Comparative Analysis of Air Quality Around Gas Flaring Sites in Etche And Ikwerre Local Government Areas, Rivers State, Nigeria.

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ABSTRACT

This paper examined air quality around gas flaring sites in Etche and Ikwerre Local Government Areas of Rivers State, Nigeria. Experimental research design was adopted, imploring the use of primary and secondary data. Primary data were generated through field measurements. Air quality parameters of CO, SO_2, NO_2, $SPM_{2.5}$, SPM_{10} and H_2S were measured using an ELE Analox Sensor Gas Monitor Model GC 401, multi–RAE PLUS (PGM-50), programmable Multi Gas Monitor and Multi Gas Detector (Defender ®) Model D2-2000 respectively. While Met One Instrument, Inc Aerosol Mass Monitor was used to measure Suspended Particulate Matter (SPM) of $PM_{2.5}$ and PM_{10} in the study area. Hand-held digital thermometer, logger (Testo 450), and digital anemometer were used to determined micro-climatic parameters of atmospheric temperature, relative humidity, and wind velocity respectively. Air quality measurements were collected around 12 randomly selected flare locations of Etche and Ikwerre gas flared sites. The study was anchored on the Concept of Environmental Quality, Air pollution dispersion and System theories. Inferential statistics was used to analyse the data and hypothesis was tested using two sample t-test. Findings showed that the mean concentration of NO_2, SO_2, H_2S and CO ranged from 1245.69mg/m^3 -1555.09 mg/m^3, 138.43 mg/m^3 - 202.65 mg/m^3, 60.43 mg/m^3 - 65.24 mg/m^3, and 750.0 mg/m^3 - 985.7 mg/m^3 respectively. $PM_{2.5}$ concentration ranged from 0.0237mg/m^3 -14.42 while PM_{10} concentration ranged from 0.0848 mg/m^3 - 0.094 mg/m3. The study concluded that the concentration of most of the pollutants in the selected flared locations exceeded the National Ambient Air Quality Standards (NAAQS) stipulated limits while a few others remained within acceptable limits. Thus, the study recommended amongst others installation or optimization of pollution control equipment (e.g., scrubbers, flare optimization) to reduce CO, NO_2, SO_2, and particulate emissions, well-planned sustainable afforestation programme along these flare locations should be encouraged as these trees will act as a sink to these atmospheric pollutants.

Keywords: Air quality, gas flaring, Etche, Ikwerre.

INTRODUCTION

In Nigeria, Gas flaring has been declared illegal since 1984, yet the country still ranks among the top 10 gasflare countries with about 7.4billion cubic meters of gas flared in 2018 and about 425.9billion standard cubic feet of gas flared in 2019 (Eboh, 2019). Gas flaring has negative impacts on the environment. The consequences of this act of excessive flaring are of a large contribution to global warming and climate change due to the emission of large quantities of the two major greenhouse gases (carbon dioxide and methane). Another major consequence of gas flaring is sour gas (Hydrogen Sulphide) and sulphur oxides emission, the end product of these compounds when it combines with atmospheric oxygen and water is acid rain (Odiong *et al*., 2010).

Gas flaring has taken an unprecedented effect of heat and noise on the host environments to the extent of making most host communities uninhabitable. It has also caused human displacement with the antecedents of a dilapidated ecological habitat. In fact, it has been a controversial practice as it became a severe case too delicate to evict. The upstream and downstream emissions from gas flaring are rather ubiquitous especially to climatic changes. This associated gas flaring is a source of significant amount of global GHGs and other poisonous emissions. The volume of pollutant gases emitted depends on the combustion efficiency of the flare system, while the brightness and colour depend on the original composition of the generated associated gas. One established factor is the effect of proximity to the flare facilities (Rahimpour *et al*., 2011).

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Up to 2013, about 0.456 million tons of the global black carbon emission as part of PM2.5 came from the Niger Delta of Nigeria which can be linked to gas flaring and other incomplete combustions of fossil fuel (Giwa, et al., 2014). Also, Black carbon's destructive role in human health, physical visibility and the ecosystem is of immense global concern. For instance, notwithstanding that black carbon resides in the atmosphere for few days, 1 g of it can warm the atmosphere hundreds of times than 1 g of CO_2 floating on the atmosphere in 100 years making the contribution of black carbon to global warming to be about 70% that of the CO_2 (Giwa, et al., 2014; Giwa, et al., 2016). In addition, the residual (unburnt) components consist of methane and VOCs. Findings reveal that within 20 years of exposure, 1 kg of CH4 is 62 times more damaging compared to exposure to 1 kg of CO_2 (Mafimisebi & Nkwunonwo, 2014) and 25 times as a potential global warming greenhouse gas than CO_2 based on their masses (Kaladumo & Ideriah, 2014). Specifically, the GHGs and VOCs have been labelled in photochemical formation of Tropospheric Ozone and this bad ozone consequently is harmful to both plant and humans (Nwosisi, *et al.*, 2019). Also, more than 250 toxins have been identified within flared gas including dioxin, H_2S, toluene, xylene, styrene, benzopyrene, naphthalene, benzene and its metabolites etc. (Giwa, *et al*., 2014; Mafimisebi and Nkwunonwo, 2014; Obi*, et al*., 2021a; Obi, *et al*., 2021b; Giwa, *et al*., 2017; Ekpoh and Obia, 2010; Ismail and Umukoro, 2012).

Gas flaring in the Niger Delta region of Nigeria, is responsible for 18 million metric ton of GHGs and other lethal emissions (Obi, *et al*., 2021a). Most of emitted GHGs come from flare stacks and majority of the world's flare sites are localized in the Niger Delta region of Nigeria (Adoki, 2012). This region with exceptional biodiversity, is the world's largest wetland, second largest mangrove in the world and third largest drainage basin in Africa but now saturated with over 123 gas flaring sites (Giwa, *et al.*, 2017) currently in operation. A study by Olujobi (2020), revealed that, 144 flare sites which adds to pollution of the air, soil and water. In addition, the emissions also contain VOCs such as benzene, H2S, toluene and xylene (Anosike, 2010), that make the water highly toxic for the ecosystem. The dark coloration and soured taste of this rain water due to saturated PM and soot content makes it undrinkable (Adoki, 2012; Nkwocha and Pat-Mbano, 2010).

Other major opportunity costs of these anthropogenic emissions comprise the rise in sea level, coastal erosion, wildlife extinction, loss of biodiversity, acidified water penetration into coastal aquifer and other lethal endemic effects of acid rain on the coastal ecosystem in this area as highlighted in Tawari and Abowei (2012).

It has been proven that the flare system also emits substantial amount of noise and heat 0.5 km from the stack base making the flare zone too unlively for human habitation (Obi, *et al*., 2021a; Abdulkareem, *et al*., 2012). The exothermic combustion of associated gas releases significant amount of heat. Fishes as cold-blooded aquatic animals are sensitive to such water temperature rise. Abdulkareem, *et al*. (2012), also reported that, there is also premature hatching of fish eggs before their gestation period due to unusual temperature rise of the aquatic habitat and worse still, not hatching at all. In addition, the radiated heat around flare stacks have been noticed to be above tolerable limits for certain cash crops to survive. Abdulkareem, *et al*. (2012), estimated a reduction of 10%, 45% and 100% in crop yields for plants at 1 km, 0.6 km and 0.2 km from the flare stack respectively. With these regions as a heat sink to the flare stacks, now forces plants to have stunted growth and reduced propensity to pollination leading to dwindling agricultural productivity as well as diminishing wildlife and domestic biodiversity population (Edino, *et al*., 2010; Ana, 2011).

The health implications of gas flaring are enormous. The study of Obi *et al*. (2021a) and Giwa *et al*. (2017) show that short time human exposure to NO2 can cause breathing complications, increased exacerbation of asthma and other respiratory morbidities. Residents exposed to other gas flare pollutants are noticed to suffer different levels of hematological, skin and eye deteriorations. Other health issues associated with flared gas which have been reported in Niger Delta includes blindness, aggravated Asthma, Chronic Bronchitis, Cancer, Leukemia, reduced lung function, Pneumonia, impotency, miscarriages, stillbirths and other reproductive disorders as well as dysfunctional immune system (Mafimisebi and Nkwunonwo, 2014; Oni and Oyewo, 2011; Emam, 2016; Ana, 2011; Anosike, 2010; Osuoha and Fakutiju, 2017). The noise and heat have become major causes of insomnia and heat rashes respectively in addition to disruption of wake-sleep rhythm of residents especially those at close proximity to flare facilities (Ekpoh and Obia, 2010).

The release of soot and other toxic gases emanating from the flare site causes a deterioration effect on air quality.

Gas flare contains recognized toxins which are confirmed carcinogens like benzene, benzopyrene, toluene, mercury and arsenic. High concentrations of nitrogen dioxide, sulphur dioxide, carbon monoxide and suspended particulate matter above international standard have also been recorded around flare sites. This deterioration in air quality poses serious health risks to humans living within the area including cancer and lung damage, as well as deformities in children, asthma, bronchitis, pneumonia, neurological and reproductive problems (Allison *et al.,* 2018).

In the local communities of Etche and Ikwerre Local Government Areas of Rivers State which is a part of the Niger Delta region, flare sites still exist till date and associated gases have been flared for over 20 years now while the vagaries of gas flaring have been neglected. Despite the negative impacts of gas flaring on the environment and health status of residents reiterated above, the oil companies operating within Etche and Ikwerre communities are still in the practice of releasing these toxic atmospheric pollutants into the environment.

Studies have also shown that several pollutants from gas flared cause respiratory problems, insomnia, headache, cancer, bronchitis and depression, blood disorders, damage to the skin, asthma and anaemia (Adienbo & Nwafor, 2010; Ajugwo, 2013; Gobo *et al*., 2009; Maduka & Tobin-West, 2017).

Aim and Objectives of the Study

The aim of this research was to compare air quality around gas flaring sites in Etche and Ikwerre Local Government Areas of Rivers State. The objectives of the study include, to:

1. assess the levels of key air pollutants (e.g., carbon dioxide, hydrogen sulphide, nitrogen oxides, sulfur dioxide, and particulate matter) in the study areas.
2. examine the concentration levels of meteorological parameters (Temperature, relative humidity and wind speed).
3. determine the significant variation in observed meteorological parameters between Etche and Ikwerre flared sites.

Research Questions

The study is poised to address the following research questions;

1. What are the levels of air pollutants in Etche and Ikwerre LGAs flared sites?
2. What are the concentration levels of meteorological parameters in Etche and Ikwerre LGAs flared sites?
3. Is there any significant variation in observed meteorological parameters between Etche and Ikwerre LGAs (flared) sites?

The Study Area

The study area (Etche and Ikwerre Local Government Areas) is located in Rivers State, Nigeria. Etche Local Government Area is located at the North-Eastern part of Rivers State, Nigeria. It lies within latitude 4^0 45'N – $5^0$17'N and longitude $6^0$55'E – $7^0$17'E (Fig. 1.2) and approximately 641.28km^2 in size. It is bounded in the north by Imo State, east-wards by the Imo River, then Omuma L.G.A. while, Obio-Akpor and Oyigbo in the south. Ikwerre L.G.A. is found at the west ward. Ikwerre Local Government Area is located within latitudes $4^0$55′ and $5^0$15′ N and between longitudes $6^0$40′ and $6^0$55′ E. It is approximately 1,099 km^2 in size and shares boundaries with Imo State at its north, Emohua Local Government Area in the West, Etche Local Government Area in the East, Obio/Akpor Local Government Area in the south.

Conceptual Clarification

Concept of Environmental Quality

Quality has been defined as conformance to necessities. Environmental qualities are conformance to fundamental requirement of a wholesome land, water and air resources (Agarwal, 2016).

Johnson (2015) opined that environmental quality is a set of properties and characteristics of the environment, either generalized or localized, as they impinge on human beings and other organisms. It is a measure of conditions of an environment relative to the requirements of one or more species and/or any human need or purpose.

Environmental Justice Theory (Robert D. Bullard, 1970)

Robert D. Bullard is often called the "father of environmental justice" for his pioneering research in the field, other key authors include David Schlosberg and Hazel M. Johnson. Environmental justice is the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, in the development, implementation, and enforcement of environmental laws and policies. This theory highlights the disproportionate impact of environmental degradation on marginalized or less powerful communities. It stresses the need for equitable distribution of environmental benefits and risks and acknowledges that environmental hazards and benefits are not distributed equitably and advocates for communities to have access to a healthy environment and be able to participate in decisions that affect their communities and well-being. The theory emphasizes on fair distribution of resources, meaningful involvement, broader scope and origin for the communities to enjoy a healthy environment. Communities in Rivers State often face significant environmental and health impacts from gas flaring without commensurate benefits, making this theory apt for assessing inequality in exposure and responsibility (UNEP, 2011).

METHODOLOGY

The experimental research design was adopted for this study. The data for the study was derived from secondary and primary sources. Secondary data were obtained from secondary sources. The primary data were obtained through field measurements of the concentration levels of carbon monoxide (CO), sulphur dioxide (SO_2), Nitrogen oxide (NO_2), Hydrogen sulphide (H_2S) and Particulate matter ($PM_{2.5}$ & PM_{10}) and prevailing meteorological parameters at selected sampling locations. The sampling frame of the present work consists of one (1) kilometer each of the two gas flare stations of the Etche and Ikwerre LGA flow stations. Thus, these constitute two (2) kilometres away from the gas flare stack as the area of study. The researcher generated a sampling frame of all points at 50 metres interval away from the flow station which gives a sampling frame of 40 sampling points. Hence the researcher made use of sample size of 12 accounting for 30% of the total sampling points for the present study using random table numbers.

Sampling Procedure

These 12 sample points were collected at twelve (12) different locations at a graded distance of 500m (0.5km) away from each flare point (Umuechem and Umuebulu) coded SP1, SP2, SP3, SP4, SP5, SP6 for Etche LGA and (Aluu and Igwuruta) coded SP1, SP2, SP3, SP4, SP5, SP6 for Ikwerre LGA respectively. The parameters that were measured include air temperature, relative humidity, wind speed, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), Hydrogen Sulphide (H_2S) and suspended particulate matter (SPM).

Methods of Data Analysis

The collected data were analysed using SPSS, descriptive and inferential statistics.

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RESULTS AND DISCUSSION

The results of the various concentration levels of air quality and micro climatic parameters of the sampling points in the study area are shown in Table 1 and 2 below.

Data presentation

Table 1: Data of Air Quality and Micro Climatic Parameters in Etche LGA Across the Sampling Points

S/N	Location	CO (mg/m^3)	PM$_{2.5}$ (mg/m^3)	PM$_{10}$ (mg/m^3)	NO$_2$ (mg/m^3)	SO$_2$ (mg/m^3)	H$_2$S (mg/m^3)	Wind Speed (m/s)	R.H (%)	Temp (^{o}C)
1	SP1	1120	0.030	0.089	1825.00	105.25	94.64	2.2	66.9	33.0
2	SP2	1130	0.025	0.044	1722.50	140.00	82.53	3.1	56.9	36.1
3	SP3	0.00	0.022	0.084	99.74	166.25	13.39	3.2	35.8	29.7
4	SP4	1110	0.031	0.170	2305.50	143.75	87.65	3.0	67.9	31.7
5	SP5	1140	0.023	0.076	1521.40	141.60	56.48	2.4	53.7	34.0
6	SP6	0.00	0.011	0.046	0.000	133.75	27.88	1.3	44.6	31.1

Source: Researcher's Fieldwork Analysis, 2024

Table 2: Data of Air Quality and Micro Climatic Parameters in Ikwerre LGA Across the Sampling Points

S/N	Location	CO (mg/m^3)	PM$_{2.5}$ (mg/m^3)	PM$_{10}$ (mg/m^3)	NO$_2$ (mg/m^3)	SO$_2$ (mg/m^3)	H$_2$S (mg/m^3)	Wind Speed (m/s)	R.H (%)	Temp (^{o}C)
1	SP1	1151.23	22.23	0.098	2830.00	203.22	98.74	1.11	75.9	32.07
2	SP2	1153.74	31.25	0.064	936.650	230.00	74.62	1.10	68.9	31.13
3	SP3	1300.00	0.022	0.098	1834.00	256.23	16.28	1.30	45.8	31.70
4	SP4	1165.0	21.031	0.182	2407.50	253.65	88.55	1.02	77.6	33.75
5	SP5	1144.11	12.023	0.086	1322.40	231.3	76.46	2.32	53.7	32.67
6	SP6	0.000	0.001	0.035	0.000	41.55	36.78	3.21	45.6	31.52

Source: Researcher's Fieldwork Analysis, 2024

DISCUSSION OF RESULTS

Table 1 above displayed air quality and micro climatic parameters in Etche LGA across the sampling points. It is observed that extremely high values of Carbon Monoxide (CO) are recorded at most locations (SP1, SP2, SP4, SP5), ranging between 1110–1140 mg/m³, indicating significant CO emissions. CO is absent at SP3 and SP6, suggesting genuinely lower emissions at these spots.

In terms of Particulate Matter ($PM_{2.5}$ and PM_{10}), $PM_{2.5}$ values are relatively low, ranging from 0.011–0.031 mg/m³, which corresponds to 11–31 µg/m³. While below dangerous thresholds for $PM_{2.5}$, these concentrations may still contribute to health concerns with prolonged exposure. PM_{10} values are higher, ranging from 0.044– 0.170 mg/m³ (44–170 µg/m³), with the highest concentration at SP4. Elevated PM10 levels indicate significant coarse particulate pollution, likely from combustion and dust. Furthermore, NO_2 concentrations vary significantly across locations, with SP4 showing the highest level at 2305.50 mg/m³. SP6 records no NO_2, which might indicate reduced combustion processes or equipment (flow station) shutdown. Sulphur Dioxide (SO_2), levels are consistently high at most locations, ranging between 105.25–166.25 mg/m³, except at SP3, where it reaches a peak of 166.25 mg/m³. This is expected in gas flare stations, as SO_2 is a major byproduct of sulfur-rich fossil fuel combustion. H_2S levels are highest at SP1 (94.64 mg/m³), which may indicate localized sulfur-rich gas emissions. Other locations also have moderately high levels, except SP3 and SP6, which show significantly lower H_2S concentrations.

In terms of meteorological parameters, the table 1 above equally revealed that wind speeds range from 1.3 m/s at

SP6 to 3.2 m/s at SP3, suggesting moderate air dispersion potential. Lower wind speeds at SP6 could lead to pollutant accumulation, although measured levels there are relatively low. Similarly, relative humidity levels vary widely, from 35.8% at SP3 to 67.9% at SP4, likely influencing pollutant dispersion and chemical reactions in the atmosphere, while temperatures range from 29.7°C to 36.1°C, consistent with conditions near gas flaring stations, where elevated temperatures are expected.

Table 2 above displayed air quality and micro climatic parameters in Etche LGA across the sampling points. The result of the analysis in the table above showed that carbon monoxide (CO) levels are significantly high in locations SP1 to SP5, with concentrations exceeding 1100 mg/m³, indicating heavy pollution likely from vehicular emissions, flow station stack emission, industrial activity, or fossil fuel combustion. SP3 has the highest CO concentration (1300.00 mg/m³), suggesting that this location has the highest level of combustionrelated activities. SP6 has a CO concentration of 0.000 mg/m³, which could indicate a pristine environment. $PM_{2.5}$ levels are highest at SP2 (31.25 mg/m³), reflecting potentially dangerous air quality, as fine particles penetrate deep into the lungs and can cause respiratory problems. SP3 and SP6 have the lowest $PM_{2.5}$ concentration (0.022 mg/m³ 0.001mg/m³), indicating better air quality in terms of fine particulate matter. Other locations (SP1, SP4, SP5) showed moderate $PM_{2.5}$ levels, suggesting the presence of airborne particles from urban or industrial activities. Similarly, PM_{10} levels are relatively low across all locations, ranging from 0.035 mg/m³ (SP6) to 0.182 mg/m³ (SP4). SP4 has the highest PM_{10} concentration, which may indicate increased dust, construction activity, or coarser particulate pollution in that area.

Furthermore, it is observed from the table 2 above indicate that NO_2 concentrations vary widely, with SP1 showing the highest level (2830.00 mg/m³), likely due to industrial emissions or emission arising from flow station as a result of gas flare activities. SP6 has no detectable NO (0.000 mg/m³), which could be due to an absence of combustion sources or limited activity in that area. SP2 and SP5 show lower levels compared to SP1, but still significant enough to impact air quality. SP3 has the highest SO_2 concentration (256.23 mg/m³), which may point to industrial processes such as fossil fuel combustion or mining. SP6 has the lowest SO_2 level (41.55mg/m³), indicating minimal sulfur-related pollution. Overall, SO_2 levels are moderate to high in other locations, suggesting varying levels of gas flare activity.

The result further revealed that hydrogen sulphide (H_2S) in SP1 has the highest concentration (98.74 mg/m³), which might indicate the presence of industries or natural gas activities emitting sulfur compounds. SP6 has the lowest concentration (36.78 mg/m³), suggesting minimal exposure to this pollutant. The variations across locations may reflect industrial or natural sources of H_2S emissions.

In terms of meteorological parameters, SP6 has the highest wind speed (3.21 m/s), which can help disperse pollutants and improve air quality. SP4 has the lowest wind speed (1.02 m/s), potentially contributing to stagnation and higher pollutant concentrations in the area. Relative Humidity levels range from 45.6% (SP6) to 77.6% (SP4). Higher humidity (SP4, SP1) may contribute to the formation of secondary pollutants like smog. Lower humidity (SP6, SP3) may reduce these processes but could allow particulate matter to remain airborne longer while Temperatures are relatively consistent across locations, ranging from 31.13°C (SP2) to 33.75°C (SP4). Higher temperatures (SP4) can enhance photochemical reactions, leading to increased levels of ozone and other secondary pollutants.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

The followings are the summary of the findings of the study:

1. There is significant spatial variation in the concentration levels of carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxide (NO_x), and hydrogen Sulphide (H_2S) between Etche and Ikwerre flared sites.

2. The research also revealed exceedances in particulate matter concentration in Ikwerre selected flared sites in the study area.

3. The study revealed statistically significant difference in the meteorological data between the flared sites in the area. This implies that the meteorological variables in Etche LGA flared sites significantly varied from those in the Ikwerre LGAs flared sites.

4. This research also established exceedances in the mean concentration level of sulphur dioxide and Nitrogen dioxide in Etche and Ikwerre LGAs selected flared locations while the mean concentration levels of carbon monoxide and hydrogen sulphide did not exceed the National Ambient Air Quality Standards (NAAQS) stipulated limits.

CONCLUSION

This study has shown that sulphur dioxide and Nitrogen dioxide in Etche and Ikwerre LGAs selected flared locations exceeded the National Ambient Air Quality Standards (NAAQS) stipulated limits. It is therefore pertinent to say that this poses a great health hazard to residents who resides in that area. SO_2 concentrations are uniformly elevated, ranging from 105.25 to 166.25 mg/m³, except at SP6 (133.75 mg/m³). These values far exceed the WHO 24-hour guideline of 20 µg/m³ (0.02 mg/m³), indicating high sulphur content in the flared gas. SO_2 poses health risks, particularly for individuals with respiratory conditions, and contributes to acid rain. The study has also shown that despite the role gas flaring contributes to air pollution in the study area, the concentration of most of the pollutants have remained within acceptable limits. This can be as a result of the trees and vegetation predominant in the study area which acts as carbon sink and aids in the dispersion and absorption of these pollutants.

RECOMMENDATIONS

Based on the findings of this study the following recommendations are put forward:

1. Increased awareness and enlightenment on the health impact of gas flaring through key stakeholders (policy and decision makers, journalists and industrialists) should be encouraged.
2. A well-planned sustainable afforestation programme along these flare locations should be encouraged as these trees will act as a sink to these atmospheric pollutants.
3. Adequate health facilities should be put in place in communities close to flare locations in order to cater for the urgent health needs of residents who may be exposed to sulphur dioxide exceedances.

4. The study recommends periodic monitoring of air quality parameters most especially during both wet and dry seasons to ascertain seasonal variations.
5. Further work on this research study should be carried out to find out if there is any technological equipment or tool that the major International Oil Companies (IOC) that flare gas installs on their gas flare stack to reduce atmospheric pollutants to barest minimum in a such a way that it does not impact on the environment.
6. Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) control system should be mounted at sampled gas flare stations. vii.) There should be installation or optimization of pollution control equipment (e.g., scrubbers, flare optimization) to reduce CO, NO_2, SO_2, and particulate emissions.

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