Uniport Journal of Engineering and Scientific Research (UJESR)

Vol. 8, Issue 1, 2023, Page 100-108
ISSN: 2616-1192

(www.ujesr.org)

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Assessment of Variation in the Concentrations of Air Quality Parameters between Seasons Around a Typical Flow Station in Imo State, Nigeria

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Abstract
This study assessed the variation in the concentrations of air quality parameters between seasons around a typical flow station in Imo State. Field measurement was carried out at ten (10) sampling points (AQ1-AQ10) and two (2) control points (AQ11 & AQ12). The pollutants of interest were Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Volatile Organic Compounds (VOCs), and Particulate matters ($PM_{2.5}$ and PM_{10}), measured every week for two months for both wet and dry seasons, using an AEROQUAL S-500 air quality meter (for SO_2, NO_2, and CO) and a pre-calibrated Suspended Particulate Matter (for $PM_{2.5}$ and PM_{10}). Results obtained showed that the concentration of pollutants within seasons (wet/dry) did not exceed WHO limits except for a few pollutants (CO, NO_2, SO_2) at locations AQ5, AQ6, and AQ7 which are the tank farm, flare stack and wellhead areas respectively with the possibility of releasing more emissions. The ANOVA carried out revealed that there was a significant difference in the concentrations of CO, SO_2, VOC, $PM_{2.5}$, and PM_{10}, and no significant difference in the concentrations of NO_2, between the wet and dry seasons. The air quality index of the study area was found to be moderate for dry and good for the wet season. Generally, the concentrations of the air quality parameters in both the control and sampling points in both seasons were relatively similar except for a few pollutants (CO, NO_2, SO_2) and sampling points (AQ5, AQ6, and AQ7).

Keywords: *Air emissions, Flow station, Air quality parameters, Environmental aspect, Imo State*

Received: 30th November, 2023 *Accepted: 31st December, 2023*

1. Introduction

Oil exploration and production activities have always had varying impacts on the natural environment across oil-producing communities around the world. Most of the impacted physical environmental components are the air, surface water, groundwater, and land resources (UNEP, 2011). Once an oil facility begins operation, several issues must be dealt with, such as spills caused during oil production and the disposal of water (produced water) and the flaring of gas (produced gas) generated alongside the oil. All these activities and their effects leave an environmental footprint (UNEP, 2011). Oil and gas operations and activities account for a huge percentage of the world's energy supply. However, the big concern is the challenge of meeting global energy needs without adversely impacting the various environmental components, especially the air (OGP, 2020). Globally, the main source of emissions into the environment comes from the production, distribution, and use of hydrocarbons as fuel or feedstock. Climate change is the most serious impact of these emissions (Havard, 2013).

Several communities in Imo State, Nigeria, play host to many oil and gas industry operators. Imo State communities are integral to the environmentally sensitive Niger Delta region. Therefore, in view of the several oil and gas flow stations and oil field operations in different parts of Imo State, there is a need for proper analysis of the air emissions from the activities and operation of flow stations in Imo State that could impact the air quality around the operating environment. Much of the population in the oil-producing areas of the Niger Delta relies on the natural environment for livelihood support and opportunities such as fishing, subsistence agriculture and associated opportunities and therefore requires good quality air to exist. For the people in oil-producing communities in Imo

State and like any other Niger Delta community, environmental quality and sustainability are fundamental to their overall well-being and development. Therefore, pollution of air, water and land poses significant risks to the health and well-being of the people.

In recent times, there have been doubts among host communities regarding the air quality around oil installations like flow stations. According to Tiwari (2015), rising industrial and other development activities have made the issue of air pollution and its associated detrimental ecological and health repercussions worse. Following concerns, worries and doubts arising from various interested parties and host community representatives on the state of their air quality in view of flow station operations, it became essential to analyze the components of air emissions as a typical environmental aspect created by flow station activities. Thus, the aim of this study was to assess the variations in the concentrations of air quality parameters between seasons around a typical flow station in Imo State, Nigeria.

2. Materials and methods

2.1 Study area

This study was conducted in and around a typical flow station in Imo State as shown in Fig. 1. The selected flow station is currently carrying out production operations and hydrocarbon processing in a marginal field in OML 16 located in Ohaji/Egbema Local Government Area of Imo State as shown in Fig 2. The field is located onshore in Imo State, about 26.5km west of Owerri with an equipped flow station having a design capacity of 15,000bopd and a current production of about 3000bopd.

The flow station is about 6km from the nearest community, and surrounded by bushes mainly used for farming by the locals. The flow station has different departments, namely the production, facility, operations, HSSE, IT and security departments. The main activity at the flow station is the separation of crude oil which comes directly from the wellhead into the separating vessels. The station is powered by both diesel and gas generators which are synchronized to automatically complement each other. The means of transportation within the facility is mainly diesel vehicles, this is because of the peculiarity of the environment which is a hydrocarbon processing area.

There are seven (7) producing wells in the field, six (6) of which are oil-producing wells and one NAG (Non-Associated Gas) well. The field receives mixtures of oil, water and gas from several wellheads flowing into its production facility (flow station). The oil field within this location in Imo State is a beehive of operational activities including a functional flow station all contributing to emissions into air. Furthermore, considering the locality harbouring the flow station as a part of the fragile and sensitive Niger Delta justifies the need to conduct this study with a view to ascertaining the probability of pollution of the air of the host community due to the operations of the flow station.

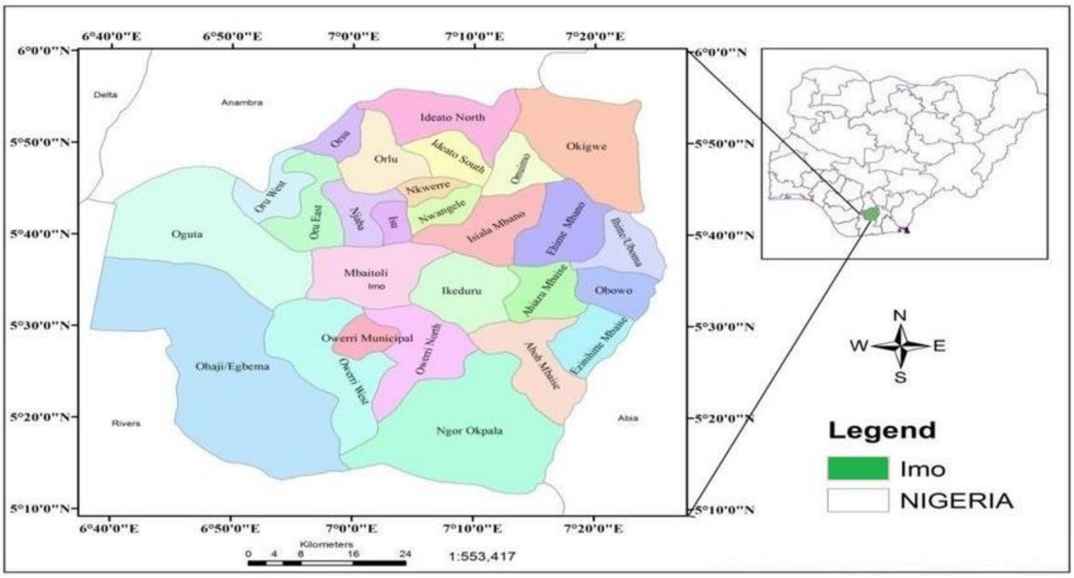

Fig. 1: Map of Imo State showing the LGAs including Ohaji/Egbema where the studied flow station is located

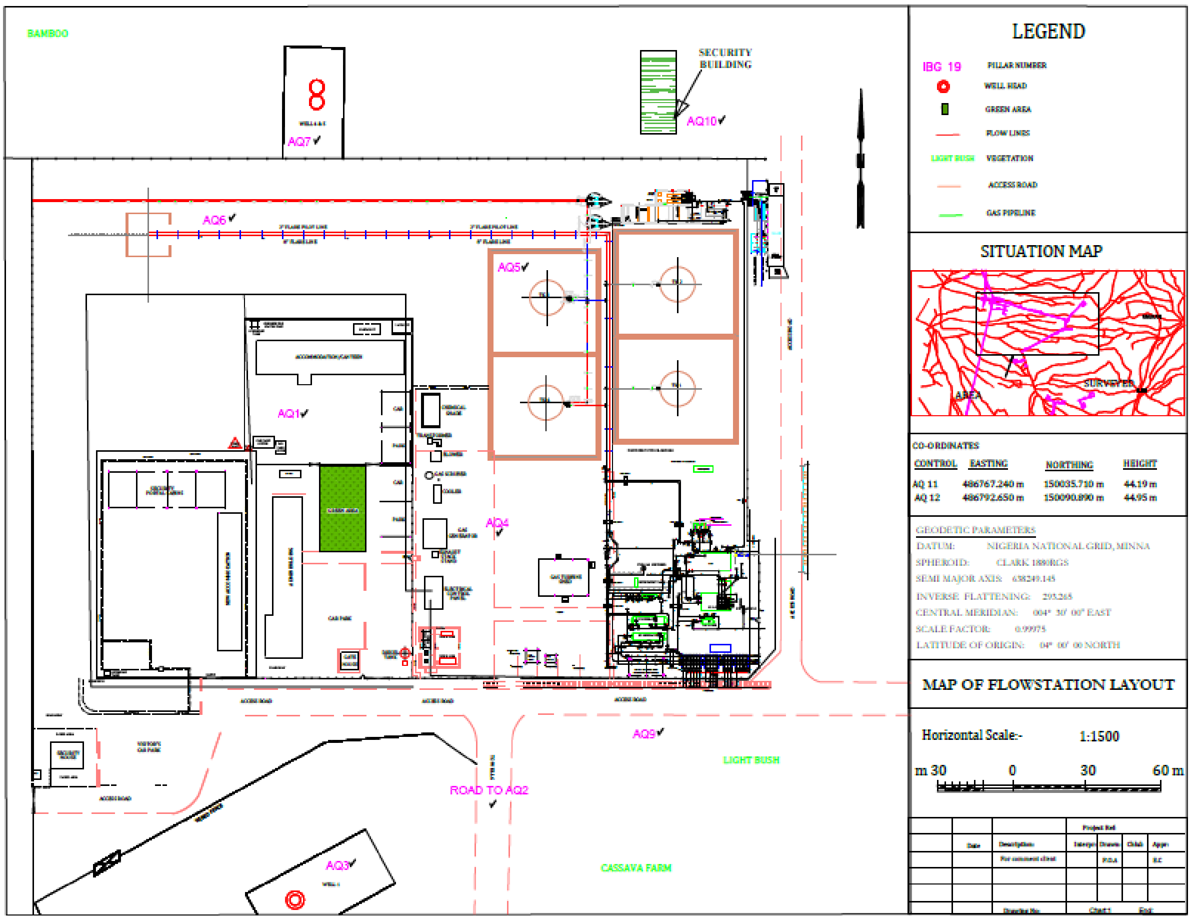

Fig. 2: Map of the studied flow station showing the sampling points

2.2 Measurement of air quality parameters

Measurements of concentrations of the air quality parameters were carried out at twelve (12) different sampling points including two (2) control points in the flow station. The choice of sampling points was made considering the prevailing wind direction. The two control points as shown in Table 1 were chosen due to their distance from the facility. The Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Volatile Organic Compounds (VOCs), were determined using an AEROQUAL S-500 air quality meter. The meter was turned on at each sampling point and values read off after the instrument had stabilized for about 3 minutes. Once a stable result was obtained, a different sensor for another air pollutant was installed, and the reading taken. Suspended particulate matters (SPM), comprising $PM_{2.5}$ and PM_{10} were determined using SPM meter. The pre-calibrated SPM meter was turned on at each sampling point for about 3 minutes and SPM values read off and recorded after the instrument had stabilized. The wind speed (m/s) and direction were determined using an anemometer and Bryotech combined wind vane. Measurements were done from the hours of 8am when operations in the facility fully kickstarts till 5pm to ensure all sampling locations are duly covered. The possible sources of emissions were noted within the facility. Measurements in each location were done once weekly.

Table 1: Sampling coordinates for air emissions/noise monitoring in the flow station

S/N	Sampling Point	Location	Geographical Coordinates	
			Northings	Eastings
1	AQ1	Old Accom.	$5^{O}21'13.9''$	$6^{O}50'23.8''$
2	AQ2	Well 6,7,8	$5^{O}21'4.5''$	$6^{O}50'23.8''$
3	AQ1	Well 1	$5^{O}21'9.1''$	$6^{O}50'23.8''$
4	AQ1	Gas Engine Generator	$5^{O}21'11.9''$	$6^{O}50'25.1''$
5	AQ5	Tank Farm	$5^{O}21'15.0''$	$6^{O}50'26.0''$
6	AQ6	Gas Flare	$5^{O}21'16.1''$	$6^{O}50'23.2''$
7	AQ7	Well 4	$5^{O}21'18.9''$	$6^{O}50'23.8''$
8	AQ8	Well 9,10,11	$5^{O}21'22.2''$	$6^{O}50'10.7''$
9	AQ9	Genesis Accom.	$5^{O}21'9.3''$	$6^{O}50'26.2''$
10	AQ10	Military Camp	$5^{O}21'17.0''$	$6^{O}50'25.8''$
11	AQ11	Military Check Point	$5^{O}20'23.9''$	$6^{O}48'59.5''$
12	AQ12	Along Opete Road	$5^{O}20'37.0''$	$6^{O}49'22.7''$

AQ1 – AQ10 – Monitoring points; AQ11 – AQ12 – Control points

2.3 Air quality index calculation

The air quality index (AQI) of each measured air pollutant was calculated using Equation (1). The results were compared between the seasons (wet and dry).

$$AQI = \left[\frac{(AQI_{max} - AQI_{min}) \times (P_{meas} - P_{min})}{(P_{max} - P_{min})}\right] + AQI_{min} \quad (1)$$

where AQI_{max} is the maximum AQI value for colour category corresponding to P_{meas}, AQI_{min} is the minimum AQI value for colour category corresponding to P_{meas}, P_{meas} is the measured average concentration of pollutant, P_{max} is the maximum concentration AQI colour category containing P_{meas}, and P_{min} is the minimum concentration AQI colour category containing P_{meas}.

2.4 Statistical analysis

The data obtained were analysed using descriptive and inferential statistics. Inferential statistics such as ANOVA was used to determine if there is any significant difference between the concentrations of air emissions / air quality parameters measured between the seasons (dry and wet).

3. Results and discussion

3.1 Concentrations of air quality parameters for dry and wet seasons

Fig. 3 shows the average concentrations of NO_2 for dry and wet seasons. Generally, the dry season concentrations had higher values (0.055 - 0.001ppm) when compared to the wet season concentrations (0.014 -0.001ppm). The same trend applies to the control locations (AQ11 and AQ12). When compared with the WHO standard (0.012ppm), the dry season concentrations exceeded the WHO standard at more sampling locations than the wet season concentrations. The highest concentration was recorded during the dry season at location AQ1. This location is where the flow station old accommodation building is located and about 15meters behind it is the flare stack. The possible explanation to the high concentration of NO_2 is the closeness of the old accommodation building to the flare stack. The lowest reading obtained was during the wet season at locations AQ3, AQ8, AQ9 and control points AQ11 and AQ12. These locations are the wellhead area and genesis accommodation area which are a bit distant from the flow station. NO_2 is hazardous to human health and the environment when permissible limits are exceeded. Excessive levels of NO_2 can decrease the strength of textiles, discolour fabrics and corrode metal surfaces.

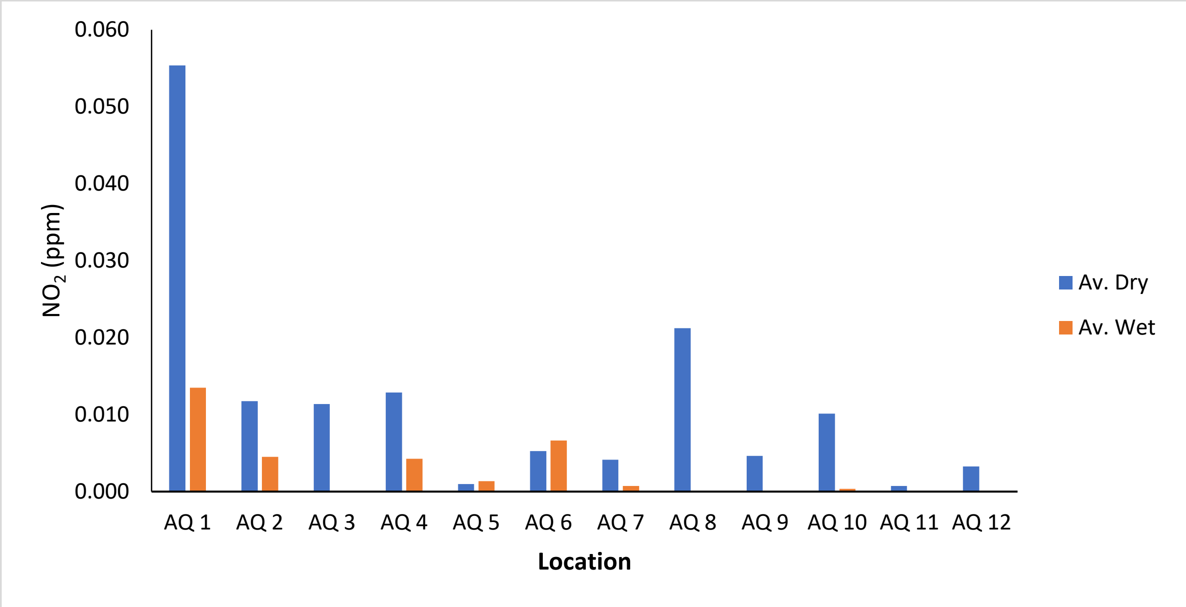

Fig. 3: Dry and wet season concentrations of NO_2 in the studied area

Fig. 4 shows the average concentrations of SO_2 for dry and wet seasons. Generally, the dry season had higher concentrations (0.050 - 0.005ppm) than the wet season values (0.001 - 0.00ppm). However, no difference in concentrations between seasons was observed at the control locations (AQ11 and AQ12). While the concentrations at four of the locations (AQ1, AQ6, AQ7 and AQ10) exceeded the WHO standard (0.014ppm) in the dry season, the concentrations at all locations were below the standard in the wet season. The highest concentration was recorded during the dry season at location AQ6. This location is where the flow station flare stack is installed and functioning, and this explains the reason for the high concentration of SO_2 at the location. The lowest concentrations were obtained in the wet season at locations AQ3, AQ8, AQ9 and control points (AQ11 and AQ12). These locations are the wellhead area and accommodation. The possible explanation for this would be that at the time of this study, the wellheads were shut-in either for well optimization or maintenance. Also, the concentrations in the wet season may have been diluted by rainfalls hence the recorded lower concentrations. SO_2 is a pungent, colourless and irritating gas, produced from fossil fuel combustion and oil and gas production platforms. Health effects associated with SO_2 include bronchitis, asthma and other respiratory irritation and disorders. SO_2 can damage plant cells by interfering with the green colouring pigment (stomata) and chlorophyll synthesis process. In the atmosphere, SO_2 mixes with water vapour to produce acid rains (EPA, 1995).

Fig. 5 shows the average concentrations of CO for dry and wet seasons. Generally, the dry season had higher concentrations (4.606 - 0.00ppm) than the wet season concentrations (0.105 - 0.00ppm). Similar trend was observed at the control locations (AQ11 and AQ12). When compared with the WHO standard (0.003ppm), the dry season concentrations exceeded the standard at more sampling locations than the wet season concentrations. The highest concentration was recorded during the dry season at location AQ10 which is the military camp area. This high concentration could be due to the military operation vehicles that constantly transits around the camp. The lowest concentration was obtained in the wet season at locations AQ1 which is the old accommodation building. CO is a colourless, odourless and poisonous gas produced by the incomplete combustion of fossil. CO impairs the oxygen-carrying capacity of the blood at higher concentrations, owing to its high affinity for haemoglobin which is the component of the blood for the transportation of oxygen.

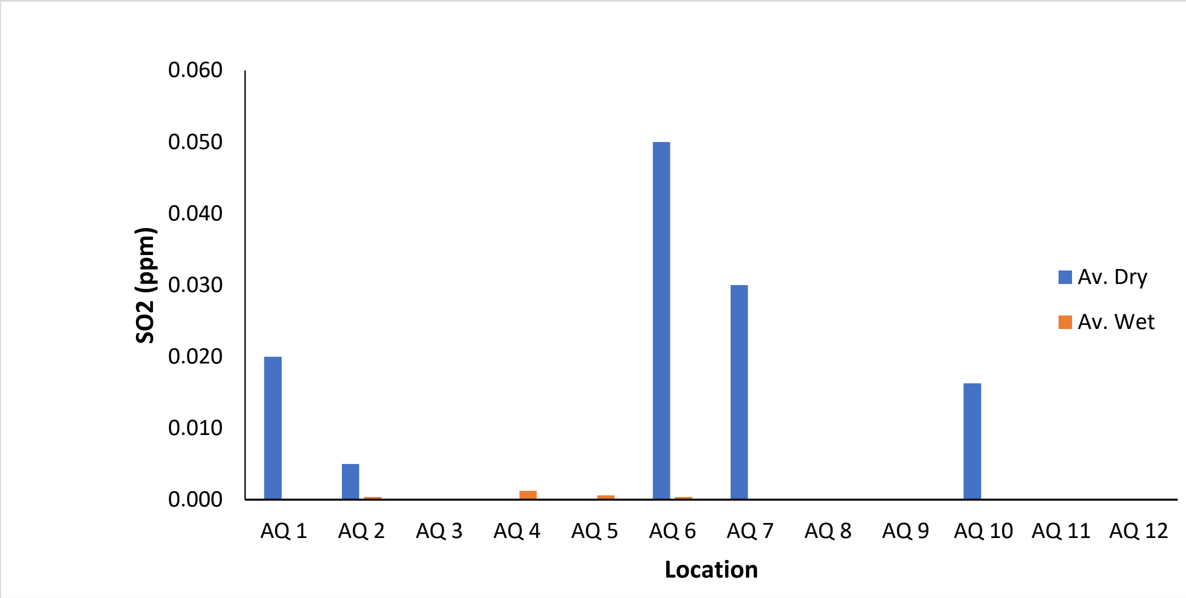

Fig. 4: Dry and wet season concentrations of SO_2 in the studied area

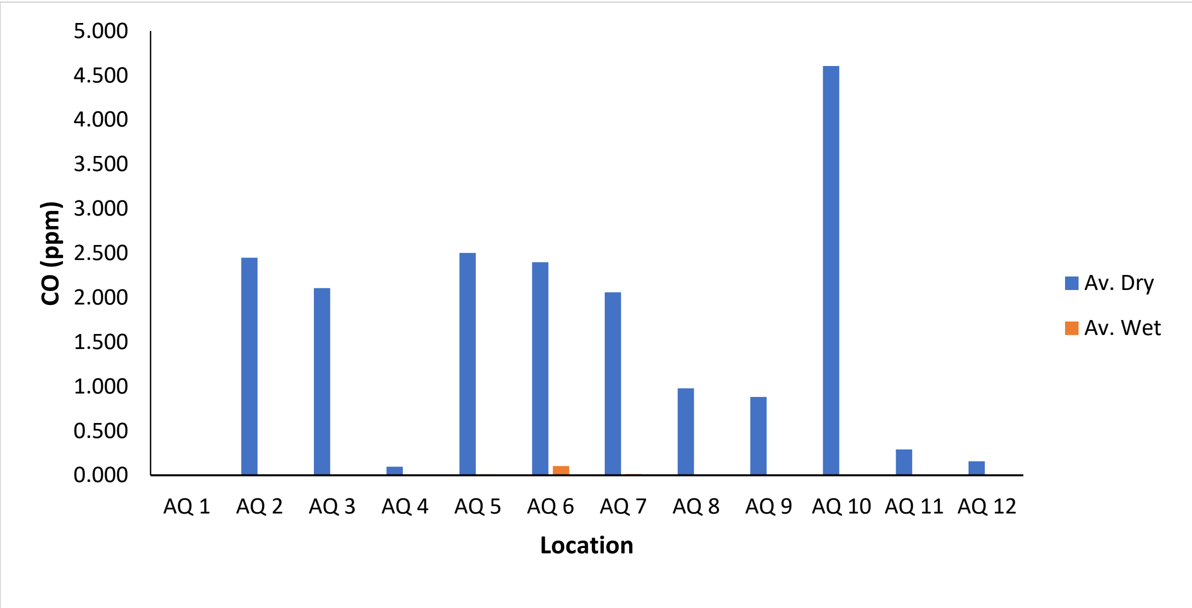

Fig. 5: Comparison of dry and wet season concentrations of CO in the studied area

Fig. 6 shows the comparison of dry and wet season average concentrations of VOC. The average concentrations of VOC in the dry season across the sampling locations (AQ1 to AQ10) ranged from 3.850 to 8.350 ppm, while the wet season concentrations ranged from 1.763 to 2.388ppm. Generally, the average concentrations in the dry season were higher than those of the wet season concentrations. More so, the dry season concentrations were above those of the control locations (AQ11 and AQ12) while the wet season concentrations were below those of the control locations. When compared with the WHO standard (0.00ppm), both the dry and wet seasons concentrations exceeded the regulatory limit. The highest value obtained was at location AQ2 which is at well head 6,7&8 locations. At this well head location, chemical injection process is continuously ongoing to help break the emulsion from the well, this could explain the reason for the high value of the VOC recorded. The lowest value was obtained at AQ8 and control points AQ11 and AQ12. Location AQ8 contains well head 9,10 and 11 locations. Both well 9 and 10 do not require chemical injection as they flow naturally, and well 11 is a water re-injection well.

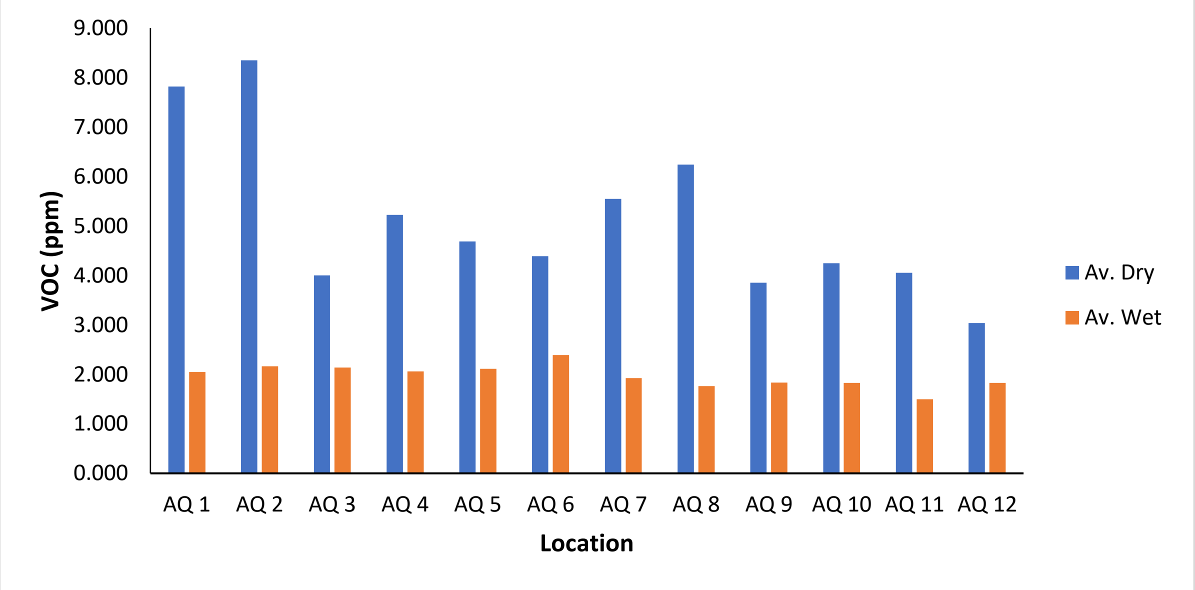

Fig. 6: Comparison of dry and wet season concentrations of VOC in the studied area

The comparison of dry and wet season average concentrations of $PM_{2.5}$ is presented in Fig 7. The average concentrations of $PM_{2.5}$ in the dry season across the sampling locations (AQ1 - AQ10) ranged from 0.028 to 0.0466 μg/m^3, while the wet season concentrations ranged from 0.00 to 0.0105 μg/m^3. Generally, the average concentrations in the dry season were higher than those of the wet season concentrations. $PM_{2.5}$ has the highest concentration at location AQ6 which is the area of the flare stack. This high value can be attributed to emission for gas flaring activity around that area. However, the high values recorded for both wet and dry seasons are within the WHO regulatory limits of 15 μg/m^3. The lowest value recorded for $PM_{2.5}$ was at the control points (AQ11 and AQ12).

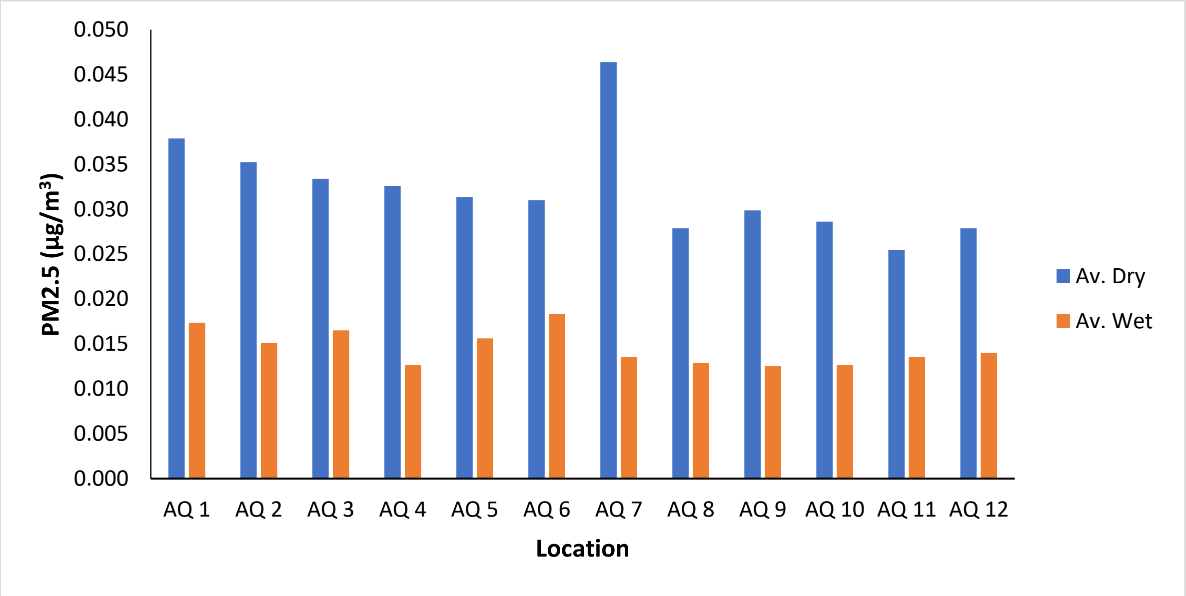

Fig. 7: Comparison of dry and wet season concentrations of $PM_{2.5}$ in the studied area

Fig. 8 shows the comparison of dry and wet season concentrations of PM_{10}. The average concentrations of PM_{10} in the dry season across the sampling locations (AQ1 - AQ10) ranged from 0.063 to 0.087 μg/m^3, while the wet season concentrations ranged from 0.016 to 0.023 μg/m^3. Generally, the average concentrations in the dry season were higher than those of the wet season concentrations. $PM_{2.5}$ and PM_{10} have the highest concentration at location AQ6 which is the area of the flare stack. This high value can be attributed to emission for gas flaring activity around that area. However, the high values recorded for both wet and dry seasons are within the WHO regulatory limits of 45 µg/m^3. The lowest value recorded for PM_{10} was at the control points (AQ11 and AQ12).

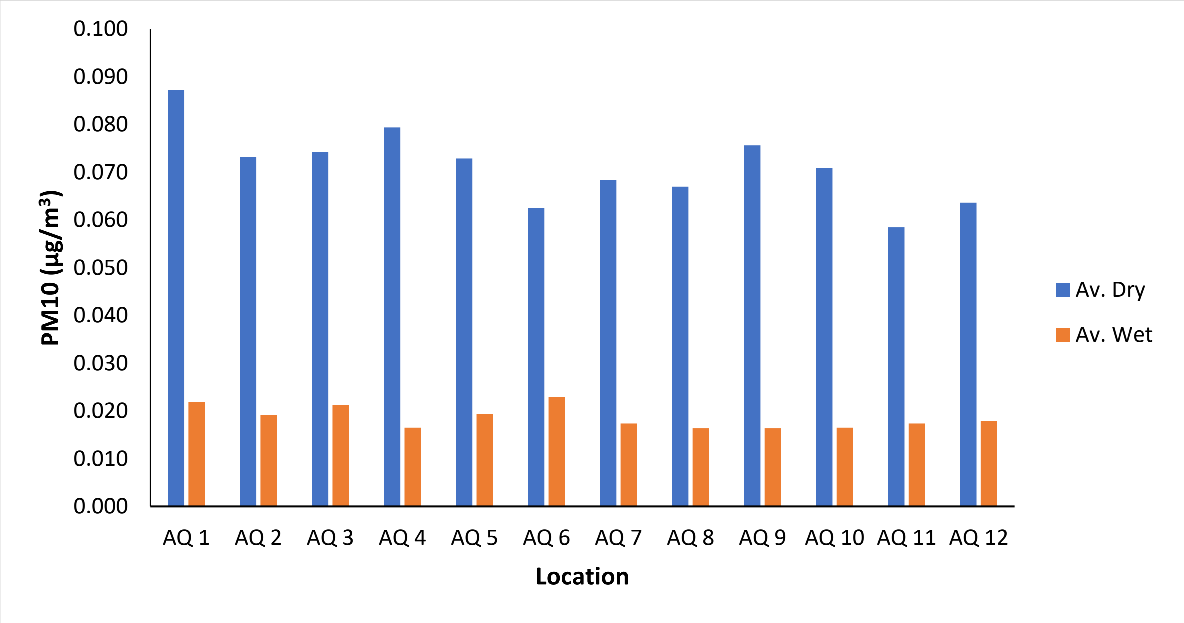

Fig. 8: Comparison of dry and wet season concentrations of PM_{10} in the studied area

3.2 Statistical analysis

ANOVA was used to determine if there is any significant difference between the concentrations of selected air quality parameters measured within and between dry and wet seasons. The ANOVA output of NO_2 concentrations within dry season gave p-value (0.48) > α (0.05), indicating that there no significant difference between NO_2 concentrations within dry season. However, the ANOVA outputs of SO_2, CO, VOC, $PM_{2.5}$ and PM_{10} concentrations within dry season gave p-values less than α-value, suggesting that there is a significant difference between SO_2, CO, VOC, $PM_{2.5}$ and PM_{10} concentrations within dry season. The ANOVA outputs of NO_2, SO_2, CO, $PM_{2.5}$ and PM_{10} concentrations within dry season gave p-values greater than α-value, signifying that there no significant difference between NO_2, SO_2, CO, $PM_{2.5}$ and PM_{10} concentrations within wet season. However, ANOVA output of VOC concentrations within wet season gave p-value (2.93E-05) < α (0.05) which implies that there is a significant difference between VOC concentrations within wet season. The ANOVA output of NO_2 concentrations between dry and wet seasons gave p-value (0.052) > α (0.05), inferring that there no significant difference among NO_2 concentrations between dry and wet seasons. However, the ANOVA outputs of SO_2, CO, VOC, $PM_{2.5}$ and PM_{10} concentrations between dry and wet seasons gave p-values less than α-value, implying that there is a significant difference among SO_2, CO, VOC, $PM_{2.5}$ and PM_{10} concentrations between dry and wet seasons.

4. Conclusion

The assessment of the variation in the concentrations of air quality parameters within and between the dry and wet seasons around a typical flow station in Imo State has been conducted. The activities of the flow station impacted the concentration of the air quality parameters. This impact was more in the dry season than in the wet season. Rainfall during the wet season is believed to have diluted the concentrations of the air quality parameters hence the general lower concentrations observed in the wet season compared to the concentrations in the dry season. Therefore, it is suggested that the operators of the flow station should step up their mitigation strategy to reduce the impact of their operation on the air environment.

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