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Evaluation of Effects of Gaseous Emissions from Gas Flare Sites on Air and Rain Water Quality in Afam, Oyigbo Local Government Area Rivers State

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Abstract: Study examined effect of gaseous emissions from gas flare sites on air and rainwater quality in Afam, Oyigbo LGA, and Rivers State, Nigeria. Primary data involved air and rain water quality sampling using monitoring equipment. Air quality sampling was carried out for eight hour period daily (morning;7am to 11 am) and evening (12pm to 4pm) for 3 days within a distance of 200m, 400m, 600m, 800m and 1000m away from gas flaring site. Sampled air quality parameters were CO, SO_2, NO_2, CH_4, VOCs, H_2S and $PM_{2.5}$; while weather parameters were temperature, heat index, relative humidity, wind speed direction. Rainwater samples were collected directly from rain sources during rain fall in Afam community around Afam gas flaring site. Composite sampling technique was deployed for air quality monitoring while systematic sampling methods was deployed for rainwater sampling using maximum standards for contaminated water analysis. Laboratory test for water samples were for physico-chemical and carcinogenic properties of pH, conductivity, TDS, salinity, DO, sulphate, nitrate, hydrogen carbonate, chloride, total hydrocarbon content (THC), BOD, Cu, Cr and Fe. Descriptive statistics explained the values of air and rain water quality. Hypotheses 1 and 3 were tested using ANOVA; hypothesis 2 was tested using Pearson Correlation; hypothesis 3 was tested using the one Sample T-test. Statistical analyses were performed in SPSS version 24.0. Results showed that concentration of gaseous pollutants and content of rainwater quality parameters varied among sampling distances away from gas flaring site. Heat index and relative humidity significantly correlates with CO ($r=0.579$ and 0.585 at $p=0.05$), SO_2 ($r=0.754$ and 0.478 at $p=0.05$), VOC ($r=0.566$ and 0.576 at $p=0.05$), and H_2S ($r=0.595$ and 0.536 at $p=0.05$). Mean concentration values of air quality parameters were higher than WHO standards except for mean concentration of CH_4 which showed concentration values (0.27ppm and 0.23 ppm) higher than WHO standards at 200m away from gas flare site. Rainwater quality parameters recorded mean content values within WHO acceptable limit except for Cr. Results further revealed significant effects of gaseous emissions from Afam gas flare site. Study recommends amongst others; that governments should as a matter of urgency ensure that multinational oil companies adhere to environmental standards for controlling and managing oil exploration activities leading to gas flaring in the study area.

Keywords: Evaluation, Effects, Gases Emissions, Gas Flare, Afam.

1. Introduction

Before the discovery of crude-oil in the Niger Delta Region, there was a healthy and effective micro-oil economy, such as weaving with hands, netting, making of palm wine and palm oil, constructing boats, and tapping trees (Omofonmwan & Odia, 2009). At this stage, the betterment of the agricultural sector was largely relied upon to the progress of the rural economy. Specifically, people travelled a great distance to trade in with these communities. Since crude oil was found in Oloibiri in 1956 and 1958, these communities economy as well as the environment was adversely affected. However, this intrusion in the local economy has decreased production in terms of lumbering, fishing, farming and local craft making thereby shrinking of the rural economy (World Bank, 2007, Ibaba & Olumati, 2009). The Afam communities where oil and gas are currently being explored are faced with several socio-economic and environmental problems with respect to pollution and most specifically emissions of gases which affect the total environment (Edino,et al.,2010). Environmentalists in Nigeria have long pointed to the activities of major international oil companies (IOCs) as responsible for the pollution and damage to the environment in the area where the oil was produced. The primary disadvantages of flaring being the depletion of our natural resources, including air and water (World Bank, 2011). Until the exploration of crude oil began, the regions which thither to had a healthy climate, soils and sediments, water, land and aquatic habitats, wildlife, and ecosystems, as well as the earth's crust, became devastated. More recently, however, the climate has been negatively impacted by air and water quality reductions, depletion of forest, and improvements in the landscape due to gas flaring, causing deterioration of soil, resulting in low agricultural yields and other socio-economic consequences. In a community where most residents are a growing population, and they live amidst where gas flaring occurs, it is risk to their health and to the environmental quality. According to Ogheneoh (2005), nitrogen oxide (NOx), sulphur dioxide (SOx) and carbon dioxide (CO2) combines with atmospheric water to produce acid rain. It is therefore imperative to evaluate the quality of air and rain water in this environment in Afam, Oyigbo Local Government Area, Rivers State, Nigeria.

2. Aim and Objectives of the Study

The aim of the study was to evaluate the effects of gaseous emissions from gas flaring on air and rainwater quality in Afam, Oyigbo Local Government Area Rivers State, Nigeria. The specific objectives were to:

1. Determine the status of air quality in respect to air quality parameters of CO, NO_2, SO_2, CH_4, VOC, H_2S and $PM_{2.5}$ and meteorological conditions of temperature, heat index, relative humidity, wind speed and wind direction within the gas flare site in the study area.
2. Examine the relationships between air quality parameters and meteorological parameters around gas flare sites in the study area.
3. Analyse the quality of water from selected rainwater sources around gas flare sites in the study area.
4. Compare the status of air and rainwater quality in the study area with WHO standards.

Hypotheses

1. The concentration of gaseous pollutants and weather parameters significantly differ among sampling points in the study area.
2. There is no significant relationship between the concentration of gaseous pollutants and weather parameters in the study area.
3. The physico-chemical properties of selected rainwater sources significantly differ in the study area.
4. There is no significant difference between the air and rainwater quality parameters with WHO standards.

3. Method of Study

The study deployed the correlational and experimental research design. The correlational method sought to establish relationships between variables of interest while the experimental method was a scientific approach to research, where one or more independent variables are manipulated and applied to one or more dependent variables to measure their effects on the latter (Mitchell, 2015). Correlational and experimental research design were deployed because they aided the research in showing relationship from the test samples collected from the field work exercise and also to aid in establishing relationships concerning the stated hypotheses in order to reach valid conclusions about their relationships especially between independent and dependent variables of interest in the study.

4. Nature and Sources of Data

The study made use of primary and secondary data sources. The primary data was acquired from the fieldwork while the secondary data was from relevant journals, books and magazines that relates to the study. The study area was geo-rectified in relation to the sampling stations established for the purpose of measuring air and water quality using a hand held global positioning system (GPS – Garmin GPS Map 78sc). The air quality parameters which were measured include; CO, NO_2, SO_2, CH_4, H_2S, VOC and $PM_{2.5}$ while the weather parameters were; wind speed and direction, temperature, and relative humidity (RH). The air quality parameters were measured using air quality equipments while the weather parameters were measured using weather tracker (Singh et al.,2018). The water quality was collected in triplicates from rainwater samples into pre-rinsed 1 litre plastic bottles for physico-chemical analysis of the rainwater at household level. Standards of air quality and water quality by World Health Organization (WHO) in relation to guidelines were followed during the process for comparison purposes.

5. Experimental Design

Sampling design adopted for the study was composite sampling techniques. This design emphasises taking records at a point in different times. The Afam gas flaring site was the reference point from which air quality and weather parameters were measured. Air quality parameters and weather parameters were collected with respect to varying distances at established sampled stations in relation to some selected residential apartments from the gas flaring site (that is, air quality and rainwater quality were collected at same point in the study area). The water samples for rain water quality were collected at household level by selecting six (6) residential houses at every distance of 200m. In other words, some selected houses in Afam located close to the gas flaring site were used as points of measurements of air quality as well as points where rainwater samples were collected. The field sampling methods involve randomly selecting six residential houses each within a distance of 200m starting from the first identified house to a distance of 1000m. Thus, rainwater samples were collected during rainfall season. This means that both air quality and rainwater quality were obtained during the rainy seasons in the study area. In other words, six samples of rainwater were collected from six selected residential apartments at every distance of 200m in Afam community which was surrounding the gas flaring site. A total of 30 water samples (6 each at distance of 200m) were collected into plastic water bottles within a distance of 1000m (200m, 400m, 600m, 800m, and 1000m) for laboratory analysis (Kucera & Fitz(1995).

6. Air Quality Sampling and Testing

A series of hand held air quality monitoring equipment were used for monitoring air quality in the study area. Sampling in each case was for a period of eight hours per day with readings of all the parameters determined for four (4) hours in the morning and evening periods for 3 days. That is, eight hours monitoring period was carried out in order to take readings from morning periods (7am to 11 am) and evening periods (2 pm to 6 pm) over the three (3) days monitoring period. The air quality measurements include establishing one station for air quality measurements for a cluster of six residential apartments at every distance of 200m during morning and evening sessions. Readings were taken at each distance of 200m, 400m, 600m, 800m and 1000m. This makes a total of 5 established stations for air quality monitoring measured at different time periods (7am to 11am for morning and 2pm to 6pm for evening periods). Measurements were rendered by keeping the numerous air quality control sensors at an estimated two-meter altitude in the prevailing wind and readings were obtained. Various air quality and meteorological parameters were tracked in the field such as Carbon monoxide (CO), nitrogen dioxide (NO2), sulphur dioxide (SO) and hydrogen sulphide (ppm), as well as organic molecules (VOCs) and PM) compounds (CH4. Other parameters were PH, temperature (^oC), and wind speed as well as a monitoring station at 10,000m away from residential apartments for comparisons. Measurements were taken both in the morning and evening hours. (Ehidge,et al.,2009).

7. Rainwater Sampling Methods and Laboratory Analysis

Rainwater samples were collected in triplicates from rainwater sources directly obtained at the very period of rain fall around selected residential houses using a systematic sampling method. The rainwater samples were collected in pre-rinsed 1litre plastic bottles (screw capped plastic containers) directly from the sources for physico-chemical analysis of the water; and in specialized 50cl glass bottles treated with concentrated hydrochloric acid for hydrocarbon analysis and stored in ice coolers below 4ºC after which they were transferred to the laboratory for analysis using maximum standards for contaminated water analysis (APHA, 2009). During the monitoring periods, six residential houses were grouped together at each established point for air quality measurement at a distance of 200m. Rainwater samples were also obtained at the control station which was located at a distance of 10,000m away from the residential apartments during the morning and evening periods to compare with the data collected on rainwater at the other stations. The physio-chemical parameters like pH, electrical conductivity, total dissolved solids (TDS), salinity, dissolved oxygen (DO), chloride (Cl), sulphate, nitrate, hydrogen carbonate, total hydrocarbon content (THC), BOD, Copper (Cu), Chromium (Cr) and Iron (Fe) were all tested from the rainwater samples collected (Khanyan et al.,2014).

Table 1.1: Details of Rainwater Quality and Air Quality Measurements

S/N	Air Quality Stations per distance of 200m (m)	Rainwater samples at every distance of 200m (6 house in each 200m distance)	Established Stations for air quality	Total no. of rainwater samples collected
1	200	1, 2, 3, 4, 5, 6	1	6
2	400	7, 8, 9, 10, 11, 12	2	6
3	600	13, 14, 15, 16, 17, 18	3	6
4	800	19, 20, 21, 22, 23, 24,	4	6
5	1000	25, 26, 27, 28, 29, 30	5	6
	1000m	**30 houses (apartments)**	**5 stations**	**30**
	Control (1000m)			

(Source: Researcher’s Computation 2024)

8. Results

Morning Periods: The information for the status of air quality around gas flaring site morning periods was displayed on table 1.1. The meteorological conditions around gas flaring site indicated that the values of temperature (^{0}C) ranged between 26.6 ^{0}C to 28.1 ^{0}C during the morning periods. The heat index also showed ranged values between 33.9 ^{0}C to 37.2 ^{0}C during the morning period. The temperature condition and heat index was generally stable during the morning periods of measurements in the study area. The percentage composition of RH (%) fluctuated between 72.5% and 90.3% with varying wind speed of 0.8 m/s to 2.4 m/s. Carbon monoxide (CO) concentration measurements were slightly higher in around 400m distance away from gas flaring site with a mean value of 10.7 ppm. NO_2 (ppm) also showed ranged concentration with highest mean values of 1.8 ppm, 1.7 ppm, and 1.5 ppm in sampling distance of 400m for the three days. The concentration of SO_2 ppm ranged between 0.1 ppm to 1.4 ppm at stations 800m and 1000m respectively. The general concentration of methane (CH_4) ranged between 0.0 ppm and 0.27 ppm from the lowest to the highest. The concentration of VOC (ppm) showed minimum concentration values of 0.0 ppm and maximum concentration values of 6.7 ppm. H_2S (ppm) concentration values also ranged between 0 ppm to 1.7 ppm in the study area. Particulate matter ($PM_{2.5}$) was made up of dust, smoke and soot and the sources are usually wood burning, diesel and industrial plants. The commercial activities around the gas flaring site may have contributed to the relatively high concentration values. These activities may have influenced the concentration of particles in air around sampled stations. However, the air quality values recorded for the control stations in terms of temperature, heat index, RH and wind speed showed slight variations, but zero pollution levels for CO, NO_2, SO_2 CH_4, and VOC; while the concentration of particulate matter was lower (Osuji & Awviri, 2005).

Table: 1.1: Status of Air Quality and Weather Parameters around Gas Flaring Site (Morning Period)

Air quality Parameters	Day 1 Distance (m)					Day 2 Distance (m)					Day 3 Distance (m)					*Control
	200	400	600	800	1000	200	400	600	800	1000	200	400	600	800	1000	
Temp (^{o}C)	27.2	27.6	26.6	27.9	27.5	26.9	27.2	26.8	28.1	27.5	26.9	27.4	26.9	28.1	27.3	27.8
Heat Ind (^{o}C)	33.9	34.6	34.8	37.2	35.3	35.1	34.4	34.2	36.9	35.9	34.8	34.3	35.2	36.9	36.3	36.5
RH (%)	90.3	80.4	78.1	86.6	77.5	84.5	82.7	79.5	73.7	74.2	83.7	82.7	80.1	73.6	72.5	78.2
Windspeed	2.4	1.3	1.7	0.8	1.4	2.3	1.9	1.9	1.1	0.9	2.2	2.1	2.1	1	1.1	1.8
CO (ppm)	8.7	10.3	1.3	0.7	2	13	10.7	2	0.7	0.4	10.3	10.7	2	0.8	0.4	0
NO_2 (ppm)	1.2	1.8	1	1.3	1.1	1.3	1.5	1.3	1	1.4	1.3	1.7	1.5	1.1	0.9	0
SO_2 (ppm)	0.74	0.9	0.7	0.1	0.2	0.6	0.9	0.7	0.3	0.3	0.6	1.4	0.7	0.2	0.2	0
CH_4 (ppm)	0.27	0.23	0.1	0.1	0	0.3	0.2	0.1	0.06	0	0.2	0.23	0.2	0	0	0
VOC (ppm)	6.7	2.7	0.4	0	0	5.3	1.3	0.3	0	0	5.7	1.3	0.3	0	0	0
H_2S (ppm)	1.7	0.6	0	0	0	1.3	0.5	0	0	0	1.7	0.3	0	0	0	0
$PM_{2.5}$ (ug/m^3)	231.7	264.7	192.7	180	161.7	184.3	240	154	179	173	173.3	239	180.7	181.3	181.3	84

Source: Researcher's Computation 2024,
Wind direction = South west (SW); * Control station at 10,000m away
Coordinates = 200m (4.850368 N; 7.252722 E); 400m (4.847974 N; 7.255003 E); 600m (4.757411; 7.160343 E); 800m (4.844587 N; 7.259022 E); 1000m (4.844592 N; 7.259044 E)

Evening Periods: The information for the status of air quality around gas flaring site evening periods is displayed on table 1.2. The meteorological conditions around gas flaring site indicated that the values of temperature (^{0}C) ranged between 26.1 ^{0}C to 28 ^{0}C during the evening periods. The heat index also showed ranged values between 33.2 ^{0}C to 36.2 ^{0}C during the evening period. The temperature condition and heat index was also generally stable during the evening periods of measurements the same as the morning periods in the study area. The percentage composition of RH (%) fluctuated between 72.2% and 85.7% with varying wind speed of between 0.9 m/s to 3.2 m/s. Carbon monoxide (CO) concentration measurements were slightly higher in distance around 400m away from gas flaring site and this was measured on the third day of the exercise. The concentration of NO_2 (ppm) also showed high concentration values with highest mean values of 2.1 ppm, 1.9 ppm, and 1.5 ppm in locations 400m (day 3), 400m (day 2) and 400m (day 1) and lowest concentration values in 0.8 ppm in location 600m (day 2) in the study area. The concentration of SO_2 ppm recorded minimum values of

0.17 ppm and maximum values of 0.9 ppm in the study area. The concentration of methane (CH_4) also showed similar values in the morning periods with the minimum and maximum values ranging between 0.0 ppm and 0.27 ppm. The concentration of VOC (ppm) showed minimum concentration values of 0.0 ppm and maximum concentration values of 5.7 ppm. H_2S (ppm) concentration values also recorded minimum and maximum values of 0 ppm and 3 ppm during the field measurements. Particulate matter ($PM_{2.5}$) was made up of dust, smoke and soot and the sources are usually wood burning, diesel and industrial plants. Commercial activities around the gas flaring site may have contributed to the relatively high concentration values of $PM_{2.5}$. These activities may have influenced the concentration of particles in air around sampled stations. Minimum concentration value of 162.7 ug/m^3 and maximum concentration value of 268.3 ug/m^3 were recorded for the lowest and highest concentration of particulate matter ($PM_{2.5}$) in the study area. However, the air quality values recorded for the control stations in terms of temperature, heat index, RH and wind speed showed slight variations, but zero pollution levels for CO, NO_2, SO_2 CH_4, and VOC; while the concentration of particulate matter was lower in the control station. (Odiong, et al.,2010).

Table:1.2: Status of Air Quality and Weather Parameters around Gas Flaring Site (Evening Period)

Air quality Parameters	Day 1 Distance (m)					Day 2 Distance (m)					Day 3 Distance (m)					*Control
	200	400	600	800	1000	200	400	600	800	1000	200	400	600	800	1000	
Temp (^oC)	27.5	27.6	26.9	27.7	27.7	27.2	27.6	27.6	28	27.2	27.3	27.5	27.1	27.7	26.1	26.6
Heat Ind (^oC)	33.2	34.7	34.3	36.2	34.6	34.3	34.1	35.1	36.5	35.6	34.4	34.7	34.6	36.2	35.1	30.2
RH (%)	85.3	85.7	79.9	83.8	82	79.9	79.1	77.3	72.2	72.8	78.9	79.1	77.5	73.8	72.9	86.2
Windspeed	2.1	1.6	2.6	0.9	1.6	1.8	1.7	3	1.4	2.2	1.8	1.7	3.2	1.4	3.2	2.4
CO (ppm)	6	7.2	1.5	2.2	2.3	7.3	8.7	1.7	1.6	1.2	8.7	9.3	2.1	1.1	0.9	0
NO_2 (ppm)	1.3	1.5	0.9	1.3	1.4	1.3	1.9	0.8	1.1	1.1	1.4	2.1	0.9	1.1	1.1	0
SO_2 (ppm)	0.9	0.9	0.6	0.2	0.17	0.7	0.7	0.7	0.2	0.13	0.8	0.8	0.7	0.2	0.3	0
CH_4 (ppm)	0.23	0.13	0.1	0.03	0.0	0.2	0.27	0.2	0.0	0.3	0.3	0.13	0.01	0.0	0.0	0
VOC (ppm)	5.7	3.3	0.4	0.0	0.0	7	2	0.3	0.0	0.0	6	1.7	0.2	0.0	0.0	0
H_2S (ppm)	3	0.9	0.0	0.0	0.0	1.7	1	0.0	0.0	0.0	1.3	1.8	0.0	0.0	0.0	0
$PM_{2.5}$ (ug/m^3)	185.7	268.3	195	177.3	188	183	222.7	162.7	187.3	174.7	184.7	223	144.7	186	184	76

Source: Researcher's Computation 2024
Wind direction = South west (SW); *Control station
Coordinates = 200m (4.850368 N; 7.252722 E); 400m (4.847974 N; 7.255003 E); 600m (4.757411; 7.160343 E); 800m (4.844587 N; 7.259022 E); 1000m (4.844592 N; 7.259044 E)

9. Correlation Matrix between Air Quality Parameters and Weather Parameters

The correlation matrix between air quality parameters and weather parameters is displayed on table 1.3. The results revealed that CO (ppm) has a relatively high relationship with heat index (^0C) (r=0.579;p=0.05) and RH (%) (r=0.585;p=0.05). This shows that heat index (^0C) and RH (%) can explain 33.5% and 34.2% concentration of CO (ppm) in the atmosphere in the study area. The correlation matrix between NO_2 and weather parameters indicate a relatively low relationship with heat index (r=0.342;p=0.05), RH (r=0.359;p=0.05) and wind speed (r=0.228;p=0.05). Thus, 11.7%, 12.9% and 5.2% concentration of NO_2 can be explained by these weather parameters in the study area. The relationship between SO_2 (ppm) and weather parameters revealed that a relatively high relationship exist between SO_2 (ppm) and heat index (r=0.754;p=0.05); and a relatively low relationship with RH (r=0.0.478;p=0.05) and wind speed (r=0.398;p=0.05). Therefore, heat index can explain 56.9% concentration of SO_2 (ppm) in the study area. The relationship between CH_4 (ppm) and weather parameters showed that temperature has a relatively low relationship with CH_4 (ppm) (r=0.402;p=0.05); but slightly higher with heat index (r=0.474;p=0.05); RH (r=0.294;p=0.05) and wind speed (r=0.456;p=0.05). The relationship between VOC (ppm) and weather parameters recorded relatively high relationship with heat index (r=0.566;p=0.05) and RH (r=0.576;p=0.05); but a very low relationship with temperature (r=0.167;p=0.05) and wind speed (r=0.202;p=0.05). The correlation coefficient r between H_2S (ppm) and weather parameters showed that H_2S (ppm) has a relatively high relationship with heat index (r=0.595;p=0.05) and RH (r=0.536;p=0.05); but a low relationship with wind speed (m/s). Similarly, the distribution also showed that the correlation matrix between particulate matter and weather parameters showed relatively low relationship with heat index (r=0.323;p=0.05) and RH (%) (r=0.404;p=0.05) and very low relationship with temperature (r=0.124;p=0.05) and wind speed (r=0.119;p=0.05) in the study area.

Table 1. 3. Correlation Matrix between Air Quality Parameters and Weather Parameters

Air Quality Parameters	Correlation Coefficient values	**Meteorological Parameters** Temp (^{0}C)	Heat Index (^{0}C)	RH (%)	Windspeed (m/s)
CO (ppm)	r	0.115	0.579	0.585	0.174
	r^2	0.013	0.335	0.342	0.030
	% estimation	1.32	33.5	34.2	3.0
NO_2 (ppm)	r	0.120	0.342	0.359	0.228
	r^2	0.014	0.117	0.129	0.052
	% estimation	1.4	11.7	12.9	5.2
SO_2 (ppm)	r	0.261	0.754	0.478	0.398
	r^2	0.068	0.569	0.228	0.158
	% estimation	6.8	56.9	22.8	15.8
CH_4 (ppm)	r	0.402	0.474	0.294	0.456
	r^2	0.162	0.225	0.086	0.208
	% estimation	16.2	22.5	8.6	20.8
VOC (ppm)	r	0.167	0.566	0.576	0.202
	r^2	0.028	0.320	0.332	0.041
	% estimation	2.8	32.0	33.2	4.1
H_2S (ppm)	r	0.066	0.595	0.536	0.161
	r^2	0.004	0.354	0.287	0.026
	% estimation	0.4	35.4	28.7	2.6
$PM_{2.5}$ (ug/m^3)	r	0.124	0.323	0.404	0.119
	r^2	0.015	0.104	0.163	0.014
	% estimation	1.5	10.4	16.3	1.4

Source: Researcher's Computation, 2024

10.Rainwater Quality of Selected Rainwater Sources around Gas Flaring Site

The distribution of the physico-chemical and carcinogenic parameters of selected rainwater sources for rainwater quality test was examined around the gas flaring site and the results is displayed on table 1.4. It was revealed that pH values of rainwater revealed a minimum value of 5.40 and a maximum value of 7.40 with a mean value of 6.44. The pH describes the acidic or basic character of a solution. The pH of natural water typically falls between 6 and 9. Thus, a pH level as measured is slightly acidic because water with a pH of less than 7 is considered acidic. The conductivity level in water showed range values between 4.00 (us/cm) and 8.10 (us/cm) with a mean value of 6.21 (us/cm). Conductivity in water shows the water's capacity to allow electrical flow. Conductivity is linked to TDS; which represents the amounts of dissolved salts and ions present in water. The concentration of salinity (mg/l) in water showed range values between 0.00 mg/l and 0.60 mg/l. Salinity is the level of saltiness or dissolved inorganic salt content in water. TDS (mg/l) is a composite measure of total amount of dissolved matter in water. The level of TDS (mg/l) in sampled water showed range values between 2.00 mg/l and 15.00 mg/l with a mean value of 8.07 mg/l. The amount of dissolved oxygen (DO) mg/l revealed minimum values of 2.80 mg/l and maximum values of 6.00 mg/l with a mean value of 4.59 mg/l. DO (mg/l) refer to the level of free non-compound oxygen in water. Healthy drinking water should have DO concentration of above 6.5 to 8.5 mg/l. The concentration of sulphate (mg/l) revealed minimum values of 1.01 mg/l and maximum concentration values of 2.60 mg/l with a mean concentration value of 1.41 mg/l. The concentration of nitrate (mg/l) also showed range values of 0.20 to 1.40 mg/l in the study area. The mean value of nitrate mg/l was 0.40 mg/l. Hydrogen bicarbonate (mg/l) in water usually describes the bicarbonate salts in water and a water sample with pH above 7.5 is usually associated with high bicarbonate. Thus, mean concentration value of 0.02 mg/l from minimum and maximum values of 0.01 mg/l and 0.04 mg/l show a lesser concentration of bicarbonate in sampled rainwater in the study area. Chloride (Cl) (mg/l) recorded range values of 12.02 mg/l and 24.40 mg/l with a mean concentration value of 18.40 mg/l. Cl increases the electrical conductivity of water and thus increases its corrosivity. It reacts with metal ions to form soluble salts, which means that more Cl in water will mean more metal concentration in water. THC (mg/l) recorded minimum and maximum values of 0.0 mg/l; thus, zero concentration was detected. BOD (mg/l) recorded range values of 0.01 mg/l to 0.05 mg/l, with a mean value of 0.03 mg/l. Copper (Cu) (mg/l) showed lowest value of 0.01 to highest value of 0.07 mg/l and a mean concentration of 0.04 mg/l. Chromium (Cr) (mg/l) had zero minimum concentration value and 2.75 mg/l maximum concentration value. The concentration of Fe (mg/l) in sampled rainwater recorded minimum concentration value of 0.05 mg/l and maximum concentration value of 0.53 mg/l and a mean concentration value of 0.20 mg/l. The concentration limit for Fe (mg/l) in water is 0.3 mg/l. Thus, excessive amounts of Fe (mg/l) in drinking water can cause harm (Omofonma & Odia, 2009).

Table 1.4: Physico-chemical & Carcinogenic Parameters of selected Rainwater Sources around Gas Flaring Site

Rainwater Parameters	N	Minimum	Maximum	Mean±SD
pH	30	5.40	7.40	6.4433±0.41828
Cond (us/cm)	30	4.00	8.10	6.2133±1.15959
Salinity (mg/l)	30	0.00	0.60	0.2600±0.20778
TDS (mg/l)	30	2.00	15.00	8.0667±3.72506
DO (mg/l)	30	2.80	6.00	4.5867±0.86173
Sulphate (mg/l)	30	1.01	2.60	1.4117±0.47463
Nitrate (mg/l)	30	0.20	1.40	0.3987±0.32400
Hyd_Carb (mg/l)	30	0.01	0.04	0.0223±0.01135
Cl (mg/l)	30	12.02	24.40	18.4007±3.04954
THC (mg/l)	30	0.00	0.00	0.0000±0.00000
BOD (mg/l)	30	0.01	0.05	0.0290±0.01296
Cu (mg/l)	30	0.01	0.07	0.0373±0.02067
Cr (mg/l)	30	0.00	2.75	0.8083±0.80907
Fe (mg/l)	30	0.05	0.53	0.1990±0.11789

N= No. of Rainwater samples; SD= Standard Deviation

11. Comparison of Air Quality Parameters & Rainwater Quality Parameters with WHO Standards Mean Concentration Values of Air Quality (Morning & Evening) Parameters with WHO Standards

The information displayed on table 1.5 on the comparison between air quality parameters and WHO standards revealed that all sampled gaseous pollutants for air quality parameters (CO, NO_2, SO_2, VOC, H_2S and $PM_{2.5}$) showed higher mean values when compared to WHO standards and permissible limits. Similarly, the mean value of temperature (^{0}C) also showed slightly higher values when compared with WHO standards. However, the concentrations of CH_4 were within the WHO permissible limits. These indications have several implications on health and well being of the people living close to the gas flaring site in the study area.

Table 1. 5: Comparison of Air Quality Parameters with WHO Standards

Air Quality Parameters	Mean concentration values	WHO* Standards	Remark
Temp (^{o}C)	27.4	20-27	Slightly Higher
Heat Ind (^{o}C)	35.1	NA	-
RH (%)	79.3	NA	-
Windspeed	1.8	NA	-
CO (ppm)	4.5	0.05	Higher
NO_2 (ppm)	1.3	0.05	Higher
SO_2 (ppm)	0.6	0.08	Higher
CH_4 (ppm)	0.13	0.22	Within Limit
VOC (ppm)	1.7	0.24	Higher

H_2S (ppm)	0.6	0.08	Higher
$PM_{2.5}$ (ug/m^3)	192.8	25	Higher

*WHO (2010) Guidelines on Air Quality

12.Mean Concentration Values of Rainwater Quality Parameters with WHO Standards

The distribution on table 1.6 revealed that the concentration of salinity (mg/l) was found within the WHO limit. For TDS (mg/l) an excellent drinking water has TDS less than 300 mg/l; good, between 300 and 600 mg/l; fair, between 600 and 900 mg/l; poor, between 900 and 1200 mg/l; and unacceptable, greater than 1200 mg/l. However, no effect has been detected from drinking water with low TDS (Water Quality Association (WQA), 2019). The level of dissolved oxygen (DO) (mg/l) was found to be within the limit. However, sulphate (mg/l) and nitrate (mg/l) showed lower mean values when compared to the WHO limits. Conversely, natural processes can cause low levels of nitrate in drinking water, usually less than 3 mg/l; high levels of nitrate in water can be a result of runoff or leakage from fertilized soil, waste water, landfills, septic tank system or urban drainage. In this case, the sampled rainwater sources have no connection with the above listed sources of high nitrate content in water. Thus, the low levels of sulphate and nitrate means this were naturally levels in water. According to United States Environmental Protection Agency (USEPA) (1995) naturally occurring levels of nitrates do not exceed 4-9 mg/l for nitrate and 0.3 mg/l for nitrite; while that of sulphate should not be higher than 500 mg/l. Water with high hydrogen bicarbonate levels are usually associated with pH levels above 7.5, however, since the pH levels of the sampled rainwater sources were not higher than 6.5, it thus means that the content of bicarbonate is still within limit especially when one considers the fact that no WHO standards were applicable for this rainwater parameter. Chloride content was found to be within limit, while there was no THC content in sampled rainwater because zero values were recorded. The BOD mg/l content shows low content when compared with WHO standard, but it is still within limit, and this indicate natural content levels because the greater the BOD the more the oxygen in water rapidly depletes. The content of Cu (mg/l) and Fe (mg/l) are within the WHO limit. Exposure to high Cu (mg/l) and Fe (mg/l) can be harmful to health. The slight higher content of Cr (mg/l) when compared with WHO standard may have been influenced by the gas flaring site.

Table 1. 6: Comparison of Rainwater Quality Parameters with WHO Standards

Rainwater Quality Parameters	Mean	WHO*	Remark
pH	6.4	6.5-8.5	Within limit
Conductivity (us/cm)	6.2	NA	-
Salinity (mg/l)	0.26	0.5-1	Within limit
TDS (mg/l)	8.1	500	Low
DO (mg/l)	4.6	7.5	Within limit
Sulphate (mg/l)	1.4	100	Low
Nitrate (mg/l)	0.40	50	Low
Hydrogen Carb. (mg/l)	0.03	NA	-
Cl (mg/l)	18.4	200	Within limit
THC (mg/l)	0.00	0.07-1	Within limit
BOD (mg/l)	0.030	10	Low
Cu (mg/l)	0.040	0.2-1.0	Within limit
Cr (mg/l)	0.81	0.1	Higher
Fe (mg/l)	0.20	0.3	Within limit

*WHO (2005); NA = Not Applicable

Hypothesis 1:

H_0: The concentration of gaseous pollutants and weather parameters do not differ significantly among sampled points in the study area.

The result of the One-way ANOVA test of significance among sampled air quality parameters is presented on table 1.7. It was revealed that the F-ratio of 7.010, 23.254, 4.385, 5.627, 62.298, 11.864, 38.789, 9.666, 186.803, 27.885 and 18.381 for temperature, heat index, relative humidity, windspeed, carbon monoxide, nitrous oxide, sulphur dioxide, methane, volatile organic carbon, hydrogen sulphide, and particulate matter respectively were 0.001, 0.00, 0.008, 0.002, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, and 0.00 at p=0.05 (95% probability value). Thus, since these significance levels were all lesser than the p-value of 0.05 we therefore, reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1) for all the air quality parameters. This means that the concentration of gaseous pollutants and weather parameters significantly differ among sampled points in the study area.

Table 1. 7: One-way ANOVA Computed for Hypothesis 1 Test of Differences among Parameters

Air quality Parameters		Sum of Squares	Df	Mean Square	F-ratio	Significance at p≤0.05
Temp	Between Groups	3.148	4	0.787	7.010	0.001
	Within Groups	2.807	25	0.112		
	Total	5.955	29			
Heat_index	Between Groups	22.585	4	5.646	23.254	0.000
	Within Groups	6.070	25	0.243		
	Total	28.655	29			
RH	Between Groups	273.382	4	68.346	4.385	0.008
	Within Groups	389.612	25	15.584		
	Total	662.994	29			
WS	Between Groups	5.825	4	1.456	5.627	0.002
	Within Groups	6.470	25	0.259		
	Total	12.295	29			
CO	Between Groups	446.649	4	111.662	62.298	0.000
	Within Groups	44.810	25	1.792		
	Total	491.459	29			
NO_2	Between Groups	1.778	4	0.444	11.864	0.000
	Within Groups	.937	25	0.037		
	Total	2.715	29			
SO_2	Between Groups	2.570	4	0.643	38.789	0.000
	Within Groups	.414	25	0.017		
	Total	2.984	29			
CH_4	Between Groups	.212	4	0.053	9.666	0.000
	Within Groups	.137	25	0.005		
	Total	.348	29			
VOC	Between Groups	161.298	4	40.324	186.803	0.000
	Within Groups	5.397	25	0.216		
	Total	166.695	29			
H_2S	Between Groups	15.095	4	3.774	27.885	0.000
	Within Groups	3.383	25	0.135		
	Total	18.479	29			
$PM_{2.5}$	Between Groups	20011.039	4	5002.760	18.381	0.000
	Within Groups	6804.100	25	272.164		
	Total	26815.139	29			

Source: Researcher's Computation, 2024.

Hypothesis 2:

H_0: There is no significant relationship between the concentration of gaseous pollutants and weather parameters in the study area.

The result presented on table 1.8 is on the relationship between gaseous pollutants and weather parameters in the study area. Pearson Correlation Analysis was employed for the test of hypothesis 2. It was revealed that temperature has a significant relationship with CH_4 (r=0.402; p=0.05). RH has a significant relationship with all sampled gaseous pollutants (CO, NO_2, SO_2, CH_4, VOC, H_2S and $PM_{2.5}$ at p=0.05. Wind speed has a significant relationship with SO_2 and CH_4 at p=0.05. Thus, the relationship between temperature and CO, NO_2, $SO_{2,}$ VOC, H_2S and $PM_{2.5}$ was not significant and the null hypothesis (H_0) was accepted for this relationship except for CH_4. However, the null hypothesis was rejected for the relationship between RH and gaseous pollutant while the alternative hypothesis (H_1) was accepted. The relationship between windspeed and gaseous pollutants revealed that H_o was accepted for CO, NO_2, VOC, H_2S and $PM_{2.5}$; while the H_0 was rejected for gaseous pollutants SO_2 and CH_4 and accepted the alternative hypothesis (H_1) in the study area. Therefore, there is no significant relationship between the concentration of gaseous pollutants (CO, NO_2, SO_2, VOC, H_2S and $PM_{2.5}$) and weather parameter (temperature) in the study area. There is no significant relationship between the concentration of gaseous pollutants (CO, NO_2, VOC, H_2S and $PM_{2.5}$) and weather parameter (windspeed) in the study area. However, there is a significant relationship between the concentration of gaseous pollutants (CO, NO_2, SO_2, CH_4, VOC, H_2S and $PM_{2.5}$) and weather parameters (relative humidity (RH)) in the study area.

Table 1.8: Pearson Correlation Analysis for Hypothesis 2

Gaseous pollutants	Weather Parameters								
	Temperature			Relative Humidity			Windspeed		
	r	r^2	p-value (0.05)	r	r^2	p-value (0.05)	r	r^2	p-value (0.05)
CO	0.115	0.013	0.546	0.585*	0.342	0.001	0.174	0.030	0.358
NO_2	0.120	0.014	0.529	0.359*	0.129	0.05	0.228	0.052	0.227
SO_2	0.261	0.068	0.163	0.478*	0.228	0.008	0.398*	0.158	0.029
CH_4	0.402*	0.162	0.028	0.294*	0.086	0.041	0.456*	0.208	0.026
VOC	0.167	0.028	0.379	0.576*	0.332	0.001	0.202	0.041	0.283
H_2S	0.066	0.004	0.729	0.536*	0.287	0.002	0.161	0.026	0.397
$PM_{2.5}$	0.124	0.015	0.513	0.404*	0.163	0.027	0.119	0.014	0.531

Source: Researcher's Computation, 2024; *Correlation is significant at p=0.05; r=Correlation coefficient; p-value (95% probability)

Hypothesis 3:

H_0: The physico-chemical and carcinogenic properties of selected rainwater sources do not significantly differ in the study area.

The stated hypothesis 3 was tested using the One-way ANOVA and the result is presented on table 1.9. The result revealed that the F ratio of 0.555 (pH), 2.106 (Conductivity), 0.755 (sulphate), 0.807 (nitrate), 1.056 (Hyd. Carb), 0.362 (Cl), 1.385 (BOD), 0.748 (Cu), 0.790 (Cr) and 0.897 (Fe) were 0.817, 0.079, 0.657, 0.615, 0.434, 0.940, 0.259, 0.663, 0.629 and 0.546 respectively. Thus, the null hypothesis (H_0) was accepted for these rainwater quality parameters since their level of significance was higher than the p-value of 0.05 (95% probability). On the other hand, the null hypothesis (H_0) was rejected for these rainwater quality parameters (salinity, TDS, and DO) because their significance level was lower than the p-value of 0.05. Therefore, the alternative hypothesis (H_1) was accepted. This means that the physico-chemical and carcinogenic properties (pH, Conductivity, sulphate, nitrate, Hyd. Carb, Cl, BOD, Cu, Cr and Fe) of selected rainwater sources do not significantly differ in the study area. However, on the other hand, the physico-chemical properties (salinity, TDS and DO) of selected rainwater sources significantly differ in the study area.

Table 1.9: One-way ANOVA Computed for Hypothesis 3

		Sum of Squares	df	Mean Square	F ratio	p-value at 0.05
pH	Between Groups	1.014	9	0.113	0.555	0.817
	Within Groups	4.060	20	.203		
	Total	5.074	29			
Cond.	Between Groups	18.975	9	2.108	2.106	0.079
	Within Groups	20.020	20	1.001		
	Total	38.995	29			
Salinity	Between Groups	.712	9	0.079	2.930	0.022*
	Within Groups	.540	20	0.027		
	Total	1.252	29			
TDS	Between Groups	237.593	9	26.399	3.204	0.014*
	Within Groups	164.813	20	8.241		
	Total	402.407	29			
DO	Between Groups	12.681	9	1.409	3.183	0.015*
	Within Groups	8.853	20	0.443		
	Total	21.535	29			

Sulphate	Between Groups	1.657	9	0.184	0.755	0.657
	Within Groups	4.876	20	0.244		
	Total	6.533	29			
Nitrate	Between Groups	.811	9	0.090	0.807	0.615
	Within Groups	2.233	20	0.112		
	Total	3.044	29			
Hyd_Carb	Between Groups	.001	9	0.000	1.056	0.434
	Within Groups	.003	20	0.000		
	Total	.004	29			
Cl	Between Groups	37.817	9	4.202	0.362	0.940
	Within Groups	231.874	20	11.594		
	Total	269.691	29			
BOD	Between Groups	.002	9	0.000	1.385	0.259
	Within Groups	.003	20	0.000		
	Total	.005	29			
Cu	Between Groups	.003	9	0.000	0.748	0.663
	Within Groups	.009	20	0.000		
	Total	.012	29			
Cr	Between Groups	4.979	9	0.553	0.790	0.629
	Within Groups	14.004	20	0.700		
	Total	18.983	29			
Fe	Between Groups	.116	9	0.013	0.897	0.546
	Within Groups	.287	20	0.014		
	Total	.403	29			

Source: Researcher's Computation, 2024
*THC was not computed because of 0 mean values

Hypothesis 4:

H_0: There is no significant difference between the status of air quality and rainwater quality parameters with WHO standards.

Table 1.10 presents the results computed for the stated hypothesis 4 using the One Sample T-test. The distribution showed that the level of significance of 0.000, 0.000, 0.000, 0.000, 0.000, 0.001, 0.008, 0.000, 0.000, 0.000, 0.000, 0.000, 0.00, 0.00, 0.00, 0.00, 0.00, 0.000, and 0.000 were lower than the significant level of 0.05 (95%) probability level for air quality and rainwater quality parameters. This means that all were significant at degrees of freedom (Df) of 29. Thus, the null hypothesis (H_0) was rejected for all tested air quality and rainwater quality parameters. The alternative hypothesis (H_1) was accepted, which means that there is a significant difference between the status of air quality and rainwater quality parameters with WHO standards in the study area.

Table 1.10: One Sample T-test Computed for Hypothesis 4

Air quality & Rainwater quality Parameters	One sample T-test						Remark
	T test	Df (n-1)	Significant At 0.05 alpha level	Mean Difference	95% Confidence Interval of the Difference		
					Lower	Upper	
Temp	4.271	29	0.000	0.35333	0.1841	0.5225	S
CO	-3.956	29	0.000	-2.97333	-4.5105	-1.4361	S
NO_2	22.139	29	0.000	1.23667	1.1224	1.3509	S
SO_2	7.706	29	0.000	.45133	.3315	.5711	S
CH_4	-5.513	29	0.000	-.11033	-.1513	-.0694	S
VOC	3.716	29	0.001	1.62667	.7314	2.5219	S
H_2S	2.859	29	0.008	.41667	.1186	.7147	S
$PM_{2.5}$	30.223	29	0.000	167.79333	156.4387	179.1479	S
pH	-13.837	29	0.000	-1.05667	-1.2129	-.9005	S

Salinity	-12.917	29	0.000	-.49000	-.5676	-.4124	S
TDS	-723.325	29	0.000	-491.93333	-493.3243	-490.5424	S
DO	-18.517	29	0.000	-2.91333	-3.2351	-2.5916	S
Sulphate	-1137.701	29	0.000	-98.58833	-98.7656	-98.4111	S
Nitrate	-838.506	29	0.000	-49.60133	-49.7223	-49.4803	S
Cl	-326.167	29	0.000	-181.59933	-182.7381	-180.4606	S
BOD	-4214.382	29	0.000	-9.97100	-9.9758	-9.9662	S
Cu	-149.119	29	0.000	-.56267	-.5704	-.5549	S
Cr	4.795	29	0.000	.70833	.4062	1.0104	S
Fe	-4.692	29	0.000	-.10100	-.1450	-.0570	S

Source: Researcher's Computation, 2024
* S – Significant
* NS - Not Significant
* THC was not computed because of 0 mean value

13.Status of air quality in respect to air quality parameters and meteorological parameters around Afam gas flaring site

Findings revealed that temperature condition and heat index was generally stable during the morning periods of measurements in the study area. The percentage composition of RH (%) fluctuated between 72.5% and 90.3% with varying wind speed of 0.8 m/s to 2.4 m/s. Carbon monoxide (CO) concentration measurements were slightly higher in around 400m distance away from gas flaring site with a mean value of 10.7 ppm. NO_2 (ppm) also showed ranged concentration with highest mean values of 1.8 ppm, 1.7 ppm, and 1.5 ppm in sampling distance of 400m the three days. The general concentration of methane (CH_4) ranged between 0.0 ppm and 0.27 ppm from the lowest to the highest. The concentration of VOC (ppm) showed minimum concentration values of 0.0 ppm and maximum concentration values of 6.7 ppm. H_2S (ppm) concentration values also ranged between 0 ppm to 1.7 ppm in the study area. $PM_{2.5}$ concentration values ranged from a minimum value of 154 ug/m^3 to a maximum value of 268.3 ug/m^3. Generally, the air quality values measured at the control stations were lower than those measured at the experimental stations.

14.Correlation Matrix between Air Quality Parameters and Weather Parameters

Findings of the study revealed that temperature has a low relationship with CO (ppm). However, CO (ppm) has a relatively high relationship with heat index (^{0}C) (r=0.579;p=0.05) and RH (%) (r=0.585;p=0.05). The correlation matrix between NO_2 and weather parameters indicate a relatively low relationship with heat index (r=0.342;p=0.05), RH (r=0.359;p=0.05) and windspeed (r=0.228;p=0.05). The relationship between SO_2 (ppm) and weather parameters revealed that a relatively high relationship exist between SO_2 (ppm) and heat index (r=0.754;p=0.05); and a relatively low relationship with RH (r=0.0.478;p=0.05) and wind speed (r=0.398;p=0.05). The relationship between CH_4 (ppm) and weather parameters showed that temperature has a relatively low relationship with CH_4 (ppm) (r=0.402;p=0.05); but slightly higher with heat index (r=0.474;p=0.05); RH (r=0.294;p=0.05) and windspeed (r=0.456;p=0.05). VOC (ppm) and temperature (^{0}C) recorded a low relationship, while a relatively high relationship was recorded between VOC (ppm) with heat index (^{0}C) and RH (%). Hydrogen sulphide records a low relationship with temperature (r=0.167;p=0.05) and wind speed (r=0.202;p=0.05), but a relatively high relationship with heat index and RH (%). $PM_{2.5}$ (ug/m^3) recorded a low positive relationship with temperature, heat index, RH and wind speed.

15.Rainwater Quality of Selected Rainwater Sources around Gas Flaring Site

Findings of the study showed that pH values ranged between 5.40 and 7.40 with a mean value of 6.44. The conductivity level in water showed range values between 4.00 (us/cm) and 8.10 (us/cm) with a mean value of 6.21 (us/cm). The concentration of salinity (mg/l) in water showed range values between 0.00 mg/l and 0.60 mg/l. The level of TDS (mg/l) in sampled water showed range values between 2.00 mg/l and 15.00 mg/l with a mean value of 8.07 mg/l. The amount of dissolved oxygen (DO) mg/l revealed minimum values of 2.80 mg/l and maximum values of 6.00 mg/l with a mean value of 4.59 mg/l. The concentration of sulphate (mg/l) revealed minimum values of 1.01 mg/l and maximum concentration values of 2.60 mg/l with a mean concentration value of 1.41 mg/l. The concentration of nitrate (mg/l) also showed range values of 0.20 to 1.40 mg/l in the study area. The mean value of nitrate mg/l was 0.40 mg/l. Hydrogen bicarbonate showed minimum and maximum content of 0.02 mg/l and 0.04 mg/l. Chloride (Cl) (mg/l) recorded range values of 12.02 mg/l and 24.40 mg/l with a mean concentration value of 18.40 mg/l. BOD (mg/l) recorded range values of 0.01 mg/l to

0.05 mg/l, with a mean value of 0.03 mg/l. Copper (Cu) (mg/l) showed lowest value of 0.01 to highest value of 0.07 mg/l and a mean concentration of 0.04 mg/l. Chromium (Cr) (mg/l) had zero minimum concentration value and 2.75 mg/l maximum concentration value. The concentration of Fe (mg/l) in sampled rainwater recorded minimum concentration value of 0.05 mg/l and maximum concentration value of 0.53 mg/l and a mean concentration value of 0.20 mg/l.

16.Comparison of Air Quality Parameters & Rainwater Quality Parameters with WHO Standards

Findings revealed that all sampled gaseous pollutants for air quality parameters (CO, NO_2, SO_2, VOC, H_2S and $PM_{2.5}$) showed higher mean values when compared to WHO standards and permissible limits. Similarly, the mean value of temperature (^{0}C) also showed slightly higher values when compared with WHO standards. However, the concentrations of CH_4 were within the WHO permissible limits. As regards rainwater quality, the mean content of pH, salinity, TDS, DO, sulphate, nitrate, Cl, BOD, Cu and Fe were all within the WHO limit; but Cr (mg/l) recorded mean value higher than WHO standard.

Test of Hypotheses: The results of the research demonstrated that concentrations of gaseous contaminants and weather parameters differed between locations in the study region. Using the gas–parameter relationship and weather conditions, it was discovered that temperature strongly correlates with CH4 (PPM), NO2, SO2, H2, VOC, H2S, and PM5 while wind speed strongly correlates with CO, NO2, SO2, H2, VOC, and H2. Although the content of salinity, TDS, and DO, varies greatly among the sites, the other sampled water quality parameters were found to be negligible. The One-sample T-test showed that there is a substantial difference between the air quality and rainwater quality parameters in the study region.

17.Conclusions

The Afam gas flaring site is a source of atmospheric pollution which has several implications on air quality and environmental stability in the study area. Findings revealed higher mean concentration values of air quality parameters when compared with WHO standards except for methane which was within the WHO limit. The status of rainwater quality using water quality parameters showed variations in their content but results still revealed mean values within the WHO acceptable limits except for Chromium content in water which when consumed for a long period of time may lead to kidney damage. However, based on the content of other rainwater quality parameters analyzed for the study, the water is still potable for drinking. Thus, proactive measures should be directed at establishing adequate controlling methods ensured at tackling air quality issues around gas flaring site in the study area.

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