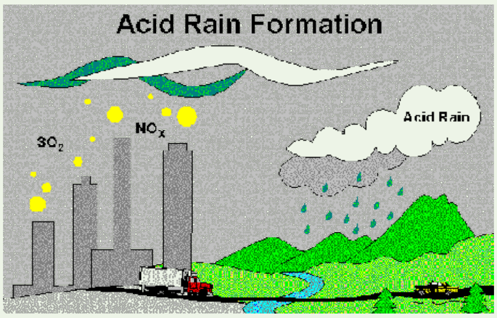

Figure 1: Graphic representation of acid rain formation.

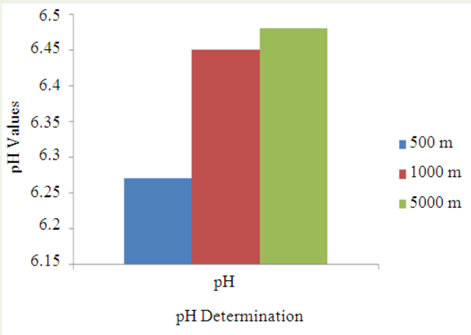

Figure 2: Mean pH Values (1998-2000) at the different distances.

by the Alberta Energy and Utilities Board (EUB) in Canada shows that in 1996 about 92% of gases were conserved or used in some manner. The remaining 8% was flared. This socially responsible attitude towards gas conservation, as demanded partly by environmental requirements in Canada and other advanced countries, does not apply in Nigeria. Nigeria is estimated to have 187 trillion cubic feet (TCF) of proven natural gas reserves as of December 2010 according to the BP Statistical Review of World Energy- a value which makes Nigeria the ninth largest natural gas reserve holder in the world and the largest in Africa [2]. Due to unsustainable exploration practices coupled with the lack of gas utilization infrastructure in Nigeria, the country flares 75% of the gas it produces and re-injects only 12% to enhance oil recovery. It has been reported that of the 3.5 billion cubic feet (99,000,000 m^3) of associated gas (AG) produced annually, 2.5 billion cubic feet (71,000,000 m^3), or about 70% is wasted via flaring, supporting the fact that Nigeria flares more natural gas associated with oil extraction than any other country. This amounts to about 70 million tonnes of carbon dioxide [3].

The gaseous emission products from gas flaring activities can be deposited (dry or wet) into water bodies, onto soil and vegetation [4]. Residents of oil-producing areas in Nigeria, have long complained about how their corrugated roofs have been corroded by the composition of the rain that falls as a result of flaring [5]. The primary causes of acid rain are emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x), which combine with atmospheric moisture to form sulfuric acid and nitric acid respectively [4-6]. The graphic representation of how acid rain falls is given in Figure 1 above [7].

Acid rain causes acidification of lakes and streams. It contributes to damage of trees at high elevations and accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage. Prior to falling to the earth, SO_2 and NO_x gases and their particulate matter derivatives, sulphates and nitrates, contribute to visibility degradation and harm public health [7,8]. In the Delta, an oily hue is often observed on collected rainwater. The continued process of gas flaring has not only meant that a potential energy source and source of revenue-has gone up in smoke, but it is also a major contributor to air pollution and CO_2 emission [9]. Literatures have shown that the gas flaring of other carbonaceous fuels, apart from producing oxides of carbon (CO_X), sulfur (SO_X) and nitrogen (NO_X), water vapour, also produces volatile and non-volatile heavy metals such as Lead (Pb), Mercury (Hg), Cadmium (Cd) and Arsenic (As) [10]. Also, a greater number of people within the community housing the gas plant may be exposed to the risk of toxic metals (especially vanadium) through the usage of harvested rainwater [11].

Nigeria gets about 90 per cent of its petroleum from the sprawling Delta in the south, an area inhabited by "minority" ethnic groups such as the Itsekiris, Urhobos, Ijaws, Ibibios, Ogonis, Kalabaris, Efiks, Ikwerres, Ilajes and Ibibios. In spite of the enormous resources it generates for the national coffers, the Niger Delta is perhaps the least-developed area of the country. The Delta lacks good roads, electricity, potable water and good schools. Unemployment is high because the rivers, creeks and streams which provide people with their main source of livelihood fishing have been extensively polluted through the activities of the more than a dozen oil companies operating in the area [12,13].

No comprehensive study is known to have been carried out into the health impacts of gas flaring on communities in the Delta, including the level of pollutants in the food chain. However, communities firmly believe that the flaring is damaging their health, reducing crop

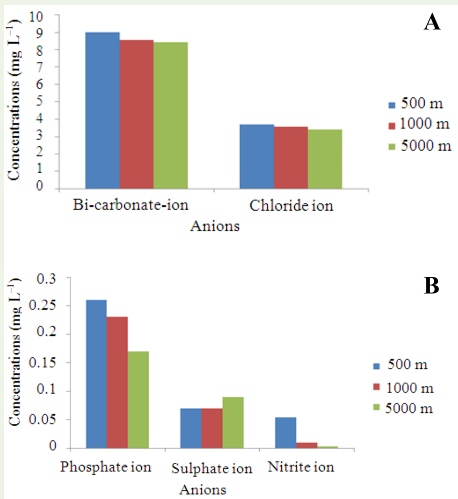

Figure 3: (A) Mean concentrations of anions (1998-2000) at the different distances.
(B) Mean concentrations of anions (1998-2000) at the different distances.

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Table 1A: Summary of the annual mean values of physico-chemical and level of heavy metals in rainwater samples from utorogu gas plant (1998).

Parameters	Distances away from flare site (m)	Mean	± Std. Deviation	Ranges
pH	500	6.2	0.87	4.60-7.2000
	1000	6.39	0.53	5.77-7.2100
	5000	6.57	0.75	5.60-7.6500
CND(μScm^{-1})	500	18.93	7.24	10.00-30.000
	1000	14.24	8.18	10.00-30.000
	5000	12.29	3.16	10.00-16.900
Ca^{2+} (mg L^{-1})	500	1.62	1.072	0.60-3.2000
	1000	1.35	1.022	0.40-3.2000
	5000	0.97	0.89	0.80-1.6000
Mg^{2+} (mg L^{-1})	500	0.33	0.23	0.12-0.7300
	1000	0.28	0.43	0.010-1.200
	5000	0.25	0.14	0.12-0.4900
Na^{+} (mg L^{-1})	500	1.12	1.068	0.26-3.3900
	1000	1.52	1.19	0.16-3.5400
	5000	0.78	0.5	0.21-1.6900
K^{+} (mg L^{-1})	500	0.31	0.23	0.070-0.720
	1000	0.43	0.43	0.070-1.110
	5000	0.1	0.1	0.010-0.320
HCO_3^- (mg L^{-1})	500	8.27	4.81	1.83-13.600
	1000	8.032	4.51	2.44-13.000
	5000	8.31	2.94	5.49-13.240
	500	4.58	1	3.00-6.2200
Cl^- (mg L^{-1})	1000	4.51	1.019	3.00-6.0300
	5000	4.52	1.09	3.00-6.0000
PO_4^{3-}(mg L^{-1})	500	0.29	0.21	0.001-0.640
	1000	0.32	0.23	0.10-0.7400
	5000	0.19	0.21	0.090-0.640
SO_4^{2-}(mg L^{-1})	500	0.08	0.068	0.010-0.200
	1000	0.097	0.14	0.010-0.400
	5000	0.19	0.18	0.010-0.600
	500	0.21	0.69	0.001-1.800
NO_2^-(mg L^{-1})	1000	0.012	0.026	0.001-0.068
	5000	0.002	0.004	0.002-0.003
Zn^{2+} (mg L^{-1})	500	0.14	0.17	0.010-0.490
	1000	0.61	1.45	0.001-4.000
	5000	0.75	1.45	0.001-4.000
Pb^{2+} (mg L^{-1})	500	0.021	0.024	0.001-0.065
	1000	0.01	0.017	0.001-0.030
	5000	0.016	0.011	0.005-0.030
V^{3+} (mg L^{-1})	500	0.006	0.007	0.001-0.020
	1000	0.008	0.014	0.001-0.040
	5000	0.007	0.006	0.001-0.020
Ni^{2+} (mg L^{-1})	500	0.042	0.091	0.007-0.240
	1000	0.097	0.25	0.001-0.610
	5000	0.052	0.079	0.002-0.200

production and damaging their homes. While other factors may be at play, the lack of attention paid to this crucial issue, means that villagers' questions and fears are unanswered. Conviction that oil production is such damaging force fuels community anger against oil companies. This work therefore, through the chemical analysis of rainwater samples collected within the Utorogu community would help to highlight further the impacts gas flaring activities have on the environment and the general health or well being of the community dwellers.

Materials and Methods

Site Description

The Niger-Delta area of Nigeria is endowed with petroleum resources. Daily a lot of oil prospecting and processing activities are carried out with concomitant release of effluent, gaseous wastes (resulting from the flaring of residual gases) into the environment, and the improperly handling of these wastes with time can result into pollution of the environment in the vicinity of the oil installations and beyond. The inhabitants of the Niger Delta are farmers and fishermen. They live off of the land and are dependent upon the productivity of that land for survival. Destruction of farmland by oil/gas prospecting and processing activities has pushed tens of thousands of people to the brink of starvation and prevented income generation from that land. Fisheries, farms, mangrove swamps, rain forests and water have all suffered severe damage from the impacts of petroleum exploration and energy consumption on these communities, threatening the survival of the people of the Niger Delta.

The Utorogu community belongs to the Ughelli-North Local Government Area of Delta State, Nigeria. It houses the Gas Plant- a natural gas processing plant, which processes natural gas and associated crude oil. Ughelli-North falls within latitude 5 °30^1 N and longitude 5 °59^1 E.

Analytical Procedures

pH and Electrical conductivity were determined insitu on the field while the heavy metal ion samples were preserved with concentrated nitric acid (pH < 2). All samples were transported to the laboratory for immediate further analysis in ice-bergs below 5 °C. All the physico-chemical parameters and heavy metal ions analyzed for all the samples were analyzed using standard analytical methods [14].

Results and Discussion

Results

The physico-chemical properties and level of heavy metals in rainwater samples collected from Utorogu Gas Plant location as well as those of Okere Area 1 and 2 Reference locations are contained in Tables 1A-1C and 2A, 2B respectively.

All the parameters analyzed for the rainwater samples collected from the studied area show a gradual decrease in concentrations with increase in distance away from the flare site, except for few cases, which might be due to wind current movement across the area. Based on the obtained results it is possible to conclude that the spread of pollutants is limited by the distance of 1000 m and above from the emission sources. The annual mean pH values of the rainwater samples collected from the Utorogu natural gas producing community are found to be generally low (Tables 1A-1C) respectively. The results of the rainwater analysis show relatively high monthly mean values for Bicarbonate ions (HCO_3^-) and chloride ions (Cl^-); while a generally low monthly mean values are recorded for NO_2^--N (nitrite ion), PO_4^{3-}-P (Phosphate ion) and SO_4^{2-}-S (Sulphate ion) (Tables 1A-1C) respectively. This observations suggest that the rainwater is very rich

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Table 1B: Summary of the annual mean values of physico-chemical and level of heavy metals in rainwater samples from utorogu gas plant (1999).

	Distances away from		± Std.	
Parameters	flare site (m)	Mean	Deviation	Ranges
pH	500	6.47	0.51	5.84-7.2100
	1000	6.46	0.49	5.90-7.1500
	5000	6.61	0.44	5.90-7.1000
CND (µS cm^{-1})	500	11.39	2.12	9.05-14.200
	1000	11.43	2.05	9.10-14.100
	5000	11.6	1.66	10.10-13.900
Ca^{2+} (mg L^{-1})	500	1.81	0.82	1.00-3.2100
	1000	1.73	0.82	0.94-3.1000
	5000	1.76	0.92	0.90-2.4000
Mg^{2+} (mg L^{-1})	500	0.29	0.18	0.11-0.6100
	1000	0.26	0.13	0.10-0.4300
	5000	0.26	0.12	0.10-0.4400
Na^{+} (mg L^{-1})	500	1.22	0.77	0.44-6.2800
	1000	1.25	0.64	0.50-2.2500
	5000	1.32	0.77	0.50-2.7000
K^{+} (mg L^{-1})	500	0.38	0.2	0.13-0.7100
	1000	0.39	0.19	0.16-0.6900
	5000	0.41	0.18	0.19-0.7000
HCO_3^- (mg L^{-1})	500	8.82	2.049	5.67-11.270
	1000	8.4	2.32	4.20-11.100
	5000	8.061	2.16	4.14-10.210
	500	3.59	1.4	2.01-6.0100
Cl^- (mg L^{-1})	1000	3.51	1.4	2.00-5.9400
	5000	3.2	1.22	2.00-5.4000
PO_4^{3-}(mg L^{-1})	500	0.27	0.14	0.11-0.5300
	1000	0.22	0.12	0.10-0.4600
	5000	0.21	0.1	0.10-0.4100
SO_4^{2-}(mg L^{-1})	500	0.065	0.021	0.04-0.1000
	1000	0.058	0.02	0.04-0.0800
	5000	0.052	0.016	0.03-0.0800
	500	0.004	0.003	0.001-0.008
NO_2^-(mg L^{-1})	1000	0.008	0.017	0.001-0.050
	5000	0.007	0.014	0.001-0.140
Zn^{2+} (mg L^{-1})	500	0.33	0.26	0.01-0.7200
	1000	0.31	0.24	0.10-0.6900
	5000	27	0.21	0.10-0.6000
Pb^{2+} (mg L^{-1})	500	0.012	0.01	0.001-0.041
	1000	0.005	0.004	0.001-0.013
	5000	0.004	0.003	0.001-0.009
V^{3+} (mg L^{-1})	500	0.002	0.0008	0.001-0.003
	1000	0.001	0.0005	0.001-0.020
	5000	0.001	0.0005	0.01-0.0020
Ni^{2+} (mg L^{-1}	500	0.02	0.017	0.01-0.0600
	1000	0.02	0.01	0.01-0.0400
	5000	0.015	0.008	0.01-0.0300

in calcium bicarbonate ions-(Ca $(HCO_3)_2$). Bicarbonate ion exists in rainwater through dissolution of CO_2 present in the atmosphere mainly from gas flaring and other particulate carbonates in cloud droplets. Its concentration depends on the pH of the sample.

Tables 1A-1C respectively also gave the mean values of the macronutrient metals: (Potassium (K), Sodium (Na), Calcium (Ca) and Magnesium (Mg) at the respective distances, which can be described to be generally low; but for Ca in conjunction with the bicarbonate ions that appeared to be the most abundant cation and anion in the rainwater samples. Annual mean electrical conductivity values of the rainwater samples collected from over the community of interest are generally low throughout the sampling periods (Tables 1A-1C). The annual mean concentrations of heavy metals: Lead (Pb), Vanadium (V), Nickel (Ni) and Zinc (Zn) in rainwater samples at the respective distances within the community being investigated are observed to be generally low (Tables 1A-1C) and when compared with the National Guidelines and Standards for Water Quality in Nigeria for the different heavy metals for drinking water their concentrations could be said to be within limits [15] (Table 2). The pictorial represention Olfeht fo various analyzed parameters are contained in Figures 2-6 respectively.

Discussion

The low pH values recorded (pH values within acidic range, pH less than 6.50) suggests acidic precipitation within the immediate vicinity of the natural gas crude/oil (Tables1A-1C). Acid rain is described as a generic term used for precipitation that contains an abnormally high concentration of tetraoxosulphate (VI) and trioxonitrate (V) acid, which are formed in the atmosphere when industrial gas emissions--nitrogen oxides (NO_x) and sulphu (IV) oxide (SO_2)--combine with water. It has negative impacts on the environment and human health. Acid rain is also believed to pose the biggest threat to the temperate deciduous forests. Over time, it damages tree leaves, causes trees to produce fewer and smaller seeds and reduces resistance to disease [8,11,16]. Acidified waters may leach toxic metals from watersheds and water distribution systems and the presence of these metals in drinking water (ponds, streams and rivers) can result in a number of serious human health impacts [17]. Acidic ground water has been detected as well in United States, Sweden and Norway. Eriksson hypothesized that when precipitation turns acidic; it attacks the cation- exchange capacity of the soil. When this capacity is depleted, aluminum hydroxides are attacked, and in the presence of high sulphate concentrations, the aluminum oxides are transformed into basic soluble sulphates. These sulphates eventually leach down to underlying ground water formations [18]. This phenomenon was observed in the study carried out by Edu et al. In their study, they got some sites with pH around 4.4 having elevated levels of aluminum. Within the Eket Local Government Area, it was revealed, the highest value of 714.4 μgL^{-1} of Al was found in Ikot Udofia village bole hole with a pH of 4.4, while in the Uyo Local Government Area; an Al concentration of 861.9 µg L^{-1} was recorded in Nsukara Offot village bole hole with a pH of 4.2 [18]. The variation of the mean pH values (1998-2000) of the rainwater samples collected at the different distances away from the flare site are given in Figure 2.

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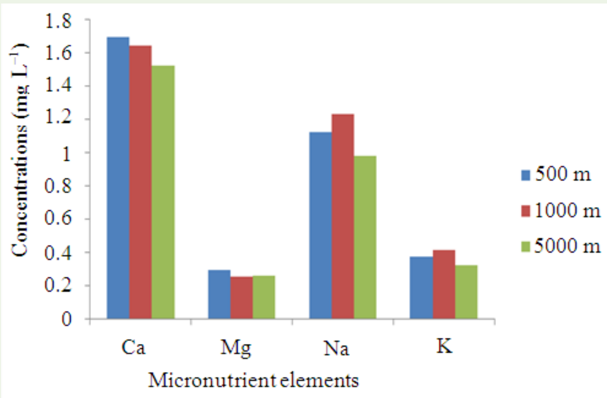

Figure 4: Mean concentrations of micronutrient elements (1998-2000) at the different distances.

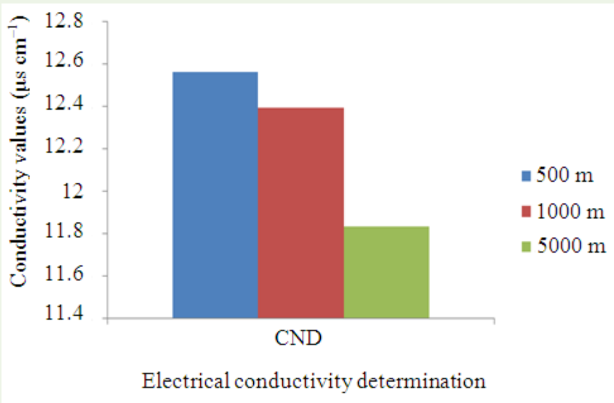

Figure 5: Mean electrical conductivity values (1998-2000) at the different distances.

The annual mean pH values of rainwater samples collected from over the community being investigated are much lower than those of the Reference Locations (Tables 1A-1C vs 3B), a factor which may not be unconnected with some organic acids released in the gas flare streams. The much higher pH mean values (pH > 6.50) recorded for the rainwater samples collected over the Reference Locations indicates little or no acidic deposition over the area and hence, the impacts of the environmental hazards associated with acid rain may not be too adverse on the area.

The results of the analysis show that the bicarbonate ions (HCO_3^-) seem to contribute most to the total acidity of the rainwater within the community, followed by chloride ions (Cl^-) while other ions: NO_2^- -N (Nitrite ion), PO_4^{3-} -P (Phosphate ion) and SO_4^{2-} -S (Sulphate ion) recorded a minimal contributions (Table 4). This observations suggest that the rainwater is very rich in calcium bicarbonate ions-($Ca(HCO_3)_2$). This finding is in strong agreement with the observations of [19,20], who in their studies reported higher concentrations for bicarbonate ions (HCO_3^-), at the flare site, relative to areas not exposed to gas flaring. Also, [21,22]; in separate studies confirmed the presence of the presence of parameters such as NO_2, CO_2, SO_2, etc. which in combination with moisture in the presence of

Table 1C: Summary of the annual mean values of physico-chemical and level of heavy metals in rainwater samples from utorogu gas plant (2000).

Parameters	Distances away from flare site (m)	Mean	± Std. Deviatio0n	Ranges
pH	500	6.14	0.49	5.65-6.9200
	1000	6.49	1.4	5.68-9.8600
	5000	6.26	0.52	5.6-6.99000
CND (µS cm^{-1})	500	10.36	2.17	6.80-14000
	1000	11.5	1.63	10.05-14.000
	5000	11.59	1.38	10.83-14.000
Ca^{2+} (mg L^{-1})	500	1.96	0.9	1.01-3.3300
	1000	1.85	0.86	0.96-3.0500
	5000	1.84	1.01	0.9-3.57000
Mg^{2+} (mg L^{-1})	500	0.26	0.12	1.11-0.4200
	1000	0.2	0.11	0.07-0.3800
	5000	0.26	0.38	0.09-1.2100
Na^+ (mg L^{-1})	500	1.008	0.36	0.58-1.6100
	1000	0.93	0.55	0.08-0.7400
	5000	0.85	0.56	0.03-1.7400
K^+ (mg L^{-1})	500	0.41	0.2	0.11-0.6900
	1000	0.4	0.2	0.10-0.7200
	5000	0.44	0.29	0.04-0.9200
HCO_3^- (mg L^{-1})	500	9.91	2.16	7.22-13.210
	1000	9.19	1.84	7.18-12.160
	5000	8.85	1.79	6.98-11.540
	500	2.86	1.02	1.39-4.2200
Cl^- (mg L^{-1})	1000	2.6	0.97	1.25-3.9800
	5000	2.49	0.95	1.20-3.8900
PO_4^{3-}(mgL^{-1})	500	0.22	0.12	0.09-0.4100
	1000	0.16	0.12	0.04-0.3800
	5000	0.1	0.085	0.02-0.2400
SO_4^{2-}(mg L^{-1})	500	0.07	0.02	0.04-0.1000
	1000	0.04	0.015	0.02-0.0700
	5000	0.034	0.016	0.01-0.0600
	500	0.002	0.001	0.001-0.004
NO_2^-(mg L^{-1})	1000	0.002	0.001	0.001-0.004
	5000	0.002	0.03	0.001-0.010
Zn^{2+} (mg L^{-1})	500	0.47	0.18	0.10-0.6600
	1000	0.45	0.14	0.27-0.6900
	5000	0.36	0.11	0.22-0.5300
Pb^{2+} (mg L^{-1})	500	0.02	0.001	0.001-0.004
	1000	0.002	0.0008	0.001-0.003
	5000	0.001	0.0005	0.001-0.002
V^{3+} mg L^{-1})	500	0.01	0.0005	0.001-0.002
	1000	0.01	0	0.001-0.001
`	5000	0	0	0.00-0.0000
Ni^{2+} (mg L^{-1})	500	0.016	0.009	0.01-0.0300
	1000	0.014	0.008	0.01-0.0.30
	5000	0.013	0.008	0.01-0.0300

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Table 2: National guidelines and standards for water quality in Nigeria [15].

Parameters	Drinking water	Livestock uses	Agricultural uses	
			All soils	Natural- Alkaline
PH	6.50 -8.50	-	-	-
K	-	-	-	-
Na	200.00 mg L^{-1}	-	-	-
Ca	-	1000.00 mg L^{-1}	-	-
Mg	-	-	-	-
Cl^-	-	-	(100-700) mgL^{-1}	-
NO_2^- -N	-	-	-	-
PO_4^{3-} -P	> 5.0 mg L^{-1}	-	-	-
SO_4^{2-} S	500 .00 mg L^{-1}	1000.00 mgL^{-1}	-	-
HCO_3^-	-	-	-	
Pb	0.05 mg L^{-1}	0.10 mgL^{-1}	0.20 mg L^{-1}	2.00 mgL^{-1}
V	0.01 mg L^{-1}	-	0.10 mg L^{-1}	1.00 mgL^{-1}
Ni	0.05 mg L^{-1}	1.00 mgL^{-1}	0.20 mg L^{-1}	2.00 mgL^{-1}
Zn	5.00mg L^{-1}	-	0.00 (solid	-
			pH<6.50)	
			5.00 (solid	
			pH>6.50)	

Table 3A: Physico-chemical properties and level of heavy metals in rainwater samples from okere area- 1 reference location, warri (annual mean values).

Parameters	Mean± Std.	Deviation	Ranges
PH	06.65	0.92	5.57- 8.4700
CND(μScm^{-1})	0.06	0.030	0.01- 0.1200
K^+ (mgL^{-1})	0.72	0.240	0.10 - 0.9500
Na^+ (mgL^{-1})	0.29	0.080	0.22- 0.4500
Ca^{2+} (mgL^{-1})	18.75	1.990	15.77- 21.380
Mg^{2+} (mgL^{-1})	18.90	2.500	13.93-21.950
Cl^-(mgL^{-1})	6.93	5.420	0.89-15.070
Zn^{2+} (mgL^{-1})	0.23	0.040	0.17- 0.2900
Pb^{2+} (mgL^{-1})	0.08	0.020	0.05-0.1000
V^{3+} (mgL^{-1})	0.06	0.020	0.03- 0.0800
Ni^{2+} (mgL^{-1})	0.04	0.012	0.02- 0.0600
NO_2^--N (mgL^{-1})	0.02	0.030	0.003-0.090
PO_4^{3-} - P ($mgL^{-1)}$)	0.003	0.002	0.001- 0.006
SO_4^{2-} - S (mgL^{-1})	4.71	2.890	1.10-10.990
HCO_3^- (mgL^{-1})	15.15	10.960	3.66-30.500

photochemical reactions produce the various acidic radicals (HCO_3^-, NO_2^-, SO_4^{2-} etc), which produce adverse effects on the environment and human health. Bicarbonate ion exists in rainwater through dissolution of carbon (IV) oxide present in the atmosphere mainly from gas flaring and other particulate carbonate in cloud droplets. Its concentration depends on the pH of the sample.

The variations of the mean concentrations (1998-2000) of bi-carbonate, chloride, phosphate, sulphate and nitrite ions of the rainwater samples at the different distances are given in Figures 3A & 3B respectively. The observed annual mean concentrations of bi-carbonate, chloride, nitrite, phosphate and sulphate ions for the rainwater samples collected over the studied community are generally low compared to those of the Reference Locations (Tables 1A-1C vs 2B) this reveals that gas flaring within this community contributes less of these acidic radicals to the environment when compared to their contributions from vehicular exhausts. The Reference Locations are observed to be under the influence of heavy vehicular traffic.

The annual mean concentrations obtained for K, Ca and Mg in the rainwater samples from the studied station are generally below those of the rainwater samples from the Reference Locations; except that of Na (Tables 1A-1C vs 2B). Also, [10], reported low concentrations of sodium, potassium, calcium and magnesium in rainwater analyses he carried out within Afiesere, an oil producing community in the Niger Delta area of Nigeria. Calcium and magnesium have been described to be essential in the biological processes of aquatic animals, especially for bone and scale formation in fish. Also, maintaining precise levels of internal salts for normal heart, muscle and nerve function is premised on the presence of environmental calcium [23]; and higher intake of magnesium is said to be associated with improved lung functions. It also helps the body to absorb calcium and potassium and prevent depression [24]. Potassium helps the cells to control what can enter or leave them while sodium allows the body to maintain the right blood chemistry and the correct amount of water in the blood [24]. The variations of the mean concentrations (1998-2000) of the different macronutrient elements in the analysed rainwater samples are presented in Figure 4.

Figure 5 gives the variations of electrical conductivity mean

Table 3B: Physico-chemical properties and level of heavy metals in rainwater samples from okere area- 2 reference location, warri (annual mean values).

Parameters	Mean± Std.	Deviation	Ranges
PH	6.80(6.73)	1.13	5.41-9.2500
CND(μScm^{-1})	0.05(0.055)	0.04	0.01- 0.1300
K^+ (mgL^{-1})	0.64(0.68)	0.15	0.43- 0.9000
Na^+ (mgL^{-1})	0.27(0.28)	0.06	0.16- 0.3700
Ca^{2+} (mgL^{-1})	18.75(18.75)	1.99	15.77- 21.380
Mg^{2+} (mgL^{-1})	18.90(18.90)	2.5	13.93- 21.950
Cl^-(mgL^{-1})	6.93(6.93)	5.42	0.89-15.070
Zn^{2+} (mgL^{-1})	0.23(0.03)	0.04	0.17- 0.2900
Pb^{2+} mgL^{-1})	0.08(0.08)	0.02	0.05- 0.1000
V^{3+} (mgL^{-1})	0.06(0.06)	0.02	0.03- 0.0800
Ni^{2+} (mgL^{-1})	0.04(0.04)	0.012	0.02- 0.0600
NO_2^--N (mgL^{-1})	0.02(0.02)	0.03	0.003-0.0300
PO_4^{3-} - P ($mgL^{-1)}$)	0.003(0.003)	0.002	0.001- 0.006
SO_4^{2-} - S (mgL^{-1})	4.71(4.71)	2.89	1.10-10.9900
HCO_3^- (mgL^{-1})	15.15(15.15)	10.56	3.66-30.5000

( ) : The mean of mean values of reference locations 1&2.

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Table 4: Contributionsof ions to total ion mass in rainwater composition (%).

Ions	Contributions of ions (%)
K^+	1.8
Na^+	7.33
Ca^{2+}	8.42
Mg^{2+}	1.31
Cl^-	29.06 (35.81)*
NO_2^--N	0.45 (0.56)*
PO_4^{3-}-P	1.19 (1.47)*
SO_4^{2-}-S	0.79 (0.97)*
HCO_3^-	49.65 (61.19)*
( )*	Contribution to total acidity

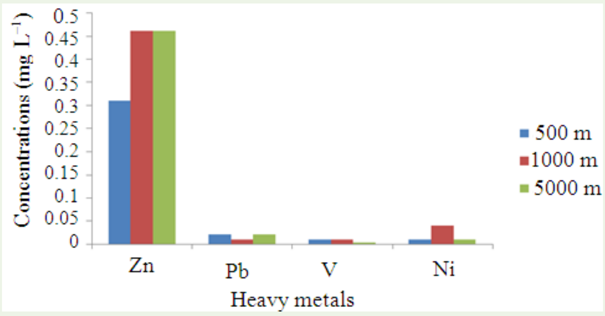

Figure 6: Mean concentrations of heavy metals (1998-2000) at the different distances.

values (1998-2000) at the respective distances. The mean electrical conductivity values of the rainwater samples collected over the studied station are well above those of the Reference Locations (Tables 1A1C vs 3B), which may be due to the presence of some dissolved organic ions from the combusted crude oil. Conductivity is often used as an indirect measure of the salt concentration in water bodies. Also, [13], observed higher electrical conductivity values of rainwater samples harvested from community with highest level of gas flaring activities relative to communities with reduced gas flaring activities.

The annual mean concentrations of the analyzed heavy metals contained in the rainwater samples collected at the different distances over Utorogu gas plant within the Utorogu oil producing community are found to be below those of the Reference Locations (Tables 1A-1C vs 3B). This perhaps, suggests a good heavy metal abatement installations at the gas processing plant; and the observed high concentrations of Pb, V and Ni in rainwater samples collected over the Reference Locations may be attributable to contributions from vehicular exhausts as the area is said to be under heavy traffic influence. The annual mean concentrations of Zn for the rainwater samples from the Reference Locations are, however, below those from the studied station. Some trace metals such as zinc and copper are important in small quantities for biological processes in plants and animals; however, at higher concentration they constitute an increasing hazard to humans through the food chain [25]. Most of the heavy metals act as enzyme inhibitor and disrupt the metabolic processes of organisms. Concern over the presence of heavy metals in an environment arises from the fact that they cannot be broken to non-toxic forms. Thus, once aquatic ecosystems are contaminated by heavy metals, they remain a potential threat for many years.

Small amounts of heavy metals (Cd, Zn, Ni, Pd, Cu etc.) are actually necessary for good health, but at higher concentrations they can cause chronic toxicity. Their toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys and other vital organs. Lead is known to account for most of the cases of pediatric heavy metal poisoning. Its target organs are the bones, brain, blood, kidneys and thyroid gland; and for iron. it is liver, cardiovascular systems and kidneys [26,27]. Figure 6 presents the variations of the heavy metal mean Concentrations (1998-2000).

Conclusion

Total conservation of the environment is unattainable if development is to take place and a compromise has to be struck between development and the maintenance of the environment. A more relevant factor is the ability of the environment to breakdown and absorb polluting substances. Thus, in the improvement of facilities and operating practices, in the oil and any industry, efforts should be made to monitor the environment so that the least possible change is done. This would amount to the plant complying with international standards in order to produce an environmentally friendly natural gas/crude oil processing operations. Also, a stop to gas flaring would amount to improvement on the environment, health and livelihoods of local communities and the relationships between International Organization Committees and local communities in the Niger Delta. The observation and findings obtained from this study are believed, would be useful for prelim nary assessments of the influence of gas flaring on atmospheric pollution and indirectly rainwater constituents within the Utorogu community.

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