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Short-term atmospheric pollution monitoring in a selection of European capitals

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Abstract
Air pollution is increasing in the context of uncontrolled emissions from human activities, mostly from industry, transportation and agriculture. Urban agglomerations concentrate most environmental pollution sources, given the high population density and their needs of transportation and energy, both of electrical and thermal types, along with huge quantities of wastes, whose improper management leads to heavy pollutant emissions in atmosphere, but also to pollutant leakage in waters and soil. In general, in each country, at least in Europe, the capital is the most populated city, which also concentrates important industrial sites, leading to poor air quality. This affects the population both on short and long term. Studies have shown that air pollution even induces chronic diseases, not only of respiratory-type, but also of the heart, up till reducing life expectancy. When dealing with urban air pollution, one must also consider the physical-geographical conditions, which may accentuate or, on the contrary, may diminish pollution through an intense air circulation, thus dispersing pollutants.
A selection of European capitals was chosen for the study presented here, as related to their air quality which was monitored for short term within the peak of the recent pandemic, in order to have a view and even a reference of the expected reduced pollution status as compared to the normal urban life conditions. The chosen capitals were: Paris, Berlin, Bucharest and Skopje, which are well-spread geographically across Europe and also have different economic statuses, along with different landscape conditions and climate influences, making them appropriate for comparison, differences being expected.

Keywords: atmospheric pollution, capitals, Europe, pandemic reference.

1. INTRODUCTION

Air pollution can be defined as the contamination of the indoor or outdoor air with a chemical, physical or biological agent which has negative effects on living things: plants, animals and humans.

For humans, oxygen is essential for life, but when inhaling it from the atmosphere, we could also easily inhale potentially harmful gases, such as carbon dioxide, CO2, carbon monoxide, CO, nitrogen dioxide, NO2, sulfur dioxide, SO2, ozone, O3 etc., along with particulate matter, PM. Above a specific threshold and/or for long-time exposure, each of these gases or PMs, induce various health effects, which cannot be neglected [1-3].

The main sources of anthropogenic pollution are:

- fossil fuels burning (i.e. coal, natural gas and petroleum and its derivatives - gasoline, diesel, GPL) for electricity production, transport, industry and households;
- industrial processes;
- agriculture (fertilizers, pesticides, animal waste);
- waste management.

Frequently, people forget that air pollution also damages vegetation and entire ecosystems. Thus, the most harmful air pollutants in terms of ecosystem damage are ozone, ammonia and nitrogen oxides, known as 'nox', from the general chemical formula, NOx (standing for NO and NO2 as nitrogen oxygen pollutants, while N2O is not a real pollutant, but a greenhouse gas). In 2016, the EU target value for vegetation protection from ozone was exceeded in approximately 15% of the agricultural area of the EU-28 and in 19% of all European countries [4].

Air pollution is an old problem, especially of indoor-type, since heating with wood and mostly with coal induces strong pollutant emissions of gases and PM which even before Middle Age, lead to lung problems, asthma, cardiovascular diseases etc. [5]. When combined with fog, as in London, air pollutants determine smog, which can lead even on short-term to numerous deaths, either as a direct consequence or as a complication of old ailments. Thus, in 1952, a smog episode in London caused about 4000 deaths in one month.

The industrial age, starting in the 1750's has accentuated outdoor air pollution and moreover, the 20th century brought motor vehicles whose exhausts affect heavily air quality.

All the pollutants listed above are mostly emitted through human activities, even though extensive wildfires and intensified volcanic activity (i.e. volcanic eruptions) throw large quantities of dust and oxides in the atmospheres [6], but their incidence isn't that high as comparing to continuous anthropogenic emissions, which are on an increasing rate. In 2020, wildfires were estimated as the second most important source of greenhouse gases in California, where often this phenomenon appears [7]. Still, it is interesting to notice that recent studies have shown that the aerosols released in the atmosphere contain nutrients for phytoplankton [8]. One should also not forget that aerosols resulting either from natural or anthropogenic causes have not only a direct effect on the environment, such as the respiratory problems on humans and animals, but also a greenhouse effect, by direct absorption and reemission of infrared radiation, and even further, by stimulating vapor precipitation and cloud formation, which also have an important greenhouse effect [9].

It is well-known that carbon dioxide results mostly from the burning processes of organic materials, mainly from conventional fuel-transportation, industry and households. Biomass burning is also a source of carbon dioxide, but breathing, namely exhaling is a major source, not only of an increasing human population, but also of the animals raised for food. Unfortunately, the only relevant sink for carbon dioxide in the atmosphere is the photosynthesis process, which strongly varies with vegetation growth and spread, but also with the solar radiation which mediates the process, such as the carbon dioxide in the atmosphere varies with latitude and season, where is the case [10, 11]. Another sink for the atmospheric CO2 is represented by precipitation. Even though this is an useful process for the atmosphere, diminishing its carbon dioxide content, instead, it gives a strong negative effect on the hydrosphere and even on soil, since it diminished their pH, rendering it more acid, with devastating effect on the animal and plant kingdoms. For example, ocean acidification affects the bioavailability of calcium carbonate, for carbonate secreting organisms (e.g. foraminifera and pteropods), such that it cannot produce their shells, which are essential for their protection and life type [12]. Also, fish population is strongly affected by water acidification, even from embryonic stage [13].

Along with carbon dioxide acidification, the other oxides sent into the atmosphere mainly by human activities, namely sulfur dioxide, SO2 and nitrogen dioxide, NO2 induce strong corroding, toxic acids, i.e. sulfuric acid, H2SO4, sulfurous acid, H2SO3, nitric acid, HNO3, nitrous acid, HNO2, through chemical reactions with water from the atmosphere or from ground level. Precipitation mixed with acids makes the famous acid rain which not only affect plants directly, by their chemical burn, which affects and even stops their lifecycle, but also indirectly, through the hydrosphere and soil, reaching the animals and humans through the food chain [14, 15]. Acid rain also affects the construction materials, such that the highly populated places, i.e., the cities and moreover, the capitals, leads to easier and more particulate matter release, thus potentiating pollution [16]. Another aspect related to big human communities is related to the intense agriculture which must be performed in order to fulfill the food needs. Thus, nitrogen-based fertilizers are used on a large scale, along with various pesticides (e. g. fungicides, rodenticides, herbicides, insecticides etc.) which induce further pollution, not only of the soil and hydrosphere, but also of the atmosphere, at the end of the plants and animals lifecycle, but also along with plant and animal metabolism, mediated by bacterial activity [17, 18]. For example, manure is a strong source of methane, nitrous oxide (N2O) and carbon dioxide (CO2), which are not only pollutants, but also the strongest greenhouse gases [18, 19].

From all of the above it can be seen that humanity strongly influences and worsens atmospheric pollution and the environment pollution, in general, and most of these pollutants, either directly or through secondary products further intensify the negative effect, such as nowadays, there are numerous human-inhabited places where the air is downright unbreathable and people wear masks not to protect themselves from viruses, but to reduce pollutants inhalations [20]. Thus, considering world capitals, Delhi (India) is the most polluted city in terms of fine particles, PM2.5, with an annual average of 113.5 μg/m3 for 2018. Cities such as Mexico City (19.7 μg/m3), Paris (15.6 μg/m3) or Berlin (11.7 μg/m3), are also some of the 50 world capitals with the highest air pollution with fine particulate matter, while, on the contrary, cities such as Helsinki (7.2 μg/m3), Stockholm (6.6 μg/m3) or Reykjavik (5.8 μg/ m3) have low pollution levels, in line with WHO – World Health Organization – recommendations [21, 22].

The worsening of air quality is currently caused by the existence of too many cars, too many factories based on old, polluting technologies or with unavoidable pollutant emissions, all these phenomena being determined, in fact, by population growth along with not only its basic needs, but also by the increasing demand of more comfort from the modern society, including the use of automotive in its life, which implies intensified industry, transportation and waste.

The attraction for comfort, but also the instable economy has changed significantly the percentage of urban and rural population in favor of the former. The migration to the cities further developed them and increasing pollution came along.

Finally, one should not forget that air quality is not a local problem, since pollutants can travel along with air masses on long distances, easily across borders, also inducing water and soil pollution through precipitation, but also polluting less inhabited regions, such as mountain areas or forests, further reducing the clean and healthy environment and its possibilities to auto regenerate.

2. DATA UNDER STUDY AND WORK METHODOLOGY

The data chosen for the study concerned 6 atmospheric pollutants, monitored in 4 European capitals: Paris, Berlin, Bucharest and Skopje, chosen according to a group of mixed criteria that include both the economic and touristic importance of the capitals, as well as their wide-spread disposition in Europe. Thus, Paris was chosen as heavily populated not only by French people, but also by numerous tourists reaching for one of the most well-known romantic cities in the world, city situated close to the Atlantic Ocean, then Berlin was chosen as highly economically developed, along with its more Central Europe, continental-type of laying out. Bucharest was chosen as the most developed city in Eastern Europe, with some influences both from the Mediterranean Sea and the Black Sea, while Skopje, the capital of Macedonia, was chosen as being situated in South-Eastern Europe, in the heart of the Balkan Peninsula, but also for being known for its touristic attraction as having 2000 years of tradition, and moreover for being known for its high level of air pollution, accentuated by a landscape which does not favour the dispersion of pollutants. The pollutants under study were some of the most relevant for human health: nitrogen dioxide, NO2, ozone, O3, sulphur dioxide, SO2, particulate matter (fine, PM2.5 and coarse, PM10), as well as CO, known for its asphyxiating effect.

The atmospheric pollution data were correlated with the population and surface versus number of registered cars in each of the capitals under study, since traffic is a main source of urban pollution along with the other human activities, which are strongly correlated to the population and the area available for activities. Table 1 presents the data related to the capitals under study.

The data on atmospheric concentrations of pollutants were taken through the application provided by the Copernicus atmospheric monitoring service, in which hourly values of several pollutants in European cities are given, found at the following address: https://weather.com/. The Copernicus Atmospheric Monitoring Service (with the acronym CAMS) provides detailed and controlled information on pollution and air quality, solar energy and greenhouse gases, anywhere in the world, based on satellite measurements performed hourly.

Table 1. Data on the population, surface area and number of cars in the selected capitals [22]

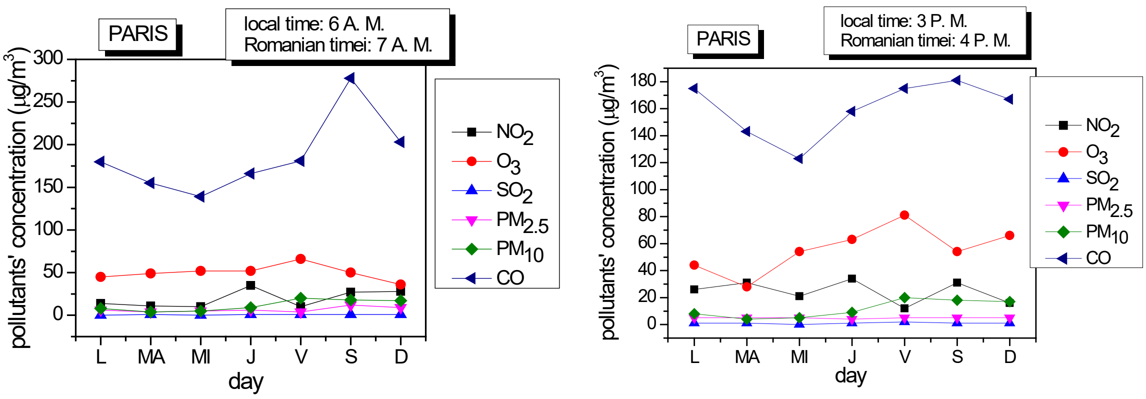
Crt. No.	Capital	Population in 2020 (millions inhabitants)	Surface (km^2)	No. cars (millions)
1.	Paris, France	11.017	105.4	5.4 (2020)
2.	Berlin, Germany	3.562	891.7	1.24 (2022)
3.	Bucharest, Romania	1.803	228	1.6 (2019)
4.	Skopje, North Macedonia	0. 595	571.46	unreported

The data were taken during a week in March 2020, in full COVID 19 pandemic conditions and lockdown, where one should expect an important pollution decrease because of closed or reduced human activities. Since human activities, in general, and those in the cities, in particular, largely vary with the time of day, two moments were chosen to read pollution data: early morning and after lunch. As an initial idea, the same moment was chosen to assess the pollution level in all the capitals under study. Thus, 7 A. M. local time and 4 P.M. local time in Romania were the moments chosen for study in each of the days, as one would expect heavy traffic at these moments, since people are going to and leaving work, such as also the pollution levels are expected to be higher than on a 24 hours average.

The pollution level of each capital and each pollutant chosen for study was assessed by comparing the data with the European Union (EU) and WHO air quality standards for health protection, given as concentration limits per hour [24, 25]: NO_2 - 50 µg/m^3; SO2 - 350 µg/m^3; O_3 - 180 µg/m^3; CO - 30 µg/m^3; $PM_{2.5}$ - 20 µg/m^3; PM_{10} - 50 µg/m^3.

3. RESULTS AND DISCUSSION

Fig. 1 shows the evolution of selected pollutants for Paris, the capital of France, both at 6 A.M. local time and at 3 P.M. local time, throughout the week between March 9th, 2020 and March 15th, 2020. These graphs show a relatively uniform evolution for the concentrations of SO_2 and PM2.5 and PM10, while, on the other hand, NO_2, O_3 and CO presented variations during the week selected for analysis both in the morning and in the afternoon. It is worrying that, on any of the selected days of the week from March 2020, the atmospheric concentrations of CO have exceeded by far the hourly limit value, which is 30 µg/m^3, all of them being above 120 µg/m^3, which means 4 times the limit value provided by the EU and WHO legislations.



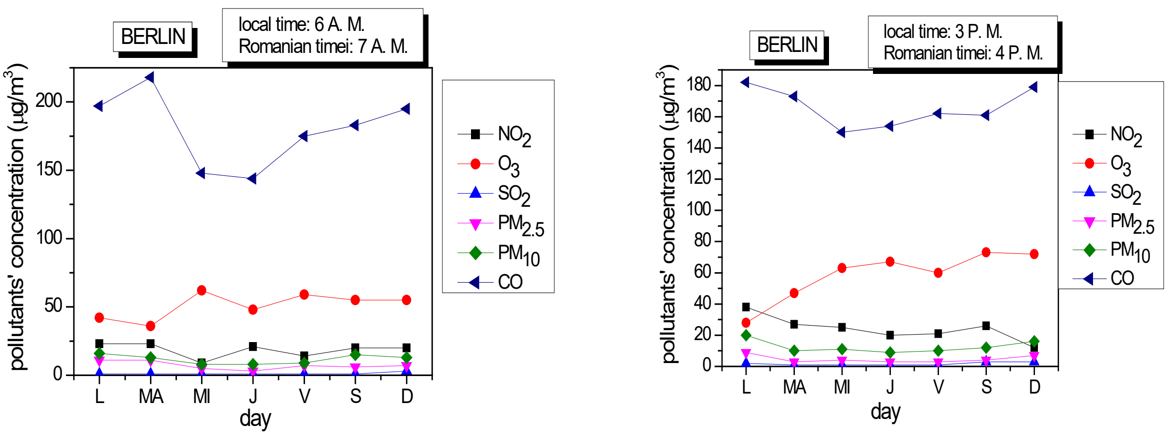
a. morning data *b. afternoon data*

Fig. 1 The evolution of the selected pollutants in Paris, during one week, between 9th – 15th of March, 2020

As for O_3, the hourly limit value is 180 µg/m^3, and it was found that for Paris, this value was not exceeded in any of the days under study. For O_3, the Friday of the selected week turned out to be one in which the concentrations, both in the morning and in the afternoon, recorded much higher values than in the rest of the week. It is known that ozone is a secondary pollutant resulting from the combustion of fossil fuels, and CO is a direct pollutant resulting from the combustion of these fuels, so it is associated with the intense traffic existing in Paris even at such an early morning local time. The transport associated with the supply causes these pollutants to have recorded high concentrations in the atmosphere. As for the concentrations of the other pollutants, the SO_2 values were well below the hourly limit of 350 $\mu g/m^3$, while for PM2.5, the hourly limit value of 20 $\mu g/m^3$ was not exceeded, reaching only around 12 $\mu g/m^3$ on Saturday, March, the 14th, at 6 A.M. local time, while for PM10, the limit value of 50 $\mu g/m^3$ was not exceeded, neither in the morning, nor in the afternoon, when only value slightly above 35 $\mu g/m^3$ were recorded.

For Paris, there is a fairly good correspondence between the values of the atmospheric concentrations for each of the pollutants both in the morning and in the afternoon, with the exception of CO and O_3.

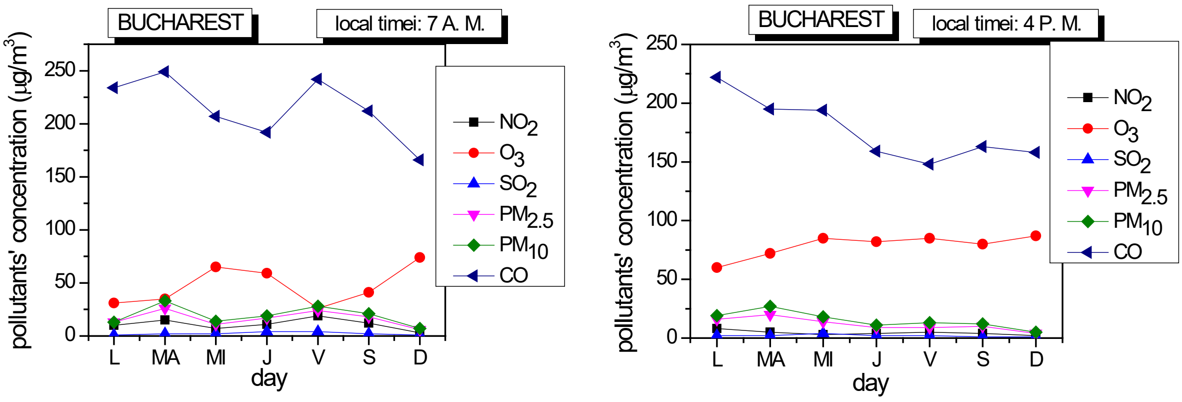
Fig. 2 shows the evolutions of the 6 selected pollutants in Berlin at 6 A.M. and 3 P. M. local time, respectively. The evolution of CO is different in the case of Berlin as compared to Paris, with a maximum being recorded on Tuesday, and otherwise, in the afternoon hours, the variations were not significant throughout the whole week, but they also exceeded the hourly limit values. The other pollutants did not register significant variations except for O_3, which, at least in the afternoon, registered an increasing trend throughout the whole week, with values that, however, did not exceed the hourly limit, not registering values over 80 $\mu g/m^3$. For Berlin, one can notice that there are differences between morning and noon/afternoon for the atmospheric concentration of CO, especially for Tuesday, March 10th, 2020. On the same day, there are also some differences in the $PM_{2.5}$ values between morning and afternoon, with higher values for local time 6 A. M. (not visible in the graphs because of the common concentration scale, with large differences between CO and the rest of the pollutants under study). In the rest, the other pollutants registered fairly small differences between the values recorded in the morning and in the afternoon.



a. morning data *b. afternoon data*

Fig. 2 The evolution of the selected pollutants in Berlin, during one week, between 9th – 15th of March, 2020

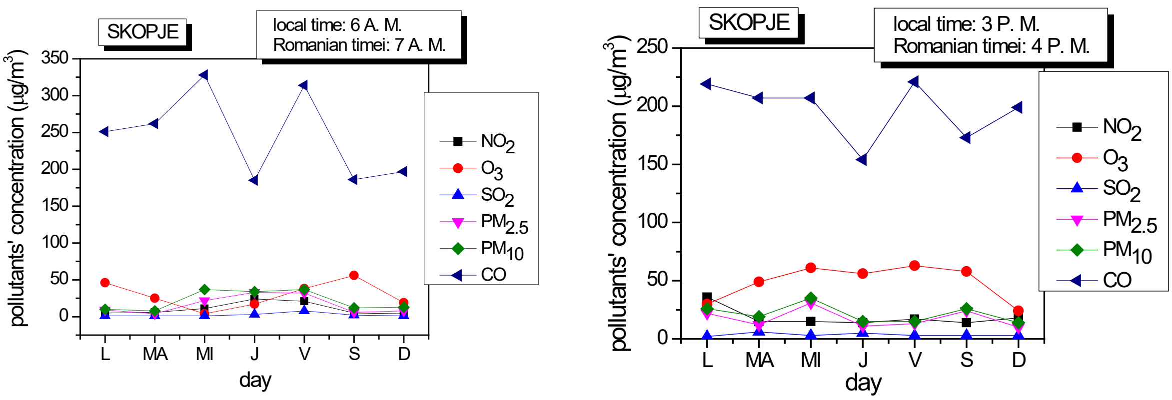
In the case of Bucharest, the capital of Romania, the evolutions of atmospheric concentrations of selected pollutants are presented in Fig. 3, from which it can be seen that there were small differences between the atmospheric concentrations of PM’s, SO_2, and even NO_2, both between them and throughout the whole week. On the other hand, O_3 recorded quite important fluctuations especially at 7 A.M. local time, while in the afternoon, it registered an increasing evolution throughout the whole week. Exceeding of the hourly concentrations for CO are also recorded for Bucharest with a somewhat downward trend throughout the entire working week, from Monday to Friday, especially in the afternoon.



a. morning data *b. afternoon data*

Fig. 3 The evolution of the selected pollutants in Bucharest,
during one week, between 9th – 15th of March, 2020

For Skopje, the capital of Macedonia, the evolutions of selected pollutants are presented in Fig. 4. In the case of CO in Skopje, quite important fluctuations are recorded from one day to the next both during the morning and in the afternoon, each time exceeding the hourly limits of 30 µg/m^3. Ozone concentrations also presented important fluctuations between a minimum of less than 5 µg/m^{3}on Wednesday, March 11th and a maximum of almost 60 µg/m^{3}on Saturday, March 14th, for 6 A. M. local time. In contrast, during the afternoon, the concentration of O_3 showed an increase from Monday to Wednesday, a slight decrease on Thursday and then an increase again on Friday and Saturday and with a relevant decrease on Sunday afternoon, associated most probably also with the decrease in traffic related to Sunday afternoons, when people prepare to start a new work week, and thus travel less.



a. morning data *b. afternoon data*

Fig. 4 The evolution of the selected pollutants in Skopje,
during one week, between 9th – 15th of March, 2020

The other pollutants did not have very important variations during the week of March 9 - 15, 2020 in Skopje, slight increases were recorded by PM10, but its values did not reach 40 µg/m^3 neither in the morning, nor in the afternoon, which means values below the limit hourly of 50 µg/m^3 established by EU standards. A slight increase in the atmospheric concentration of PM2.5 was recorded from Wednesday to Friday morning in Skopje, with values exceeding the hourly limit of 20 µg/m^3 during the morning, and in the afternoon only on 3 of the 7 days of that week, namely, the concentrations exceeded the hourly limit on Monday, Wednesday and Saturday, respectively.

4. CONCLUSIONS

The evolution of air quality is influenced mainly by population growth, the pressure exerted by the industrial sector, the transport sector and the energy sector, especially that intended for domestic use, while somewhat smaller contributions are given by agriculture and tourism.

This paper presents the results of the short-term monitoring of the evolution of the most relevant 6 atmospheric pollutants in a selection of 4 representative European states, chosen in terms of position on the continent and as economic and physical-geographical influencing factors.

It was found that, every time, the atmospheric concentrations of carbon monoxide exceeded the limit values for all the capitals selected for analysis, while the atmospheric concentrations of the other pollutants rarely exceeded the hourly limits. When comparing the 4 capitals chosen for study, none of them prevails in terms of NO2 concentration. However, for Bucharest, 4 P.M. local time represents an hour with average traffic, given that here, there are many companies which allow for lunch break and thus, the end of the working day stretches up till 5 P.M. As carbon monoxide is concerned, Skopje holds the record in the morning, while Berlin takes over in the afternoon. Passing to PM2.5 in the 4 capitals, in the morning, Skopje led again on 2 of the 7 days of the monitored week, and also in the afternoon, for 6 out of the 7 days under observation, and the same behavior was noticed for PM10. These high pollution levels in Skopje are given by the bad urban planning following an intense earthquake in 1963, resulting in a chaotic development and uncontrolled urban spread, still holding a closed, fortification-type of city which, in combination with local gorge-like topography, gives rise to high pollution levels.

Thus, even with a small selection of relevant capitals, one can notice that the atmospheric pollution is an issue that cannot be ignored, and some states have even considered banning diesel cars or to limit private transportation for some periods, in order to limit the amplification of the phenomenon. A more careful urban planning, an appropriate alternation between built surfaces and green spaces, an urban micro-relief that favors the dispersion of pollutants are just some of the measures that can be taken, on medium and long term, to limit the pollution increase, along with the pollution reduction at the source.

References

1. Trejos E.M., Silva L. F.O., Hower J.C., Flores E.M.M., González C.M., Pachón J.E., Aristizábal B.H., Volcanic emissions and atmospheric pollution: A study of nanoparticles, Geoscience Frontiers, 12 (2), 746-755, 2021.
2. Zhang L., Wilson J.P., Zhao N., Zhang W., Wu Yu, The dynamics of cardiovascular and respiratory deaths attributed to long-term PM2.5 exposures in global megacities, Science of The Total Environment, 842, 2022, 156951
3. Yazdi M.D., Wei Y., Di Q., Requia W.J., Shi L., Sabath M.B., Dominici F., Schwartz J., The effect of long-term exposure to air pollution and seasonal temperature on hospital admissions with cardiovascular and respiratory disease in the United States: A difference-in-differences analysis, Science of The Total Environment, 843, 156855, 2022.
4. Barn P., Jackson P., Suzuki N., Kosatsky T., Jennejohn D., Henderson S., McCormick W., Millar G., Plain E., Poplawski K., Setton E., Air Quality Assessment Tools: A Guide for Public Health Practitioners, National Collaborating Centre for Environmental Health, 2011.
5. Castro A., Calvo A.I., Blanco-Alegre C., Oduber F., Alves C., Coz E., Amato F., Querol X., Fraile R., Impact of the wood combustion in an open fireplace on the air quality of a living room: Estimation of the respirable fraction, Science of The Total Environment, 628–629, 169-176, 2018.
6. Xue C., Krysztofiak G., Ren Y., Cai M., Mercier P., Le Fur F., Robin C., Grosselin B., Daële V., McGillen M.R., Mu Y., Catoire V., Mellouki A., A study on wildfire impacts on greenhouse gas emissions and regional air quality in South of Orléans, France,Journal of Environmental Sciences, In Press, 2022.
7. Jerrett M., Jina A.S., Marlier M.E., Up in smoke: California's greenhouse gas reductions could be wiped out by 2020 wildfires, Environmental Pollution, 310, 119888, 2022.

8. Wang Y., Chen H.-H., Tang R., He D., Lee Z., Xue H., Wells M., Boss E., Chai F., Australian fire nourishes ocean phytoplankton bloom, Science of the Total Environment, 807 (1), 150775, 2022.
9. Schmidt A., Carn S., Chapter 17 - Volcanic emissions, aerosol processes, and climatic effects, Editor(s): Carslaw K.S., in Aerosols and Climate, Elsevier, 707-746, 2022.
10. Campbell P., Middleton E., Huemmrich K., Ward L., Julitta T., Yang P., van der Tol C., Daughtry C., Russ A., Alfieri J., Kustas W., Scaling photosynthetic function and CO2 dynamics from leaf to canopy level for maize – dataset combining diurnal and seasonal measurements of vegetation fluorescence, reflectance and vegetation indices with canopy gross ecosystem productivity, Data in Brief, 39, 107600, 2021.
11. Weissert L.F., Salmond J.A., Turnbull J.C., Schwendenmann L., Temporal variability in the sources and fluxes of CO2 in a residential area in an evergreen subtropical city, Atmospheric Environment, 143, 164-176, 2016.
12. Panchang R., Ambokar M., Ocean acidification in the Northern Indian Ocean: A review, Journal of Asian Earth Sciences, 219, 104904, 2021.
13. Rodriguez-Dominguez A., Connell S.D., Baziret C., Nagelkerken I., Irreversible behavioural impairment of fish starts early: Embryonic exposure to ocean acidification, Marine Pollution Bulletin, 133, 562-567, 2018.
14. Wang C., Fang Y., An W., Zeng C., Wang W., Sardans J., Fernández-Martínez M., Peñuelas J., Acid rain mediated nitrogen and sulfur deposition alters soil nitrogen, phosphorus and carbon fractions in a subtropical paddy, CATENA, 195, 104876, 2020.
15. Gerhardsson L., Skerfving S., Oskarsson A., Chapter 15 - Effects of acid precipitation on the environment and on human health, Editor(s): Paul N. Cheremisinoff, Nicholas P. Cheremisinoff, Advances in Environmental Control Technology: Health and Toxicology, Gulf Professional Publishing, 1997, 355-364, ISBN 9780884153863.
16. Lu C., Wang W., Zhou Q., Wei S., Wang C., Mechanical behaviour degradation of recycled aggregate concrete after simulated acid rain spraying, J. Cleaner Production, 262, 121237, 2020.
17. Xia L., Lam S.K., Wang S., Zhou W., Chen D., Yan X., Optimizing nitrogen fertilization rate to enhance soil carbon storage and decrease nitrogen pollution in paddy ecosystems with simultaneous straw incorporation, Agriculture, Ecosystems & Environment, 298, 106968, 2020.
18. Gu J., Yang J., Nitrogen (N) transformation in paddy rice field: Its effect on N uptake and relation to improved N management, Crop and Environment, 1 (1), 7-14, 2022.
19. Zhuang M., Shan N., Wang Y., Caro D., Fleming R.M., Wang L., Different characteristics of greenhouse gases and ammonia emissions from conventional stored dairy cattle and swine manure in China, Science of The Total Environment, 722, 137693, 2020.
20. Liu H., Tian Y., Cao Y., Song J., Huang C., Xiang X., Li Man, Hu Y., Fine particulate air pollution and hospital admissions and readmissions for acute myocardial infarction in 26 Chinese cities, Chemosphere, 192, 282-288, 2018.
21. World Health Organization (WHO), Fact sheets on sustainable development goals: health targets: Air quality and health, 2018.
22. https://worldpopulationreview.com/world-cities
23. https://weather.com/
24. European Environment Agency, Air quality in Europe — 2019 report, Luxembourg: Publications Office of the European Union, 2019, doi:10.2800/822355
25. https://www.who.int/