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Air Deterioration Gases in the Social Confinement Period by COVID-19 in Bogotá, Quito, Lima, Santiago de Chile and Buenos Aires

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Restrictions on industry and vehicular and pedestrian traffic during the COVID-19 public health emergency were explored to determine associations with increases or decreases in air-impairing gases. Social immobilization is one method of controlling infectious diseases in an emergency and/or quarantine context, resulting in a decrease in environmental contamination. Therefore, this research evaluated the influence of CO, NO_2, O_3 and SO_2 gases in the cities of Bogota, Buenos Aires, Lima, Quito and Santiago. Data from Sentinel-5P netCDF files were used with the help of SNAP Desktop and Qgis software, and governmental regulations dictated by the different governments of each country were also reviewed. The results showed that the cities of Bogota, Buenos Aires, Lima and Quito had significant negative decreases and associations for CO, NO_2 and O_3 gases, and SO_2 gas was statistically disregarded. In addition, the city of Santiago de Chile showed an increase in CO gas. Finally, it is concluded that social immobilization positively influenced the reduction of air pollutant gases and consequently improved the environmental quality of each city.

1. Introduction

Traditional energy consumption, population density, urban agglomeration, infrastructure and transportation cause the reduction of air quality and are responsible for PM10, CO, CO_2, SO_X, NO_X and volatile organic compounds, exposing the population to different air pollutants (Wang et al. 2019; Islam et al. 2020). These activities were prevented by the governments of each country in the presence of SARS-CoV-2, as a social mobility control measure to avoid the proliferation of contagions in the human population (Kraemer et al. 2020). With this measure of social confinement by COVID-19 there was a significant favourable correlation because there was a reduction in the concentrations of pollutants present in the air, determining that there is a positive impact on environmental quality (Abdullah et al. 2020; Zhu, Xie, Huang and Cao, 2020; Fareed et al. 2020).
Different studies mention that algorithmic models can quantify air pollutants, and their implementation in monitoring is of vital importance because they are accurate in achieving replication of observed concentrations through proper characterization of the stochastic nature of atmospheric processes (Lee et al. 2020; Araki, Shima and Yamamoto, 2020; Rao et al. 2020). Other studies used land-use regression (LUR) models to assess the influence of air pollution on lung function, inflammation and aging (Altuğ et al. 2020), as well as regional air quality models such as CHIMERE, LOTOS-EUROS, EMEP MSC-W, etc. to investigate atmospheric composition on a regional scale (Blechschmidt et al. 2020).
Social restrictions improve environmental quality, reducing atmospheric emissions and consequently improving air quality (Cheng et al. 2020; Raffaelli et al. 2020; Dantas et al. 2020). Moreover, these partial and total blocking measures to social mobility generally reduce air deterioration gases (Collivignarelli et al. 2020). These environmental policies are framed in environmental improvement and minimization of negative environmental impacts. The implementation of these control measures in gaseous emissions regulates and reduces pollution, identifying exposure risks and preventing the increase of volatile organic compounds and aerosols (Biggart et al. 2020; Calla and Lujan 2018; Islam et al. 2020). Also as an environmental policy, there is the reduction of greenhouse gases (GHG) that involves the management of friendly alternatives in energy production that are

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embodied in the improvement of the environment (Akdag and Yildirim, 2020; Ma and Kang, 2020; Shi and Brasseur, 2020).
Incomplete combustion of hydrocarbons from sources such as transportation, industry and living areas produce secondary pollutants that pose a risk to ecosystems through so-called acid rain (Panagi et al. 2020; Feng et al. 2020). This exposure to harmful particles and gases contributes to the presence of cardiovascular and respiratory diseases, and also contributes to increased cases of COVID-19 contagion, which has generally been found to be associated with more severe coronavirus outcomes (Moelling and Broecker, 2020; Isaifan, 2020; Fareed et al. 2020). Transportation and industrial activity constitute the most important sources of CO, NO_X, hydrocarbon, PM, and smog emissions, causing air quality decline in urban cities (Aguilera et al. 2018; Angatha and Mehar, 2019). On the other hand, emissions from vehicular traffic during the period of social confinement by COVID-19 were decreased and showed positive effects on air quality (Gautam, 2020; Andersson et al. 2020). For the aforementioned reasons, the research determined the level of reduction of gases that deteriorate the atmosphere with the use of satellite images obtained from the Sentinel-5P sensor of the European Space Agency (ESA) Copernicus platform, in the context of social confinement by COVID-19 in the cities of Bogota, Quito, Lima, Santiago de Chile and Buenos Aires. For this purpose, the governmental regulations issued in each of the study countries were reviewed and the SNAP Desktop and Qgis programs were used for data and information analysis.

2. Materials and methods

2.1 Study area

The study area included the most important cities (capitals) of the countries of Colombia, Ecuador, Peru, Chile and Argentina, which are located in the South American region of the American continent. These cities correspond to Bogotá, Quito, Lima, Santiago de Chile and Buenos Aires.

2.2 Obtaining the concentration values of the gases

The main sources of NO_X emissions are industries and transportation; for CO, transportation and power generation; for CO_2 and SO_2, fossil fuel, construction cement, vehicle combustion and power generation; for particulate matter (PM10, PM 2.5 and others), emissions from vehicle exhaust, construction, improper disposal of solid waste, among others. The concentration values of air-deteriorating gases (SO_2, NO_2, O_3 and CO) were obtained from the .netCDF files of the Copernicus platform. These files store the information of the different atmospheric components obtained by the Copernicus program of the European Space Agency that has the Sentinel-5P Pre-Operations Data Hub service (Richter, 2015). In the research, 4 groups with different study periods were worked to make the comparisons and determine the increase and/or decrease of gas concentrations in each city (Table 1).

Table 1: Range of dates studied in the research

Groups	Date range	Time (weeks)
1	15-03-2019 / 28-03-2019	2
2	01-03-2020 / 14-03-2020	2
3	15-03-2020 / 28-03-2020	2
4	29-03-2020 / 11-04-2020	2

2.3 Sentinel-5P image processing

The Sentinel-5P images were downloaded taking into consideration the processing level, the detection period and the quadrant of the study area. SNAP Desktop Software was used to extract the information from the .netCDF files and project them to the WGS-84 system. In addition, Qgis software was used to create the point shape of the cities and store the data in the .dbf files to be later worked in Microsoft Excel. Finally, data recording was performed with the values of the gases studied to perform the statistical analysis.

2.5 Descriptive and inferential statistical analysis

The Shapiro-Wilk statistic was used for normality and Levene's statistic for data homogeneity. In addition, Pearson's correlation was used for parametric data and Spearman's correlation for nonparametric data.

3. Results and discussion

3.1 Pearson's and Spearman's correlations

For the statistical analysis, NO_2 and O_3 gases were used in the cities of Bogotá, Quito, Lima, Santiago de Chile and Buenos Aires. The CO gas was worked in the cities of Bogota, Quito, Lima and Santiago de Chile. For SO_2 gas, the data were disregarded because they did not have a good significance. Table 2 shows the Pearson and Spearman correlation coefficients for the gases studied in the different cities.

Table 2: Summary of correlation coefficients

Gas	City	Correlation				Regression	
		Pearson	Sig	Spearman	Sig	R^2	Sig ANOVA
NO2	Lima	-0.569	0.000	-	-	0.511	0.000
	Quito	-0.632	0.000	-	-	0.370	0.003
	Bogotá	-0.604	0.000	-	-	0.333	0.005
	Santiago	-0.318	0.048	-	-	0.101	0.048
	Buenos Aires	-	-	-0.678	0.000	0.462	0.899
SO2	Lima	-	-	0.187	0.171	0.083	0.163
	Quito	-0.020	0.896	-	-	0.007	0.692
	Bogotá	0.123	0.431	-	-	0.041	0.334
	Santiago	-	-	0.153	0.273	0.191	0.029
	Buenos Aires	-0.017	0.924			0.009	0.654
CO	Lima	-	-	-0.400	0.010	0.174	0.007
	Quito	-0.636	,000	-	-	0.410	0.001
	Bogotá	-0.663	,000	-	-	0.501	0.000
	Santiago	0.455	,001	-	-	0.364	0.003
	Buenos Aires	-	-	-0.221	0.299	0.051	0.287
O3	Lima	-0.534	0.000	-	-	0.325	0.002
	Quito	-	-	-0.410	0.003	0.372	0.001
	Bogotá	-0.542	0.000	-	-	0.225	0.014
	Santiago	-0.663	0.000	-	-	0.532	0.000
	Buenos Aires	-0.620	0.000	-	-	0.423	0.000

From Table 2 it was observed that the Pearson correlation showed a strong negative association for NO_2 gas in all cities and a moderate negative association in Santiago. For SO_2 gas, no city met the significance level. For CO gas, there was a strong negative association in Quito and Bogota and a moderate positive association in Santiago. For O_3 gas, the cities of Lima, Bogota, Santiago and Buenos Aires had a strong negative association. On the other hand, Spearman's correlation showed a strong negative association for NO_2 gas in the city of Buenos Aires. For SO_2 gas, the city of Santiago did not meet the significance level. For CO gas, the city of Buenos Aires did not meet the significance level. For O_3 gas, the city of Quito had a moderate negative association and met the significance level.

3.2 Level of increase or decrease in NO_2, CO and O_3 gases

Figure 3 shows the average concentration of the medians of the gases in each city studied. Concerning the concentration of NO_2 gas, it is observed that the medians are reduced as the sanitary measures are implemented in the cities of Lima, Quito, Bogota, Santiago and Buenos Aires. In addition, it is shown that the city with the highest NO_2 concentration is Santiago and the city with the lowest concentration is Quito.
For the concentration of CO gas, it was observed that the concentration values are decreasing in the cities of Lima, Quito, Bogota, and only in Santiago is there a pattern of increase in the medians. In the case of Santiago, the increase in CO is due to the social mobilizations (marches, strikes, demonstrations or others) carried out during the months of October 2019 until March 2020. These protests revolved around the constituent process of drafting a new constitution until March 18, 2020 when the Chilean government decreed a state of constitutional exception of catastrophe for a period of 90 days. In addition, it is shown that the city with the highest concentration of CO is the city of Lima and the city with the lowest concentration is Santiago.
Finally, concerning concentration of O_3 gas, the values reflected that the medians have greater variability and decrease in the fourth group, as in the cities of Lima, Quito, Bogota, Santiago and Buenos Aires. In addition, it is shown that the city with the highest O_3 concentration is the city of Buenos Aires and the city with the lowest concentration is Quito.
Air quality during the COVID-19 pandemic was also analyzed in 22 Indian cities for the period 2017 to 2020, showing insufficient changes in SO_2, a decrease of 10% in CO and 18% in NO_2, and an exceptionally increase by 17% in O_3 (Sharma et al. 2020). Similarly, analysis of air quality in 120 cities in China, in the period from January 23 to February 29, 2020, showed positive associations in CO, NO_2 and O_3, and a negative association in SO2 (Zhu, Xie, Huang and Cao, 2020). In Rio de Janeiro, air quality during the period from March 2 to April

16, 2020 showed significant levels of reduction in CO and NO_2 generated by industrial activity and diesel, in addition to the increase in O_3 due to the decrease in NO_X levels (Dantas et al. 2020). Likewise, the air quality in Milan for the period from January 1 to April 10, 2020, determined a significant reduction in CO and NO_X, an increase in O_3, and also SO_2 remained unchanged in the peripheral areas (Collivignarelli et al. 2020). Some meteorological variables such as wind and temperature were considered in the mentioned studies, and the changes in SO2 could be due to the restrictions applied in power plants, non-suspended industrial activities and the operation of some hydrocarbon companies during the quarantine (Sharma et al. 2020).

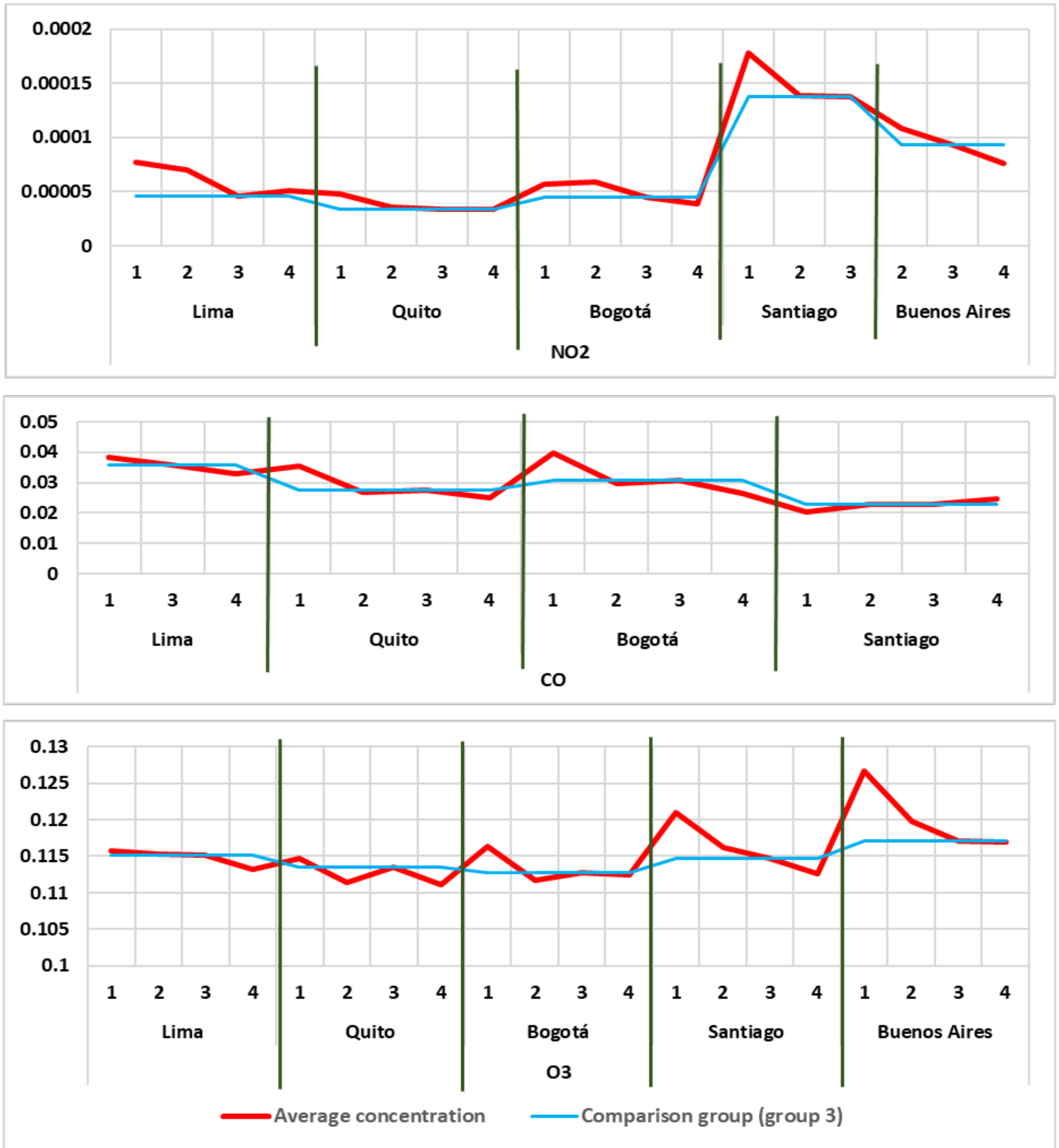

Figure 1: Increase or decrease in the concentration of air pollutant gases (NO_2, CO and O_3) during the range of dates (groups 1, 2 and 3) studied

Public policies applied as a measure to reduce polluting gases must integrate industrial processes in CO_2 emissions and absorption, since energy resource consumption in the industrial and transportation sectors is based mainly on coal, oil and/or natural gas. Therefore, socioeconomic indicators (energy consumption) and transport demand contribute to estimate air pollutants (NO_X, CO, SO_2, O_3, particulate matter) in order to develop scenarios to reduce and control greenhouse gas emissions (Geng and Meng, 2018; Atkins et al., 2018; Tran, 2019; Wang et al., 2019).

4. Conclusions

NO_2, CO and O_3 gases decreased in all cities except for the city of Santiago where CO gas increased. Pearson and Spearman statistics showed significant negative associations between strong and moderate. On the other hand, the values for SO_2 gas were disregarded because they did not present significantly important values. It was observed that there are associations in the concentrations of gases that deteriorate the air and compliance with the policies and/or regulations issued by the different governments. Regarding the concentration of NO_2 gas, it was observed that the values of the concentrations were decreasing, with the city of Santiago de Chile having the highest concentration and the city of Quito having the lowest concentration. For the concentration of CO gas, it was observed that the concentration values also decreased, with the city of Lima having the highest concentration and the city of Santiago de Chile having the lowest concentration. Finally, concerning the concentration of O_3 gas, the values reflected that the concentrations had greater variability, with the city of Buenos Aires having the highest concentration and the city of Quito having the lowest concentration.

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