THE IMPACT OF RESTRICTION MEASURES IMPLEMENTATION DUE TO COVID-19 ON PARTICULATE ATMOSPHERIC POLLUTION IN GREEK URBAN AREAS

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Abstract

In this work, the variation on the levels of suspended particulates, in Greek urban areas, was examined, for the period of the restrictive measures implementation (period 1: March to May 2020 and period 2: November 2020 to January 2021) due to the pandemic caused by the COVID-19 virus. The PM_{10} and $PM_{2.5}$ concentrations are measured by the National Air Pollution Monitoring Network of Greece monitored by the Energy/Environment Ministry. In particular, a comparison of the PM_{10} and $PM_{2.5}$ concentration levels was made, concerning the above time periods, with the corresponding atmospheric pollution levels during the periods 2001-2009 (period before the Greek economic crisis), 2010-2019 (period during the Greek economic crisis), as well as with the entire time period 2001-2019. The assessment showed a significant reduction in the levels of both PM_{10} concentrations, which ranged from 8% to 45%, and $PM_{2.5}$ concentrations, which ranged from 13% to 48%, thus demonstrating the effectiveness of the control measures in improving air quality in Greek urban areas. The above findings show that with appropriate emission control strategies, vital improvements in the air environment of urban areas can be achieved.

Keywords

Atmospheric pollution, Particle pollution, COVID-19 pandemic, restrictive measures.

Introduction and background

Airborne particulate matter, particularly PM_{10} (particles with an aerodynamic diameter equal to or less than 10μm) and $PM_{2.5}$ (particles with an aerodynamic diameter equal to or less than 2.5μm), are frequently investigated in urban areas due to their adverse health effects such as respiratory problems, cardiovascular diseases and neurodevelopmental effects [1-2]. Particularly, PM_{10} and $PM_{2.5}$ include inhalable particles that are small enough to penetrate the thoracic region of the respiratory system, which cause health effects that include respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms, an increase in hospital admissions and mortality from cardiovascular and respiratory diseases as well as from lung cancer [3]. In 2020, exposure to concentrations of fine particulate matter above the 2021 WHO guideline level resulted in 238,000 premature deaths in the 27 EU Member States (EU-27), although in 2020, the number of premature deaths attributable to exposure to fine particulate matter above the WHO guideline level fell by 45% in the EU-27, compared to 2005 [4]. Besides premature deaths, in 2019, exposure to $PM_{2.5}$ led to 175,702 years lived with disability (YLDs) due to chronic obstructive pulmonary disease in 30 European countries [4]. For these reasons, over the last two decades, several time-series and cohort epidemiological studies have been conducted to investigate the health significance of ambient particulate matter [5-6] and established the association between human exposure and the risk of increased mortality and morbidity.

The largest metropolitan urban areas in Greece suffer from poor air quality due to variety of emission sources, topography and climatic conditions favoring the accumulation of pollution. Nevertheless, over the last two decades, a significant reduction in PM concentration levels was observed in the largest Greek urban areas due to evolution of the environmental legislation, with more stringent air quality standards coming into effect, the replacement of old polluting vehicles, the improvement of fuel quality, the establishment of various measures and traffic interventions and the new socio-economic conditions that come up, after 2010, due to the Greek economic crisis (cutback in private car use, fuel price increase, etc.) and especially in the 2010-2019 decade the constantly increasing use of natural gas as an energy source in various industrial production processes and for building heating [7-17]. The decreasing trend of the PM_{10} and $PM_{2.5}$ concentrations, due to the above-mentioned changes in emissions sources, is particularly encouraging for the air quality in Greek cities. Nevertheless, the exceedances of the annual PM_{10} EU limit remain frequently, in Athens and Thessaloniki [7, 17].

The COVID-19 pandemic caused an unprecedented and multi-layered global crisis, and the implementation by the state of a set of restrictive measures to limit the spread of Covid-19, in addition to the health and economic consequences, brought about a change in the emission of air pollutants.

The question of the effects of restriction measures on the variation of the particulate matter concentrations in urban cities has been addressed in several studies internationally [18-21]. These studies agree that there has been a significant reduction in particulate matter concentrations during the periods of implementation of traffic control measures, due to the COVID-19 pandemic. As a result, over four Italian cities (Milan, Turin, Bologna, and Florence), concentrations of PM_{10} and $PM_{2.5}$ decreased, up to 23% and 21%, respectively [18]. Also, in Milan-Italy a decrease of PM_{10} and $PM_{2.5}$ was found up to 48.0% and 47.2%, respectively [22]. Additionally, in the five largest cities of Poland (Warsaw, Wroclaw, Lodz, Krakow and Gdansk) a decrease of the PM_{10} and $PM_{2.5}$ concentrations, up to 33.9% and 26.4%, respectively, was found [23]. Moreover, in Chandigarh-India a significant decrease of PM_{10} and $PM_{2.5}$ concentrations was found, up to 36.8% and 28.8%, respectively [24] while in Canada's four largest cities (Toronto, Montreal, Vancouver, and Calgary) a decrease up to 17% in $PM_{2.5}$ was found [25]. Kumari and Toshniwal [26] reviewed data from 162 monitoring stations from 12 cities across the world and concluded that the lockdown restrictions led to, PM_{10} and $PM_{2.5}$ concentrations decreases by, 24–47% and 20–34%, respectively. As far as the Greek region, the studies for the PM_{10} and $PM_{2.5}$ levels showed a decrease of $PM_{2.5}$ concentrations, up to 18%, in the Greater Area of Athens [27], while in the city of Volos, a reduction of 37.4% in mean daily $PM_{2.5}$ concentration was found, according to Kotsiou et al. [28] and also, a decrease, up to 24%, for the PM_{10} concentrations in the city center of Athens [29]. Furthermore, on the air of Western Macedonia, according to Begou et al. [30], a decrease in average $PM_{2.5}$ concentrations was found, ranging from −1% to −36% and a higher decrease in average PM_{10} concentrations ranging from −13% to −40% was found.

In this work, the variation of the suspended particulate levels, in major Greek cities, were examined, for the two periods of the implementation of the government restrictive measures (period 1: March to May 2020 and period 2: November 2020 to January 2021), due to the pandemic, caused by the COVID-19 virus, in comparison to the corresponding months of three specific periods. These periods were 2001-2009 (the period before the Greek economic crisis), 2010-2019 (period during the Greek economic crisis), as well as with the entire time period 2001-2019. The study was conducted to investigate the changes in the PM_{10} and $PM_{2.5}$ concentration levels, during the above mentioned two periods when the restrictive measures were implemented by the state in Greek urban and suburban areas in order to examine the impact of these control measures on air pollution levels.

The present study was extended to all the major cities in Greece, for which there were available PM concentration data. Therefore, PM_{10} and $PM_{2.5}$ concentration measurements for Athens, Thessaloniki, Patra, Larisa and Volos, were examined during an extended time period, from 2001 to 2019. Thus, the comparison of the PM_{10} and $PM_{2.5}$ concentration levels, during the two periods of the restrictive measures implementation due to the pandemic caused by the COVID-19 virus, were studied in the largest Greek cities not only during this entire 19-years period, but also, during the time interval 2001-2009 that is a period before the Greek economic recession and the 2010-2019 time interval that is a period during the Greek economic crisis (during this period the prevailing economic conditions may affect air pollution concentrations levels). This quantitative assessment in the measured PM concentration levels can be proved essential in order to show the effectiveness of the control measures in improving air quality in Greek urban areas.

Materials and Methods

Air quality data, and in particular, the PM_{10} and $PM_{2.5}$ hourly concentrations measurements, from ground-based monitoring stations, located in the greater area of Athens, Thessaloniki, Patra and Volos, were provided by the National Air Pollution Monitoring Network (NAPMN), of the Department of Atmospheric Quality, of the Ministry of Environment and Energy of Greece [31]. From these monitoring stations, the hourly concentration measurements of PM_{10} and $PM_{2.5}$ (μgm^{-3}), during 2001 to 2019, were used in the analysis [7]. The PM_{10} and $PM_{2.5}$ analyzers are using the beta-gauge principle, according the EU standards [32], while the calibrations of the analyzers were based on standard sample of known particulate concentration and performed according to the technical standards of the instruments [31]. For the study of the variations of PM_{10} and $PM_{2.5}$ levels, representative monitoring stations (see Fig.1 and Table 1) from NAPNM [31] were selected, in deferent sites of major Greek cities.

Table 1. The representative monitoring stations of the National Air Pollution Monitoring Network (NAPMN), of the Department of Atmospheric Quality, of the Ministry of Environment and Energy of Greece in greater area of Athens, Thessaloniki, Patra, Larisa and Volos [31].

Station name and code	WGS84		GGRS 87		Altitude	type of monitoring station
	Geographical longitude	Geographical latitude	X (m)	Y(m)	(m –asl)	
Aristotelous (ARI)	23,7276178492125	37,9880660501340	475932	4204238	75	urban traffic
Lykovrysi (LYK)	23,7889866802124	38,0677931723947	481341	4213070	234	suburban background
Marousi (MAR)	23,7873721482217	38,0308379318551	481190	4208970	170	urban background
Peiraias I (PIR)	23,6452301569805	37,9446567667974	468679	4199446	4	urban traffic
Agia Paraskevi (AGP)	23,8194215757818	37,9951106089158	483995	4205000	290	suburban background
Thracomacedones (THR)	23,7581958361834	38,1435214274982	478662	4221479	550	suburban background
Koropi (KOR)	23,8790262856793	37,9013083393701	489215	4194584	140	suburban background
Agia Sophia (AGS)	22,9450997512424	40,6337247192803	410641	4498347	12	urban traffic
Panorama (PAO)	23,0316894494349	40,5889178187916	417909	4493289	363	suburban background
Kordelio (KOD)	22,8932185580361	40,6734529005153	406309	4502811	30	Industrial
Sindos (SIN)	22,8021687222328	40,6578424569135	398590	4501179	14	Industrial
Patras -2 (PAII)	21,7345123031810	38,2464695337774	301601	4235301	8	urban traffic
Volos -1 (VOL)	22,9429220469889	39,3667116624368	408789	4357718	31	urban background
Larisa (LAR)	22,4145498503763	39,6355309133568	363796	4388220	85	urban background

Thus, the monitoring stations were located in the city center (urban traffic monitoring station), in the peripheral areas of the city (urban background monitoring station), in the greater area of the city (suburban background monitoring station) and in the industrial area of the city (industrial monitoring station). The measurements of the suspended particulates were used only if they met the following criteria:

- They were recorded for at least 10 years between 2001 and 2019.
- They were recorded during the months when the government imposed restrictive measures due to the COVID-19 pandemic.

Therefore, PM_{10} and $PM_{2.5}$ mean monthly values, during these two periods [March-May 2020 (for the 1st period of the restrictive measures) and November 2020-January 2021 (for the 2nd period of the restrictive measures], were compared with the PM_{10} and $PM_{2.5}$ mean monthly values of the corresponding months, during three specific periods. As mentioned before these periods were 2001-2009 (the period before the Greek economic crisis), 2010-2019 (the period during the Greek economic crisis - during this period the prevailing economic conditions may affect air pollution concentrations levels), as well as with the entire time period 2001-2019.

Figure. 1. The representative monitoring stations (marked with a red circle/frame) of the National Air Pollution Monitoring Network (NAPMN), in the greater area of Thessaloniki (upper part) and in the greater area of Athens (lower part) [31].

Results, Discussion

PM_{10} and $PM_{2.5}$ mean monthly concentrations (μgm^{-3}), of the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), were calculated and compared with the PM_{10} and $PM_{2.5}$ mean monthly values and the standard deviation (±1σ), during the corresponding months, through the three specific time intervals (2001-2009 - period before the Greek economic crisis, 2010-2019 - period during the Greek economic crisis and with the entire time period 2001-2019), at representative monitoring stations, in major Greek cities. Also, the linear regression trend of the PM_{10} and $PM_{2.5}$ mean yearly concentrations, was calculated through the entire period (2001-2019).

From the figures and tables below (Fig. 2-5(a) and Tables 2-5) we found a clear decrease in the concentrations of both PM_{10} and $PM_{2.5}$ levels, for the months under review (1st period March-May 2020 and 2nd period November 2020-January 2021), when the restrictive measures were in force due to the COVID-19 pandemic, in all major Greek cities (Athens, Thessaloniki, Patra, Volos and Larisa). This decrease was found, almost similarly, at the urban traffic sites (Fig. 2(a) and Table 2), which are located in the centers of the cities, at urban background sites (Fig. 3(a) and Table 3), which are located in the peripheral areas of the cities, at the suburban background sites (Fig. 4(a) and Table 4), which are located in the greater areas of the cities and also at the industrial areas of the cities (Fig. 5(a) and Table 5). Moreover, this significant decrease, in almost all cases, exceeds the range of values of the standard deviation (+/-σ), of both PM_{10} and $PM_{2.5}$ mean monthly concentrations, of the corresponding months, throughout the three specific periods (2001-2009, 2010-2019 and 2001-2019).

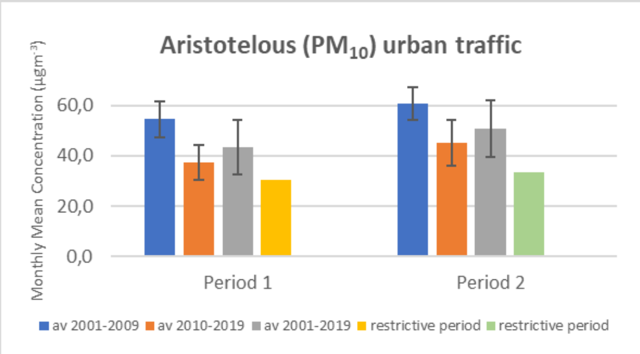
The assessment showed that this significant percentage reduction in the concentration levels (Tables 2-5), over the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), when the restrictive measures were in force, due to the COVID-19 pandemic, for PM_{10} levels ranged, from 19% to 45%, at the urban traffic sites (Fig. 2(a) and Table 2), from 10% to 41%, at urban background sites (Fig. 3(a) and Table 3), from 24% to 41%, at the suburban background sites (Fig. 4(a) and Table 4), and from 8% to 43%, at the industrial areas of the cities (Fig. 5(a) and Table 5). Accordingly, for $PM_{2.5}$ levels the reduction ranged, from 33% to 48%, at the urban traffic sites (Fig. 2(a) and Table 2), and from 13% to 44%, at suburban background sites (Fig. 4(a) and Table 4).

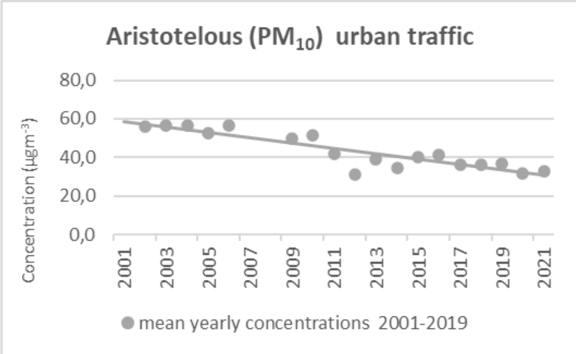
We also note, that the reduction in the concentrations of both PM_{10} and $PM_{2.5}$ levels during the months of the two periods of the restrictive measures, was, almost in all cases, higher in the period 2001-2009, compared to the period 2010-2019 and the entire period 2001-2019 (Fig. 2-5(a) and Tables 2-5). This was mainly due to the significant reduction in the levels of air pollutants resulting from the new socio-economic conditions that arose, after 2010, because of the Greek economic crisis [7, 10-12, 14-15] and the ever-increasing use of natural gas as an energy source in various industrial production processes and for building heating, especially in the 2010-2019 decade [7, 11-13], while the continuously changing environmental legislation imposed ever more stringent systems of air pollution control and control of industrially emitted pollutants [11, 14-16].

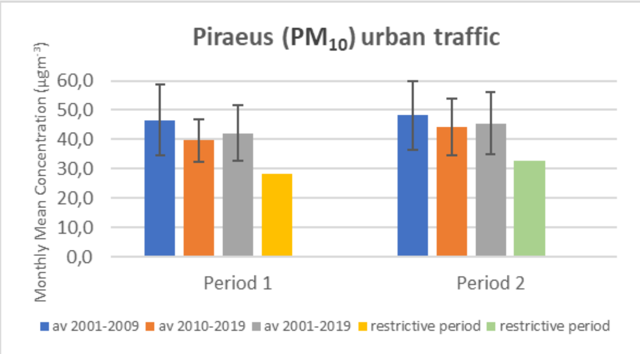
In addition, it was found that the reduction in PM_{10} and $PM_{2.5}$ concentrations was roughly of the same order of magnitude over the two periods of the restrictive measures (Tables 2-5), which was calculated in comparison, respectively, with the PM_{10} and $PM_{2.5}$ mean monthly values, for the corresponding months, during the three periods (2001-2009, 2010-2019 and 2001-2019), in major Greek cities. This founding was found, even though in the first period of the restrictive measures (March-May 2020) a complete reduction in vehicle traffic (and thus emissions) was imposed. One possible explanation of this result may be the meteorological conditions and the dispersion processes that prevail, at each measurement site, as well as the local characteristics of each site, which determine decisively the degree of accumulation of the particulate pollutants. It must also be noted that both PM_{10} and $PM_{2.5}$ levels show significant seasonal variation, resulting in increased PM levels during the winter period of the year, mainly due to the increased vehicle traffic emissions and the emissions from building heating, especially in densely populated urban areas [7, 9-12, 14-17]. It should be pointed out, that the second period of the restrictive measures, when the PM levels increase, was implemented during winter period November 2020-January 2021. Also, the PM_{10} and $PM_{2.5}$ levels, during these two periods, were below the European Union annual limit of $40\mu g/m^3$ for PM_{10} and the corresponding annual limit of $25\mu g/m^3$ for $PM_{2.5}$.

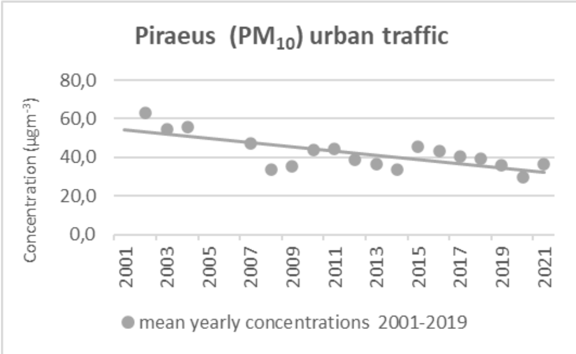
PM$_{10}$ Urban Traffic Stations

Greater Athens area

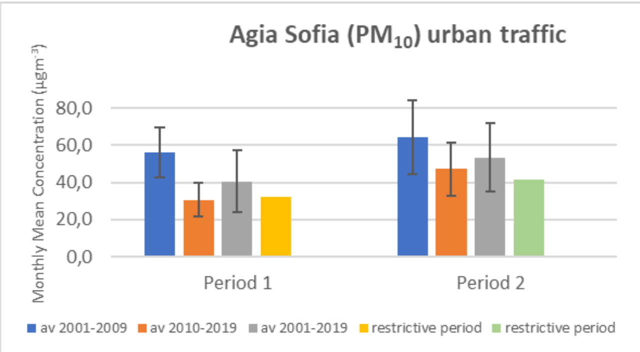


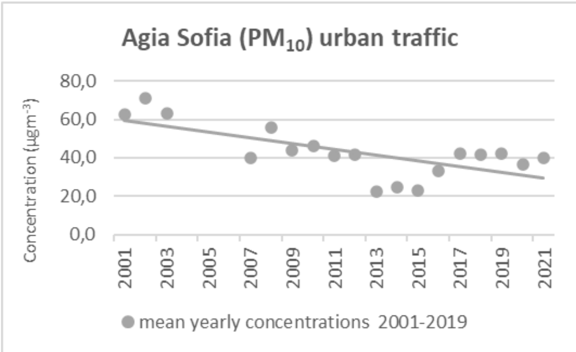




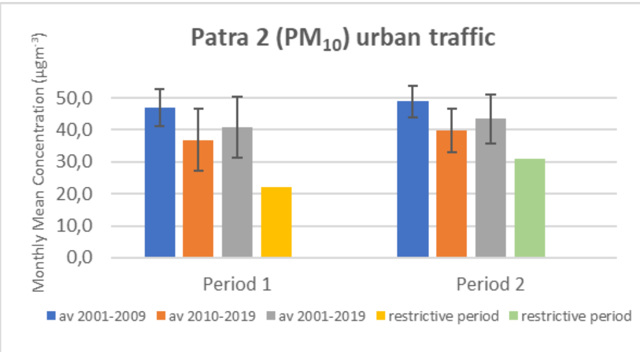


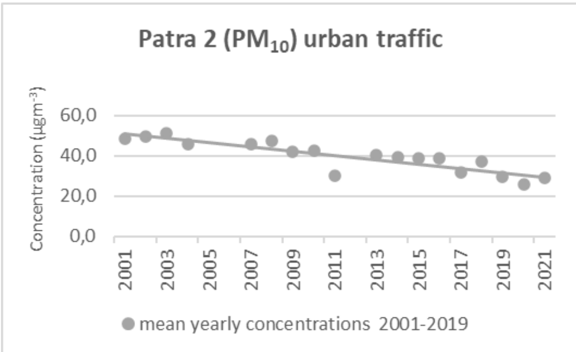
Greater Thessaloniki area





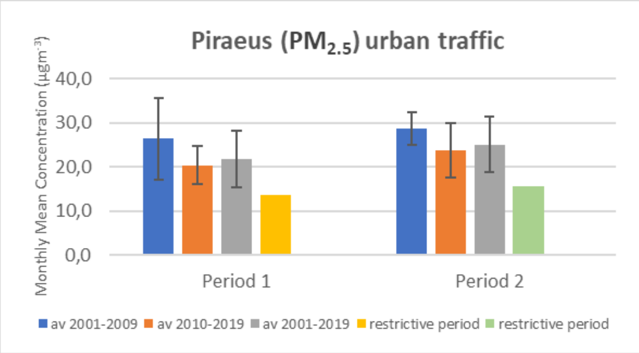
Patra





$PM_{2.5}$ Urban Traffic Stations

Greater Athens area



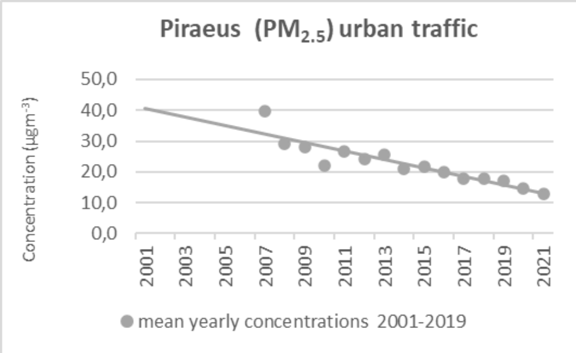


Figure. 2. (a) PM_{10} and $PM_{2.5}$ mean monthly concentrations (μgm^{-3}), during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), in comparison, respectively, with the PM_{10} and $PM_{2.5}$ mean monthly values and standard deviation (+/-σ), of the corresponding months, through the three specific periods (2001-2009, 2010-2019 and 2001-2019), at urban traffic sites, in major Greek cities. (b) The linear regression trend of the PM_{10} and $PM_{2.5}$ mean yearly values (μgm^{-3}), through the entire period (2001-2019), at urban traffic sites, in major Greek cities.

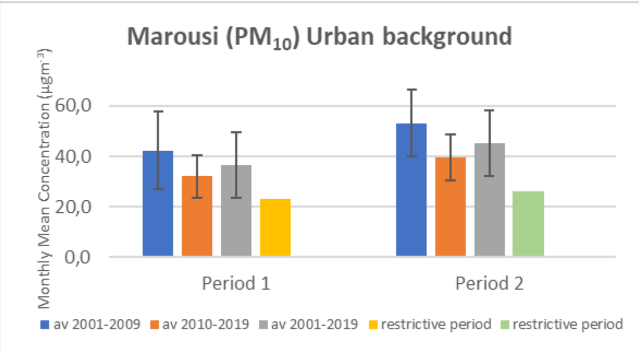
Table 2. The percent (%) differences of PM_{10} and $PM_{2.5}$ mean monthly concentrations, during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), which were calculated, respectively, in comparison with the PM_{10} and $PM_{2.5}$ mean monthly values, for the corresponding months, during the three time intervals (2001-2009, 2010-2019 and 2001-2019), at urban traffic sites, in major Greek cities.

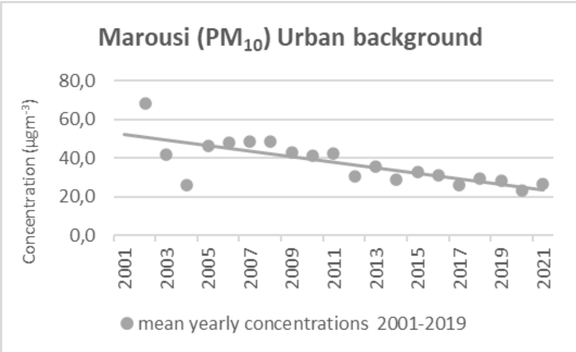
PM_{10} Urban Traffic Sites		
Time interval	1st period	2nd period
2001-2009	-45%	-37%
2010-2019	-19%	-21%
2001-2019	-32%	-28%

$PM_{2.5}$ Urban Traffic Sites		
Time interval	1st period	2nd period
2001-2009	-48%	-45%
2010-2019	-33%	-34%
2001-2019	-38%	-37%

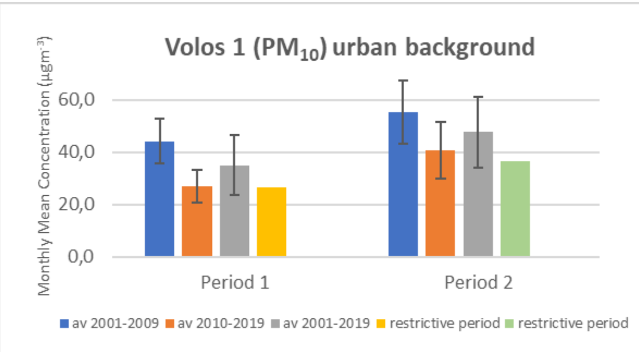
PM_{10} Urban Background Stations

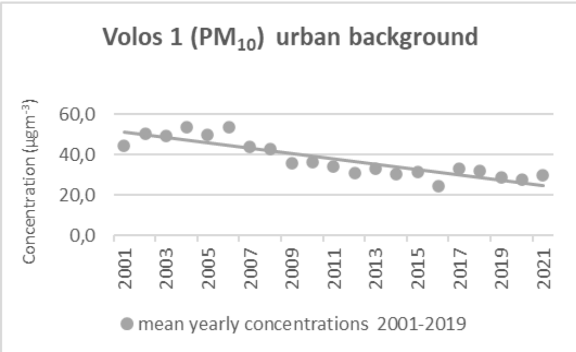
Greater Athens area





Volos





Larisa

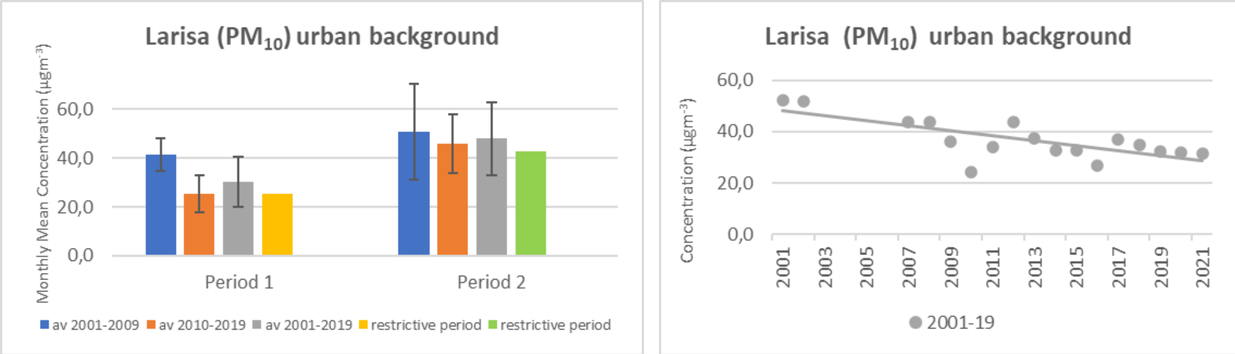


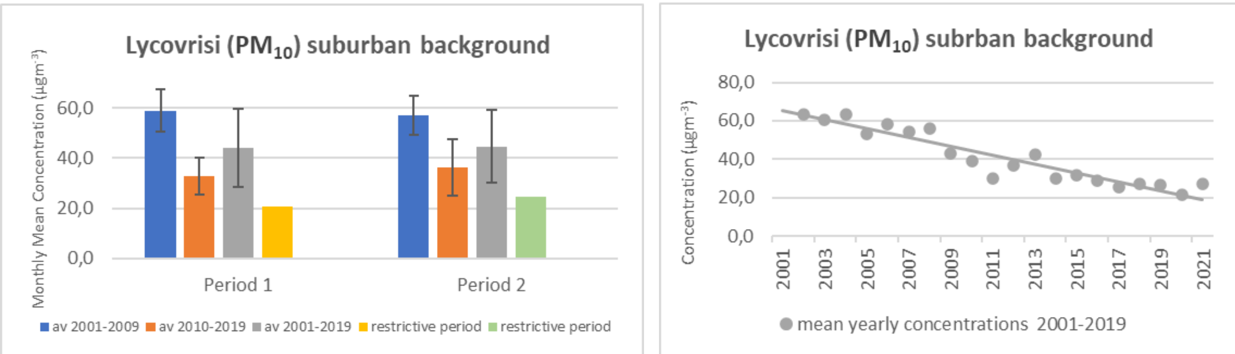
Figure. 3. (a) PM_{10} mean monthly concentrations (μgm^{-3}), during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), in comparison, respectively, with the PM_{10} mean monthly values and standard deviation (+/-σ), of the corresponding months, through the three specific periods (2001-2009, 2010-2019 and 2001-2019), at urban traffic sites, in major Greek cities. (b) The linear regression trend of the PM_{10} mean yearly values (μgm^{-3}), through the entire period (2001-2019), at urban background sites, in major Greek cities.

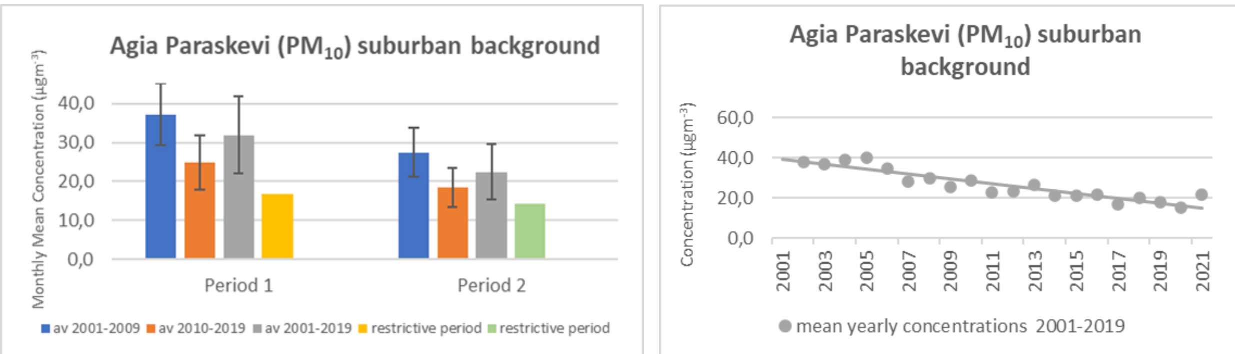
Table 3. The percent (%) differences of PM_{10} mean monthly concentrations, during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), which were calculated in comparison, respectively, with the PM_{10} mean monthly values, for the corresponding months, during the three time intervals (2001-2009, 2010-2019 and 2001-2019), at urban background sites, in major Greek cities.

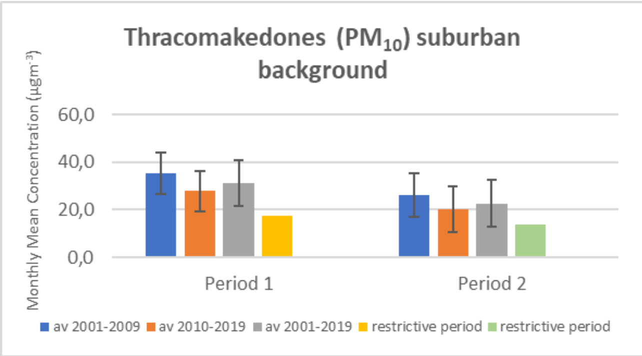
PM_{10} Urban Background Sites		
Time interval	1st period	2nd period
2001-2009	-41%	-33%
2010-2019	-10%	-16%
2001-2019	-26%	-25%

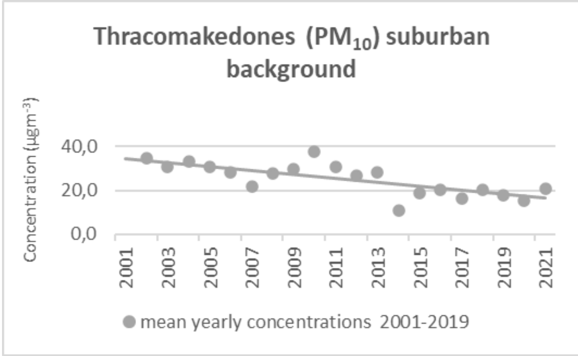
PM_{10} Suburban Background Stations

Greater Athens area

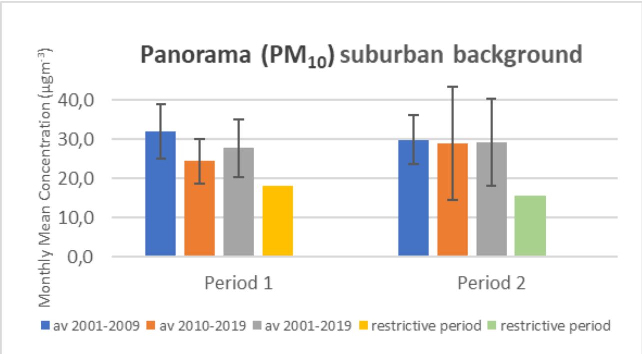


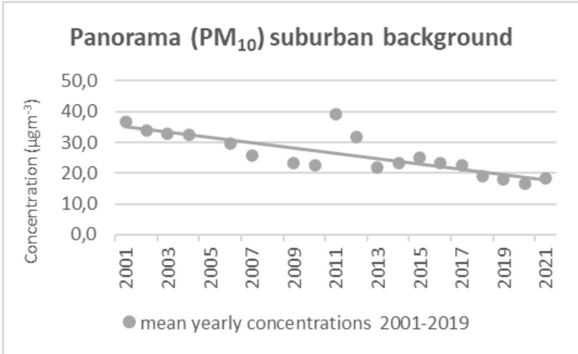






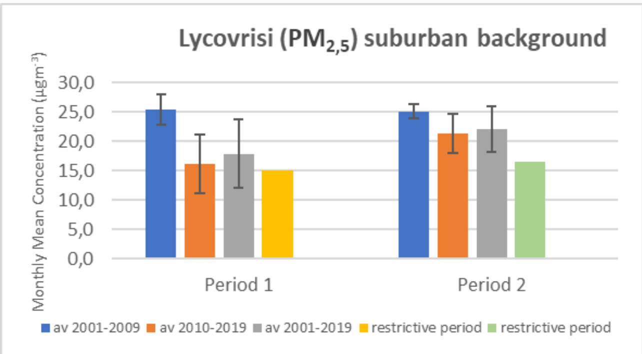
Greater Thessaloniki area

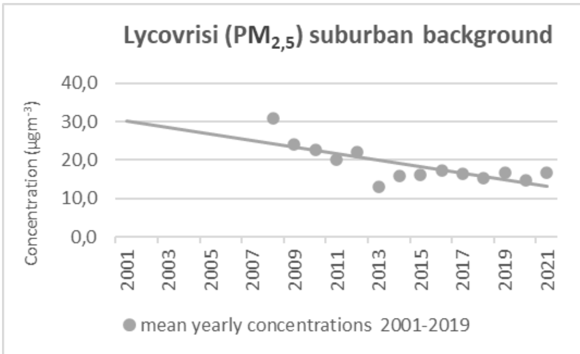


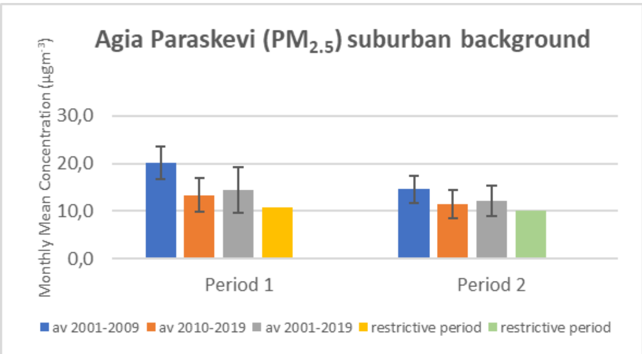


$PM_{2.5}$ Suburban Background Stations

Greater Athens area







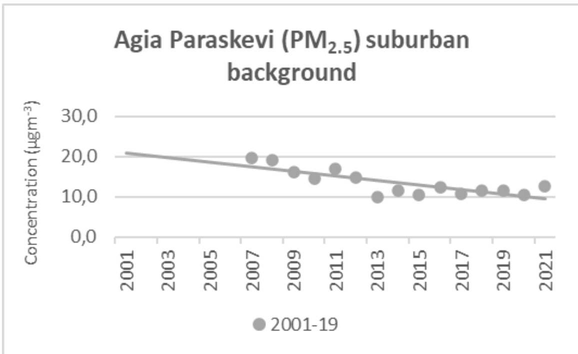


Figure. 4. (a) PM_{10} and $PM_{2.5}$ mean monthly concentrations (μgm^{-3}), during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), in comparison, respectively, with the PM_{10} and $PM_{2.5}$ mean monthly values and the standard deviation (+/-σ), of the corresponding months, through the three specific periods (2001-2009, 2010-2019 and 2001-2019), at urban traffic sites, in major Greek cities. (b) The linear regression trend of the PM_{10} and $PM_{2.5}$ mean yearly values (μgm^{-3}), through the entire period (2001-2019), at suburban background sites, in major Greek cities

Table 4. The percent (%) differences of PM_{10} and $PM_{2.5}$ mean monthly concentrations, during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), which were calculated, respectively, in comparison with the PM_{10} and $PM_{2.5}$ mean monthly values, for the corresponding months, during the three periods time intervals (2001-2009, 2010-2019 and 2001-2019), at suburban background sites, in major Greek cities.

PM_{10} Suburban Background Sites		
Time interval	1st period	2nd period
2001-2009	-41%	-39%
2010-2019	-24%	-27%
2001-2019	-31%	-32%

$PM_{2.5}$ Suburban Background Sites		
Time interval	1st period	2nd period
2001-2009	-44%	-30%
2010-2019	-13%	-13%
2001-2019	-22%	-18%

PM_{10} Industrial Stations

Greater Thessaloniki area

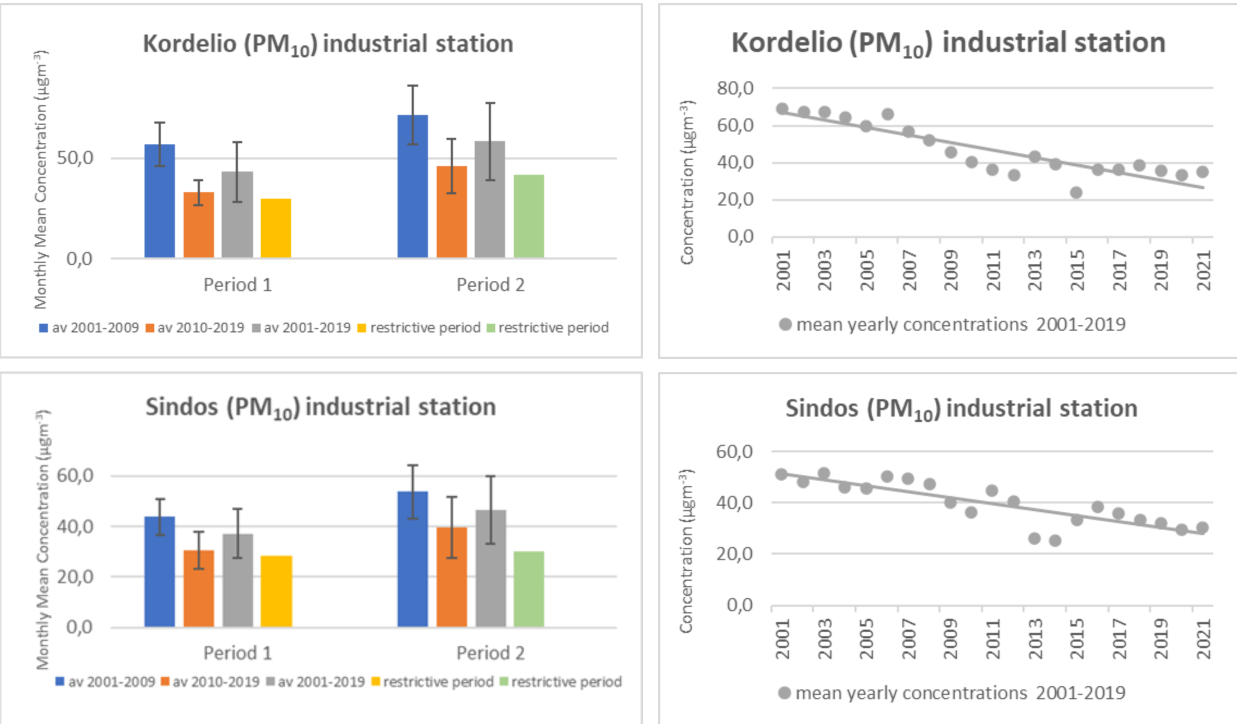


Figure. 5. (a) PM_{10} mean monthly concentrations (μgm^{-3}), during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), in comparison, respectively, with the PM_{10} mean monthly values and the standard deviation (+/-σ), of the corresponding months, through the three specific periods (2001-2009, 2010-2019 and 2001-2019), at urban traffic sites, in major Greek cities. (b) The linear regression trend of the PM_{10} mean yearly values (μgm^{-3}), through the entire period (2001-2019), at industrial sites, in major Greek cities.

Table 5. The percent (%) differences of PM_{10} mean monthly concentrations, during the two periods of the restrictive measures (1st period March-May 2020 and 2nd period November 2020-January 2021), which were calculated, respectively, in comparison with the PM_{10} mean monthly values, for the corresponding months, during the three periods time intervals (2001-2009, 2010-2019 and 2001-2019), at industrial sites, in major Greek cities.

PM_{10} Industrial Sites		
Time interval	1st period	2nd period
2001-2009	-42%	-43%
2010-2019	-8%	-17%
2001-2019	-28%	-32%

From the above assessment (Fig. 2-5(b)) we have also found that over the last two decades there has been a significant downward trend in both PM_{10} and $PM_{2.5}$ concentration levels in the atmosphere of major Greek cities, which is due to various mitigation measures taken in Greece, such as the replacement of old polluting vehicles, the improvement of fuel quality and the various traffic interventions (such as ring roads, metro and tram in Athens, bus lanes, unleveled intersections, etc.) Also, the important downward trend in both PM_{10} and $PM_{2.5}$ concentration levels can be attributed to the evolution of the environmental legislation, with more stringent air quality standards coming into effect and the new socio-economic conditions that come up, after 2010, due to the Greek economic crisis (decrease in private car use, fuel price increase, etc.) and especially in the 2010-2019 decade the constantly increasing use of natural gas as an energy source in various industrial production processes and for building heating [7, 11-12, 14-17].

Moreover, the PM_{10} and $PM_{2.5}$ percentage reductions, almost in all cases examined, were higher in the period 2001-2009, compared to the period 2010-2019 and the entire period 2001-2019. Finally, these decreases in the concentrations of both PM_{10} and $PM_{2.5}$ levels, during the months of the restrictive measures due to the COVID-19 pandemic, in all major Greek cities were similar to the results of other researchers in Greek urban areas [19-20, 27-30].

Conclusions

In summary, the analysis of the data showed that there was a significant reduction in the PM_{10} and $PM_{2.5}$ concentrations levels in all sites (urban, suburban and industrial areas) of major Greek cities that were examined in the present study, during the two periods of the traffic restriction measures taken due to the COVID-19 pandemic. The assessment showed a reduction in the PM_{10} concentration levels which ranged from 8% to 45%, and in the $PM_{2.5}$ concentration levels which ranged from 13% to 48%.

Pollution control strategies are based in law, policy, regulation, and technology, are science-driven, and focus on the protection of public health. The strategies include targeted reductions in emissions of pollutants, transitions to non-polluting, renewable sources of energy, the adoption of non-polluting technologies for production and transportation, and the development of efficient, accessible, and affordable public transportation systems [1-3, 6]. The above assessment show that the emissions control measures adopted during the last two decades in Greek urban areas [7-8, 11-17, 33] if they are in line with proposed mitigation strategies [34] can be crucial in order improve the air quality in large Greek cities.

In conclusion, the present study found that the mandatory traffic restriction and the resulting reduction of human activities, improved the atmospheric conditions, in terms of particulate pollutants, in urban, suburban areas and industrial areas of Greek cities, during the two periods of implementation of the restrictive measures in Greece, due to the pandemic caused by the COVID-19 virus. Therefore, it is concluded that with appropriate emission control strategies, a significant improvement in air quality can be achieved.

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