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Impact of Corona Virus Stay-at-Home Policies on Traffic Emissions and Ambient Pollutant Concentrations in Ghana, West Africa

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Abstract

The objective of this study is to determine how policies for stay-at-home (lockdown) and phases of easing the lockdown, implemented by the Government of Ghana to slow the spread of COVID-19, impacted traffic emissions and ambient concentrations of particulate matter (PM10, PM2.5). Monthly data was collected from January 2020 to June 2020 from four roadside monitoring locations using mini vol air samplers. High-volume ambient samplers were used to collect PM data at two permanent (industrial and residential) locations. Monthly concentrations were presented in tables over the six-month period. Results showed that PM2.5 concentrations decreased over Greater Accra in the month of April during the initial lockdown when only essential workers went to work and increased thereafter. Compared with 2019 data, the PM2.5 concentrations of roadside monitoring points at Kaneshie First Light, Shangri-la, Tantra Hill, and Amasaman were lowered by 45.5%, 46.7%, 82.4%, and 72.7%, respectively. This was consistent with the measured reductions in mobility during the lockdown. However, PM10 concentrations were higher at the same four roadside monitoring points and industrial monitoring points near the power plant during the lockdown compared to the same period in 2019. This increase may have been due to residential biomass burning during stay-at-home orders, or increased electricity production to support home activity. In conclusion, worldwide researchers collected pollution data using remote sensing and satellite whereas in this study conducted in Ghana pollution data was collected using ground-level monitors.

Keywords: Tactical air sampler; Portable Air Sampler; Traffic emissions; Air pollution; Particulate matter; Stay-at-home policies.
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1. Introduction

The outbreak of coronavirus disease (COVID-19), which started in Wuhan, China, becomes a cause to declare a public health emergency worldwide.[1] The concern was mitigation of the spreading of the virus across the world to protect possibly large-scale populations. In response to the fast-spreading virus, countries across the globe implemented a range of public health and social measures, including movement restrictions, partial closure or closure of schools and businesses, quarantine, and international travel restrictions.[2] These interventions led to a reduced number of vehicles on the road and diminished factory production, contributing generally to the improvement of air quality around the world.[3] Several studies have examined the impact of COVID-19 lockdown policies on air quality in Africa, specifically in Uganda in East Africa; Morocco and Egypt in North Africa; Ghana in West Africa; and South Africa. Kampala, in East Africa, is Uganda's capital city with the highest particulate matter (PM)2.5 level.[4-6]

Meji *et al.*[7] found that the lockdown policies improved Kampala's air quality index by 6.6% compared to the same period of the previous year. The study found that PM2.5 levels in Kampala declined by 35% during quarantine compared to one month prior to quarantine.[8] El-Sheekh *et al.*[9] reported that the ambient PM and nitrogen oxide levels decreased after the lockdown in northern Egypt. Khomsi *et al.*[10] found reductions in nitrogen dioxide, carbon monoxide, and PM2.5 due to the lockdowns in two cities of Morocco and northwest Africa compared to 2016-2019 data; ground-level ozone,

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however, was not clearly reduced. Barbieri *et al.*[11] collected survey data regarding perceived air quality in Ghana and South Africa before and during COVID-19 restrictions. Using space-borne remote sensing data, Das *et al.*[12] found that PM2.5 levels in Ghana increased in March and April 2020, compared with October and December 2019; nitrogen dioxide levels in South Africa showed a negligible increase during the same period. Increases in PM2.5 were attributed to the late lockdown measures in Ghana, but they could also have been due to seasonal variability.

Ghana is a regional power in West Africa with a growing economy.[13] Survey data and remote sensing data have been used to assess the impact of COVID-19 lockdowns on air quality.[14] However, arguably the most reliable source of data ground-level monitors has not been used.[15] The goal of this research was therefore to evaluate the impact of the coronavirus stay-at-home policy orders of the Ghana government on traffic emissions and ambient pollutant concentrations. The analysis was conducted for particulate matter in the Greater Accra region. Accra is the capital and largest city of Ghana and is currently the only city in the country with permanent monitors. Recent studies have identified particulate matter as the major contributor to ambient air pollution from energy consumption and transportation in Ghana.[16] The results of this analysis can provide information to regulatory bodies concerning whether significant improvement in air quality could be expected if air quality control measures are strictly enforced. Ghana had the first coronavirus case on March 12, 2020, when two infected people from Norway and Turkey visited Ghana. On March 30, the president of Ghana held his first press conference and placed the country under a two-week complete lockdown to limit the spread of the virus, except for essential service providers such as hospital and supermarket workers. This measure was extended one more week till April 19, 2020. On April 20, the president announced an ease in the lockdown measure; therefore, more than two people from each household could go out. However, still, a limited number of people could gather at a time, and all other COVID-19 protocols were practiced. Based on the lockdown measures, the mobility of individuals and vehicles, as well as the operation of some industries (Polyproduct Ghana Limited, Polylex Industries Limited, Hexagon Industries limited) emitting air pollutants, were limited.

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2. Materials and methods

2.1 Portable and permanent monitoring locations

Four roadside locations in Accra (Kaneshie First Light Motors, Tantra Hill Total Filling Station, Amasaman Puma Filling Station, and Shangri-La Tetteh Quarshie Avenue, yellow marked pin as shown in Fig. S1) were chosen as monitoring sites to assess the impact of the lockdown on traffic emissions. The sites were chosen to be spread out across Greater Accra in locations with busy traffic, and where the population is concentrated to indicate potential high pollution levels that could pose health challenges. Two portable Mini Vol samplers (duplicates) were used to collect continuous measurements of traffic emissions (PM10 and PM2.5) at each of these sites from January 2020 to June 2020, which included measurements before and after the lockdown. Vehicles can contribute substantially to both PM2.5 and PM10 emissions.[17] Zhou *et al.*[18] found that vehicle emissions, tire and brake wear, and road dust contributed to both PM2.5 and PM10 levels in Accra. Hence, both PM2.5 and PM10 were measured. Fig. S2(a and b), Fig. S3(c and d), Fig S4(e and f), and Fig. S5(i and j) are the photographs of the 4 roadside portable samplers, installed about 5 feet from the lanes and satellite images of the locations.

In addition, two permanent high-volume samplers in Accra Tisch Environmental (TE) 6000 are fixed at residential and industrial zones and were used to assess the impact of the lockdown on PM10 concentrations in industrial and residential areas. Fig. S6 and Fig. S7 show the photographs and satellite images of the 2 permanent sampler locations (indicated in red).

The North Industrial Area monitor was used to indicate ambient concentrations in an industrial area harboring the Electricity Company of Ghana Station "E", and the Dansoman Police Station was used as an example of a residential area. Data were obtained from the permanent samplers for the same period (January 2020 – June 2020) for the portable roadside monitors. Environmental Protection Agency (EPA) employees in Ghana collected the air quality data for analysis in this paper on the designated locations as shown in supplementary figures. Data from January 2019 to June 2019 were also obtained for comparison. Meteorological data for the data collection periods are unfortunately not available.

2.2 Monitor descriptions

The Mini Vol Portable Air Sampler (Air Metrics, 2001 shown in (Fig. S8) and High-Volume Sampler Tisch Environmental TE 6000, 2010 (Fig. S9) are ambient air samplers for particulate matter and non-reactive gases. The patented low-flow technology used in the Mini Vol was developed jointly by the U.S. Environmental Protection Agency (EPA) and the Lane Regional Air Pollution Authority in an effort to address the need for portable air pollution sampling technology. The air samplers were installed at an elevated height of at least 6 feet above the ground, to approximate breathing height.

2.3 PM10, PM2.5 concentration estimation

The data obtained from the air samplers was gravimetric data, measured in units of mass, micrograms. Additional parameters such as the flow rate, atmospheric pressure, ambient temperature, volume of air, and height of monitoring post required were obtained to estimate the PM values in micrograms per cubic meter. Equations 1[19] and 2[20,21] are used to calculate air flow rate at ambient conditions, Q_{act}, and the slope of the calibration (m_{vol}), and the intercept ($b_{vol.}$) was taken from the calibration curve.

$$Q_{\text{act}} = m_{\text{vol}} \times (Q_{\text{ind}} + b_{\text{vol}}) \times \left(\frac{P_{\text{std}}}{P_{\text{act}}} \times \frac{T_{\text{act}}}{T_{\text{std}}}\right) \quad (1)$$

where P_{std} = standard atmospheric pressure (760 mm Hg); T_{std} = 298 K and T_{act} = 273 + $T_{measured}$

$$P_{\text{act}} = P_{\text{sea}} \times \left(1-\frac{E}{145330}\right)^{5.25}, P_{\text{sea}} = P_{\text{std}} \quad (2)$$

where $T_{measured}$: the ambient temperature at the monitoring area; Q_{ind}: adjusted flowrate on the flowmeter of the TAS (5 l/min); E: height of the monitoring post from the ground in feet

Equation (3)[22] is used to calculate the volume of air that passes through the filter during sampling time at ambient conditions:

$$V_{\text{act}} = \frac{\frac{60\text{mins}}{\text{hr}} \times Q_{\text{act}} \times \text{time(hr)}}{1000\text{ l}}, m^3 \quad (3)$$

Equation (4)[23] was used to calculate the concentration of PM in the ambient air; M = mass of PM collected on the filter paper during sampling and C_{act} = concentration of PM

$$C_{\text{act}} = \frac{M}{V_{\text{act}}}, \left(\frac{\mu\text{g}}{m^3}\right) \quad (4)$$

3. Finding and results

Table 1 shows average monthly concentrations of PM2.5 from January 2019 to June 2019 and from January 2020 to June 2020 at four roadside monitoring locations namely (Kaneshie First Light, Shangri-la, Tantra Hill, and Amasaman). It shows all 4 roadside monitoring locations, PM2.5 concentrations were lower in April 2020 during the lockdown than during the months preceding the lockdown (Jan 19 – March 19). Compared with Jan 2019, the PM2.5 concentration in Jan 2020 is significantly lower as we can see Jan 2019 PM2.5 concentration at locations Kaneshie (101.85); First Light, Shangri-la (111.11), Tantra Hill (105.56) and Amasaman (97.22) and Jan 2020 PM2.5 concentration are 50.83, 69.44, 59.03, 66.58, respectively. The minimum PM2.5 concentration was recorded in April 2020 at locations Kaneshie (27.78); First Light, Shangri-la (27.78), Tantra Hill (13.89), and Amasaman (13.89) as data shown in Table 1.

Table 2 shows the average monthly concentrations of PM10 from January 2019 to June 2019 and from January 2020 to June 2020 at the four roadside monitoring locations namely (Kaneshie First Light, Shangri-la, Tantra Hill, and Amasaman). It shows that for all 4 roadside monitoring locations, the PM10 concentrations were higher in April 2020 during the lockdown than during the months preceding the lockdown (Jan 19 – March 19) because people were at home and using more biofuel. This results in the concentrations of PM10 during the stay-at-home time being higher. The PM10 concentration in April 2019 at locations Kaneshie (90.27); First Light, Shangri-la (48.61), Tantra Hill (100.69), and Amasaman (129.62) in comparison to Jan 2020 PM10 concentrations are 225.09, 178.88, 161.11 and 186.66 respectively. The highest PM10 concentration was recorded in April 2020 in residential locations, excessive utilization of biogases in the result PM10 concentration has been recorded higher during the lockdown. The PM2.5 concentrations were recorded lower due to low traffic movements on the roads.

Data collected from the permanent monitoring locations Dansoman cover residential locations) and AL-Afra (which covers the north industrial area) are shown in Table 3. PM2.5 concentration significantly drop in both permeant stations as a result of lower vehicles traffic on the roads as well industrial units were shut down or reduced operation hours

Table 1. Monthly roadside PM2.5 concentrations at four portable monitoring sites (2019 vs.2020).

Station	Jan 2019	Jan 2020	Feb 2019	Feb 2020	March 2019	March 2020	April 2019	April 2020	May 2019	May 2020	June 2019	June 2020
Kaneshie	101.85	50.83	79.86	71.67	97.22	55.09	50.93	27.78	69.44	58.33	48.61	93.74
Shangri-La	111.11	69.44	91.67	87.96	83.33	106.48	52.08	27.75	65.11	63.89	93.75	86.81
Tantra Hill	105.56	59.03	61.11	58.33	69.44	74.07	78.70	13.89	69.44	47.22	76.39	38.19
Amasaman	97.22	66.58	87.96	61.11	69.44	78.70	50.93	13.89	50.0	61.11	74.07	48.61

Table 2. Monthly roadside PM10 concentrations at four portable monitoring sites (2019 vs. 2020).

Station	Jan 2019	Jan 2020	Feb 2019	Feb 2020	March 2019	March 2020	April 2019	April 2020	May 2019	May 2020	June 2019	June 2020
Kaneshie	211.11	136.11	129.62	215.27	194.44	152.77	90.27	225.09	149.30	113.88	177.08	145.83
Shangri-La	200.03	186.11	122.22	183.33	152.77	92.59	48.61	178.88	94.44	111.11	121.52	138.88
Tantra Hill	136.11	107.63	86.11	101.85	104.16	83.33	100.69	161.11	91.66	63.88	121.51	59.02
Amasaman	125.02	125.05	133.33	100.69	92.59	118.05	129.62	186.66	72.91	91.66	125.01	97.22

Table 3. Monthly average PM10 concentrations of residential and industrial sites (2019 vs. 2020).

Station	Jan 2019	Jan 2020	Feb 2019	Feb 2020	March 2019	March 2020	April 2019	April 2020	May 2019	May 2020	June 2019	June 2020
Dansoman	63.05	125.31	55.10	66.77	98.17	59.28	20.84	11.86	15.28	90.34	31.92	31.20
Al-Afra	158.88	184.18	125.12	171.38	73.81	57.85	45.37	67.06	49.05	49.06	47.11	58.00

**Dansoman (Residential area); Al-Afra (North Industrial area).

during the lockdown period. However, PM10 concentration at the permeant stations indicated that PM10 concentration in Jan 2020 for the residential area is 112.31 and 184.18 for the industrial area which is comparatively higher than the same period in 2019 residential 63.05 and industrial 158.88, respectively. We can see in Table 3 that the PM10 concentration for the period of 2020 is higher than in 2019 for the permeant locations sites. The consumption of biofuel has increased at homes causing a higher emission of PM10 during the lockdown period.

It shows the change in mobility to frequently visited places during stay-at-home orders. The data was obtained from the COVID-19 Community Mobility Report Center data recorded and available at Google[24] as shown in Fig. 1. Google is reporting community frequently visited places since Covid-19 outbroke. Fig. 1 shows that mobility was substantially decreased between March and April 2020, the same period of stay-at-home (lockdown) measure was strictly in place. Mobility in retail, parks, workplaces and transit stations significantly dropped during covid period. These limitations led to reductions in traffic emissions.

The average concentration of PM2.5 at four locations for the years 2019 and 2020 is compared and shown in Table 4. The findings indicated that the PM2.5 concentration in the year 2019 for the four locations are Kaneshie First Light (50.9), Shangri-la (52), Tantra Hill (78.7), and Amasaman (50.9). The PM2.4 concentration recorded lower in 2020 for the locations are Kaneshie First Light (27.8), Shangri-la (27.7), Tantra Hill (13.8), and Amasaman (13.9). The percentages for the locations are 45.5%, 46.7%, 82.4%, and 72.7% lower during the strict lockdown in the month of April 2020 for Kaneshie First Light, Shangri-la, Tantra Hill, and Amasaman roadside monitoring locations, respectively. Tantra Hill and Amasaman, which normally have lower levels of traffic, had greater percent reductions in the PM2.5 concentrations.

Table 4. PM2.5 concentration changes during 2019 *vs* 2020 in percent.

Monitoring stations	Year, 2019	Year, 2020	changes in percent (%)
Kaneshie	50.9	27.8	45.50
Shangri-La	52	27.7	46.70
Tantra Hill	78.7	13.8	82.40
Amasaman	50.9	13.9	72.70

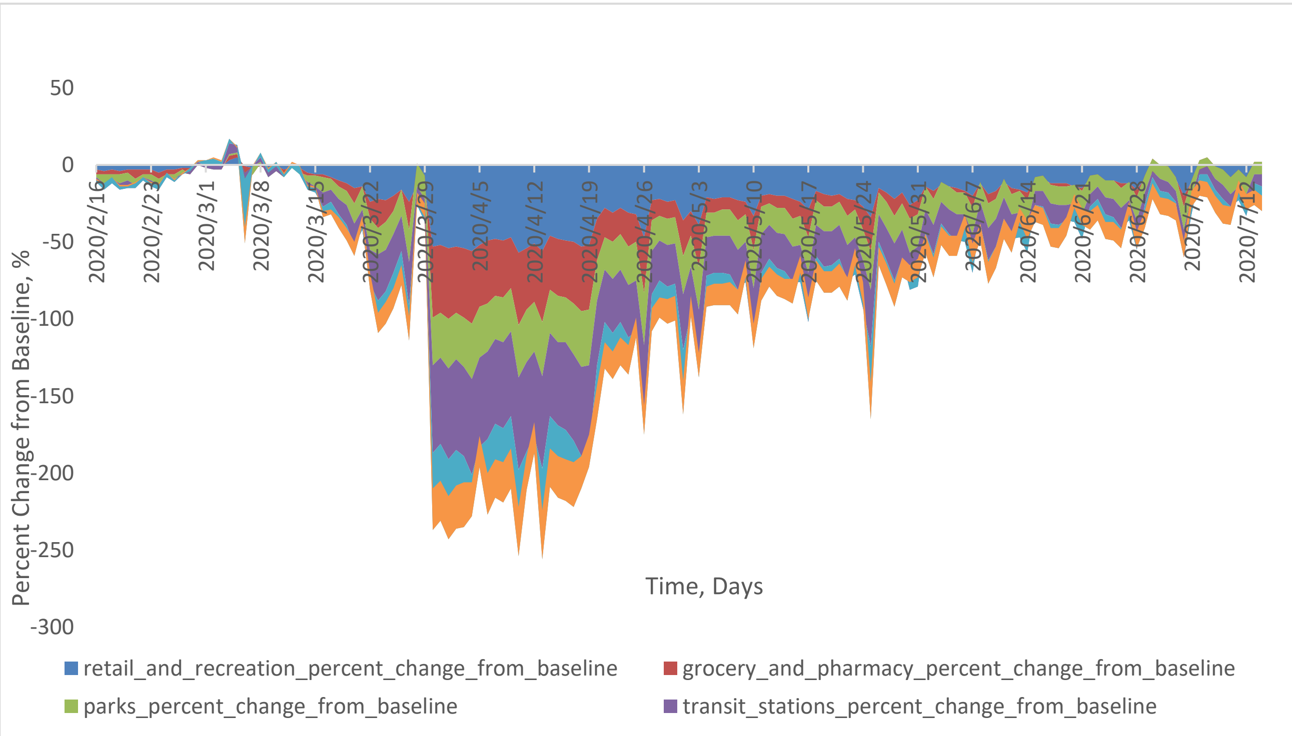

Fig. 1 Mobility to frequently visited places during stay-at-home orders versus time in Greater Accra, Ghana.[24]

4. Discussion

This study investigated PM2.5 and PM10 pollutant emissions during the stay-at-home or lockdown period started in March 2020-June 2020 in Ghana and the results compared with the previous year's same period. A total of four stations were selected and Mini Vol Portable Air Samplers were installed to monitor PM2.5 and PM 10 concentration. Data was also taken from the two-permeant air pollutant controller in the residential area and industrial area. Table 1 shows PM2.5 data collected at four stations and compared with the previous year in the same locations. The PM2.5 pollutant emission has significantly dropped due to the movement controlled. During the lockdown period, community mobility, reported by Google[24] indicated mobility to the most visited places, has significantly dropped due to a lower vehicle movement on the road, which caused an emission reduction.

On the other hand, PM10 pollutant emissions for the 4 roadside locations has increased in April 2020 compared to April 2019. This has happened because people were spending more time at home during the lockdown and burning biomass fuel, which contributed to PM10 emissions. Guojun *et al.*[25] found that biomass fuel use, emissions from traffic, and re-suspension from unpaved roads were primary contributors to spatial variability in PM concentrations in Accra. Part of Amasaman is a low-income community, which uses biomass as a fuel for cooking. Similarly, Tantra Hill has some slums with biomass fuel use. Kaneshie may have a small fraction of the population that uses biomass, although most residents of this middle-income community use liquefied petroleum gas (LPG) for cooking. Shangri-La, however, is an affluent area with offices and businesses; biomass is not used in this area. Meji *et al.*[7] conducted a study on the air quality index (AQI) of Kampala city dropped by an average of 6.6% during the COVID lockdown period compared with the same period in the previous year. El-Sheekh *et al.*[9] found that the atmospheric aerosols (PM2.5 & PM10, NO_2) were reduced during the lockdown in March 2020 in Northern Egypt. Travaglio *et al.*[26] concluded that stay-at-home policies in the UK significantly reduced air pollution, especially vehicle emissions in England.

PM2.5 concentrations at the permanent residential monitoring location at Dansoman were 43.1% lower in April 2020 compared to April 2019. This contrasts with the higher PM10 concentrations measured at the 4 roadside sites, 3 of which were located in residential areas. The Dansoman station is located southwest of the 4 roadside monitoring sites. PM10 concentrations increased at the north industrial area monitoring location for April 2020 compared to April 2019. The north industrial site is located between the Kaneshie and Shangri-La sites, and its trend is consistent with them. The increase in PM10 concentrations could also have been due to the continuous operation of power plants within the Greater Accra metropolis during the lockdown, as it was necessary to provide electricity during the depressed period. Wang *et al.*[27] and Zhang *et al.*[28] stated a reduction in emission did not fully eliminate air pollution, and O_3 actually increased, possibly because lower fine particle loadings led to less scavenging of HO_2 and as a result greater O_3 production. These results also highlight the need to control emissions from the residential sector. Allaban *et al.*[29] stated that PM10 main sources of emission are heavy combustion and pollution from industrial and cooking at home and vehicles has fractional contributions to ambient. Results showed that the stay-at-home policy in Ghana reduced vehicle mobility, which led to the reduction of PM2.5 emissions at the roadside monitoring locations during the lockdown period when compared to the data from the previous year under normal conditions. For PM10, however, concentrations increased, likely due to the increased biomass burning and/or electric power production to supply homes during the lockdown.

5. Conclusions

The results showed that the stay-at-home policy reduced vehicle mobility, which led to the reduction of PM2.5 emissions of about 45.5%, 46.7%, 82.4%, and 72.7% lower during the strict lockdown in the month of April 2020 for Kaneshie First Light, Shangri-la, Tantra Hill, and Amasaman roadside monitoring locations, respectively. Tantra Hill and Amasaman, which normally have lower levels of traffic, had greater percent reductions in PM2.5 concentrations. For PM10, however, the concentrations increased, likely due to the increased biomass burning and/or electric power production to supply homes during the lockdown. In addition, most worldwide researchers collected pollution data using remote sensing and satellite data. In this study conducted in Ghana, collected pollution data on the ground level such as Mini Vol Portable Air Sampler and High-Volume Sampler were used to collect PM2.5 and PM10 data in Greater Accra region in Ghana. The results, however, in almost all the research work pointed to a decrease in pollution data during the COVID-19 lockdown periods.

Conflict of interest

There are no conflicts to declare.

Supporting information

Applicable

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