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Influence of Social Confinement by COVID-19 on Air Quality in the District of San Juan de Lurigancho in Lima, Perù

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During the pandemic, citizens were immobilized and different anthropic activities were paralyzed, reducing contamination by vapor and gas emissions, and consequently improving air quality. Therefore, this research evaluated the influence of social confinement (from March to May) by COVID-19 on air quality in the district of San Juan de Lurigancho (SJL) in Lima, Peru. Data on pollutants (PM2.5, SO_2 and O_3) were obtained from the National Service of Meteorology and Hydrology (SENAMHI). The results showed that in 2019, before the social confinement, pollutants PM2.5, SO_2 and O_3 had average maximum values of 75.79, 22.97 and 22.94 µg/m^3, respectively. In the year 2020, during the social confinement, pollutants PM2.5 and SO_2 had a significant reduction, with average minimum values of 14.09 and 11.26 µg/m^3, respectively. Meanwhile, O_3 gas increased to 17.35 µg/m^3. After the quarantine, in the months of June to December 2020, a progressive increase in the concentration of pollutants was seen as industrial and vehicular transport activities were reestablished. Finally, it is concluded that social confinement by COVID-19 improves air quality and shows that urban control measures should be taken to reduce the concentration of air pollutants.

1. Introduction

Global air quality is constantly changing due to anthropogenic activities and the orogenic evolution of the planet (Zhang et al., 2020; Dong et al., 2020). Its pollution has been reflected since the beginning of the industrial revolution, progressively affecting major cities, ecosystems and society itself (Barbulescu et al., 2021; UNDP, 2021). The disproportionate increase in population and industry has generated a low quality of life, which is deteriorating due to the prolonged emission of harmful vapors and gases that generate vulnerability to children, pregnant women and the elderly (Guzmán, 2019; Mukherjee et al.,2021; Chu et al., 2021; Yin et al. 2021; Guillot, 2021).

The COVID-19 pandemic has forced to stop productive, extractive and industrial activities, decreasing the accumulation of PM2.5 and other pollutants, having as an improvement the increase of flora in the surroundings of the urban area and the air quality (Sunyer et al., 2021; Bayulken et al., 2021). In Peru, air pollution varies according to the region and the productive or extractive activities generated in the country, with annual average PM2.5 values higher than 54 µg/m3, and PM10 values higher than 50 µg/m3 (WHO, 2016; Pacsi, 2016; Gómez et al., 2020). During the pandemic, there was citizen immobilization and different industrial activities were paralyzed, decreasing pollution and improving air quality (Lanchipa et al., 2020; Skiriené and Stasiskiené, 2021; Suriya and Shreeshivadasan, 2021). This social containment is a mediation applied at the local level when both isolation and distancing actions have been insufficient to contain the spread of a disease (Garcia and Cuellar, 2020). This measure was applied for COVID-19 which is a severe acute respiratory syndrome caused by a coronavirus (Coskun et al., 2021).

The social restriction measures taken for this pandemic are associated with the decrease of air pollutant gases (WHO, 2020). Therefore, the evaluation of these gases is very important for the measurement of the level of immission and emission (Guevara, 2017). In Peru, the indicators for the evaluation of air quality are the ECA (Environmental Quality Standards) of air and the INCA (Air Quality Index) (MINAM, 2017; Huarancca, 2018).

In the air quality assessment of different cities, the levels of air pollutants were quantified to evaluate their impact on the social confinement period by COVID-19 (He et al., 2017; Cerrato et al., 2021). Being so, in São Paulo-

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Brazil, CO, NO and NO_2 pollutants were evaluated (Nakada and Urban, 2020); in Milan-Italy, CO and NO_2 pollutants were studied (Collivignarelli et al., 2020); in Buenos Aires-Argentina, NO_2, PM10 and PM2.5 pollutants were measured (Represa et al., 2021); and so in different cities of the world. For the aforementioned reasons, the present research evaluated the influence of social confinement (from March to May) by COVID- 19 on air quality in the district of San Juan de Lurigancho in Lima, Peru, considering the evaluation before, during and after social confinement concerning PM2.5, SO_2 and O_3 pollutants.

2. Materials and methods

2.1 Study area

The district of San Juan de Lurigancho is located to the Northeast of the Province of Lima that develops to the right of the Rímac River. It is characterized by a desert climate with an average temperature of 18°C. It also has a population of 1,038,495 inhabitants and a surface area of 131.25 km^2, which represents 4.91% of metropolitan Lima and 0.38% of Lima capital (Jurado and Valentín, 2021).

2.2 Data collection, acquisition and processing

Data for PM2.5, SO_2 and O_3 pollutants were obtained from SENAMHI (National Service of Meteorology and Hydrology of Peru). They were processed as follows:

- Data were organized by pollutant type according to the study period.
- The daily averages of each pollutant by year of study were determined in Excel 2016 software.
- Tables and figures were generated of the daily averages grouped monthly in the periods 2019 - 2020.

2.3 Data analysis

The data analysis was performed monthly by comparing tables and figures, representing the daily averages of each pollutant. Subsequently, each pollutant was compared with the ECA (Environmental Quality Standard) and INCA (Air Quality Index) for before, during and after the social confinement in the district of San Juan de Lurigancho. In the statistical analysis, the Kolmogorov-Smirnov normality test was used to determine the type of test to choose for the contaminants studied, considering a significance level of 5% ($\alpha = 0.05$).

3. Results and discussion

3.1 Assessment of air pollutants before social confinement by COVID-19

Table 1 shows the results of the air quality assessment before the social confinement, mainly the months that recorded the maximum daily concentration values of PM2.5, SO_2 and O_3. In June and July, PM2.5 exceeded the ECAs, with maximum values of 62.01 and 75.79 μg/m^3, respectively. Likewise, for INCA, June 8 and July 6 had poor air quality that possibly negatively impacted the sensitive population (children, elderly, pregnant women and people with respiratory diseases) and certain population in general. According to Centurión and Fababa (2020), PM2.5 concentration decreased in the districts of San Juan de Lurigancho (SJL), Carabayllo, Villa María del Triunfo (VMT) and San Borja of Metropolitan Lima during the quarantine, with values of 44, 53, 36 and 31%, respectively. It was found that in March 2019, the district of SJL obtained a PM2.5 concentration of 26.28 μg/m^3, while in the present investigation it was 30.69 μg/m^3. For June and July, the PM2.5 values are similar and coincide with what was found in the study.

With respect to SO_2, it was determined that in the months of January, May and September did not exceed the ECA, with daily maximum values of 11.44, 18.80 and 22.97 μg/m^3, respectively. Likewise, in January and February the air quality was moderate and in September the air quality was poor according to INCA. Anas et al. (2020) examined the variation of SO_2 concentration before social confinement in the city of Salé in Morocco, from March 11 to 20, having average values of 6.6 μg/m^3, which is a lower value according to the standards of that country. This showed that SO_2 values do not exceed air quality standards.

The evaluation carried out before the social confinement for O_3 showed that in April and May did not exceed the ECA, with maximum values of 22.94 and 21.68 μg/m^3, respectively. Likewise, for INCA, both months had good air quality. Sicard et al. (2020) evaluated O_3 gas in the period from January 1 to December 21, 2019, and indicated that the average concentration increased to 90 μg/m^3 in the cities of Turin and Wuhan.

Table 1: Variation of PM2.5, SO_2 and O_3 concentrations (µg/m³) before social confinement

Pollutant	Month	2019				ECA (µg/m³)	INCA (µg/m³)
		Day	Maximum (µg/m³)	Day	Minimum (µg/m³)		
$PM_{2.5}$	June	8	62.01	30	14.34	< 50	12.6 - 25 (Moderate) 25.1 - 125 (Poor)
	July	6	75.79	29	16.20		
SO_2	January	30	11.44	13	2.99	< 250	0 - 10 (Good) 11 - 20 (Moderate) 21 - 500 (Poor)
	May	6	18.80	8	6.79		
	Septembe r	29	22.97	18	11.48		
O_3	April	11	22.94	1	2.17	< 100	0 - 60 (Good)
	May	19	21.68	6	6.61		

3.2 Assessment of air pollutants during social confinement by COVID-19

Table 2 shows the results of the air quality assessment during the social confinement (from March to May). The pollutant PM2.5 showed acceptable values for the ECA in March, April and May, with maximum values of 14.09, 17.21 and 30.89 µg/m³, respectively. Likewise, for INCA, March and April had moderate air quality, and May had poor air quality. These values compared to 2019, are significantly reduced and do not exceed the ECA, as shown in Table 1. According to Abdullah et al. (2020), they determined that there was reduction in PM2.5 levels in Malaysia during the period between March 18 to April 14, 2020. Before immobilization, PM2.5 was between 42.5 and 69.2 µg/m³, and during quarantine it reached maximum values of 25 µg/m³, reducing its emission. These results were the product of the MCO (Movement Control Order), the institution in charge of vehicle restriction and social confinement. The MCO generated the suspension of the operation of industries, fewer motor vehicles on the road and the reduction of air pollutants in high pollution zones in Malaysia. In Peru, these measures can also be implemented to comply with the parameters established by INCA and ensure people's health.

The pollutant SO_2 showed acceptable values according to the ECA in March, April and May, with daily maximum values of 19.8, 12.77 and 11.26 µg/m³, respectively. Likewise, for INCA, these months had moderate air quality. In the research of Tobías et al. (2020), they recorded a decrease of SO_2 gas in Barcelona - Spain, with values around 18.4 µg/m³ during social confinement.

On the other hand, O_3 gas did not exceed the ECA in May, with a maximum value of 17.35 µg/m³. Likewise, according to INCA, the district of San Juan de Lurigancho has good air quality. Sicard et al. (2020) also evaluated O_3 gas in the cities of Turin and Wuhan in the period between January 1 to December 21, 2019, obtaining values of 90 µg/m³, which do not exceed air quality standards.

Table 2: Variation of PM2.5, SO_2 and O_3 concentrations (µg/m³) during social confinement

Pollutant	Month	Day	2019 (µg/m³)	Day	2020 (µg/m³)	ECA (µg/m³)	INCA (µg/m³)
$PM_{2.5}$	March	29	30.69	31	14.09	< 50	12.6 - 25 (Moderate) 25.1 - 125 (Poor)
	April	30	46.2	30	17.21		
	May	30	55.8	24	30.89		
SO_2	March	16	8.65	13	19.08	< 250	11 - 20 (Moderate) 21 - 500 (Mala)
	April	16	20.92	29	12.77		
	May	6	18.8	1	11.26		
O_3	May	30	14.15	27	17.35	< 100	0 - 60 (Good)

*O_3 had no data in March and April due to the maintenance of the SJL station

3.3 Assessment of air pollutants after social confinement by COVID-19

Table 3 shows the results of the air quality assessment after social confinement. The PM2.5 showed acceptable values for the ECA in June (34.44 µg/m^3) and higher values in July (53.44 µg/m^3). Likewise, in June and July the air quality was considered poor according to INCA. This is due to the fact that from the end of May to July, concentrations of this pollutant increased due to the relaxation of social confinement measures and the reactivation of economic activities at the national level by 50%. Gaurav et al. (2021) mention that India (Central India, Coastal India and Indo-Gangetic Plain (IGP)) showed the highest reduction in PM2.5 concentration in the months of June and July (42.12 and 31.88 µg/m^3) during 2020.
O3 showed acceptable values for ECA air quality in June (31.78 µg/m^3) and September (19.13 µg/m^3). Likewise, for INCA, these months have good air quality, with the high O_3 value in June. Tobias (2020) also evaluated O_3 gas in the city of Barcelona, registering high average values in the periods from May to August (56 - 73 µg/m^3). O_3 exhibited a significant increase that could be due to the decrease in NO_X emissions coming from transport activities, being one of the main causes (Silva et al., 2018).

Table 3: Variation of PM2.5, SO2 and O3 concentrations (µg/m3) after social confinement

Pollutant	Month	2020				ECA (µg/m^3)	INCA (µg/m^3)
		Day	Maximum (µg/m^3)	Day	Minimum (µg/m^3)		
PM2.5	June	26	34.44	7	3.74	< 50	12.6 - 25 (Moderate) 25.1 - 125 (Poor)
	July	14	53.44	11	17.17		
O_3	June	21	31.78	2	8.37	< 100	0 - 60 (Good)
	September	19	19.13	1	3.92		

*SO_2 does not have sufficient data for the analysis due to the maintenance of the SJL station

3.4 Statistical analysis

Table 4 shows the results of the Kolmogorov-Smirnov normality test for each contaminant.

Table 4: Kolmogórov-Smirnov normality test

Pollutants	Influence of social confinement by COVID-19	Significance
PM2.5	Before	0.200
	During	0.200
	After	0.200
SO_2	Before	0.200
	During	0.000
O_3	Before	0.175
	During	0.047
	After	0.035

From Table 4 it is observed that PM2.5 has a significance level greater than 0.05 and follows a normal distribution, therefore the ANOVA parametric test was used. The rest of the pollutants such as SO2 and O3 do not have a normal distribution, therefore the non-parametric U-Mann Whitney test was used.
Table 5 shows the hypothesis test applied to each pollutant to determine if social confinement by COVID-19 significantly influences the improvement of air quality in the District of San Juan de Lurigancho.

Table 5: Hypothesis testing using the ANOVA parametric test and the non-parametric U-Mann Whitney test

Pollutants	Significance	Null hypothesis
PM2.5	0.000	Reject the null hypothesis
SO_2	0.000	Reject the null hypothesis
O_3	0.000	Reject the null hypothesis

Table 5 showed statistically significant values (<0.05) for PM2.5, SO_2 and O_3 pollutants, indicating the rejection of the null hypothesis and accepting the researcher's hypothesis, which indicates that social confinement by COVID-19 significantly influences the improvement of air quality in the District of San Juan de Lurigancho.

4. Conclusions

Social confinement by COVID-19 improved air quality in the district of San Juan de Lurigancho (SJL), demonstrating that urban control measures should be taken to reduce the concentration of air pollutants. The pollutant that obtained the greatest reduction was PM2.5, reaching values of 14.09, 17.21 and 30.89 µg/m^3 in the months of March, April and May 2020, respectively. While, in 2019 (before social confinement), the values were 30.69, 46.20 and 55.80 µg/m^3 in the months of March, April and May, respectively. SO_2 gas had a significant reduction with average minimum values of 11.26 µg/m^3, and O_3 gas increased to the value of 17.35 µg/m3. After the quarantine, in the months of June through December 2020, a progressive increase in the concentration of pollutants was seen as industrial activities and vehicular transport were reestablished. Statistical analysis showed significant values (<0.05) for PM2.5, SO_2 and O_3 pollutants, indicating that social confinement by COVID-19 significantly influenced the improvement of air quality.

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