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Air quality in urban areas. Pollutants, issues related to the monitoring of concentrations of gaseous pollutants and aerosols

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Abstract. Despite the latest global developments (new materials and less polluting technologies) and in spite of the treaties signed at world level (the Kyoto Protocol 1997 and the Doha-2012 amendment, the Paris Treaty 2015) regarding global climate change, the implementation of these measures to reduce pollution, protect the environment and strictly respect them, leave it to be desired. Climate change caused by global pollution, in large industrial regions and in major cities of the world, has led to and continues to lead to a decline in the air quality we breathe in Europe and in the world. The degree of urban and industrial agglomeration of the cities, contributes significantly to the increase of local pollution by mixing all the pollutants present in the air, this mixture of pollutants is favoured by street canyons and implicitly by the significantly lower dispersion of pollutants in atmosphere. Monitoring air quality in the urban environment and measuring as accurately as possible the concentrations of air pollutants, through the presence of as many sensors and monitoring stations in the monitored area as possible, as well as the implementation of analysis and interpretation hardware and software solutions of the data gathered in real time by these monitoring stations, is very important for the future of large urban agglomerations.

1. Introduction

We will present in this article a review of air quality in urban areas and also some of the issues related with the monitoring of concentrations of gaseous pollutants and aerosols in urban areas.

In recent years, in the world there have been several studies that have documented in detail that especially disadvantaged people tend to live in areas that have as their main characteristic the increased pollution [1]. This is mainly due to the fact that they have access to cheap housing and many of these homes not even meeting the standards in force at the time of their construction [1].

In Europe, however, it is observed that people from the middle layers of society tend to live in the heavily polluted areas of cities [1]. These differences, between the results of the studies carried out on other continents and the studies carried out in Europe, are due both to the different methodologies [1] and to the different degree of urbanization and the special characteristics of Europe (many old cities with narrow streets and intense industrialization in the city and in surroundings). So, pollution it is presented everywhere in the urban areas and it is a by-product of urbanization. It is also a result of the enrichment of the urban population and the increase of the access to own means of locomotion which are used daily to the detriment of the public transport. From this point of view, and according to a recent study from 2019 [2], Bucharest, the capital of Romania and the richest city of Romania, is the seventh most polluted city in Europe, out of a total of 84 analyzed cities. Bucharest is followed by other big cities from Romania in this top of pollution in urban areas: Iasi - 30th place, Timisoara - 33rd place, Cluj-Napoca - 57th place, Brasov - 67th place [2].

This process of increasing pollution in the urban environment began with the beginning of the Industrial Revolution. Europe was at the origin of the Industrial Revolution, which began in England at the end of the 18th century and spread to other major European countries, such as France, Germany, but also overseas in the United States [3] (steel factory in Ohio United States Figure 1) and subsequently in the whole "civilized" world. Also, the migration of the human population from the rural to the urban area has increased with the beginning of the Industrial Revolution.

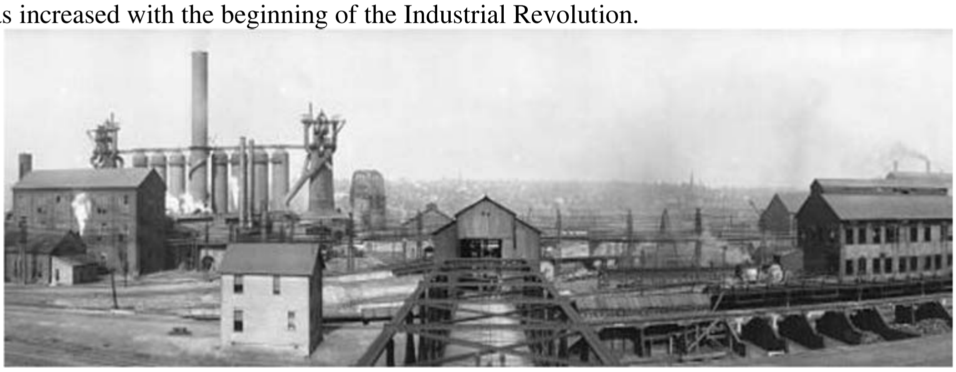

Figure 1. Panorama of the Ohio Carnegie Steel Factory, 1910 [3].

Now, in recent times, in Europe, many cities are crowded, sprawling, with crowded suburbs and intense industrial activity, the streets are narrow, the number of cars in circulation is increasing from year to year [4].

Especially in the big cities and urban agglomerations, all these things mentioned above, lead to the accentuation of the mixing and increasing phenomena of pollutants concentration in the urban environment, and also to a slowing down of the natural processes of dispersion in the atmosphere of the respective pollutants [5].

2. Types of pollutants monitored

In urban areas, the restricted space of streets surrounded by various buildings, trees, other road objects, significantly influences the pollution existing at street level in the urban environment. The most common types of pollutants in the urban environment are carbon monoxide, nitrogen oxide, various volatile organic compounds and particulate matter of various sizes (PM10, PM2.5, PM1 and PM0.1) [6]. Below we can see a capture of air pollution over Europe – Figure 2 and also the legend of air pollution over Europe is presented in Figure 3.

Figure 2. Capture of air pollution picture [7].

All the dots from this air pollution map (Figure 2) represents the measurement stations from all over Europe. Various dots color from Figure 2 represents various pollutant measurements from those stations all over Europe. Those measured values are shown in Figure 3.

Pollutant	Index level (based on pollutant concentrations in µg/m3)				
	Good	Fair	Moderate	Poor	Very poor
Particles less than 2.5 µm ($PM_{2.5}$)	0-10	10-20	20-25	25-50	50-800
Particles less than 10 µm (PM_{10})	0-20	20-35	35-50	50-100	100-1200
Nitrogen dioxide (NO_2)	0-40	40-100	100-200	200-400	400-1000
Ozone (O_3)	0-80	80-120	120-180	180-240	240-600
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-1250

Figure 3. Legend of air quality from Figure 2 [7].

According to the World Health Organization (WHO) guidelines, gaseous pollutants and aerosols in the urban atmosphere are associated with a whole spectrum of acute and chronic diseases [8]. A significant percentage of approximately 25% lung cancers, 8% COPD (chronic obstructive pulmonary disease) and 15% chronic obstructive pulmonary disease are caused by urban pollution [8]. All these diseases have economic costs of derivative effects quantified in 2010 at 1.5 trillion euros [9] and the trend is still increasing, affecting to a large extent the world economy.

Compared to the countries of Western Europe, the countries of Eastern Europe are characterized by lower air quality in the urban area (implicitly more gaseous pollutants, aerosols and particulate matter present in the breathable air in the streets), their cities are on top positions in Europe pollution index 2019 [2] and as we can see from Figure 3 presented above in this article, they have a smaller number of monitoring stations.

3. Types of air quality monitoring and air control policies

An important step in solving the problems of air quality in the urban environment, is the awareness of the problem and the understanding of the profound changes, but so necessary for the society, so that the health of the people living in the urban environment will improve from year to year.

Breaking the negative trend of increasing pollution, in the sense of stopping and reversing the increase in pollution in the urban environment, is the next step. This can be done by constant monitoring of pollution in the urban environment through sensors and monitoring stations located in key points of cities, intelligent and instantaneous collection of data provided by sensors, by high-performance information systems for analyzing, interpreting and predicting pollution evolution in the urban environment. Ideally, the results should be considered by city and state authorities in order to develop coherent policies to limit pollution in the urban environment.

There are many institutions and organizations in the world that have implemented various systems of monitoring air quality. For example, in the following image, Figure 4, provided by the US non-profit organization Berkeley Earth, we can see a capture of air pollution over Europe:

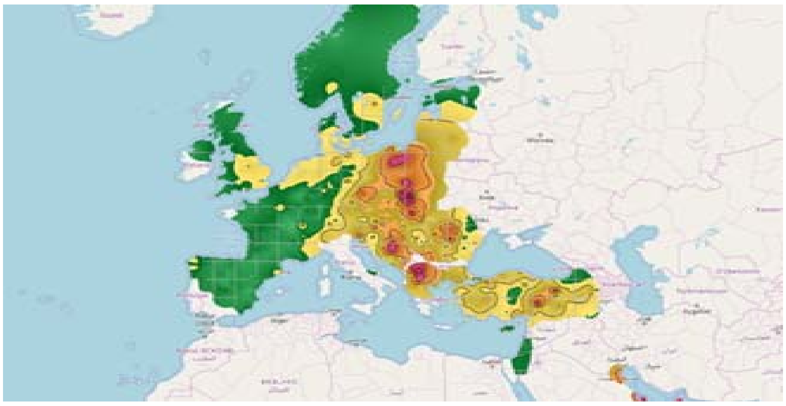

Figure 4. Capture of air pollution picture of Europe [10].

The real-time information on PM2.5 particulate pollution in Europe - 2019, can be observed. They also monitor: PM10, nitrogen dioxide, ozone, sulphur dioxide as we can see in Figure 5 from below with a very suggestive color code used to present pollution over Europe:

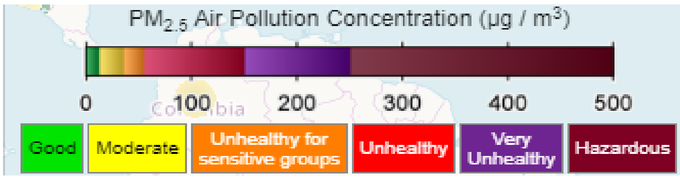

Figure 5. Legend of air quality from Figure 4 [10].

Essentially, there are two types of monitoring sensor stations: ambient monitoring stations and emissions monitoring stations [11].

Ambient monitoring stations have one or several sensors packed together and each of those sensors is specially designed to measure one pollutant from the urban environment (carbon monoxide, nitrogen oxide, aerosols, various volatile organic compounds and particulate matter etc.) [11][12].

Around the world, emissions monitoring stations are used especially in places known as large pollutants. Many of those facilities are required to use such monitoring stations to ensure that the pollutants emitted in daily operation from them, do not increase over time, or to prevent a big pollution event by using automatic shut-off mechanisms triggered by a spike increase of measured pollutant or pollutants.

In the urban environment, the most important sources of PM10, PM2.5, PM1 and PM0.1 are cars with diesel engines (in particular) and petrol, having pollution norms Euro 2, 3, 4. Number of cars with higher norms of pollution Euro 5 and Euro 6 - 6d is small and as we know very well, there are very big differences between the pollution produced by an automobile with a Euro 6d pollution norm and a car with a Euro 2 pollution norm [13].

In recent years there is a new trend in the production and purchase of hybrid and fully electric cars. Those with hybrid technology, by the specificity of the technology, have a low degree of pollution, the electrical ones have a reduced degree of pollution towards zero in the urban environment. Their prohibitive price, currently influences the purchase of cars of this type, so in the short term the influence of these latest generation cars in mitigating pollution in the urban environment, is very small.

The pollution produced by cars in cities is not only caused by the exhaust gases emitted by the car (in the case of electric ones, these exhaust gases do not exist) but also by the PM created by brake pads and tyres in the braking process. Also, there are some liquids that are consumed and transformed in aerosols and volatile compounds, during the operation of the car (oil, cooling liquid etc.). All those pollutants are added to the pollutants produced by the exhaust gases and all the other sources of pollution from the big urban agglomerations. Also, there is the pollution produced by the production of the main electric current in thermoelectric power stations. Due to the fact that this pollution is usually done outside the urban centres, its impact in the cities is reduced if we compare it with a car with diesel engine or petrol engine.

Pollution control policies by restricting access to central areas of large cities appear to be some of the few measures with immediate effect to reduce pollution. Also, improving public transport by increasing the number of state-of-the-art buses (hybrid, electric) is one of the measures successfully adopted in Europe's major cities.

Comparing the price of electric cars with gasoline, to which new technologies are applied to reduce the emission of engines, we can conclude that, at this moment, the cost for applying new technologies to existing thermal engines is much lower, compared to the costs required to electrify the engines [14].

Some major cities in Western Europe have recently adopted drastic new pollution control policies in the urban environment, whose main feature is to total ban the access of cars with diesel engines inside the cities, these cars are being stopped at the entrance to cities.

4. Atmospheric dispersion of pollutants

The restricted space of streets from urban areas surrounded by buildings, trees and other street objects, it is not a place that is helping the dispersion of pollutants in upper atmosphere. In urban area, pollutants tend to mix and to accumulate. Of course, there are differences from the rural environment. To properly understand and view the dispersion of pollutants in urban area we must be able to calculate that. This can be done with Gaussian atmospheric dispersion of pollutants [5].

Gaussian dispersion model is a mathematical model that can be used to successfully estimate the concentration of pollutants at a distance from the source of pollution. For example, in the case of punctual pollution (a chimney of smoke), with the help of equations and coefficients of atmospheric dispersion, several graphical representations of the concentration of the pollutants can be obtained depending on the surface and the contour. Spatial characteristics used in calculations are the following: distance from earth - z axis = 2 meters, x axis 1000 meters y axis 200 meters.

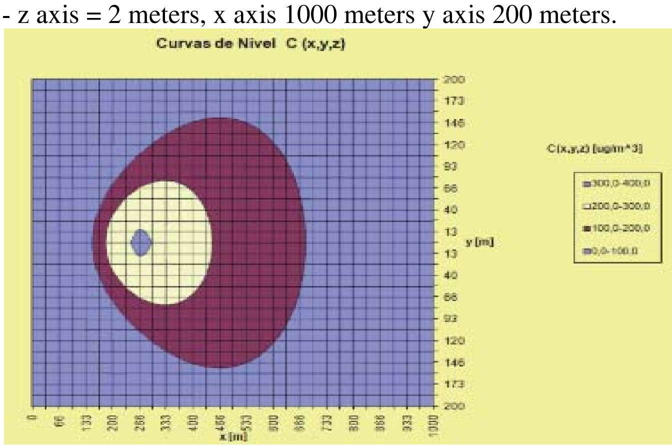

Figure 6. Evolution of concentration in the urban area depending on the distance from the source of pollution [5].

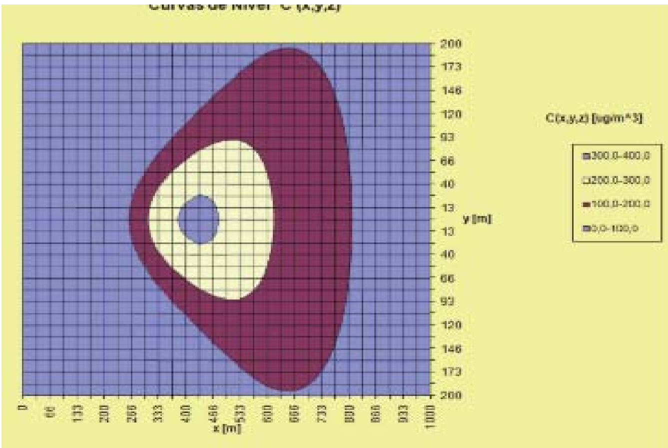

Figure 7. Evolution of the concentration in the rural area according to the distance from the source of pollution [5].

Based on the test before, we can see above, in Figure 6 and Figure 7, a graphic comparison of the evolution of smoke from a chimney of smoke in urban areas versus the evolution of pollutants in rural areas. Z axis is constant and equal to 2 meters, so the images from above are generated only by two axis x and y.

Also, in another interesting study [15] regarding the dispersion of dust pollution in the urban environment, a study conducted in Budapest, as a result of the study, we can see below two computer

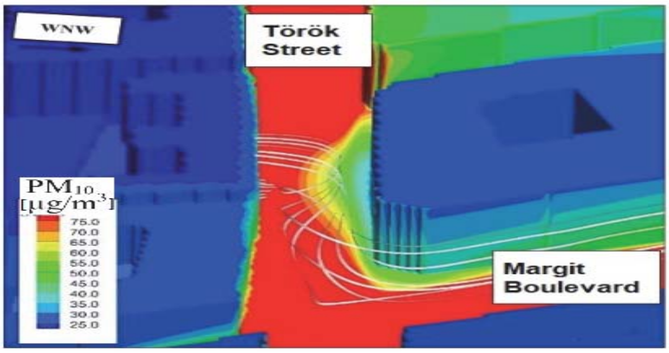

Figure 8. Street canyon vortex (a) with PM10 concentration values between 25–75 μg/m3 [15].

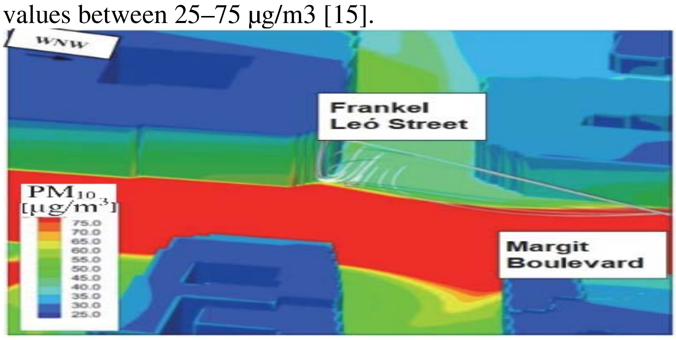

Figure 9. Street canyon outflow (b) with PM10 concentration values between 25–75 μg/m3 [15].

generated images – Figure 8 and Figure. 9 from a swirl and a street canyon exit in Budapest with PM10 concentrations between 25-75 µg / m³ [15].

IOP Conf. Series: Earth and Environmental Science **664** (2021) 012101 doi:10.1088/1755-1315/664/1/012101

In order to properly understand the dispersion of air pollutants in urban area and their evolution in time, new methods must be implemented. Also must be increased the number of monitoring stations from urban area. A big number of monitoring stations will lead in time to a proper understanding of air pollution in urban areas. This will be done be storing large amount of data on servers configured as data centres. That data can be used in improving the calculations made with the help of various deterministic or statistic methods and also can be used with the deep learning methods.

5. Prediction possibilities of air quality in urban areas

Over the time, the increased pollution from urban area has led to the developing of various methods used to properly predict air quality and the evolution in time of pollutants: statistical methods, deterministic methods and of course, deep learning methods.

Every method used until now, do have some strengths, but also have some limitations such as expensive computations on deterministic methods, statistical methods are based on linear assumption and they cannot make a good forecast in case of a space limited but big pollution event, deep learning methods are based on the data that are feed into the system and if that data is not relevant or if that data is not supplied in large amounts, learning is slow. Also, [16] is proposing a deep learning method named: transferred bi-directional long short-term memory (TL-BLSTM) model for air quality prediction. This method is using the deep learning model TL-BLSTM to learn from the data that have been acquired and learned from smaller to larger temporal resolutions. In 1997, [17] where the first to propose this method LSTM, which is fact, an enhanced method evolved from RNN (Recurrent neural network). From that year, there have been designed many other systems that can learn from large scale datasets in TensorFlow [18].

All the deep learning methods require and array of wired or wireless sensors that are connected to a server with a data center where the data is analyzed and stored. The data is transferred to the server using GSM (Global System for Mobile Communications) module or a GPRS (General Packet Radio Service Modem) module attached and connected to the monitoring station. The deep learning algorithm used to analyze de data, is learning, interpreting and forecasting the evolution of the measured pollutants.

In conjunction with the latest advances in computer science and hardware technology, the deep learning methods using large data sets for learning, and prediction software, are in the first place on the race towards development of intelligent applications used to predict the evolution of pollutants in the urban area.

In this context, the first and most important goal is to predict air quality for a specific spatial point, using all the data available for that point from the data center and using the meteorological data, traffic information and also industrial emissions available at that point.

6. Conclusions

Monitoring of air quality in the urban environment is a priority for local and state authorities. The acquisition and installation of new high-performance sensors and monitoring stations connected wirelessly to intelligent computer systems for monitoring and predicting air pollution in the urban environment is extremely necessary.

Through these systems of monitoring of pollutants gases, aerosols and particulate matter, the public authorities will have access to important and constantly updated data, in order to be able to implement effective monitoring measures and why not, pollution control in the periods when, due to some special atmospheric conditions (such as fog or intense heat in the summer), urban pollution is accentuated and may lead to an increase in the incidence of diseases among the population.

Some of these actions, for example, can be the temporary closure (if possible) of the heating capacities in the big cities, to reduce the pollution coming from this part of urban industry, the guidance of the drivers in the traffic to avoid certain areas and routes, the introduction of traffic restrictions or even change of average speed imposed, limitation of traffic in central areas of big cities, limitation of access of polluting cars in central and crowded areas of cities, reduction of construction activities and

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industrial activities, depending on the characteristics of local industry, significant improvement of local transport to cities by using state-of-the-art buses and hybrid or electric engines.

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