Impact of Human Activities on the Carbon Monoxide Levels in Port Harcourt Metropolis: A Rare Experience with Covid-19 Lockdown

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ABSTRACT

This study was conducted to monitor the impact of human activities on the air quality of Port Harcourt Metropolis, during and after the Covid-19 Lockdown period where human activities were brought to an all-time low. Ten selected locations, evenly distributed around Port Harcourt Metropolis were studied while Rivers State University served as the Control Site. The meteorological parameters studied alongside carbon monoxide were atmospheric temperature, relative humidity, wind speed, and wind direction. Standard methods were applied in capturing data in-situ, using hand-held devices. Data were collected for six months capturing rainy and dry season months and the lockdown periods. Air Quality Indices were also calculated for CO. The results obtained reveal that meteorological data gathered were characteristic of the study area. The values of carbon monoxide were higher in the Sampling Sites with a mean range of (0.632 – 3.291) ppm in the rainy season and (0.422 – 9.037) ppm in the dry season) than in the Control Site with a mean of (0.133 ppm in the rainy season and 0.493 ppm in the dry season). The level of CO was higher in the dry season as compared to the rainy season. There was strong positive correlation with respect to carbon monoxide amongst sampling locations with similar human activities. The correlation of the sampling locations with the Control Site were mostly weak. A reduction of the concentrations of carbon monoxide was recorded during the Covid-19 Lockdown periods. The AQI values indicate that the air quality was categorized as good with respect to carbon monoxide in the lockdown periods and was between moderate to unhealthy in the non-lockdown periods. It is clearly evident that air quality is a function of the level of human activities, especially those that result in the emission of noxious air pollutants. It is recommended that the air quality be put under regular monitoring in order to regulate the human activities that can impact on the air quality.

Keywords: Air Quality, Covid-19 Lockdown, Human Activities.

I. INTRODUCTION

Air pollution can be defined as a situation in which substances are present in the atmosphere at concentrations sufficiently higher than their normal ambient levels to produce a measurable and undesirable effect on humans, animals, soil, vegetation, or materials [1]. The concentrations of pollutants in the atmosphere are a measure of air quality.

There has been a challenge of poor air quality, especially in the urban cities worldwide [2]–[4]. This is mainly attributed to industrialization and increase in population with its associated activities that lead to the emission of pollutants into ambient atmosphere. Some of these pollutants are oxides of sulphur (SO₃), oxides of nitrogen (NOₓ) and also carbon monoxide (CO). Meteorological data, due to their strong influence on the spatio-temporal distribution of airborne pollutants, are considerable factors in air quality. These meteorological data include atmospheric temperature, relative humidity, wind speed and wind direction.

Sources of air pollutants can be classified into two major categories, natural sources and anthropogenic sources. Natural sources can be dust from large areas of land not covered by vegetation; methane gas is emitted from digestive tracts of animals and also from methanogenic organisms found in marshes, smoke and carbon monoxide generated from wildfires are also considered as natural sources. Significant amounts of volatile organic compounds in some regions are also emitted by vegetation such as black gum, poplar, oak and willow vegetation. Nature, however, exists in equilibrium and can manage natural sources of pollution with little or no adverse effects [5]–[8]. It is the extra activities of man that generate pollutants that are causes of imbalance in the natural equilibrium, thereby causing harmful effects. Anthropogenic sources include paints and varnishes, fossil

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fuel power stations, factories, waste incinerators, furnaces, and combustion engines.

The health effects of air pollution are mainly respiratory problems. Air pollutants can cause respiratory illnesses and allergies ranging from cough to asthma and cancers [9]–[12]. Carbon monoxide is an odourless, colourless, and poisonous gas emitted into the atmosphere principally from the exhaust of motor vehicles and other kinds of engines. It is formed whenever there is an incomplete combustion of fossil fuel or carbonaceous materials. Exposure to concentrations of 1000 parts per million produce symptoms of breathing difficulties and headaches. Exposure to concentrations of 1,000 parts per million can be fatal [13]. Carbon monoxide is also notorious in causing suffocation and eventual death by using up oxygen carriers in the blood through the formation of carboxyhaemoglobin [14].

In December 2019, in the city of Wuhan, China, an outbreak of a viral infection named Corona Virus Disease 2019 (Covid-19) was reported as an epidemic, which has since grown out of proportion into a pandemic [15]. It has taken a lot of lives and has created panic situations, which have led various governments to institute control measures of which lockdowns to restrict movements is one.

Lockdowns result in drastic reductions of activities that emit potential air pollutants into the atmosphere. Principal among these is the reduction of automobile emissions and combustion of fossil fuels due to restricted movements and shutdown of industrial activities.

A major study was conducted on assessing the air quality status across ten cities in the world: Delhi and Mumbai in India, London, Madrid and Rome in Europe, Los Angeles and New York City in North America, Sao Paulo in South America and Seoul and Wuhan in Asia. Findings revealed that there was improvement in the air quality statuses of these major cities during the Covid-19 lockdown periods. The aim of this research is to determine the impact of human activities (industrial and vehicular emissions) on the Ambient Air Quality Status with respect to carbon monoxide in Port Harcourt Metropolis.

II. METHODOLOGY

The description of the study area, methods of sampling, data capture and methods of statistical and data analysis are presented in subsections below.

A. Study Area

The sampling stations are located within Port Harcourt metropolis, ranging from Oil Mill Junction to Borikiri as illustrated in the Map of the Study Area (Fig. 1).

Port Harcourt is the capital city of Rivers State and a hub of industrial activities in Nigeria. It is located in the Niger Delta of the Southern Nigeria. The study area lies within latitudes 4° 45’ 00” N and 4° 52’ 00” N and longitudes 6° 57’ 30” E and 7° 06’ 30” E. The metropolis stretches from Diobu axis in the North to the Borikiri axis in the South and from Rumuola axis in the West to Trans-Amadi axis in the East. The entire Port Harcourt city is an area of about 1800 km² with a population of about 2 million.

The climate of Port Harcourt city is typically tropical. It features a short dry season from November to March and a rainy season from April to October. The range of monthly rainfall is between 20.7 and 434.0 mm, with a yearly level in excess of 3000 mm [16]. Although it rains throughout the year, November to February is its lowest rainfall period while on average, December and January are the driest months of the year. Rainfall gradually increases from February to June when it experiences the first peak, which is followed by the second peak in September. Throughout the year in the metropolis, temperature is relatively constant, showing little variation. Temperatures are typically between 20.2–36.7 °C [17].
B. Sampling and Determination of Air Quality Parameters

The sampling stations and the geographical coordinates of the sampling points are stated in Table I. Sampling was carried out once per month per location, in the months of May (19th and 20th, 2020) which was the lockdown period, August (7th and 12th, 2020), September (10th and 11th, 2020) and October 8th and 9th, 2020, representing the rainy season; November (11th and 12th, 2020) and December (17th and 18th, 2020) representing the dry season.

Calibrated and power charged portable handheld electronic devices and meters used to capture the air quality parameters are as stated in Table II.

The devices were positioned at least 1m above the ground level and held against the prevailing wind direction before taking the readings. The readings were taken in triplicates and the averages recorded.

C. Air Quality Index

Air Quality Index (AQI) which is the measure of how polluted the air is with respect to carbon monoxide, was determined by Equation (1) [18].

\[
AQI = \left( \frac{I_{\text{high}} - I_{\text{low}}}{C_{\text{high}} - C_{\text{low}}} \right) x (C - C_{\text{low}}) + I_{\text{low}} \tag{1}
\]

Where AQI = Air Quality Index  
\( C = \) The Average Pollutant Concentration  
\( C_{\text{low}} = \) The Concentration Breakpoint that is \( \leq C \)  
\( C_{\text{high}} = \) The Concentration Breakpoint that is \( \geq C \)  
\( I_{\text{low}} = \) The Index Breakpoint Corresponding to \( C_{\text{low}} \)  
\( I_{\text{high}} = \) The Index Breakpoint Corresponding to \( C_{\text{high}} \)  
\( C_{\text{pHigh}}, C_{\text{pLow}}, AQI_{\text{High}}, \text{and} AQI_{\text{Low}} \) are from USEPA Pollutant Breakpoints.

The US-EPA Breakpoints for CO is tabulated in Table III. The AQI enables the Health Risk to be estimated. It is easy to interpret air quality data because of the reduction of complexity involved with concentration of air pollutants. Index value \( > 100 \) indicates the pollutant level exceeds the air quality standard. This is considered to be unhealthy first, for some sensitive groups of people, and then for everyone as AQI values increases.

| S/N  | Parameter                  | Measuring Device                  | Model                              |
|------|---------------------------|-----------------------------------|-----------------------------------|
| 1    | Carbon Monoxide           | Portable Air Quality Monitor      | Aeroqual Series 500, Aeroqual     |
|      | Meteorology:              | Extech Wireless Weather Station   | Limited, New Zealand              |
|      | Atmospheric Temperature,  | Extech Instruments, United States of|
|      | Relative Humidity, Wind   | America                            |
|      | Speed and Direction       |                                    |
| 2    | Geographical Coordinates  | Global Positioning System (GPS)    | Etrex 10, Garmin Limited, United States of|
|      |                           |                                    | America                            |
TABLE III: USEPA AIR QUALITY INDEX BREAKPOINTS AND CATEGORIES FOR CARBON MONOXIDE

| CO (ppm) | AQI Category |
|----------|--------------|
|   0.0–4.4 (8-hr) | 0–50 Good |
|   4.5–9.4 (8-hr) | 51–100 Moderate |
|   9.5–12.4 (8-hr) | 101–150 Unhealthy for Sensitive Groups |
|   12.5–15.4 (8-hr) | 151–200 Unhealthy |
|   15.5–30.4 (8-hr) | 201–300 Very Unhealthy |
|   30.5–40.4 (8-hr) | 301–400 Hazardous |
|   40.5–50.4 (8-hr) | 401–500 |

(Source: [19]).

III. RESULTS AND DISCUSSION

The results obtained for the meteorological parameters and carbon monoxide are stated and discussed in the subsections that follow.

A. Meteorology

The dispersion of air pollutants as well as formation of secondary pollutants depends not just on source concentration but are generally influenced by the prevailing micro-climate or meteorology of the ambient environment. The micro-climate is determined by wind dynamics (wind speed and wind direction) in the area, the atmospheric temperature and relative humidity amongst others.

1) Wind speed and wind direction

The wind speeds (m/s) recorded in the rainy season were minimum range of 0.1 (Oil Mill) to 1.3 (RSU) and maximum range of 2.1 (Lagos Bus-stop) to 5.2 (Oil Mill) while mean ± std dev., range was 1.36±0.42 (Lagos Bus-stop) to 2.12±0.66 (RSU) with respective % CV of 30.88% and 31.13%.

The wind speeds (m/s) recorded in the dry season were minimum range of 0.3 (RSU) to 0.8 in SS8 (RSU) and maximum range of 0.9 in SS9 (Agip Junction) to 2.5 SS7 (Mile One) while mean ± std dev., range was 0.68±0.29 in SS8 (RSU) to 1.32±0.75 in SS7 (Mile One) with respective % CV of 42.65% and 56.82%.

The wind speeds were mainly mild Class 2 (1-2 m/s) in the rainy season and milder (0-1 m/s) in the dry season.

The dominant wind direction in the rainy season was SW followed by NW and NE wind directions while in the dry season, the dominant wind directions were NE and SW. NW wind directions were also recorded.

The wind speeds and directions observed are characteristic of the study area as reported by Edokpa and Nwaigbarah [20].

2) Atmospheric temperature and relative humidity

The average atmospheric temperatures in the study area were in the range 29.0–35.4 °C in the rainy season and 26.8–35.7 °C in the dry season. These values are comparable to values obtained from a similar study in the Port Harcourt Metropolis [17]. The recorded mean temperatures are in the range 20.2–36.7 °C. The average relative humidity in this study was 72.8±9.4 % within the period of study. Uko and Tamunobereton-Ari [21] recorded 69.08% as the annual average relative humidity in the Port Harcourt Metropolis.

The trends between atmospheric temperature and relative humidity in the locations studied show that both parameters were inversely related. Similar trends were observed by Agada et al. [22] in Kano and Port Harcourt Metropolis.

B. Levels of Carbon Monoxide

The values obtained for the levels of carbon monoxide (CO) at the sampling stations within the period of the study are summarized in Table IV for the rainy and dry seasons.

The results in Table IV indicate that in the rainy season, SS10 (Rumuokoro) and SS8 (RSU) had the lowest mean concentration of CO (0.132±0.143 and 0.133±0.135 ppm respectively) while the highest was recorded in SS7 (Mile One) and SS1 (Oil Mill) (3.291±7.005 and 2.708±4.002 ppm, respectively). SS3 (Amadi-ama) and SS5 (Lagos Bus-stop) also had appreciable mean concentrations (>2.0 ppm).

In the dry season, the highest CO levels were recorded in SS2 (Trans-Amadi), SS1 (Oil Mill) and SS5 (Lagos Bus-stop) with values > 4.00 ppm, higher than the values recorded in the rainy season (Table IV). The lowest CO level was recorded in SS7 (Mile One) and SS8 (RSU) (0.422±0.902 and 0.493±0.698 ppm, respectively).

The mean concentrations were all below the World Health Organization (8-Hourly Exposure) limit of 10 ppm.

The results indicate that in the rainy season the lowest CO mean concentration of 0.132 ppm was at SS8 (RSU) while the highest value of 3.291 was recorded at SS7 (Mile One). In the dry season, the lowest mean CO concentration of 0.422 ppm was at SS7 (Mile One) while the highest value of 3.43 ppm was recorded at SS9 (Agip Junction). The average values of CO in rainy and dry seasons are illustrated in Fig. 2. A comparison of monthly average CO values of the Control Station SS8 (RSU) with monthly averages for the other locations are illustrated in Fig. 3.

The high % CV values of (106-280.2) for the rainy season and (75.68-213.7) for the dry season recorded is an indication of variations in the levels of CO in the different periods of sampling, which could be as a result of fluctuations in the levels of emissions during the sampling periods.

The range of Mean CO levels at SS8 (RSU) (0.133–0.493 ppm for rainy and dry seasons respectively) are much lower than the corresponding range of values of 0.16 - 6.57 mg/m³ observed by Ubong et al. [23] for the SS8 (RSU-Control Station) and also lower than the range of 4.8–137 ppm obtained by Adebaje, Oluwafumilayo and Oluwaseun [24] for Ijebu-Ode Nigeria. The CO mean (0.138 ppm) at SS8 (RSU) (Control Station) in the rainy season is lower than the range of means for the other stations (0.132–3.29 ppm, except in Rumuokoro (Fig. 2). The dry season RSU CO mean of 0.493 ppm was also lower than the range of 0.422–9.037 ppm observed in the other stations, except in Mile One.

The trend reveals that CO levels were higher in the dry season in most of the sampling stations. This is expected for the dry season when the arid nature of the air enhances dispersion of gases [23].

Monthly CO values for the sampling stations indicate that the lowest values were in May the lockdown month and August when the lockdown was just lifted while November had the highest (18.07 ppm). The higher value obtained in November is reflected in the dry season averages for the stations (0.422–9.037 ppm), compared to the rainy season with values ranging from 0.132 ppm at SS10 (Rumuokoro) to 3.291 ppm at SS7 (Mile One) (Fig. 2). The lower rainy season values may be explained by dissolution of CO in rainwater. However, a more likely explanation would be the Rivers State...
Government imposition of a lockdown in human and vehicular movement in May 17th–23rd, 2020, as a measure to stem the spread of the Covid-19 virus in the study area.

C. ANOVA of Carbon Monoxide Values

Comparing the mean values of CO at the sampling locations using One-Way ANOVA (Analysis of Variance) reveals that there was no significant difference (p > 0.05) between the sampling locations for both the rainy and the dry seasons.

The variations in the rainy season were higher than in the dry season. The higher variation in the rainy season can be explained by the lockdown, which may have caused lower vehicular movements at commercial than at residential areas. The lower wind speeds in the dry season may also have translated to lower dispersion of vehicular emissions, resulting in a higher variability of CO values than in the rainy season. However, statistical t-test of CO levels in the rainy and dry seasons reveals that there was no significant difference between the CO levels in the rainy and dry seasons (p > 0.05).

### TABLE IV: CARBON MONOXIDE VALUES (PPM) IN THE RAINY AND DRY SEASON

| Sampling Location | Rainy Season | Dry Season |
|-------------------|--------------|------------|
|                   | Min          | Max        | Mean       | Std. Dev. | % CV   | Min          | Max        | Mean       | Std. Dev. | % CV   |
| Oil mill (SS1)    | 0.280        | 10.800     | 2.708      | 4.197     | 154.9  | <0.001       | 18.40      | 4.963      | 7.925     | 159.7  |
| Trans-amadi (SS2) | <0.001       | 7.000      | 0.883      | 1.954     | 221.3  | 0.260        | 15.070     | 5.255      | 111.2     | 11.2   |
| Amadi-ama (SS3)   | <0.001       | 10.780     | 2.035      | 3.272     | 160.8  | 0.280        | 5.30       | 2.422      | 75.68     | 1.12   |
| Borokiri (SS4)    | <0.001       | 3.630      | 0.631      | 1.029     | 163.1  | <0.001       | 1.770      | 0.688      | 117.0     | 0.67   |
| Lagos bus-stop (SS5) | <0.001   | 8.800      | 2.147      | 3.532     | 164.5  | <0.001       | 13.25      | 4.112      | 117.4     | 1.18   |
| Rumuola (SS6)     | <0.001       | 7.400      | 1.607      | 2.768     | 172.2  | <0.001       | 2.710      | 0.952      | 116.9     | 0.92   |
| Mile one (SS7)    | 0.170        | 25.680     | 3.291      | 7.317     | 222.3  | <0.001       | 2.250      | 0.422      | 213.7     | 0.42   |
| Agip junction (SS9) | <0.001   | 8.300      | 1.018      | 3.232     | 228.2  | <0.001       | 37.43      | 9.037      | 169.7     | 9.03   |
| Rumuokoro (SS10)  | <0.001       | 5.310      | 1.018      | 0.149     | 14.900 | <0.001       | 6.46       | 2.023      | 170.8     | 2.02   |
| Waterlines (SS11) | <0.001       | 0.300      | 0.132      | 4.228     | 14.900 | <0.001       | 9.400      | 1.333      | 181.2     | 1.33   |
| Rivers state univ. (SS8, control) | <0.001 | 14.900 | 0.133 |

### AVERAGE CARBON MONOXIDE LEVELS IN THE RAINY AND DRY SEASONS

Fig. 2. Seasonal Levels of Carbon Monoxide in the Sampling Stations.

Fig. 3. Comparison of Average Carbon Monoxide Values at the Control and the other Sampling Stations.
D. Correlation Analysis of Carbon Monoxide Values

Pearson Correlation was carried out on CO levels in the locations studied. The correlations amongst the stations are stated in Tables V and VI for the rainy and dry seasons respectively.

Pearson’s Correlation among the sampling locations revealed that the most similar sampling locations with respect to CO levels were SS3 (Amadi-ama) and SS5 (Lagos Bus-stop) in the rainy season \((r = 0.868)\), the correlation coefficients amongst the other locations were all <0.7 (Table V). In the dry season, high positive correlations were recorded amongst locations with similar activities. The highest was between SS1 (Oil Mill) and SS9 (Agip Junction) with a correlation coefficient, \(r = 0.988\) (Table VI), followed by SS1 (Oil Mill) and SS10 (Rumuokoro), \(r = 0.985\) and SS8 (RSU) and SS11 (Waterlines), \(r = 0.980\). While SS8 (the Control Site) was weakly or negatively correlated with the other locations in the rainy season, it was highly correlated with SS11 (Waterlines) in the dry season. The difference is likely to be due to the restriction of vehicular movements at SS11 (Waterlines) as a result of bridge construction during the period of sampling.

E. Air Quality Index

The Air Quality Indices (AQI) were calculated using Equation 1 with the aid of USEPA Breakpoints for Carbon Monoxide as presented in Table III.

The AQI Categories as stated in Table III are 0-50 (Good Air Quality); 51-100 (Moderate Air Quality); 101–150 (Unhealthy for Sensitive Groups); 151-200 (Unhealthy Air Quality); 201-300 (Very Unhealthy Air Quality) and 301-400 (Hazardous Air Quality).

The AQI obtained from this study for CO are stated in Table VII.

Carbon monoxide AQI values in the study area during the period of the study indicate that the air quality was good in all sampled locations in the months of May, August and December (Table VII). It was also good in the month of September except at SS1 (Oil Mill) and SS11 (Waterlines), where AQI values were 93.00 and 60.30 (i.e. moderate). October AQI values showed that the air quality was good in all the stations except SS7 (Mile One) and SS3 (Amadi-ana) with AQI values of 96.40 and 68.50 respectively and may be categorized as moderate.

In November, AQI values of 218.08 and 108.27 were recorded for SS9 (Agip Junction) and SS1 (Oil Mill) corresponding to very Unhealthy and Unhealthy air qualities for sensitive groups respectively. The other locations were categorized as good to moderate in the month of November.

IV. Conclusion

The trends in levels of the air quality parameters indicate that human and industrial activities were directly related to the levels of air quality parameters. The higher the volume of human activities (vehicular emissions, wood and waste combustion, artisanal refining of crude oil etc.), the higher the level of air pollutants in the atmosphere. This was evident in the months of Covid-19 lockdown and also when in comparison with the control site where relatively lower levels of human activities were recorded.

The dominant wind directions were SW in the rainy season and NE in the dry season. Mild wind speeds recorded resulted in high coefficients of variation in the parameters studied due to the fluidity of air and rapid transportation and dispersions of emitted air pollutants. Locations with similar human activities also correlated strongly.

Carbon monoxide was higher in the dry season than the rainy season (including the lockdown period in May) and the AQI calculated were found to be between moderate and unhealthy in some locations during the non-lockdown periods.
### TABLE VII: AQI VALUES FOR CARBON MONOXIDE

|          | Oil mill (SS7) | Trans-amid (SS7) | Anamadi (SS7) | Bar Bariri (SS7) | Lagos barr-stap (SS7) | Rumunia (SS6) | Mile one (SS7) | App junction (SS9) | Rumukokwu (SS10) | Waterfowls (SS11) | Ave. AqI (port harcourt) | Rainwater area units (SS8, control) |
|----------|----------------|------------------|---------------|-------------------|----------------------|--------------|--------------|-------------------|-------------------|-------------------|----------------------|-----------------------------|
| Rainy season average | 27.03 | 10.03 | 22.47 | 7.19 | 24.14 | 18.18 | 35.80 | 11.56 | 1.48 | 16.78 | 17.47 | 1.42 |
| Dry season | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 |

### CONFIDENT OF INTEREST

Authors declare that they do not have any conflict of interest.

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