The impact of COVID-19 partial lockdown on air pollution levels – A case study of Cyprus

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Abstract

This study aims to analyze the changes in air pollution levels during lockdown measures in Cyprus. Lockdown measures came into force from March 13th 2020, few days after the first COVID-19 case was registered. The study analyses the data from different air quality monitoring stations in Cyprus in order to estimate air pollutant concentration variations during lockdown period. The data collected was compared to the previous year's monthly values of emissions. Results show that during the lockdown period, there was a significant reduction on NOx, NO and NO2 (65,07%, 75,20% and 59,67% respectively) at the traffic air quality monitoring stations. A lower reduction was observed for CO (28.50%) and C6H6 (58,34%). SO2 concentrations did not show significant reductions while ozone levels (O3) increased. The results clearly show the traffic-related air pollution and necessitate further design strategy plan about the allocation of the traffic volume and the promotion of public transportation and the use of alternative fuels.

Keywords: COVID-19; Lockdown measures; Air quality; Traffic emission reduction

1. Introduction

On March 11, 2020, the World Health Organization (WHO) declared as a pandemic, the disease caused by the new coronavirus SARS-CoV-2, COVID-19 (WHO, 2021). The main source of transmission of SARS-CoV-2 is from human-to-human by respiration of infectious droplets, indirect contact with infectious surfaces and inhalation of indoors infectious aerosol (Di Maria et al., 2020). However, during the COVID-19 pandemic there have been recorded higher numbers of infected people at the countries where there is higher concentration of air pollutants (Bao and Zhang, 2020). It is observed that under certain climatic conditions, air pollution acts as a carrier of the virus, facilitating its transmission and spreading (Zoran et al., 2020). To reduce infection, restrictive circulation measures were implemented worldwide. Due to these partial lockdowns numerous of cities worldwide experienced air quality improvements (Zambrano-Monserrate, Ruano and Sanchez-Alcalde, 2020).

Air pollution was dramatically reduced as traffic and industrial activities had decreased significantly (Tian et al., 2021). The improvement of air quality due to NO2 was evident for the first time in Wuhan and then spread to the rest of the country and eventually around the world. In China, NO2 emissions decreased by up to 30% and CO2 emissions by 25% (Dutheil, Baker and Navel, 2020). Such a reduction rate is equivalent to 1 million tons of carbon emissions, equivalent to 6% of global emissions over the same period (Wang and Su, 2020). An apparent decrease was observed towards the end of January 2020 and until the end of February 2020. In Europe, NO2 levels remained stable for the whole of February 2020 until the beginning of March 2020, when they began to decline significantly in mid-March 2020. In North America significant changes occurred between mid-to-late March 2020 due to the epidemiological situation in New York. In all cases, the reductions in NO2 concentrations were equivalent to the restrictive measures applied on each continent (Zhang et al., 2021).

According to Rodríguez-Urrego and Rodríguez-Urrego (2020) an average global decrease of PM2.5% was observed in 50 polluted cities worldwide. Specifically, the three most polluted capitals are Dhaka (Bangladesh), Kampala (Uganda) and Delhi (India) reduced PM2.5 concentrations by 14%, 35% and 40% respectively. The largest 57% decrease is recorded in Bogota (Colombia) which is considered one of the cities with the most traffic in the world (Rodríguez-Urrego and Rodríguez-Urrego, 2020). In addition, Dhaka reduced concentrations in CO, NO2 and SO2 by 8.8%, 20.4% and 17.5% respectively (Rahman et al., 2021).

Spain has recorded substantial decreases among pollutants after two weeks of lockdown. The traffic volume reduced up to 80% while fuel sales have fallen 83% for gasoline and 61% for diesel (Baldasano, 2020). As a result, the concentration of NO2 decreased by an average of 62% in Madrid and by 50% in Barcelona (Baldasano, 2020). Moreover, in Barcelona there was a significant reduction in black carbon concentrations by 45% in the urban air

pollution (Tobías et al., 2020). For PM10, the reduction was 28% in the traffic background stations and 31% in the urban (Tobías et al., 2020). Similar reductions were observed in Milan for PM10, PM2.5, NOx, CO, black carbon and C6H6 while SO2 remained unchanged and O3 increased due to lower concentrations of NO (Kanniah et al., 2020). In Paris the CO concentrations were reduced by 67% and NO2 by 39% (Connerton et al., 2020).

According to Nakada and Urban (2020), during the pandemic period in São Paulo (Brazil), NO2 concentrations decreased by 54.3% and NO concentrations by up to 77.3% at traffic stations. In the city center, CO concentrations were decreased by 64.8% and O3 concentrations increased by 30%. In Rio de Janeiro, during the first week of the restrictive measurements, there was a significant reduction of NO2 and PM10 while CO levels decreased by 30.3-48.5% as a result of the halted traffic volume (Dantas et al., 2020).

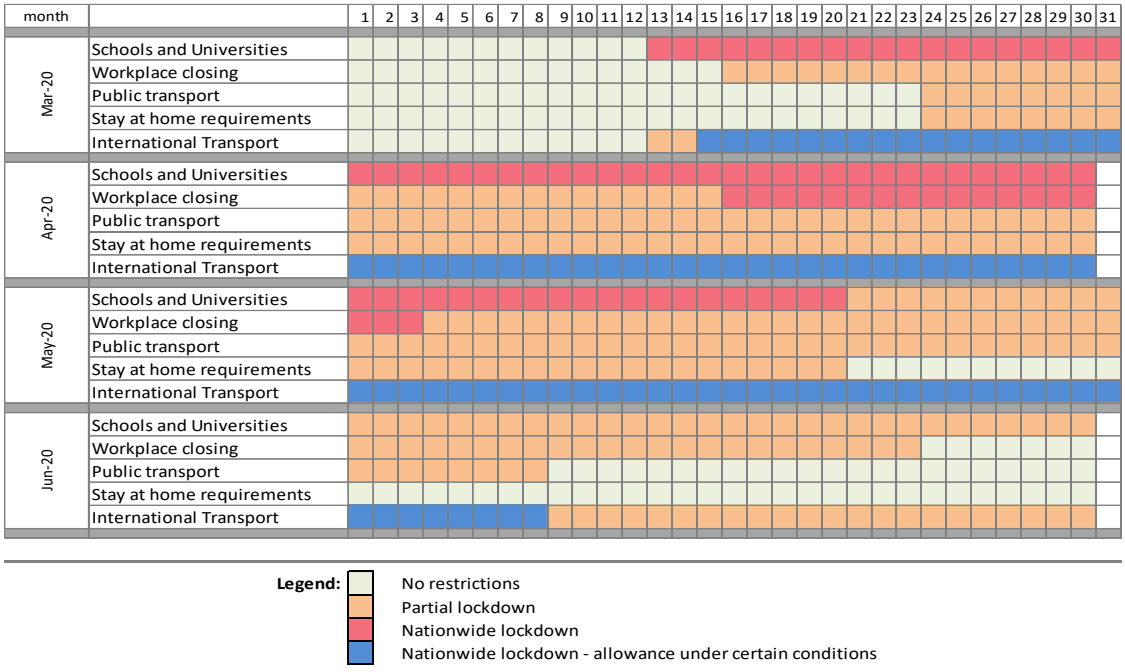
The aim of this study was to assess impacts on air quality in Cyprus, during the partial lockdown measures implemented to flatten the epidemic curve due to the COVID-19 pandemic.

2. Materials and methods

2.1 Data collection

Lockdown measures in Cyprus, were in place from March 13th to May 21st, 2020, closing elementary, middle and high schools, universities and eventually closing businesses and organizations and implement stay at home requirements. The restrictions included social distance measures and movements were prohibited. From March 15th, Cyprus closed borders prohibiting the entry to any citizen thus decreasing the demand of oil supplies to airplanes by 88.5% (Figure 1).

To study the impact of partial lockdown on air quality, the data from different air quality monitoring stations was used to assess levels of nitrogen dioxide (NO2), carbon monoxide (CO), sulfur dioxide (SO2), benzene (C6H6) and ozone (O3). Daily averages have been calculated for the previous year and during the lockdown period, assessing the variation in the mean concentration ($\mu g/m^3$) between both years, and their relative change (%).



Note: For the preparation of the table, data was gained from "Oxford COVID-19 Government Response Tracker", https://covidtracker.bsg.ox.ac.uk/

Figure 1. Scheme of activities prohibited during the partial lockdown measures in Cyprus

3. Results and Discussion

3.1 Changes in nitrogen oxides emissions

Most NO2 emissions come from burning of fossil fuels, especially from vehicles (Tian et al., 2021) while the heavy-duty diesel trucks are major sources of NO (Nakada and Urban, 2020). During April, the major month of the lockdown measures in Cyprus, there was a significant reduction on NOx, NO and NO2 concentrations decreased by 65,07%, 75,20% and 59,67% respectively in the traffic stations and by 73.25%, 71.03% and 73.59% in the urban station (Table 1). The reductions in the urban station was larger but similar to those of traffic stations as it is located in the city center and related to traffic emissions. On the contrary, the industrial stations have lower percentage reductions due to the industrial activities of Vasilikos Power Station and the cement factory that is located in the same area. The cement industry is linked to NO2 emissions from the clinker - the major raw material for cement - production burning process under high temperatures (Mosca et al., 2014).

3.2 Changes in carbon monoxide emissions

CO emissions results from the incomplete combustion of the hydrocarbons in the fuel of light-duty vehicles (Dantas et al., 2020). Thus, due to the halted traffic volume, CO concentrations were reduced by 27.46% and 28.50% in urban and traffic background stations respectively (Table 1).

3.3 Changes in sulphur dioxide emissions

SO2 is an important indicator of air pollution. İt is associated with industrial activities related to the combustion of fossil fuels and road traffic (Otmani et al., 2020). SO2 reductions are gradually observed during May (the third month of the partial lockdown measures) in the industrial and traffic background stations.

3.4 Changes in benzene emissions

Benzene is included in the volatile organic compounds (VOCs) and is mainly produced by vehicular traffic, refineries and transshipment of petroleum fuels (Collivignarelli et al., 2020). During April there is a reduction in the traffic background stations by 58.34%. Further reduction of 60.03% was observed during June in the industrial background stations that can be due to the decrease in demand for petroleum products after April 2020.

3.5 Changes in ground-level ozone

O3 is a secondary pollutant formed in the lower atmosphere by chemical reactions between NOx and VOCs in the presence of sunlight (Cooper and Alley, 2002). In urban centers, the increase in O3 levels results from the decreased of NOx in a VOCs-limited environment (Tobías et al., 2020). Also, the reduction of NO reduces O3 consumption according to the NO2 photolytic cycle: NO+O3→NO2+O2 thus reducing O3 concentrations (Cooper and Alley, 2002).

Unlike the other pollutants, O3 concentrations increased during April probably due to NO2 and NO reductions in a VOCs-limited environment of the reduced concentrations of C6H6. Moreover, during April and May the high concentrations of dust that observed may contribute to the increase of O3 levels.

4. Conclusions

Significant air quality improvements were observed during the partial lockdown in Cyprus. The most significant variation was observed for on NOx, NO and NO2 (65,07%, 75,20% and 59,67% respectively) at the traffic air quality monitoring stations. A lower reduction was observed for CO (28.50%) and C6H6 (58,34%). The results clearly show the traffic-related air pollution and necessitate further design strategy plan about the allocation of the traffic volume and the promotion of public transportation and the use of alternative fuels.

Table 1. Mean concentration and relative change of: C6H6, CO, NO, NO2, NOX, O3, SO2 in Cyprus.

Type of Station/air pollutant µg/m3	Monthly mean concentration 2019				Monthly mean concentration 2020			
	Mar	Apr	May	Jun	Mar	Apr	May	Jun
Industrial Stations								
C_6H_6	0.32	0.28	0.26	0.26	0.56	0.24	0.13	0.10
CO	158.25	178.16	163.09	190.11	216.77	161.44	254.12	312.41
NO	2.05	2.17	2.26	2.37	1.55	0.81	1.14	1.89
NO_2	8.18	8.47	10.84	10.70	9.54	6.71	8.62	13.85
NOx	11.14	11.61	14.29	14.29	11.92	7.91	10.26	16.73
O_3	67.81	76.77	80.76	70.32	72.89	79.85	76.43	65.30
SO_2	2.10	1.90	3.04	2.96	2.10	2.46	2.16	2.47
Traffic Stations								
C_6H_6	0.85	0.73	0.51	0.36	0.67	0.30	0.37	0.29
CO	363.12	339.93	296.80	311.75	294.49	243.06	246.71	244.90
NO	8.92	7.35	5.91	4.09	5.48	1.82	3.90	3.17
NO_2	23.32	21.65	21.66	16.67	17.76	8.73	14.29	14.49
NOx	37.00	32.91	30.71	22.94	26.07	11.50	20.22	19.25
O_3	61.60	69.09	78.44	71.43	66.49	81.09	77.87	75.06
SO_2	2.43	2.25	2.80	2.55	2.51	2.00	2.23	2.23
Urban								
CO	350.29	306.24	228.89	198.35	299.85	222.15	206.47	187.42
NO	5.00	3.83	2.21	1.55	2.87	1.11	1.90	1.54
NO_2	25.55	26.23	22.37	21.70	17.02	6.93	10.35	13.39
NOx	33.20	32.11	25.76	24.08	21.36	8.59	13.22	15.75
O_3	61.14	70.74	92.25	88.03	66.17	82.10	80.21	85.04
SO_2	1.76	1.43	1.81	1.53	1.96	1.70	1.70	2.22

References

Baldasano, J.M. (2020), COVID-19 lockdown effects on air quality by NO2 in the cities of Barcelona and Madrid (Spain). *Science of the Total Environment*, **741**, 140353.

Bao, R. and Zhang, A. (2020), Does lockdown reduce air pollution? Evidence from 44 cities in northern China. *Science of the Total Environment*, **731**, 139052.

Collivignarelli, M.C., Abbà, A., Bertanza, G., Pedrazzani, R., Ricciardi, P. and Carnevale Miino, M. (2020), Lockdown for CoViD-2019 in Milan: What are the effects on air quality? *Science of the Total Environment*, **732**, 1–9.

Connerton, P., de Assunção, J.V., de Miranda, R.M., Slovic, A.D., Pérez-Martínez, P.J., Ribeiro, H., Slovic, A.D., Pérez-Martínez, P.J. and Ribeiro, H. (2020), Air Quality during COVID-19 in Four Megacities: Lessons and Challenges for Public Health. *International Journal of Environmental Research and Public Health*, **17**, 5067.

Cooper, D.C. and Alley, C.F. (2002), *Air Pollution Control: A Design Approach*. 3th Editio ed. Waveland Press, Inc.

Dantas, G., Siciliano, B., França, B.B., da Silva, C.M. and Arbilla, G. (2020), The impact of COVID-19 partial lockdown on the air quality of the city of Rio de Janeiro, Brazil. *Science of the Total Environment*, **729**, 139085.

Dutheil, F., Baker, J.S. and Navel, V. (2020), COVID-19 as a factor influencing air pollution? *Environmental Pollution*, **263**, 2019–2021.

Kanniah, K.D., Kamarul Zaman, N.A.F., Kaskaoutis, D.G. and Latif, M.T. (2020), COVID-19's impact on the atmospheric environment in the Southeast Asia region. *Science of the Total Environment*, **736**, 139658.

Di Maria, F., Beccaloni, E., Bonadonna, L., Cini, C., Confalonieri, E., La Rosa, G., Milana, M.R., Testai, E. and Scaini, F. (2020), Minimization of spreading of SARS-CoV-2 via household waste produced by subjects affected by COVID-19 or in quarantine. *Science of the Total Environment*, **743**, 140803.

Mosca, S., Benedetti, P., Guerriero, E. and Rotatori, M. (2014), Assessment of nitrous oxide emission from cement plants: Real data measured with both Fourier transform infrared and nondispersive infrared techniques. *Journal of the Air & Waste Management Association*, **64**, 1270–1278.

Nakada, L.Y.K. and Urban, R.C. (2020), COVID-19 pandemic: Impacts on the air quality during the partial lockdown in São Paulo state, Brazil. *Science of the Total Environment*, **730**, 139087

Otmani, A., Benchrif, A., Tahri, M., Bounakhla, M., Chakir, E.M., El Bouch, M. and Krombi, M. (2020), Impact of Covid-19 lockdown on PM10, SO2 and NO2 concentrations in Salé City (Morocco). *Science of the Total Environment*, **735**, 139541.

Rahman, M.S., Azad, M.A.K., Hasanuzzaman, M., Salam, R., Islam, A.R.M.T., Rahman, M.M. and Hoque, M.M.M. (2021), How air quality and COVID-19 transmission change under different lockdown scenarios? A case from Dhaka city, Bangladesh. *Science of The Total Environment*, **762**, 143161.

Rodríguez-Urrego, D. and Rodríguez-Urrego, L. (2020), Air quality during the COVID-19: PM2.5 analysis in the 50 most polluted capital cities in the world. *Environmental Pollution*, **266**, 115042.

Tian, X., An, C., Chen, Z. and Tian, Z. (2021), Assessing the impact of COVID-19 pandemic on urban transportation and air quality in Canada. *Science of the Total Environment*, **765**, 144270.

Tobías, A., Carnerero, C., Reche, C., Massagué, J., Via, M., Minguillón, M.C., Alastuey, A. and Querol, X. (2020), Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic. *Science of the Total Environment*, **726**, 138540.

Wang, Q. and Su, M. (2020), A preliminary assessment of the impact of COVID-19 on environment – A case study of China. *Science of the Total Environment*, **728**, 138915.

WHO, 2021. *WHO | World Health Organization*. [online] Available at: <https://www.who.int/>.

Zambrano-Monserrate, M.A., Ruano, M.A. and Sanchez-Alcalde, L. (2020), Indirect effects of COVID-19 on the environment. *Science of the Total Environment*, **728**, 138813.

Zhang, H., Lin, Y., Wei, S., Loo, B.P.Y., Lai, P.C., Lam, Y.F., Wan, L. and Li, Y. (2021), Global association between satellite-derived nitrogen dioxide (NO2) and lockdown policies under the COVID-19 pandemic. *Science of The Total Environment*, **761**, 144148.

Zoran, M.A., Savastru, R.S., Savastru, D.M. and Tautan, M.N. (2020), Assessing the relationship between ground levels of ozone (O3) and nitrogen dioxide (NO2) with coronavirus (COVID-19) in Milan, Italy. *Science of the Total Environment*, **740**, 140005.