

Atmospheric Properties and Their Observable Correlations with Volatile Organic Compounds Emission Concentration at Some Gas Stations in Port Harcourt City

Robert James J.^{1*}, Nwamadi Cornelius I.¹ & Igbo Nkechinyere²

¹Department of Physics, Ignatius Ajuru University of Education, Rumuolumeni, Port-Harcourt, Nigeria.

²School of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi state, Nigeria.

Corresponding Author (Robert James J.) Email: robert.james@iaue.edu.ng*



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ABSTRACT

This study focused on atmospheric properties and their observable correlations with volatile organic compounds (VOCs). Six gas stations and the nearest residential buildings within Port Harcourt City were selected for the study. At each of the gas stations and the nearest buildings, a well calibrated handheld IGERESS VOCs detector was positioned 1.5m above the ground and in the direction of the wind to determine the levels of VOCs concentration. Atmospheric Properties (temperature and relative humidity) of the selected gas stations and the nearest buildings were determined accordingly. These were done in the morning and evening hours for a period of two weeks. The study's findings revealed gas stations emit VOCs and that the VOCs emission concentrations in the morning and evening sessions were within safe limits. But the measured mean VOCs concentration at the gas station (0.343ppm) is above the United States Environmental Protection Agency (USEPA) maximum allowable air concentration Standard of 0.20 ppm. The recorded mean value of the VOCs concentration at the gas stations (0.343ppm) shows that the average exposure limit from the gas stations for the period under study is in agreement with the permissible limits of between 0.3 ppm to 0.5ppm established by World Health Organization (WHO) and the National Institute of Occupational Safety and Health (NIOSH) respectively. The calculated correlation values between VOCs concentration and temperature at the gas stations and nearest buildings are 0.0020 (weak positive correlation) and -0.0111 (negative correlation) respectively. Similarly, VOCs concentration showed a negative correlation with the relative humidity at the gas stations and the nearest residential buildings. The calculated correlation values are -0.1952 and -0.7257, respectively. These results are in agreement with some studies. A number of studies have shown that VOCs emissions are positively correlated with temperature, but that of relative humidity has no uniform conclusions. Volatile organic compounds (VOCs) pose numerous health challenges and serious environmental concerns such as poor air quality and shift in climate. Siting of gas stations far away from residential areas and the use of fuel recovery pumps are essential for the reduction of the impacts of VOCs on humans and the environment.

Keywords: Atmospheric properties; Volatile organic compound; Gas stations.

Introduction

The arbitrary siting of multiple gas stations close to residential areas in major cities in Nigeria and Port Harcourt city in particular, is quite worrisome. The situation is not going to be abated anytime soon because of the increasing population and new entrants into oil and gas business in Nigeria. Emissions from places such as gas stations are the major sources of air pollution of which Volatile organic compounds (VOCs) are part of it.

In Nigeria, there are no stringent laws to effectively control arbitrary location of gas stations and mandatory use of fuel recovery pumps at every gas station. This, no doubt, has a far reaching consequences on human health and the environment. Oil and gas industry emit dangerous toxic substances such as benzene, ethyl-benzene, and n-hexane, formaldehyde, toluene etc, commonly called volatile organic compounds (VOCs) into the environment. There are many sources of VOCs, but a considerable impact on indoor and outdoor environments in terms of VOC emissions is largely due to human activities (Na et al., 2005; Zalel and Broday, 2008).

The release of VOCs into the environment is as a result of the production, transportation, and use of fossil fuels (Atkinson and Arey, 2003). "Volatile organic compounds (VOCs) are a significant category of atmospheric pollutants, commonly found in urban and industrial areas" (Okuo et al., 2012). According to David & Niculescu (2021) "volatile organic compounds (VOCs) are organic chemical compounds found in various products that easily vaporize and reach in the environment under normal conditions".

Effects of VOCs on Human's Health and the Environment

Volatile organic compounds (VOCs) pose numerous health challenges and serious environmental concerns such as poor air quality and shift in climate. Prolonged exposure to VOCs can be fatal (Elena et al., 2021). A number of studies have shown that cardiovascular and respiratory diseases are largely associated with individual VOCs (Singh et al., 2023). Oxidation of VOCs results in plentiful production of organic acids, which in turn initiates aerosol nucleation (Guo et al., 2020). Studies have shown that "global warming has a significant and increasing impact on VOCs emissions" (Xihe et al., 2023). Most VOCs absorb infrared radiation from the earth's surface thereby making them direct contributors to global warming (David & Niculescu 2021). Organic vapours have been identified as the major cause of particle growth in the environment (Yli-Juuti et al., 2020).

VOCs, in combination with oxides of nitrogen, produce ground-level ozone (O_3) which is one of the major greenhouse gases that cause shifts in global climate (Manisalidis et al., 2020). Smog created by VOCs reduces visibility (National Geographic, 2022). This can in turn affect airline flight operations. "Their increased concentration in the atmosphere has been linked to global warming" (Murrells et al., 2007). Some VOCs are greenhouse gases and therefore exhibit the capacity to absorb emitted energy from the Earth (Lelieveld et al., 2009).

Effects of Atmospheric Properties (Relative Humidity and Temperature) On Emission Levels of VOCs

The emission of VOCs and formaldehyde can be influenced by various factors such as temperature and relative humidity (Cheng et al., 2022). Chuloh et al. (2022) reported that an increase in humidity tends to increase the level of VOCs concentrations. According to the findings of Zhou et al. (2019), an increase in relative humidity enhances the release of VOCs. But some other studies have shown that relative humidity does not always yield positive correlation with VOCs emissions (Huang et al., 2016).

A study conducted by Lee and Kim (2012) showed that temperature has a considerable effect on emission of VOCs from the tested wooden flooring materials. Corsi et al. (2009) posited that higher indoor temperatures increases VOC emission due to increased diffusion and evaporation from the tested material surface. Increase in temperature also promote the rapid biosynthesis and diffusion of VOCs from the tissues of plants (Rinnan et al., 2020).

Materials and Methods

Study Area: The study area is Port Harcourt city. Its coordinates are $4^{\circ} 47' 21''$ North and $6^{\circ} 59' 55''$ East, and has an elevation of 52ft above sea level. It is the capital of the oil-rich state called Rivers state and one of the coastal cities in Nigeria. Port Harcourt is the oil and gas capital city of Nigeria. The city plays host to many multinational companies, and is one of the most densely populated states in Nigeria. It has an average temperature of $26^{\circ}C$, and annual precipitation of about 2919 mm.

Materials: The materials employed in this study include VOCs monitor, measuring tape, stop watch, digital thermometer, digital hygrometer, and global positioning system (GPS).

Methods: Six (6) locations were considered, consisting of six (6) gas stations within Port Harcourt City. At each of the gas stations and the nearest buildings, a well calibrated handheld IGERESS VOCs detector was on and

positioned 1.5m above the ground and in the direction of the wind to determine the levels of VOCs concentration. Atmospheric variables of the selected gas stations and the nearest buildings were read and recorded accordingly. These were done morning and evening for a period of two weeks.

Results and Discussions

Table 1. The Global Positions of the Selected Gas Stations and The Nearest Buildings Investigated for Volatile Organic Compounds (VOCs)

Location	GPS Readings			
	Gas Stations Coordinates		Nearest Residential Buildings	
	North	East	North	East
East west road	04 ⁰ 49' 14"	06 ⁰ 58'. 57"	04 ⁰ 49'. 12"	06 ⁰ 58'. 54"
Iwofe road	04 ⁰ 48'. 52"	06 ⁰ 56'. 94"	04 ⁰ 48'. 50"	06 ⁰ 56'. 90"
Aba road	04 ⁰ 45'. 49"	06 ⁰ 58'. 64"	04 ⁰ 45'. 47"	06 ⁰ 58'. 61"
Ikwerre road	04 ⁰ 47'. 52"	06 ⁰ 57'. 24"	04 ⁰ 47'. 51"	06 ⁰ 57'. 20"
PH Town	04 ⁰ 46'. 57"	07 ⁰ 54'. 05"	04 ⁰ 46'. 55"	07 ⁰ 54'. 04"
Trans Amadi	04 ⁰ 44'. 49"	06 ⁰ 55'. 84"	04 ⁰ 44'. 48"	06 ⁰ 55'. 82"

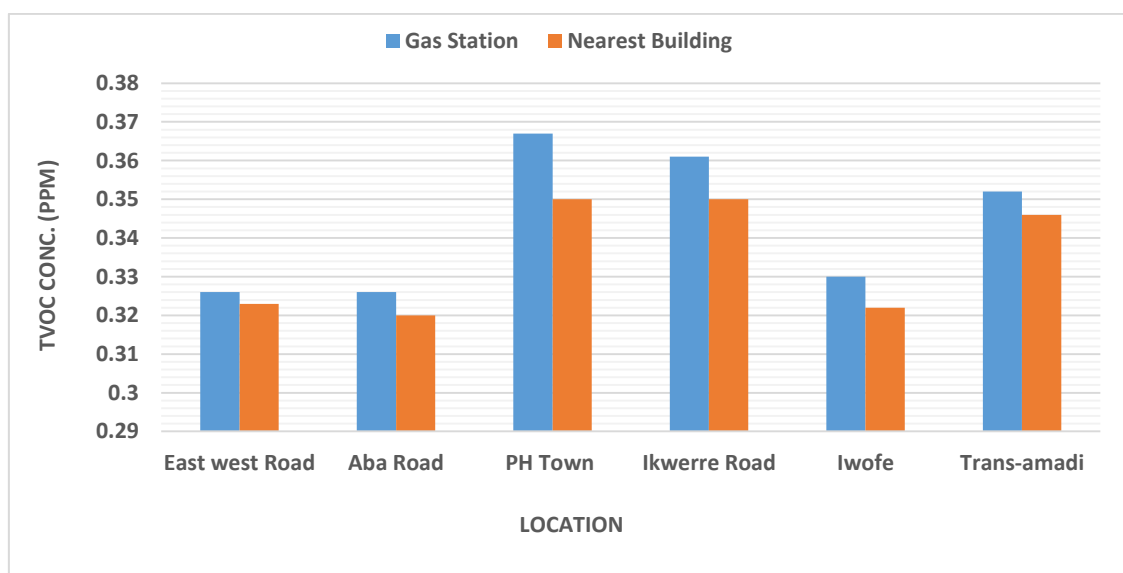


Figure 1. Mean concentrations of the volatile organic compound (VOC) at the selected gas stations and the nearest residential buildings

Figure 1 shows the volatile organic compound mean concentrations at the selected gas stations and the nearest residential buildings. At East West road gas station, for the period under study, the minimum VOCs concentration recorded was 0.324ppm, and maximum concentration was 0.329ppm. While for the nearest residential building, a minimum concentration value of 0.320ppm was recorded and the maximum concentration was 0.326ppm. From

figure 1, the mean concentration VOCs levels for the gas station at East West road and the nearest residential building are 0.326ppm 0.323ppm respectively. At Aba road gas station, the minimum VOCs concentration recorded was 0.324ppm and its maximum concentration was 0.329ppm. While the minimum VOCs concentration of the nearest building was 0.315ppm and the maximum concentration was 0.326ppm. The mean VOCs concentrations at the gas station and the nearest residential building as shown in figure 1 are 0.326 and 0.320ppm respectively. At Port Harcourt (PH) Township gas station, the minimum VOCs concentration recorded was 0.362 ppm, maximum concentration (0.370ppm). While for the nearest residential building, a minimum concentration value of 0.348ppm was recorded and the maximum concentration was 0.352ppm.

In figure 1, the mean VOCs concentration levels for Port Harcourt (PH) Township gas station and the nearest residential building for the period under study are 0.367ppm 0.350ppm respectively. Similarly, Ikwerre road had a minimum VOCs concentration of 0.355ppm and maximum concentration of 0.366ppm. The nearest residential building had a maximum of 0.351ppm and a minimum concentration of 0.348ppm.

The mean VOCs concentration at Ikwerre road gas station and the nearest residential building as indicated in figure 1 are 0.361ppm and 0.350ppm respectively. At Iwofe, the minimum VOCs concentration was 0.328ppm and its maximum concentration was 0.333ppm. While the minimum VOCs concentration recorded at the nearest residential building was 0.318ppm and the maximum VOCs concentration was 0.328ppm. The mean concentration levels at Ikwerre road gas station and the nearest residential building as shown in figure 1 are. 0.346ppm and 0.350ppm respectively.

Finally, Trans-amadi, the minimum VOCs concentration was 0.346ppm and its maximum concentration was 0.357ppm. While the minimum VOCs concentration at the nearest building was 0.341ppm and the maximum concentration was 0.350ppm. The mean VOCs concentrations at the gas station and the nearest building for the period under study as shown in figure 1 are 0.352ppm and 0.346ppm.

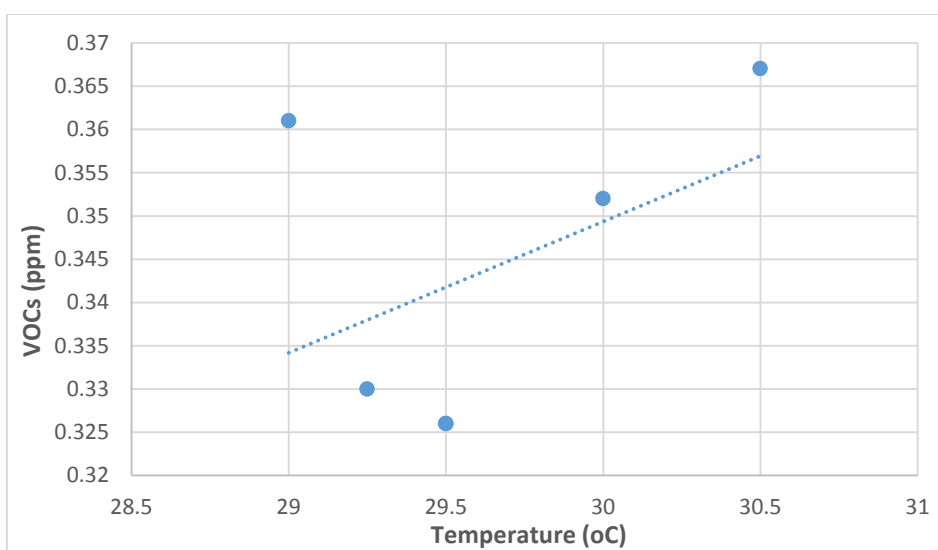


Figure 2. Scattered plot of VOCs concentration and temperature at the Gas stations

Figures 2, 3, 4, and 5 are scatter plots showing the relationship between the VOCs concentration and atmospheric properties (temperature and relative humidity).

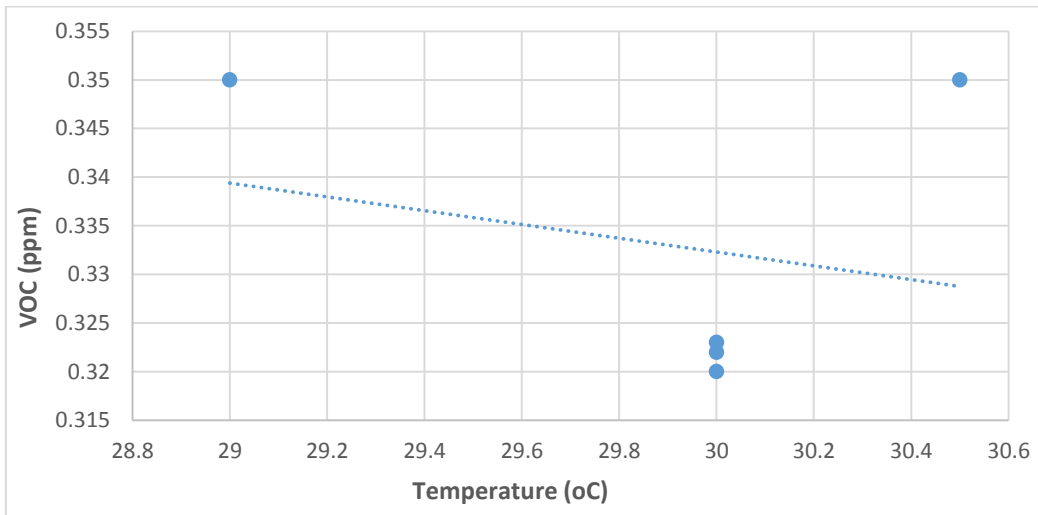


Figure 3. Scattered plot of VOCs and temperature at the nearest buildings

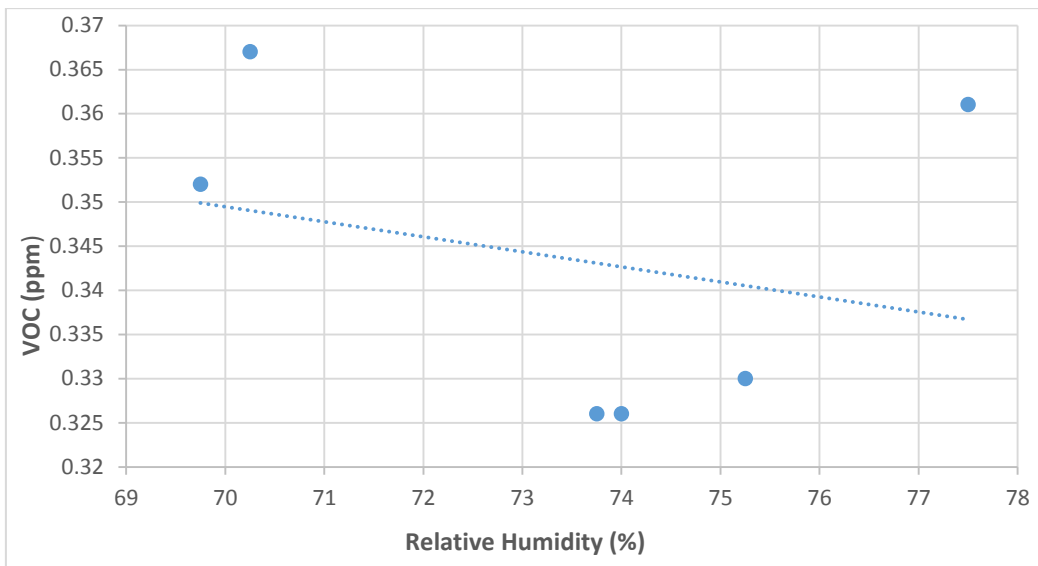


Figure 4. Scattered plot of VOCs concentration and Relative humidity at the gas stations

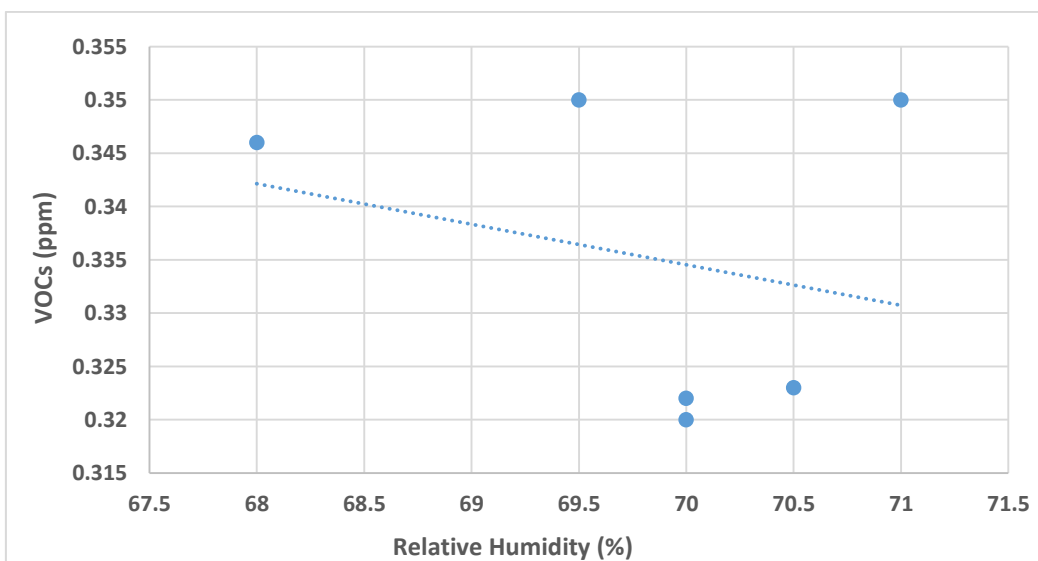


Figure 5. Scattered plot of VOCs and relative humidity at the nearest buildings

In figure 2, the observed VOCs concentration shows a positive correlation with the atmospheric property (temperature) while in figure 3, the observed VOCs concentration has a negative correlation with temperature at the nearest buildings. The calculated correlation values for both cases are 0.0020 (weak positive correlation) and -0.0111 (negative correlation) respectively.

In figures 4 and 5, the observed VOCs concentration has a negative correlation with the observed atmospheric property (relative humidity) at both gas stations and the nearest residential buildings. The calculated correlation values are -0.1952 and -0.7257 respectively.

A number of studies have shown how VOCs emissions were positively correlated with temperature, but that of relative humidity has no uniform conclusions on how it affects VOCs emissions (Shao et al., 2021).

Conclusion

The study's findings revealed that gas stations emit VOCs and that the VOC emission concentrations in the morning and evening sessions for the period under study were within the safe limits established by Occupational Safety and Health Administration (OSHA) of 0.75 ppm. But the measured mean VOC concentration at the gas stations (0.343ppm) is above the United States Environmental Protection Agency (USEPA) maximum allowable air concentration Standard of 0.20 ppm. More so, VOCs emission concentrations at the selected gas stations were generally higher than that at the nearest buildings. This could be attributed to the fact that emission level decreases as the distance between the VOCs emission source and the point of determination of VOCs concentration levels increases.

Declarations

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Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

All the authors took part in literature review, research, and manuscript writing equally.

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