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SHORT COMMUNICATION

Impact of Confinement on the Reduction of Pollution and Particulate Matter Concentrations. Reflections for Public Transport Policies

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Abstract

Different initiatives have been implemented to improve air quality in large cities, such as encouraging travel by sustainable modes of transport, promoting electro-mobility, or the car-free day. However, to date, we have not found statistics that indicate to what extent the concentration levels of particulate matter $PM_{2.5}$, PM_{10} and nitrogen oxides (NO_x) pollutants decrease as a result of public policy. We used official data from the Chilean Government's national air quality information system (SINCA) for the Santiago metropolitan region and estimated the impact of the confinement by COVID-19 on the ambient concentration average values of NO_x gases and particulate matter $PM_{2.5}$ and PM_{10}, which are the main air pollutants produced by the transport sector after CO_2. We found that in general there are significant differences between the average levels of gas emissions for 2020 compared to 2019. In particular, we found that, for the months of total confinement May-July, the monthly average levels decreased between 7% and 19% for particulate matter $PM_{2.5}$, between 18% and 50% for PM_{10} and between 34% and 48% for NO_x. With the return to the new normality, these improvements in ambient concentration levels may be affected by the increase in private transport trips, due to the reluctance of citizens to return to mass public transport. Our results, therefore, represent the maximum impact that can be expected in reducing ambient concentration levels in the city of Santiago of Chile when a mobility reduction of gasoline vehicles is implemented.

Article Highlights

- The reduction of $PM_{2.5}$, PM_{10} and NO_x was no more than 7%, 18% and 34%, respectively.
- The average concentration of $PM_{2.5}$ decreased by 7–19% compared to previous years.
- The average concentration of PM_{10} decreased by 18% and 50% compared to previous years.
- Concentrating commuting on public transport would help reduce levels of PM_{10} and $PM_{2.5}$.

Keywords Particulate Matter · Transport pollution · Policies to improve air quality

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1 Introduction

In 2015, the issue of climate change prompted UN member leaders to formulate a sustainable development agenda with specific 15-year targets (O.D.D.S 2015). One of the goals formulated is to move towards the development of sustainable cities and communities, and one aspect of this goal is the transition to sustainable mobility and improvements in air quality in large metropolises (ONU 2017a). Under this logic, different initiatives have been promoted that seek to promote and measure urban sustainability (Merino-Saum et al. 2020; He et al. 2018), improve energy infrastructure (Futcher et al. 2017), promote sustainable mobility (Nikitas et al. 2021; Celata and Sanna 2019; Sdoukopoulos et al. 2019; Mozos-Blanco et al. 2018) and electro-mobility (Cansino et al. 2018; Pisoni et al. 2019; Tucki et al. 2019; Pietrzak and Pietrzak 2020; Sofia et al. 2020; Urrutia-Mosquera and Fábrega 2021), and improve air pollution levels by reducing the concentration levels of $PM_{2.5}$ and PM_{10} that is emitted by urban transport (Rudke et al. 2022; Holnicki et al. 2021; Mądziel et al. 2021; Garling 1998).

Over the last decade, the electrification of public and private transport has been considered an important aspect to reduce pollution levels and improve air quality in megacities (Sun et al. 2021; Mehlig et al. 2021; Ke et al. 2017). Under this premise, countries such as Norway, France, Japan, South Korea, Germany, the Netherlands, and England have been pioneers in testing various initiatives and incentives, including fiscal incentives, to stimulate the adoption and use of electric and hybrid vehicles as a tool to reduce pollution levels caused by public and private urban transport (Kwon et al. 2018; Diamond 2009; Jenn et al. 2013; Jin et al. 2014; Fridstrøm and Alfsen 2014; Ghahremanloo et al. 2021; Assum et al. 2014; Wang et al. 2019). These initiatives have had a positive impact on reducing concentration levels of particulate matter $PM_{2.5}$, PM_{10}, and nitrogen oxides NO_x pollutant, as well as significant improvements in air quality (Pietrzak and Pietrzak 2020; Ferrero et al. 2016; Soret et al. 2014; Yu and Stuart 2017). For example, Belalcazar-Cerón et al. (2021) suggested that the electrification of public transport bus systems can contribute to reduce $PM_{2.5}$ levels derived from the internal combustion and re-suspension processes of gasoline vehicles. Also, Kazemzadeh et al. (2022) suggested that electric cars are a source of air pollution mitigation when using electricity from green energy sources.

There is evidence that $PM_{2.5}$ levels from exhaust emissions from combustion vehicles have been reduced due to improvements in vehicle technology, but ultrafine and coarse non-exhaust particles have not been significantly reduced due to technological improvements (Conte and Contini 2019). However, Beddows and Harrison (2021) suggest that to achieve a reduction in PM_{10} and $PM_{2.5}$ emissions from vehicle electrification, regenerative braking has to be operational in the vehicle design and/or a means of recovering brake dust used. Otherwise, there is no reduction of PM_{10} from the fleet change.

For this purpose, we use the city of Santiago de Chile as a case study. Our proxy for indirect measurement is the reduction in mobility achieved in the COVID-19 confinement period, and the statistics of particulate matter concentration levels recorded in the study period. No other initiative has contributed to improving air quality and reducing the concentration levels of $PM_{2.5}$, PM_{10} and NO_x as much as COVID-19 (Zambrano-Monserrate et al. 2020; Nakada and Urban 2020; Lokhandwala and Gautam 2020; Ghahremanloo et al. 2021).

Confinement by COVID-19 revealed different direct or indirect impacts on the environment and especially on-air quality (Zambrano-Monserrate et al. 2020; Kumar et al. 2020). Recent research has shown the positive impacts of confinement on air quality in cities around the world (Gopikrishnan et al. 2022; Baimatova et al. 2022; Balamurugan et al. 2022; Ju et al. 2021; Allu et al. 2021; Lokhandwala and Gautam 2020; Arora et al. 2020; Zangari et al. 2020; Bera et al. 2020; Selvam et al. 2020; Zambrano-Monserrate and Ruano 2020; Archer 2020; Nakada and Urban 2020; Jain and Sharma 2020).

It was also shown that NO_x levels are reduced more than $PM_{2.5}$ and PM_{10} in almost all cities of the world (Gkatzelis et al. 2021). For example, the authors showed that in Asia, a 55% median NO_x decrease was observed for China and a 67% decrease in India. In Europe, studies for Italy and the UK showed a NO_x decrease of 59%, while for North and South America, the decrease was 30% and 26%, respectively (studies in Canada, the USA and Brazil). In contrast, $PM_{2.5}$ had a median decrease of 21% in Oceania, 34% in Africa, and in South America (countries such as Brazil, Chile, Colombia, Peru and Ecuador) the average decrease was 27%. The concentration of PM_{10}, on the other hand, decreased between 18% and 40% in Asian regions, and between 8% and 30% for the whole American continent. Similar values of PM_{10} and $PM_{2.5}$ concentration reduction levels at global level were also reported in the work of Dinoi et al. (2020) for Italy and Sokhi et al. (2021) at global level.

Although the empirical evidence reported so far indicates large benefits and improvements in the reduction in the concentration of particulate pollutants, in the USA particulate matter such as $PM_{2.5}$ did not report significant decreases (Archer et al. 2020). In the case of Brazilian cities, decrease in PM_{10} and $PM_{2.5}$ levels (Rudke et al. 2022) were reported, and in Andalusia (southern Spain), a slight reduction in PM_{10} levels was also reported (Millán-Martínez et al. 2022), due to transport mobility restrictions. In the old continent, large decreases are also reported as a result of mobility restrictions. According to Jain and Sharma (2020), in almost all Indian cities, $PM_{2.5}$ concentration levels were reduced by up to 41% and PM_{10} concentration levels by up to 25%. In the case of other cities such as Quito, Ecuador, the various mobility restrictions led to reductions in $PM_{2.5}$ levels of up to 29% (Zalakeviciute et al. 2020). In the city of Tehran, Iran, decreases of PM_{10} up to 30% and $PM_{2.5}$ up to 103% were also reported. This is perhaps the largest decrease in $PM_{2.5}$ concentration reported in the literature (Broomandi et al. 2022). In the case of the Chinese cities in Hubei Province, Wuhan, Jingmen, and Enshi, central China, the confinement measurement achieved reductions of PM_{10} levels by up to 8.3% and of $PM_{2.5}$ up to 72% (Xu et al. 2020). A study in Kazakhstan also shows that thanks to the absence of vehicle traffic during confinement, $PM_{2.5}$ concentration levels were reduced by 21% compared to levels in 2018 and 2019. (Kerimray et al. 2020).

Although there is a consensus so far on the benefits, the evidence also shows that the magnitude of the impacts or benefit varies according to the mobility conditions of each locality, city, or country. As in the rest of the world, the metropolitan region of Santiago, Chile, faced a period of confinement and reduced mobility between mid-May 2019 and the end of August 2019, and total confinement between May and July 2020 (Chilean Government interventions against COVID-19) forcing most of its inhabitants to work from home and/or reduce staffing levels at work facilities (Action Plan, Government of Chile 2020).

These extreme measures had a negative impact on national economies and on the world economy. In Chile, the economy was expected to shrink by 3.1% by 2021 (International Monetary Fund 2020). Confining a country will not be a policy recommendation to combat climate change, and/or improve air pollution levels. However, important lessons can be learned from the 2020 confinement, which can be seen as a social experiment on a global scale.

In the current work, we use the confinement period as a natural experiment and indirect measurement scenario, draw on the ideas of Wang et al. (2020) and Wang et al. (2021) and based on this information, we indirectly calculate the maximum level of reduction in the concentration levels of pollutants $PM_{2.5}$, PM_{10} and NO_x that can be aspired to as a result of an eventual policy of electrification of urban transport.

For this purpose, we use the emissions data reported by the Governmental Authority (SINCA 2021), for the Metropolitan Region of Santiago de Chile. The metropolitan region has been considered because it is the region with the highest number of private vehicles in the national vehicle fleet. In addition, the metropolitan region is a locality that implements restrictions on the circulation of private vehicles in the winter, due to the concentration levels of particulate matter $PM_{2.5}$ and PM_{10}, which coincide with the period of total confinement in the region. Therefore, by using the city of Santiago de Chile as a case study, we seek to answer the following questions:

- What is the maximum reduction in the concentration levels of particulate matter $PM_{2.5}$, PM_{10}, and NO_x pollutants that can be achieved with a policy of electrification of public transport and private vehicles in the Santiago city?
- Will promoting strong restrictions on mobility have a greater impact than those achieved in the COVID-19 blocking period?

These questions are relevant to the commitment of countries to develop sustainable development policies and resilience to climate change.

The impacts of electrification on the reduction of particulate matter differ according to various physical, urban and environmental factors in cities (Beddows and Harrison 2021), and for this reason, the results of this work, from the context of Chile, can add to the international empirical evidence. We contribute to the literature by providing an estimation of the impact in terms of the maximum level of reduction of the concentration level of $PM_{2.5}$, PM_{10} and NO_x that can be expected as a result of policies related to mobility restrictions and/or the renewal of the conventional vehicle fleet by electric vehicles as a long-term policy. According to international evidence, $PM_{2.5}$ levels can be reduced by 10–50% through electrification of public transport (Rizza et al. 2021; Wang et al. 2020; Wang et al. 2021).

2 Case Study and Data Sources

Santiago de Chile is the capital of the largest metropolitan region of Chile, with an area of approximately 640 km^2, as it is also the city with the largest number of inhabitants (6,310,000 inhabitants according to the 2017 population census). It is also the city with the highest proportion of private car fleet 39.3% of a country total of 5.5 million according to figures from the National Institute of Statistics (INE 2019). It is also the only city in the country with a multimodal transport system. Finally, it concentrates the greatest amount and diversity of economic activity in the country (Munizaga and Palma 2012; Urrutia-Mosquera and Fábrega 2021).

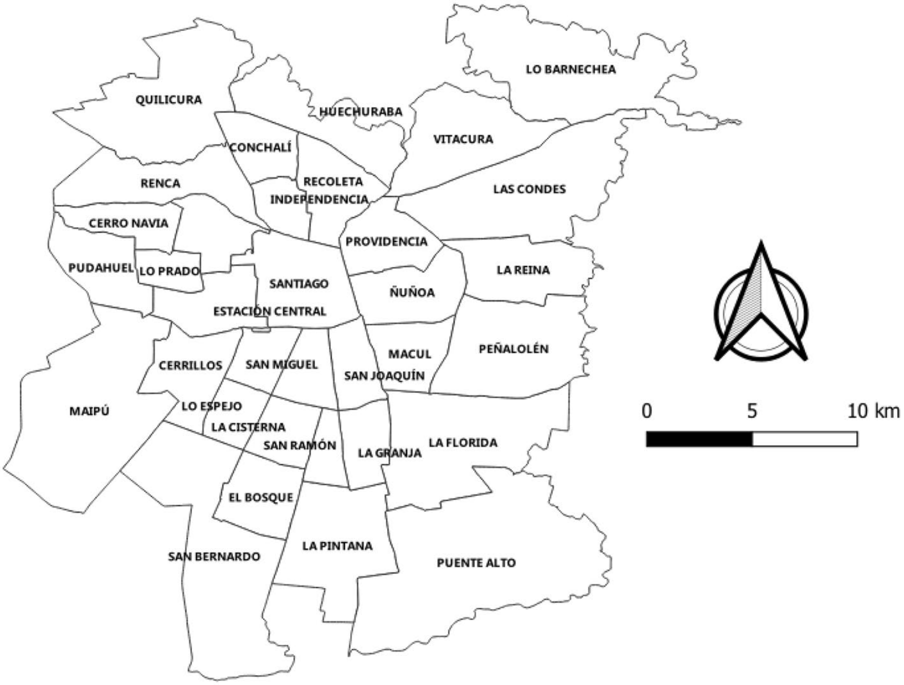


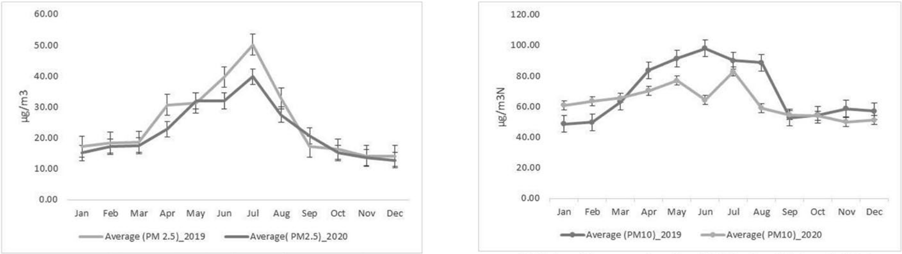
Fig. 1 Municipalities of Santiago to be considered for analysis

Due to the geographical characteristics of the Santiago city, the concentration levels of $PM_{2.5}$, PM_{10} and NO_x regularly exceed the National Ambient Air Quality Standards (NAAQS) for more than 35, 40, and 80 days of the year (Toro et al. 2021; Seguel et al. 2020; Molina et al. 2017). The transport sector is responsible for 25% of carbon dioxide emissions and particulate matter concentration levels (Gallardo et al. 2018). We use the registries of the national air quality information system (SINCA 2021), and statistically compared the differences between the concentration levels of $PM_{2.5}$, PM_{10} and NO_x for the year 2019 and 2020. Figure 1 shows the study city.

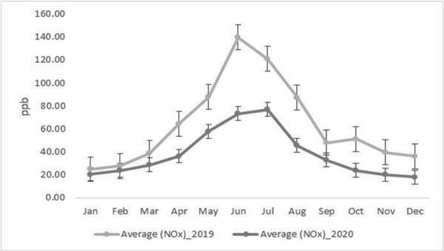
3 Methodology

The modelling approach consists of the use of inferential statistical analysis; specifically, we used hypothesis testing to test the mean differences in the concentration levels of $PM_{2.5}$, PM_{10} and NO_x.

With the daily records, we generated a distribution of sample means to make aggregate estimates for the metropolitan region. We calculated the average particulate matter concentration levels for 2019 and 2020 for the 12 months of the respective years and the 52 weeks (Fig. 2). A paired samples test was then performed with the constructed sampling distributions of means (Walpole et al. 2012; Anderson et al. 2008), which is the simplest and most parsimonious parametric approach that allows to analyse differences in the means



(a) Monthly mean levels of $PM_{2.5}$ for 2019 and 2020 **(b)** Monthly mean levels of PM_{10} for 2019 and 2020



(c) Monthly mean levels of NOx for 2019 and 2020

Fig. 2 Monthly average variations of particulate matter PM_{10}, $PM_{2.5}$*and* NO_X or the years 2019 and 2020

of observations taken on the same individual (national air quality information system) over different time periods. This approach must meet three requirements: (1) random sample; (2) paired sample; and (3) normal distribution or more than 30 observations ($n > 30$). These assumptions were validated at the data pre-processing stage. The paired samples t-test is defined as follows:

$$t = \frac{\widehat{x}_D}{\frac{s_D}{\sqrt{n}}} \,(1)$$

where: $\widehat{x}_D$ is the mean of the differences; s_D is the standard deviation of the differences; n is is the number of pairs of observations. The null hypothesis to test is H_0: $\widehat{x}_D = 0$. Alternative hypothesis is H_0: $\widehat{x}_D \neq 0$.

Rejection of the null hypothesis provides sufficient statistical evidence to validate the differences between the mean particulate matter concentration levels for the comparison years and periods. Further details of the assumptions and data requirements can be found in (Douglas 2002; Urias and Salvador 2014; Herrera Gomez 2015). Data processing, in addition to cleaning the records, involved the validation of statistical assumptions prior to estimation.

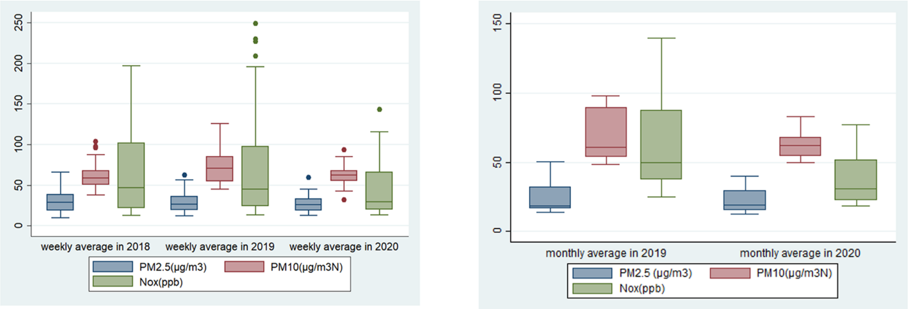
4 Results

Table 1 shows the descriptive statistics and relative differences between the mean concentration levels of $PM_{2.5}$, PM_{10} and NO_x for the year 2020 compared to the year 2019. Fig. 3a and b illustrate the differences between weekly and monthly averages of $PM_{2.5}$, PM_{10} and

Table 1 Descriptive statistics of the variables

$PM_{2.5}$ (μg/m^3)						
	μ_2019	σ_2019	μ_2020	σ_2020	μ_2020−μ_2019	% Decreasing
Jan	17.17	3.13	15.17	0.98	2	-11.7%
Feb	18.5	2,59	17.17	1.72	1.33	-7.2%
Mar	18.67	1.51	17.5	1.64	1.17	-6.3%
Apr	30.67	2.94	22.83	3.76	7.83	-25.5%
May	31.33	6.31	32	7.46	-0.67	2.1%
Jun	39.67	12.14	32	11.35	7.67	-19.3%
Jul	50.17	10.8	39.83	14.15	10.33	-20.6%
Aug	32.83	6.01	27.5	4.76	5.33	-16.2%
Sep	17.17	1.83	20.67	3.27	-3.5	20.4%
Oct	16.33	2.25	15.17	2.48	1.17	-7.1%
Nov	14.17	2.14	13.67	2.25	0.5	-3.5%
Dec	14.17	1.33	12.83	2.14	1.33	-9.4%
NO_x (ppb)						
	μ_2019	σ_2019	μ_2020	σ_2020	μ_2020−μ_2019	% Decreasing
Jan	24.86	7.24	20.57	6.68	4.29	-0.172
Feb	27.57	6.6	23.86	6.15	3.71	-13.5%
Mar	39	17.25	28.71	7.85	10.29	-26.4%
Apr	64.57	10.56	36.29	8.75	28.29	-43.8%
May	87.86	12.02	58	3.94	29.86	-34.0%
Jun	139.86	9.71	73.43	21.3	66.43	-47.5%
Jul	121.14	9.66	77	5.61	44.14	-36.4%
Aug	87.57	18.27	45.43	4.57	42.14	-48.1%
Sep	47.93	8.85	32.86	9.75	15.07	-31.4%
Oct	51.2	14.72	23.86	7.47	27.34	-53.4%
Nov	39.54	8.53	20	5.69	19.54	-49.4%
Dec	36.14	5.77	18.14	6.84	18	-49.8%
PM_{10} (μg/m^3)						
	μ_2019	σ_2019	μ_2020	σ_2020	μ_2020−μ_2019	% Decreasing
Jan	48.56	4.03	60.89	6.01	-12.33	0.203
Feb	49.78	5.43	63.67	4.95	-13.89	21.8%
Mar	63.11	6.35	65.67	6.75	-2,56	3.9%
Apr	83.67	7.35	70.44	7.95	13.22	-18.8%
May	91.44	12.13	77	11.19	14.44	-18.8%
Jun	98	14.04	64.33	14.78	33.67	-52.3%
Jul	109.89	18.82	82.89	14.41	27	-32.6%
Aug	88.78	11.36	59	6.8	29.78	-50.5%
Sep	52.78	3.56	54.44	5.55	-1.67	3.1%
Oct	54.44	3.68	54.11	4.96	0.33	-0.6%
Nov	58.56	4.42	49.89	5.18	8.67	-17.4%
Dec	57	5.29	51.22	4.89	5.78	-11.3%

NO_x concentration levels for the years 2018, 2019 and 2020, respectively. The statistics indicate a reduction between 7% and 19% of the mean concentration levels for $PM_{2.5}$ particulate material. The $PM_{2.5}$ and PM_{10} reduction levels achieved in the city during containment are consistent with the figures reported by others (Rizza et al. 2021; Dantas et al. 2020; Abdullah et al. 2020; Zalakeviciute et al. 2020).



(a) Weekly average levels of $PM_{2.5}$, PM_{10}, and NOx for the years 2018, 2019 and 2020

(b) Monthly average levels of $PM_{2.5}$, PM_{10} and NOx for the years 2018, 2019 and 2020

Fig. 3 Weekly and monthly averages variations of particulate matter PM_{10}, $PM_{2.5}$ and NO_X for the years 2018, 2019, and 2020

Table 2 Paired sample test. The global average of observations from all stations

Ho: mean ($PM_{2.5}\_2020$ - $PM_{2.5}\_2019$)=0			
Variable (µg/m^3)	*Mean*	*Std. Err.*	*t*
$PM_{2.5}\_2019$	25.06	1.45	5.43
$PM_{2.5}\_2020$	22.19	1.19	
Ho: mean (NOx_2020 - NOx_2019)=0			
Variable (ppb)	*Mean*	*Std. Err.*	*t*
NO_x_2019	63.93	5.12	6.79
NO_x_2020	38.17	2,53	
Ho: = mean ($PM_{10}_$2020 - $PM_{10}_$2019)=0			
Variable(µg/m^{3}N)	*Mean*	*Std. Err.*	*t*
PM_{10}_2019	71.33	2.2	5.5
PM_{10}_2020	62.79	1.2	

Reductions between 34% and 48% of mean concentration levels of NO_x, and reductions between 18% and 50% of particulate material PM_{10} in the months of strict confinement (mid-May to early August 2020) are shown in the metropolitan region. As it is known, these three pollutants are mainly produced by combustion vehicles (Gallardo et al. 2018), so the reduction of mobility in the period of strict confinement had a positive and significant impact on the reduction of mean concentration levels of the pollutants produced by the transport sector.

Figure 2 shows the greatest reduction in mean concentration levels in the containment period and Fig. 3 shows the mean differences for the three pollutants in the periods analysed. As can be seen, there is a slight decrease at the beginning of the pandemic due to reduced mobility, and a sharp decrease in average emission levels in the strict confinement period. Table 2, compares the averages and indicates that overall the monthly mean concentration levels of $PM_{2.5}$, NO_x and PM_{10} in 2020 are differ statistically significantly from 2019.

According to the results, the answer to the questions posed is that the maximum reduction that can be achieved in the concentration levels of NO_x, PM_{10} and $PM_{2.5}$ with the electrification of urban transport is at most 18% for NO_x, 19% for $PM_{2.5}$ and 50% for PM_{10}, compared to pre-pandemic records. This is if we consider as a counterfactual reference the maximum levels reached during total confinement, where urban mobility is no more than

10% (Olivares et al. 2020). Although an indirect measurement source is used in this work, the results are valuable in that they determine and provide a reference value against which the results of future studies with direct measurements can be compared.

According to the transport literature and data reported in different empirical works, commuting and study trips represent between 60% and 70% of total urban trips in cities (Alsger et al. 2018; Urrutia-Mosquera 2020; An et al. 2021). In this sense, if the aim is to reduce the concentration levels of $PM_{2.5}$, PM_{10} and NO_x pollutants produced by work and study trips, one learning from confinement is to alternate teleworking and online classes with face-to-face work and face-to-face classes. Such measures have been proven to have environmental benefits as reported by Guerin (2021), Tenailleau et al. (2021) and Filho et al. (2021).

In the Chilean case, the electro-mobility initiative establishes the electrification of 100% of the urban public transport fleet by 2040 and 40% of private electric vehicles by 2050. While this initiative is plausible and reasonable considering the economic challenges involved and the transformations in terms of infrastructure, it is important to consider combined options that reduce mobility and/or dependence on private vehicle use to reduce pollution levels in the short and medium term. We, therefore, consider that one of the lessons learned from confinement, which can be used as public policy, is to harmonise working from home with working in offices. Telework has been seen as a potential policy to support sustainable transport, at least in the past, as evidenced by Cairns et al. (2005). In principle, working from home for all or part of the week can reduce congestion (Santos et al. 2010), and thus, emission levels (Chen et al. 2020). In this sense, the results of this research should feed into the debate on policy options that generate short-term impacts to help achieve reductions in pollution levels produced by the urban passenger transport sector and personal vehicle use.

5 Conclusions and Policy Recommendations

We used official data from the Chilean Government's national air quality information system (SINCA) for the Santiago metropolitan region and estimated the impact of COVID-19 confinement on the average values of NO_x, $PM_{2.5}$ and PM_{10}. For this purpose, the classical analysis of hypothesis testing for paired samples was used to test whether the decreases in the mean concentration levels of PM_{10}, $PM_{2.5}$ and NO_x, in the containment period, were statistically significantly lower than the average concentration levels recorded before the pandemic. The results confirm that the differences in mean concentration levels were statistically significant. In particular, we found that for the months of total confinement, May-July, the monthly average levels decreased between 7% and 19% for $PM_{2.5}$, between 18% and 50% for PM_{10}, and between 34% and 48% for NO_x.

With the results obtained, the option of considering strong restrictions on urban mobility as a policy alternative would be completely ruled out. According to the data, the magnitude of the reduction in the concentrations of particulate matter $PM_{2.5}$ and PM_{10} does not compensate for the opportunity cost of restricting mobility in the city.

Based on the results, it is expected that a policy combining home-based and face-to-face work, as well as face-to-face and remote classes, can lead to net reductions of not less than 3.5% for $PM_{2.5}$ particulate matter, 13% for NO_x and not less than 0.6% for PM_{10} particulate matter.

The answer to the question of whether policies of electrification of the urban public transport fleet and mobility restriction allow for a decrease equal to or greater than that achieved in periods of confinement is likely to be negative. However, it can be inferred that combining electrification with home working and virtual schooling contributes to a significant decrease in private transport trips, and thus, has positive impacts on the reduction of pollution levels from the transport sector.

One limitation of this study is that it is not possible to have direct measurements of the amount of particulate matter emitted by the public transport fleet and the private vehicle fleet. This same aspect opens up a future line of work to address this shortcoming and to compare how the concentration levels of particulate matter have varied with the electrification of the public transport fleet in the metropolitan region of Santiago de Chile.

It is also necessary to perform this type of analysis considering observations for a longer period of time, pre- and post-pandemic, taking into account the traffic of petrol vehicles and the different percentage of electric vehicles in the city. This would allow for measurements that account for the effectiveness of the urban transport electrification policy in improving the city's air quality.

Another limitation related to our study relates to the impossibility of separating the impact of meteorological conditions from transport traffic and mobility conditions in a plausible way on air quality. We hope to address this aspect in future work.

Author Contributions All authors contributed to the study conception and design. **Jorge Urrutia-Mosquera**: Conceptualization Investigation, Data curation, Methodology, Estimation of results, Formal analysis, Writing – draft paper. **Luz Flórez-Calderón**: Data curation, Reviewing and Editing, Writing- Reviewing and Editing.

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Data Availability The data used in this research are from the Chilean Government's National Air Quality Information System. They are available and can be downloaded from the website: https://sinca.mma.gob.cl/.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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