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Investigation of the Impact of Natural Gas Flare on Air Quality in Warri South West, Delta State, Nigeria

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Abstract—*We investigated the impact of gas flaring on air quality using Warri South Local Government as a case study. The pollutants investigated include PM2.5, pM10, SO2, NO2, VOCs, TSP, Temp and Humidity with the execution of the study occurring in four different flow stations with distances of 60m, 80m, 100m, and 120m from the flare stack at individual flow stations. To achieve this, the air quality was measured along the flare stations and the readings of the different parameters were recorded using Aeroqual 500 Series air quality multi-parameter gas detector. The results show that the average concentration of VOCs (0.7175),* SO_2 *,(0.105),* NO_2 *(0.0718), CO (<0.001),* $PM_{2.5}$ *(15.7),* PM_{10} *(24.625), TSP (29.3) Temp*^{0}*C (36.45), Humidity % (63.425) at flare site along the flow stations exceeded both local and international regulatory levels. The variation in concentration of pollutants along the flare stations shows that concentrations of VOCs,* SO_2*, PM2.5, PM10, TSP and Humidity were relatively high, even when the distance was at 120m away from the flare stack. At one of the locations where the flare was put off due to loading activities, results show values are in excess of international regulatory values. This research efforts will help to monitor and track the concentration level of pollutants in order to avert spread of diseases arising from high pollutant concentration.*

Keywords— *Air Pollution, Air Quality Determination, Contaminant Level, Environmental Investigation, Gas Flaring.*

I. INTRODUCTION

Air is approximately 78 percent nitrogen, 21 percent oxygen and 1 percent of other gases, such as carbon dioxide, neon and hydrogen [6], and this important fluid is required in every life process including in plants and animals. While plants will require carbon dioxide (CO_2), animals will require oxygen (O_2). In addition, wind pollination of plants is activated by air while living things in marine environments need air (dissolved oxygen) to respire. Non-living things like aeroplanes and other airways need air in various forms [7]. The gravitational hold of air close to the earth's surface provides a protective blanket. Inspite of the various uses of air, its quality (or the degree to which surrounding air is considered clean) is important in air close to the earth's surface provides a protective blanket [4] many respects. Air degradation is a daily occurrence in many countries and regions and there are adverse consequences associated with polluted air. Sources of some of the air impairment or quality damage is linked to human actions and activities including shipping, transportation (vehicle emissions), incineration (industrial emissions), oil and gas flare activities, and bush burning. Typical pollutants released from these activities include SO_2, CO, NO_2, O3, SPM, and VOCs. The ideal situation is to maintain air quality and have unpolluted air with appropriate compositions. Table 01 is a typical constituent and composition of unpolluted air with its distinct characteristics.

Air quality index (AQI) helps determine the concentration of pollutants present in the air at a particular location [15] and we are, in this work, considering gas flaring as a major source of air pollution which has negatively impacted several regions and countries such as the Nigeria's Niger Delta region [5]. Gas flaring release carbon dioxide and methane, the two major greenhouse gases, and of these two, methane is considered more harmful than carbon dioxide and also more prevalent in flares that burn at lower efficiency which are more dominant in the Niger Delta. Flaring gas has led to the emission of harmful gases and toxins into the atmosphere as well as increase in temperature, causing various effect on both the populace and the marine environment. Some of the effects include increase in respiratory diseases, release of acid rain into rivers and other marine environments and subsequent lowering of their PH values thereby endangering lives due to elevated concentration of aluminum.

Considering the problems associated with air pollution due to gas flaring, questions need to be answered about the quality of air around flare sites and how this can be measured in terms of concentration and flow dynamics. We will answer these questions using a case study of a flare site in Warri South, Delta State, where a detailed investigation and analysis of the flair site is conducted guided by a benchmark WHO standard for air quality. Standards have been set by other organizations other than WHO, such as the Nigeria Federal Ministry of Environment (FMEnv) on limits for certain toxic pollutants.

Oil and gas production operations have been going on in warri south study area with associated gas flaring taken place on a daily basis. Thus, a need arises to investigate the level and extemt of these emissions caused by gas flaring and the nature of gases released into the air. As earlier indicated, some of the releases include particulate matter, volatile organic compounds (VOC), sulfur dioxide (SO2), nitrogen dioxide (NO2). We also considered the effect of temperature.

Particulate matter are tiny particles released into the air with particle size less than 2.5 micrometers in diameter implying its capacity to penetrate the lungs, irritate and corrode the alveolar wall, and result to impair lung function [10], as well as tendency to increase health problems like heart diseases, asthma and low birth weight. In addition, particles can actually be carried away over a long distance by wind and then settle on soil and leach into groundwater or surface water, and this could lead to acidic lakes and streams. An acidic lake can change the nutrient balance in coastal waters and large river basins [15].

The VOCs are emitted as gases from certain solids or liquids and they include a variety of chemicals, some of which may have both short term and long-term adverse health effects. VOCs as a result of up wind gas flaring has impacted on health. Sulfur dioxide is a stable oxide of sulfur with a choking and penetrating smell but easily liquefied by pressure. Findings also show that SO_2 causes sore or irritation to the upper respiratory tract and also worsen existing lung diseases. Moreso people with asthma are most sensitive to the effect of this pollutant. Continuous exposure to an extremely high levels of SO_2 for a long period of time can contribute to the development of lung disease [3]. SO_2 is also a key contributor to acid rain and small particle pollution.

TABLE 01: Composition of unpolluted dry air and the approximate total masses of the different constituents of the atmosphere (Many trace gases are not listed) [20]

Constituent	Molecular Formula	Volume/Fraction	Total Mass (millions metric tonnes)
Nitrogen	N_2	78.09%	3,850,000,000
Oxygen	O_2	20.8%	1,180,000,000
Argon	Ar	0.93%	65,000,000
Carbon dioxide	CO_2	0.038%	8,500,000
Neon	Ne	18ppm	64,000
Helium	He	5.8ppm	37,000
Methane	CH_4	1.3ppm	37,000
Krypton	Kr	1ppm	15,000
Hydrogen	H_2	0.5ppm	180
Nitrous Oxide	N_2O	0.85ppm	1,900
Carbon monoxide	CO	0.1ppm	5,00
Ozone	O_3	0.08ppm	8,000
Sulphur dioxide	SO_2	0.001ppm	11
Nitrogen dioxide	NO_2	0.001ppm	8

Nitrogen Dioxide (NO_2) is a yellowish poisonous gas that is produced or formed from sources like: gas flare stations, motor vehicles, manufacturing plants and utilities and it is formed when some metals are dissolved in nitric acid. Inhalation of nitrogen dioxide as a pollutant can cause bronchitis and increase the likelihood of being infected by diseases. Nitrogen dioxide (NO_2) also contribute to the formation of ozone pollution, small particle pollution and acid deposition which also lead to further acid rain [3]. Continuous exposure to high temperatures can lead to blistered skin, aging, heat stroke, cardiovascular hospitalization, respiratory diseases and dermatological issues in the habitat of the environment, it also reduces problem solving ability of children (delirium or confusion) [9].

In this work, we investigated the impact of gas flaring on the air quality in Warri South study area in Delta State and how the released pollutants impact the physical environment and to recommend existing technologies for curbing gas flaring to protect our atmosphere.

II. MATERIAL AND METHODS

2.1 Study area

Warri South West Local Government Area is located in the town of Obge-Ijoh having 10 Districts with several communities along the coastal areas in Delta State, Nigeria. This kingdom is where oil mining lease (OML) 42 is located, and which is housing seven (8) flow stations and OML 30 housing some of the flow stations. Both OMLs have over 10 gas flare-stations. It is a clear indication that acid rain, runoff, and bunkering operations will be inevitable, with heavy soot from the local refining process of crude (kpo fire) including pollution from freight transportation, of goods and services, and petrol engine boats. The headquarters of Warri South-West local government area is presently housing 5 flow stations, Egwa 1 (AQ1) flow station, lying on longitude N050 32’ 59.1 and E0050 29’ 25.7’’ Egwa 2 (AQ3) on longitude E0050 29’ 25.7’’and E0050 29’ 25.7’’ , Batan (AQ2) also on longitude N050 32’ 59.1 and E0050 29’ 25.7’ , and Odidi (AQ4) flow station lying on longitude N040 47’45.3” and E0060 58’ 13.7”, and Kurutie (AQc) on longitude N040 47 ‘ 54.4” and E0060 58’ 11.8” with all the flow stations housing a flare stack hence this study generated primary data from the four flow station and one as a control, totaling (5) oil producing communities in this study area in Gbaramatu kingdom. This study was centered on the characterization of Air quality analysis to determine the level of contamination in the air.

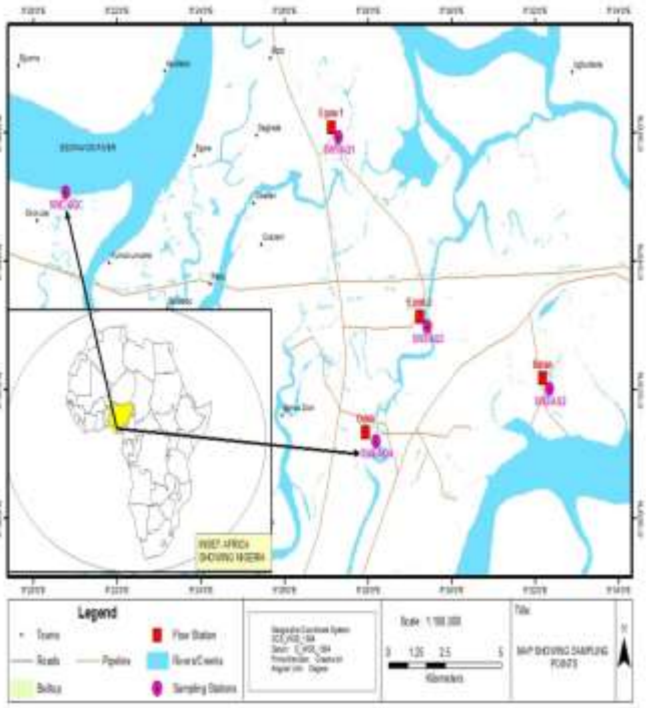

Fig. 1: Map of Study Area

2.2 Methodology

The sampling was carried out along the Escravos River in the Niger Delta Province of Nigeria (see Figure 1). The

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sampling points were partitioned into five communities with four flow stations with upwind flare stack namely: Egwa1 Flow Station

Egwa 2 Flow Station; Batan Flow Station, and Odidi Flow Station. Kurutie was used as the control sample point, and in-situ air quality measurement was taken with hand-held digital meter at an elevated height and each of the parameters was read for three minutes, and as soon as the reading was displayed on the third minute, the meter automatically stops and the displayed result was recorded. This experiment was conducted at distances of 60, 80, 100, and 120 m away from each flare stack. A speed boat, wading gear, and 105 hp engine, Aeroqual 500 serials Air Quality Multi-Parameter Gas Detector, Met One Instrument 531 Particulate Meter, Kestrel 450 Weather Tracker, life vest, note book, pens, charger and batteries were used for the experiment and to enable movement from one flow station to the other. Sample management was strictly in line with standard procedures (APHA, 1998). The study area map showing sample locations (Egwa1 as AQ1, Batan as AQ2, Egwa2 as AQ3, and Odidi as AQ4). The last sample station was Kurutie, which was used as AQc also known as the control along Escravos River.

III. Results And Discussion

3.1 Concentration of Studied Parameters in the Escravos River.

Tables 1,2,3 and 4 shows in-situ results which exhibited a linear regression trend, indicating that at distances 60m away from the flare stack, VOCs, SO2, PM2.5, and PM 10 were 1.2ppm, 0.18ppm. 17.2ppm.and 23.1ppm, respectively, which exceeded corresponding WHO standards of 0.2ppm, 0.125ppm, 0.04ppm, and 0.05ppm respectively. This was seen in the four flare stations and concentration of pollutant decreased further away from distances 80m, 100m, and 120m. These findings is also in accordance with the work done by [12] who used Pearson Product Moment Correlation (PPMC) statistical tool to determine pollutant concentration and distance away from flare stack.

TABLE 1: Location 1 EGWA 1 Flow Station (15m Height)

Parameters	Distances from flare stack 60m	80m	100m	120m	Average	WHO limits
VOCs ppm	1.2	0.9	0.7	0.7	0.7175	0.25
SO_2 ppm/ µg/m³	0.18 471.5	0.09 236.7	0.08 209.5	0.07 183.4	0.105	0.125 125
NO_2 ppm /µg/m³	0.089 167	0.074 139.2	0.062 116.7	0.062 116.7	0.07175	0.2 200
COppm/ µg/m³	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001	<0.002 2µg/m³
PM2.5ppm	17.2	15.6	15.1	14.9	15.7	0.04
PM10ppm	23.1	22.7	24.6	28.1	24.625	0.05

Figure 2 (a) shows the concentration of VOCs variation with distances of 60m, 80m, 100m, and 120m in the study area. The results show that concentration of VOCs in air varied distinctly amongst the distances and also among sampling location. It can be observed in figure 2(a) the variation in concentration, among distances and sampling location, with location 1 and 3 with higher concentration of 1.2ppm each, at distance of 60m.

TABLE 2: Location 2 AQ 3 EGWA 2 Flow Station (15m Height)

Parameters	Distances from flare stack 60m	80m	100m	120m	Average	WHO limits
VOCs	1.1	0.7	0.3	0.40	0.625	0.25
SO_2 ppm/ µg/m³	1.30 178.7	0.09 139	0.07 114.7	0.05 84.7	0.3775	0.125 125
NO_2 ppm /µg/m³	0.095 173	0.074 162	0.061 136	0.045 95	0.06875	0.2 200
COppm/ µg/m³	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001	0.002 2µg/m
PM2.5ppm	17.0	16.5	16.3	15.3	16.2	0.04
PM10ppm	25.3	28.7	30.6	28.9	28.375	0.05

TABLE 3: Location 3 AQ2 Batan Flow Station (15m Height)

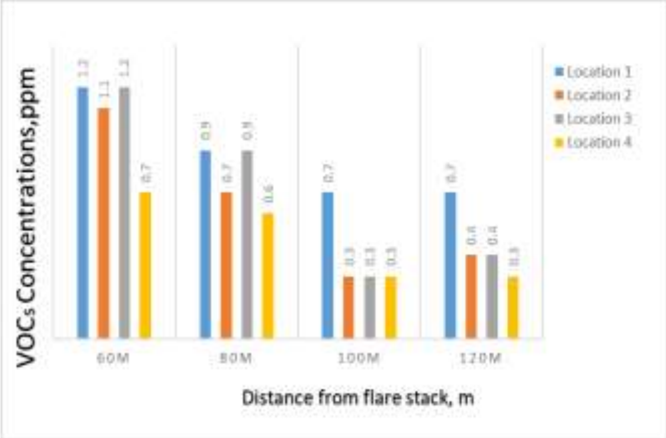
Parameters	Distances from flare stack 60m	80m	100m	120m	Average	WHO limits
VOCsppm	1.2	0.9	0.6	0.4	0.775	0.25
SO2ppm/ µg/m³	0.20 523.6	0.10 261.5	0.07 184.5	0.03 78.5	0.525	0.125ppm 125µg/m³
NO2ppm/ µg/m³	0.092 173	0.081 152	0.072 135	0.051 95	0.074	0.2ppm 200µg/m³
COppm/ µg/m³	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001	0.002 2µg/m³
PM2.5ppm	16.3	14.9	15.9	13.8	14.25	0.04ppm
PM10ppm	26.1	24.4	24.2	23.8	24.625	0.05

TABLE 4: Location 4:AQ4 ODIDI Flow Station (15m Height)

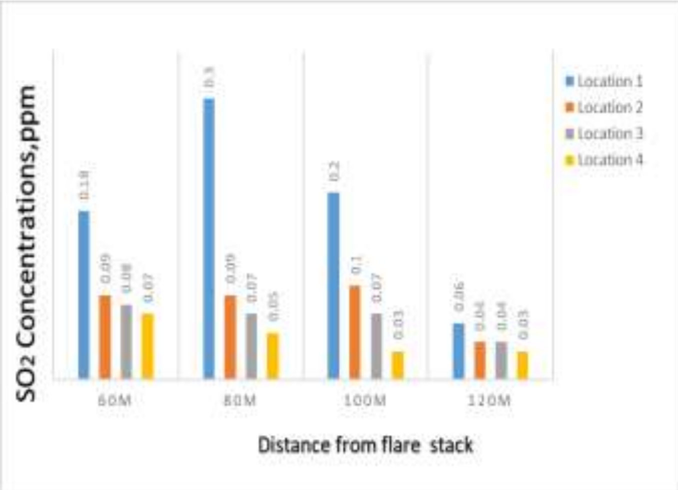
Parameters	Distances from flare stack 60m	80m	100m	120m	Average	WHO limits
VOCsppm	0.7	0.6	0.3	0.3	0.475	0.25ppm
SO2ppm/ µg/m³	0.06 157	0.04 104.7	0.04 104.7	0.03 78	0.0425	0.125ppm 125µg/m³
NO2ppm/ µg/m³	0.055 103.5	0.051 95.9	0.048 90.3	0.040 75	0.0485	0.2ppm 200µg/m³
COppm /µg/m³	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001 1.146	<0.001	<0.002ppm 2µg/m³
PM2.5ppm	17.3	15.1	14.5	14.2	15.275	0.04ppm
PM10ppm	27.3	25.4	23.7	25.5	25.525	0.05ppm

From distance 60m to 120m, all VOC concentration exceeded the WHO limits of (0.25ppm), thus urgent attention is needed as it is quite unhealthy for the habitats of this environment. It is also observed in Figure 2(b) and 2(c) that concentration of SO_2 in averaged 0.3775ppm, and 0.06875ppm, SO_2 relatively above the WHO limit of 0.125 ppm. NO_2 was within the WHO permissible limit of (0.2ppm). The concentration of CO_2 (<0.001) was within the recommended WHO limit of <0.002.

The concentration of PM2.5, PM10 as shown in figures 2d and 2e, were observed to have highest values in sampling location 1 with 17.2ppm at 60m, and 28.375 at 100m away from flare stack which were far above the WHO limit of 0.04 and 0.05 respectively, with this observation underscoring the need for this study and a call for the government and researchers to start focusing on the prevalence of these particulate matter in these study areas.



(a)



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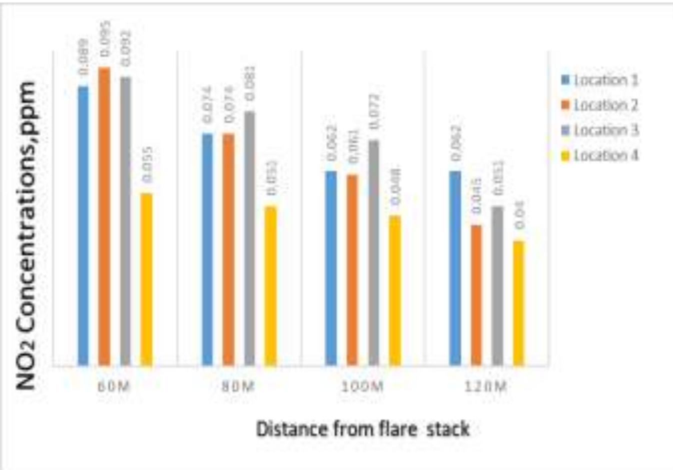

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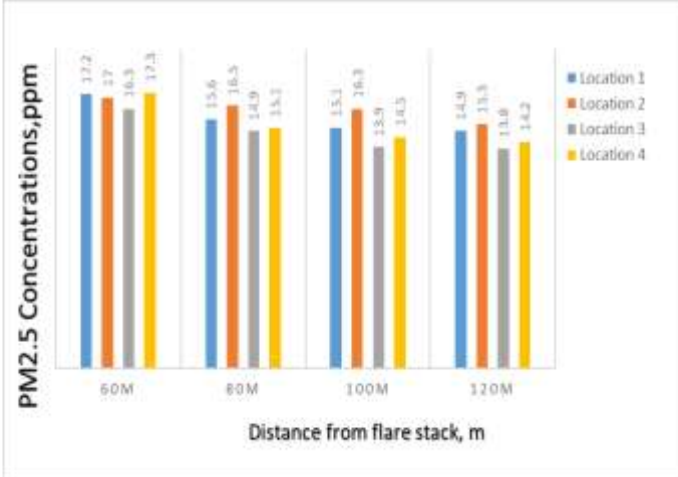

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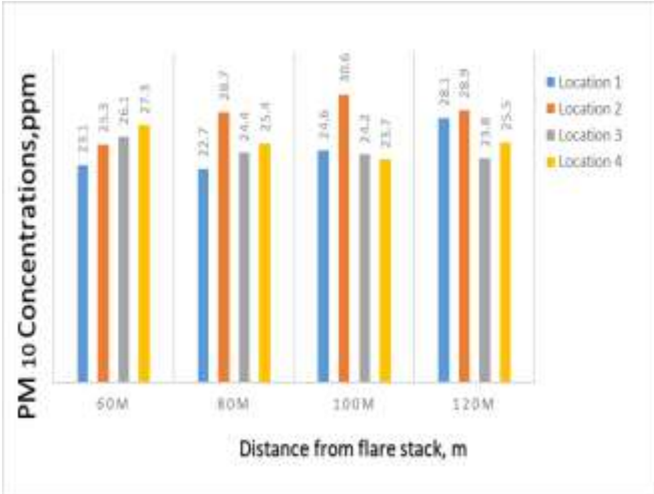

(e)

FIG. 2 (A-E): Concentration profile of VOC, SO_2, NO_2, $PM_{2.5}$, PM_{10} with distances away 60M to 120M from flare stack.

Furthermore, continuous inhalation of PM could lead to severe outbreak of heart diseases. It is also a major cause of poor visibility, and a contributing factor for haze that is predominant in the early hours of the morning in these area of study. The result of VOC, SO_2, NO_2, PM2.5, and PM10 values decreased as distance increased from the flare stack, and this was noticed in the four flare stations meaning that gas diffusion increased as distance increased. This result obtained from this investigation is in support with the result of [9] who reported same.

In respect of the average meteorological results, the temperature was observed in Figure 3 to have ranged highest at distance 60m in location 1 which was closest to the flare stack at 36.9 ^{0}C and which reduced further away from the flare as the distance increased to 120m. Temperature. was seen to have reduced to 35.075^{0}C which was also applicable to all four sample locations. A research work in [13] also reported a trend as all considered parameters show a gradient away from the flare stack in all the flow stations such as soil pH changing from acidic to near neutral away from gas flare point. Which was attributed to loss of moisture content closest to the flare stack. On the other hand, there was a reversal still in Figure 3 which is humidity profile, where you observe a significant down turn variation. Results show that humidity increased as the distance increased from the flare stack with location 1 ranking lowest with 57.95 at distance 60m and location 4 with 60.0675 at distance 120m, and this trend was seen in all four sample locations. Another set of researchers [14] also in their results from their study showed that with rise in air and soil temp of the flare site, relative humidity, soil moisture and all chemical parameters decreased towards the flare site.

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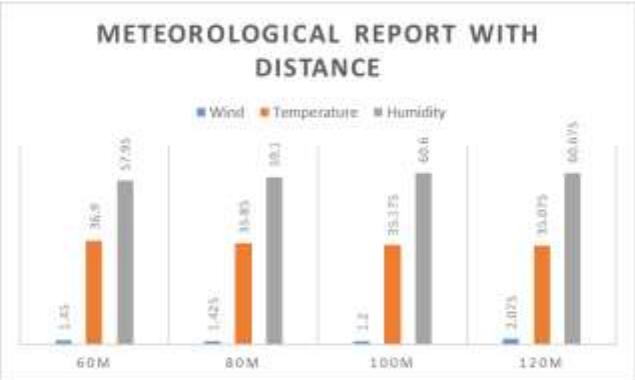

Fig. 3: Average Meteorological Report in Graphical Presentation

IV. CONCLUSION

In this study, the level of concentration of VOCs, SO_2, NO_2, CO, PM2.5, PM10, temperature, and humidity along the Escravos river housing the four under studied flare stations were investigated at distances 60m, 80m,100m, and 120meters from flare stations. Results obtained corroborated the following conclusion:

(1) The results of VOC, SO_2, NO_2, PM2.5, PM10, in the investigation flare stack area exceeded both locally and international regulatory values.

(2) The CO (<0.001) was within WHO limit of (<0.002).

(3) From the meteorological report, temperature increased closest to the flare stack.

(4) There was loss of moisture content towards the flare stack which caused moisture loss and increase in moisture content with increase in distance from the flare stack.

These results showed that the flow stations housing the flare stack and its environment is polluted. Therefore, it is recommended that the flare be converted to productive use.

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