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A Qualitative Study of Air Pollutants from Road Traffic

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1. Introduction

Air quality in urban areas continues to represent a major concern, taking into account the impact of pollution on environment and human health. Air quality study involves researchers of several scientific disciplines and requires the development of theoretical, practical and methodological concepts, always new, for understanding, controlling and combating urban air pollution. Together with monitoring, modeling air pollution is a very important tool in the management of air quality. It enables efficient verification in order to reduce emissions and make prediction of pollution levels associated with changes in urban infrastructure.

In recent decades many experimental and modeling studies have been conducted, in order to obtain information on the dispersion of pollutants and transformations suffered by them in the street canyon. Depending on the purpose, different techniques were used for monitoring and modeling. Some of these studies are purely experimental, which means they rely only on small-scale measurements. Others are purely theoretical, concentrating on investigating the various schemes of atmospheric fluid flows and dispersion of pollutants, using mathematical models. The most common are those that combine mathematical modeling with field measurements, as the models for street canyon.

This work presents a series of studies for the correlation of emissions from road traffic, meteorology and concentrations of pollutants at a local scale. It is a qualitative analysis meaning that the study compares the concentration of fictitious values. The aim of this study has been to enrich and understand how to make an analysis of the spatial and temporal variability of air pollution in urban areas.

2. Urban air pollutants

The most important urban air pollutants in terms of emissions and the impact on the environment and human health which could be taken into account are: carbon monoxide (CO), nitrogen oxides (NO and NO_2), volatile organic compounds (VOCs), ozone (O3) and aerosol particles with a diameter less than 2.5μm ($PM_{2,5}$).

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Carbon monoxide is found in abundance in urban air pollution in quantities that no other toxic gases are. Carbon monoxide is formed, usually by one of the following three processes: incomplete combustion of fuel containing carbon, reactions of carbon dioxide and materials containing carbon at high temperatures and dissociation of carbon dioxide at high temperatures.

The main nitrogen oxides are nitrogen monoxide (NO) and nitrogen dioxide (NO_2), and together are called noxious NO_x. About the effects on health, NO are considered harmless, at least at concentrations that usually exist in the street. Instead, NO2 can cause serious problems. Only a small fraction of the gases emitted by engines is represented by NO2, the principal amount being NO. This NO2 in ambient air is mainly due to further oxidation NO. Chemistry of nitrogen oxides is quite complex, but due to the small time the pollutants reside in the street canyon, the reactions of practical interest are: oxidation of nitrogen monoxide to nitrogen dioxide, nitrogen dioxide decomposition in nitrogen monoxide and oxygen and the forming of ozone resulting from the reaction between the oxygen molecule and the oxygen root.

In the category of volatile organic compounds (VOCs) there are a large number of air pollutants, emitted from industrial sources and urban traffic, as well as from other sources. In terms of chemistry, volatile organic compounds include aliphatic and aromatic hydrocarbons, halogenated hydrocarbons, some alcohols, esters and aldehydes. The importance of these compounds is obvious, considering the fact that the agency EPA (Environmental Protection Agency) has designated them as belonging to the six types of critical air pollutants.

Both natural sources and anthropogenic sources contribute to VOC emissions. Natural sources include oil, forest fires and some chemical reactions to produce these compounds. The main anthropogenic sources include fossil fuel combustion at high temperature, the obtaining of oil refined and unrefined, incineration, burning of crops and other debris after collection.

Ozone is formed and destroyed chemically in the atmosphere, the stratosphere or the low troposphere. The complicated processes of training and distribution of ozone in the stratosphere are of great importance for the amount of ultraviolet radiation reaching the earth's surface and for the energy balance of earth-atmosphere system. Ozone is formed under the influence of direct solar radiation from volatile organic compounds and nitrogen oxides. Both the training and the destruction of ozone are photochemical reactions. Ozone concentration in the troposphere has increased lately, especially in the northern hemisphere, due to increasing anthropogenic emissions. Ozone is a strong oxidizer and high concentrations at this level can cause strong negative effects on the environment and human health.

Aerosol particles cover a wide dimensional field, from the cluster of a few molecules to particles greater than 100 μm in diameter. Dimensional distribution of aerosol particles presents a certain regularity that is the result of production of nuclei from different sources and loss through different processes. Each type of particles, taken individually, has its own characteristics, related to its size, geometry, concentration, chemical composition and physical properties.

The particles with less than 2.5μm diameter are a real concern because they remain suspended in the atmosphere, where, depending on size, can be settled relatively difficult.

Aerosol particles, both those produced naturally, as well as those produced by anthropogenic sources are involved in the extinction of solar radiation, can spread the light and reduce visibility and, therefore, can influence, both direct and indirect (cloud formation), the global or regional climate. Inhalation by humans and animals may have adverse effects on health. The small particles, with the diameter less than 1μm, behave like gases; they are involved in the Brownian movement, follow the lines of fluid current near the obstacles, are able to coagulate and are deposited on the surface of the earth very hard. Particles larger than 10μm are strongly affected by gravity, being involved in processes of dry and wet settling.

3. Methods of monitoring atmospheric pollutants

The preliminary assessment of atmospheric pollution in urban area is a very important step in finding the locations where to deploy fixed monitoring stations. Such locations are selected according to information which includes: distribution of pollutants sources in the urban area, the expected maximum concentration points (hot points), the meteorological and topographical conditions, the model applications and other suitable features. The monitoring sites have to be representative of a sufficiently large area in the vicinity, so that the sampling station can be considered representative of a larger area or representative of sites characterized by similar environmental conditions.

The examination of modern methods used for air monitoring permits to answer the question: how air monitoring has to be performed. The variety of analytical methods offers a wide selection of procedures, which can be carried out by means of static, mechanized or automatic devices. The choice will depend upon the use of the monitoring data and the aim which has to be reached.

Static devices, such as the ones employed to measure the amount of deposited particles (dust fall) are used for mapping, for definition of special problem areas and for general survey.

Mechanized bubbler devices are used to collect nitrogen dioxide, mercury, and other gases and vapors. These samplers, although typically designed for collecting 24 h integrated samples, can be modified to collect 1 or 2 h samples in sequence, and thus allow definition of diurnal variations.

In automatic sampler—analyzers, collection and analysis are combined in a single device. These automatic instruments produce continuous analysis, with the output in a machine-readable format or in a suitable form to a central data-acquisition facility.

The approach of the various instruments described to monitor a pollutant either by laboratory analysis or by analyzers is the same. These instruments can be called 'point' sensors as they measure the concentration of the given pollutant at a single point. Another approach for monitoring is the 'remote sensing'. This term indicates the use of instruments which can provide the average concentration of a pollutant in a certain area either by looking at the emissions as they exit at the stack output or by sampling an optical volume at a point within the plume and conducting a spatially integrated measurement across the diameter of the plume. Remote sensing can be performed also by means of a 'long-path sensor'; this term indicates any device which permits one to measure extended or diffuse sources, such as oil refineries and chemical complexes between two points.

For some pollutants however, there are no methods of measurement based on sensors and monitors, and in that case the system requires a periodic transfer of this data.

Choosing compounds to be measured is related to the type of monitoring stations. These, according to the standards, may be:

1. Urban Background Station (for nitrogen oxides, ozone, aerosol particles and sulfur dioxide (optional));
2. Industrial / Residential Station (for nitrogen oxides, sulfur dioxide, aerosol particles and possibly other compound-specific ammonia or volatile organic compounds);
3. Traffic Station (for nitrogen oxides, carbon monoxide, aerosol particles, volatile organic compounds (benzene) and sulfur dioxide (optional));
4. Regional Background Station (for nitrogen oxides, sulfur dioxide, ozone, aerosol particles, volatile organic compounds).

In recent years the focus has been on the use of modern techniques, easy to use, inexpensive and having a good accuracy. Thus, modern information systems for monitoring air quality were made, which enable integrated approach and direct and rapid access to data. They can be used for the purpose of evaluating and planning future actions. Such a surveillance system could be consisted of:

- Sampling systems, sensors and monitors installed in special monitoring stations;
- Data package transfer systems and programs related to quality assurance and control data;
- Database for the air quality, weather and the emission of pollutants;
- Numerical or statistical models (including models of dispersion and meteorological forecasting models);
- Modules for graphic presentation of the results of tests;
- Distribution systems and communication of results through network in order to inform users and the public or for preparing strategies to reduce pollution by the authorities.

Automatic analyzers can provide continuous measurements of concentrations of pollutants without further laboratory analysis. Monitoring procedures are fully automated and use analysis techniques such as chemiluminescence or infrared absorption. Concentration determined by the analyzer is recorded in a data storage device that can be internal or external. The monitoring stations usually operate with multiple analyzers (eg CO, NO, NO2, NOx, O3), because the price is much smaller than the individual analyzers, taken together. A typical monitoring station, along with the analyzer, implies the existence of a room weatherproof and highly secure, air-conditioning system, sample collection lines, a powerful vacuum pump to absorb quantities of sample in ambient air, calibration gas, a data storage system and another data transfer.

There are several types of measurement devices with various features. It is very important to choose them properly.

To measure CO and CO_2 concentrations devices operating on the principle of non-dispersive IR analysis could be used. The IR radiation is absorbed by the CO and CO_2 at specific wavelengths. Gas sample found in the room where measurements are made, is exposed to IR radiation coming from a powerful source. Absorbed energy is measured. The camera is filled with sample gas and clean air, in turn, and the difference of energy absorbed is calculated.

Analyzer for nitrogen oxides (NO, NO_2,) works on the principle of chemiluminescence. Gas sample is first filtered through a filter that can have a Teflon membrane. Nitric oxide present in the sample reacts with ozone generated within the analyzer, producing nitrogen dioxide in the excited state. It emits electromagnetic radiation that is detected and measured by photomultiplier tube, being proportional to the concentration of NO in the sample. A catalytic converter that reduces NO_2 to NO is used to measure NO_2, allowing measurement of total amount of nitrogen oxides (NOx). The measuring cycle of the NO and NO_2 concentrations is very important for the NOx analyzer.

Low levels of O3 could be measured using a spectrophotometer. Ozone absorbs UV radiation of 254 nm wavelength, according to Beer-Lambert law (Schneider et al, 1997). The analyzer determines the concentration of ozone in the sample by measuring the attenuation of UV radiation due to ozone absorption wavelength above mentioned. The gas sample to be measured is led into an analyzer using a diaphragm pump. It passes first through a filter for aerosol particles or by a catalytic converter. The converter selectively changes the ozone sample in O2, thus generating a reference gas to contain no ozone. When the reference gas passes through the cell is set "0" of light intensity. This value is kept as a reference, by the microprocessor. When the sample gas replaces the reference gas the luminous intensity is measured and then the system calculates the difference which is proportional to the mass of ozone contained in the cell. To obtain a relationship of proportionality between light intensity and amount of light absorbed, the ozone analyzer was equipped with a temperature and pressure compensator which includes a temperature converter and a pressure converter.

To measure the particulate matters (PM), the element oscillating microbalance (Tapered Element Oscillating Microbalance- TEOM) could be used or a device based on beta radiation. Both methods are based on basic physical principles.

TEOM is a device used to measure real-time mass concentration of particles with sizes smaller than 2,5 μm (or 10 μm), indoors and outdoors. It records: mass concentration, mass ratio and total mass accumulated in the filter cartridge.

Beta radiation attenuation monitor (BAM-Beta Attenuation Monitor): the beta radiation flow, emitted by a radioactive source located inside the monitor, is directed to the filter containing deposited particles and is attenuated in proportion to the mass of collected particles. This system also allows continuous hourly (or 30 minutes) measurements of aerosol particles of different sizes.

4. The dispersion process

In the initial dispersion of pollutants from the emission sources, they are dispersed into the environment by movements that depend on weather and surveying conditions. In the dispersion process, significant weather phenomena are related to wind speed and direction, turbulence and atmospheric stability.

The wind speed plays an important role in transport and dilution of pollutants. If the emission speed is relatively constant, a doubling of wind speed will result in halving the amount of pollutants, so the concentration is inversely proportional to wind speed.

The speed of the horizontal wind is affected by friction, which is proportional to surface roughness. The last one depends on local natural features: mountains, valleys, rivers, lakes, forests, cultivated fields and buildings. Wind speed over soft surfaces (cultivated areas or lakes, etc.) is on average higher than the wind speed over rough surfaces (mountains, buildings, etc.). The effect of surface roughness on wind speed is a function of height above the earth's surface: the wind speed is lower near the surface.

Dispersion of pollutants is also affected by wind direction variability. If wind speed is relatively constant, the same area will be exposed to high levels of pollutant concentrations. On the other hand, if the wind direction will change constantly, it will disperse pollutants over a larger area, and concentrations in any of the exposed areas will be much lower. Wind direction and wind speed can be represented by a type of graph named wind rose. The spokes' length indicates wind direction frequency. This kind of graph can be used to predict dispersion from a point source or surface.

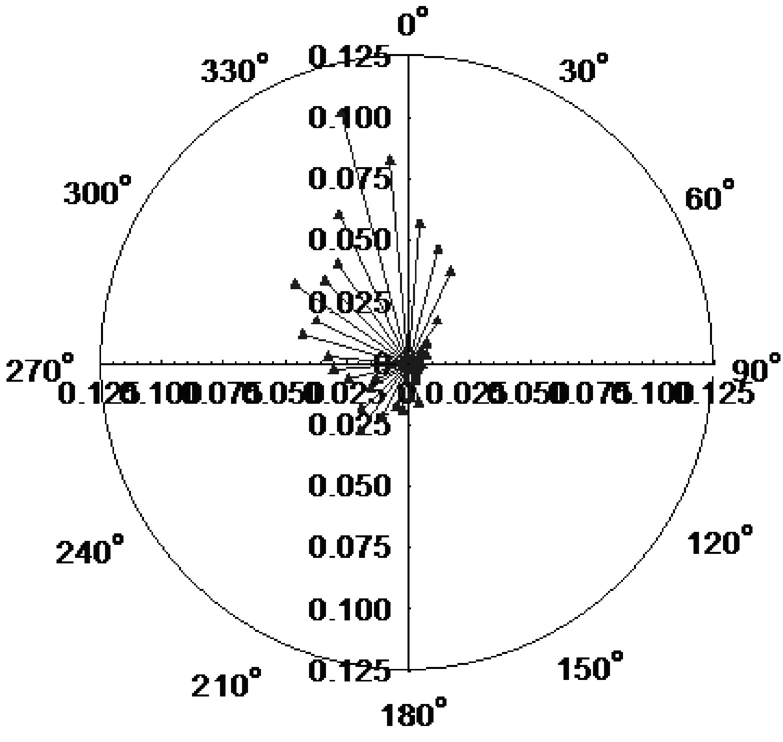

Fig. 1. Wind Rose

The air flow is not uniform near the surface of the earth, but presents a series of movements called vortices. The vortices are produced by two specific processes: thermal turbulence (turbulence caused by the atmospheric heat) and mechanical turbulence (resulting from the movement of air near various obstacles). Thermal turbulence is dominant in bright and sunny days with weak winds. Although mechanical turbulence is produced in various weather conditions, it is dominant in windy, in neutral atmospheric conditions. Turbulence has the effect of increasing the dispersion process, even when there is mechanical turbulence, on in certain areas, high concentrations of pollutants could be recorded, (Godish, 1997).

In large urban centres there are a multitude of fixed and mobile pollution sources. This urban community forms a heated and polluted island which is one of the biggest problems of the contemporary world. In an air quality analysis the ventilation rate of the entire region must be taken into account, because the dispersion can be influenced by both atmospheric mesoscale and macroscale movements. The atmospheric conditions as the anticyclones or thermal inversions slow the dispersion, resulting in high concentrations of pollutants. On the other hand, high weather variability such as moving cyclones, associated with strong winds, will enhance the dispersion of pollutants in urban areas. The pollution can move on, over very large areas, affecting air quality within hundreds of kilometers distances (Briggs, 1969).

Dispersion of car emissions is a complex process that acts at different scales of time and space and is strongly influenced by weather variability and air dynamics around vehicles and buildings. The amount of the exhaust gas varies over time, and it moves in time and space. Immediately after being discharged, the gases are dispersed due to turbulence that occurs around the vehicle, a phenomenon influenced by the non-stationary flow of air masses. A few seconds later, the dispersion is further accelerated by turbulence from other vehicles, moving within the street area.

In parallel with the mixture due to movement of vehicles, emissions are dispersed by air masses that have a dynamic movement because of the weather and topographical conditions (the buildings, trees, open areas, etc.) (Dobre et al, 2005).

Movement of vehicles creates uneven air movements (Plate, 1998) which mix the pollutants emitted from the exhaust pipe. After moving, the vehicle vortices arise. Basically, there isn't a database of local-scale air movements produced by motor vehicles in urban areas (Tate, 2004).

The influence of driving mode on vehicle emissions is of particular importance in such a study as higher emission rates are associated with certain traffic characteristics. (Tate, 2004)

The urban environment is characterized by different widths streets and buildings with different geometries. Dispersion of emissions from vehicles in narrow streets from urban areas has become a very intensely studied research theme (Chan et al, 2002, Xie et al, 2003) because it is known that very high levels of pollutants can be found within these streets, which means, most often, very high levels of pollution to which citizens are exposed.

The term "street canyon" refers to a relatively narrow street with buildings built by both sides, continuously (Nicholson, 1975). Dimensions of the street canyons are expressed usually by the characteristic ratio H / W, where H is the average height of a building located on both sides of the street, and W is the width of the street. A street canyon can be considered regular if the characteristic ratio is approximately equal to 1 and there are no major gaps in buildings on both sides of the canyon, which are like walls. If the wind blows obliquely to the direction of street-canyon, air flow reflection (wind in the roof) in the canyon wall which is exposed to the wind flow, induces a spiral flow along the canyon (Johnson and Hunter, 1999).

Atmospheric fluid dynamics inside the street canyon have been extensively studied by all types of experiments. Historically, most studies were based on idealization of the canyon with buildings placed evenly on both sides of the canyon, considering a wind perpendicular to the street (Berkowicz 1997, Chan et al, 2002). In reality, the geometry and weather conditions are statistically very unlikely.

When analyzing measurements of air pollution in street canyon it is important to have basic knowledge about the dynamics of air and wind effects on dispersion. Also, the moving vehicles generate turbulence which is preferable to be taken into account, if possible. A serious limitation of many studies of urban pollution is the lack of good data set to describe the synoptic weather conditions. Wherever possible, these critical parameters (wind speed, direction, and turbulent flows) must be measured in the area.

5. A study of spatial and temporal variability of air pollution in urban area

The purpose of this work is to understand how the examination of spatial and temporal variations of the pollutants' concentration in a street canyon could be done. It has to be linked with the traffic data, with emissions and weather conditions. To do this, the frequency of road traffic, the generation of emissions and the pollutants dispersion phenomenon must be taken into account.

A long term database is preferred, to also make an analysis of the pollutants trend. The database must be created using the raw measurements and eliminate negative values or strange data which could appear because of the device malfunctioning. If the measurement period is long, the devices must be calibrated from time to time (e.g. one time a month) and a few data could be lost. Time series plots must be done, pollutants together with traffic flow and meteorological data, to make complex analysis of the monitored data. The graphs must be analyzed, to find the correlations between different pollutants and the traffic flow. So, carbon monoxide, nitrogen oxide and particulate matter are emitted by vehicle engines during usage – primarily pollutants (Raducan and Stefan, 2009).

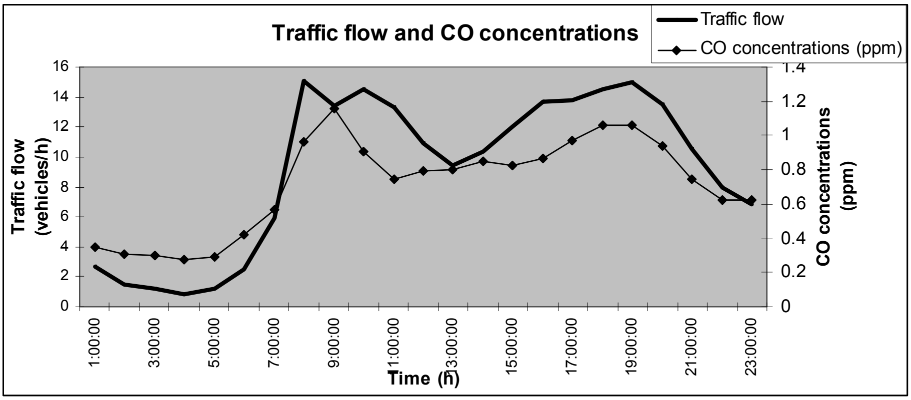

Fig. 2. Traffic flow - CO concentrations (primarily pollutant) – almost the same trend

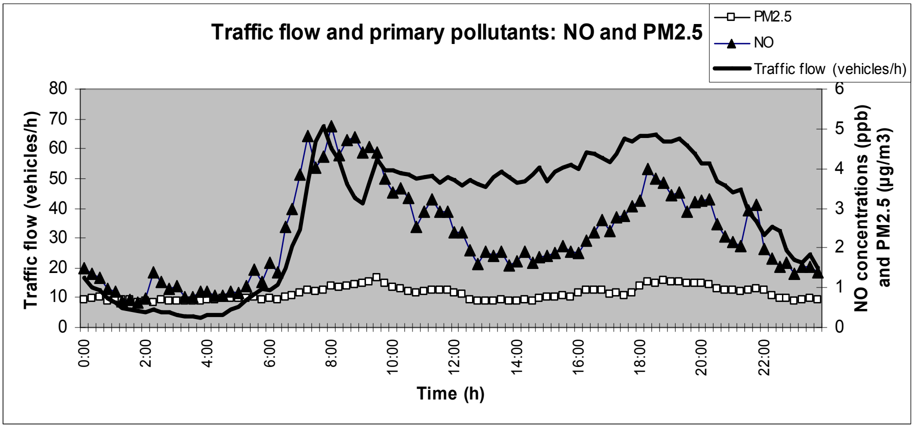

Fig. 3. Traffic flow - NO and $PM_{2.5}$ concentrations (primarily pollutants) – almost the same trend

The graphs show a relatively large amounts of traffic flow and concentration of pollutants around two moments of the day: in the morning, when people go to work and in the afternoon, when they come back, and a good correlation between the above mentioned pollutants, which demonstrates that their main source is the traffic.

Also, relatively high concentrations are recorded near the street, compared with the higher points or the more distant points from the street.

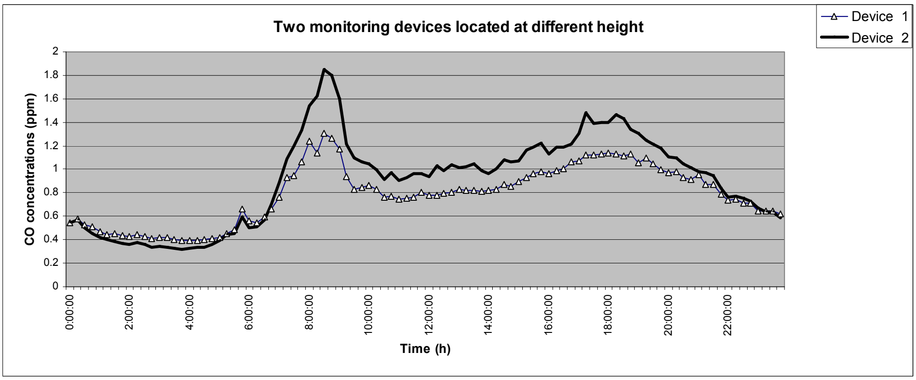

Fig. 4. The device 2 was closer by the street and it recorded higher level of pollution

When there are many devices which measure the same pollutant, installed at different heights, they must record the data as it can be seen in the graph below: the device which is set lower, records higher concentration values.

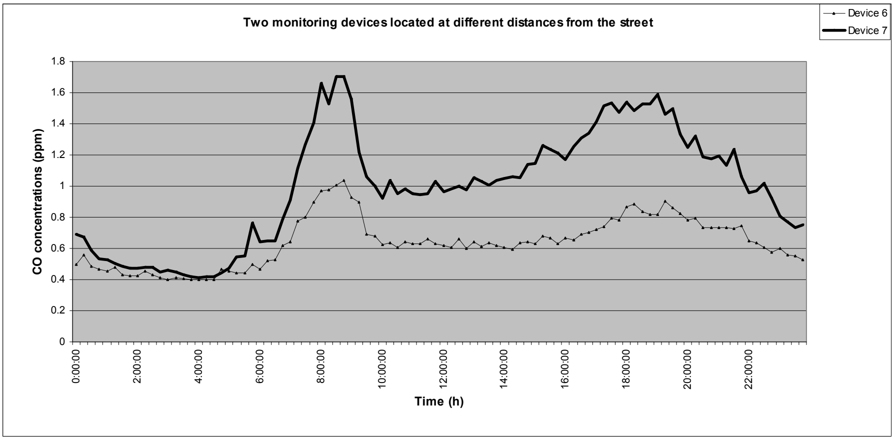

Fig. 5. The devices 6 and 7 ware situated in the same point near the street. Device 6 was located above

Meteorology has a key role; the results clearly show the importance of wind direction and speed: increasing wind speed cause a good dispersion of pollutants, so the registration of low concentration of pollutants. On the contrary, stable atmospheric conditions cause an accumulation of pollutants in the area of the street, considerably increasing concentrations.

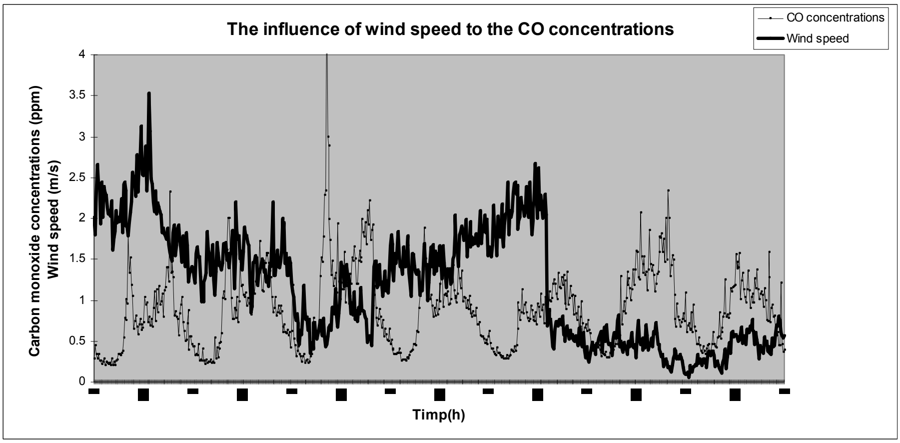

Fig. 6. When the wind speed is lower, the CO concentrations are higher

When the wind direction is perpendicular to the street, a vortex is created in the street, carrying pollutants towards the wind. If the wind direction is parallel to the street, the atmospheric fluid transports the pollutants along the street increasing the rate of concentrations in this direction. When the direction of the wind is skew toward the street the atmospheric fluid is moving helicoidally, carrying the pollutants both to the other side of the road, and along the street.

6. Air quality modeling

Mathematical modeling is one of the most powerful modern tools used in most studies of air pollution. Since the monitoring urban pollutants is very expensive, the modeling of the pollutants dispersion is an alternative that offers good results in the study of air quality.

A simple definition of the concept of "model" may be as follows: the model is a mathematical representation of facts, factors and interpretation of data quantity or situations.

The models are used mainly for: generalization and interpretation of measurement, the pollution prediction and the simulation of the pollution scenarios (answers to questions: what will happen if ...?)

Within the operational plans, the models are now widely used, the main focus being (Zanetti, 1993):

- The establishment of legislative measures to control emission of pollutants into the atmosphere, by determining the maximum emission of pollutants that can take place without exceeding air quality standards;
- The assessment of the proposed emission control techniques (air cleaning technologies);
- The selection of positions for the future pollution sources, in order to minimize environmental impact;
- The control of pollution accidents by defining the measures and strategies to be taken immediately after the accidental pollution episodes (warning systems and real-time strategy to reduce emissions);
- The assumption of the responsibilities, for higher levels of pollution, by establishing the source-receptor relationship.

Types of models

Models currently used can be classified as follows:

- Physical models;
- Empirical models;
- Mathematical models;

Physical models are small-scale representations of "real world", e.g. representations and reproductions of the phenomena of nature in the laboratory. An example of such common representations is the wind tunnel or water where they can reproduce the dispersion experiments in the presence of miniature buildings, relief, vegetation - forests, etc. Another example is the fog chambers where chemical reactions can be studied under the same atmospheric pressure, temperature, humidity and solar radiation. There are several limitations in this small-scale reproduction of the phenomena from the nature: the conditions of turbulence in wind tunnels or water can not fully simulate the real conditions, many chemical reactions occur in fog room at their walls, etc.

Physical models have shown very interesting results, revealing some mechanisms and providing validation data, then used in developing mathematical models.

Empirical models generalize the relationships between different parameters, experimentally determined.

Mathematical models, the most complex models currently developed, can be divided into:

- Statistical models based on semi-empirical statistical relationships between various data and available measurements.
- Deterministic models based on mathematical description of atmospheric processes, where the effects (e.g. air pollution) are generated by causes (e.g. pollutant emissions).

The models of type receiver could be good examples of statistical models. Receptor type models use measured data for different concentrations of pollutants, for a long time. They can identify the impact of the contribution from different sources using statistical analysis of the measured concentrations at a certain point (receiver). Receptor type models are used mainly for the interpretation of air quality measurements.

An example of a deterministic model could be a diffusion model in which the output data generated by the model (pollutant concentrations) is calculated based on mathematical computations performed on the input data (emissions, atmospheric parameters, etc.).

Deterministic models are most suitable for practical applications, because if they are correctly calibrated and used, they generate very accurate and consistent results regarding the source-receiver relationship. Establishing accurate source-receptor relationships is the target of any study which is made to improve the air quality or to keep the current levels of concentration for future development of industrial or urban areas. In other words, only deterministic models can generate clear assessment of the responsibility of each source of pollution from each receiver, this thing being absolutely necessary in the design and implementation of emission control strategies.

In terms of mathematical models, the modeling techniques used in the deterministic models must be applied to all aspects and phenomena related to air pollution. The main phenomena which are mathematically modeled:

- atmospheric transport,
- turbulent diffusion in the atmosphere,
- atmospheric photochemical and chemical reactions,
- deposition to the soil surface.

Turbulent diffusion theory is focused on the behavior of pollutant particles which follow trajectories that allegedly are caused by the wind field. Due to the randomness of atmospheric dynamics it is impossible to determine the exact distribution of pollutants concentration in the atmosphere due to the pollution sources. Although the basic equations describing turbulent diffusion can be written without difficulty, there is no single mathematical model that can be used to calculate concentrations field in all possible states of the atmosphere.

There are currently two theories developed that address turbulent diffusion: the Eulerian approach and the Lagrangian approach.

The Eulerian method is based on solving the equation of mass conservation in a fixed region of space, while the Lagrangian method is based on tracking the behavior of pollutant particles, carried along the flow lines. Each approach has a number of shortcomings that make it virtually impossible to determine the exact diffusion problems. For example, the

Eulerian approach, although capable to include complex physical phenomena in the diffusion equation (dry deposition, wet deposition, topographic effects and building, chemical reactions), has serious mathematical problems when the equations must be solved, using different parameterizations for this purpose.

Lagrangian formalism, by the statistical description of particle displacement along current lines, is mathematically easier to approach, but the results are limited by the impossibility of defining a complete statistic for a system of particles. Furthermore, Lagrangian formalism can't include a number of important physical phenomena such as nonlinear chemical reactions.

7. OSPM – A street canyon model

Operational Street Pollution Model (OSPM) has been tested many times by comparison with data obtained in different measurement campaigns (Hertel and Berkowicz, 1989a, b, c, Berkowicz, 2000a, b). Test results have helped to improve the model parameterization.

Quality of results obtained with the model depends on the quality of input data. Thus, studies by Schaedler et al. (1996, 1999) and Roeckle and Judges (1995) examined the influence of quality input data on modeled concentrations. As with any model of urban pollution, the most important parameters of the model used as input data are meteorological and background data, traffic data and emission factors that are needed to estimate emissions and topographical conditions (Pavageau et al., 1997).

Pollution generated by road traffic in a street canyon is characterized by a strong temporal but also spatial variability, both horizontally and vertically, which not only depends on diurnal variation of traffic, but also on weather conditions. Very little things are known about the vertical distribution of traffic pollution. Some of them are obtained from experiments in wind tunnels (Pavageau et al., 1999) or from direct measurements (Vachon et al., 1999). The analysis of measurements of turbulence in the street is shown in Vachon et al. (2001) and Louka et al. (2001). The dependence of urban pollutant concentrations on traffic and thermal effects, and comparison of experimental results with those modeled by OSPM was realized in Berkowicz (2000a,b).

OSPM is a semiempiric, parameterized model, where the concentrations of exhaust gas are calculated using a combination of a plume model for direct contribution and a box model for the recirculated part of the pollutants from the street. OSPM uses a very simplified parameterization of atmospheric fluid dynamics and dispersion of pollutants in street canyon. This parameterization was deducted from the analysis of experimental data and testing of the model. The results of these tests were used to improve the model's performance, especially in connection with various configurations of the street and different weather conditions. On the other hand, OSPM is based on many empirical assumptions that may not be applicable in all urban environments. The comparison data measured in the street with the OSPM model proves that a model with a simple parameterization like this can be applied to predict pollution from traffic. An important feature is the ability of the model to determine the concentrations of pollutants on a very weak wind, when it records data of severe pollution.

The results obtained with WinOSPM can be saved in a file that can be text, Excel or Access. The easiest to use is the .xls file, because it allows an easily analysis of the correlation between modeled and measured data. The modeled data is compared with those measured by calculating a set of statistical indicators used to validate the model. By this method, the quality of the output data can be determined, and so the model performance.

This data set includes the averages, the medians and the standard deviations for measured and simulated values, the mean error (bias), the normalized residue (FB), the normalized square error (NMSE), the correlation coefficient (R2) and the fraction of predicting the measured values up to a factor 2 (FA2) (Raducan, 2008b).

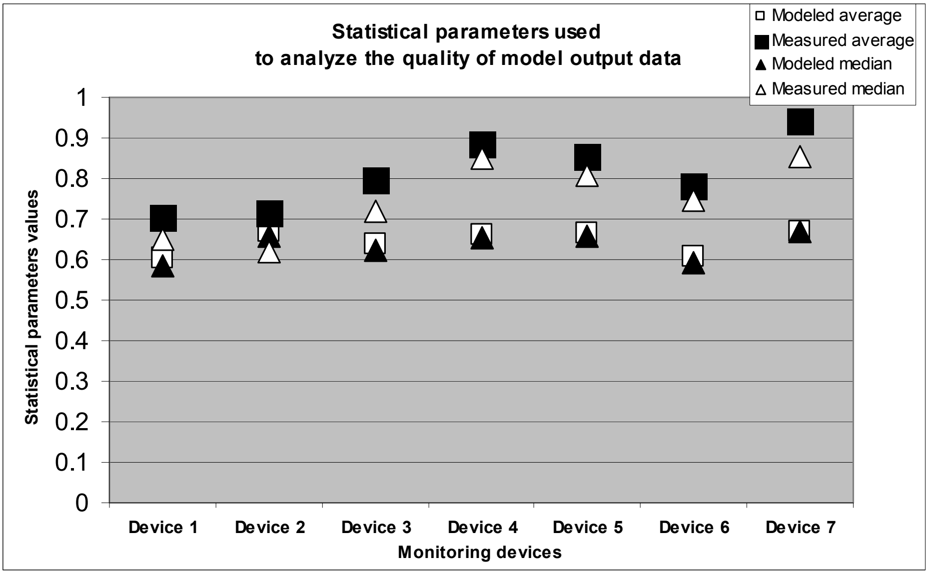

Fig. 7. The statistical parameters: the averages, the medians calculated for measured and modeled data

If the values of the averages and medians for both sets of data (modeled and measured) are close, it means that there are not very large extreme values which could be wrong.

The standard deviation shows how much variation or "dispersion" there is from the average. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values.

If Bias <0 the model underestimates. Otherwise, it overestimates. Also, if FB>0, the model underestimates. Otherwise, it overestimates. So, figure 8 shows that the model underestimates.

When the normalized square error (NMSE) is low, it indicates that the model correctly describes the processes in time and space.

Analyzing the correlation coefficients between the simulated and measured data (Raducan, 2008a) there is good correlation if $R^2 > 0{,}5$ and a weak correlation if $R^2 < 0{,}5$.

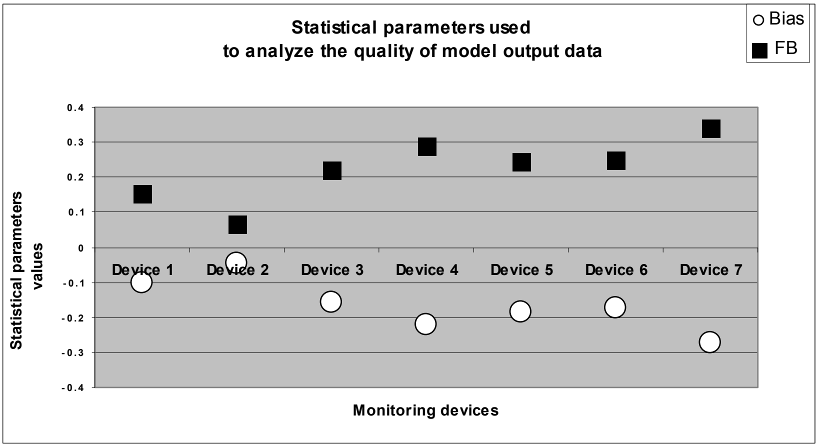

Fig. 8. The statistical parameters: the mean error (bias), the normalized residue (FB)

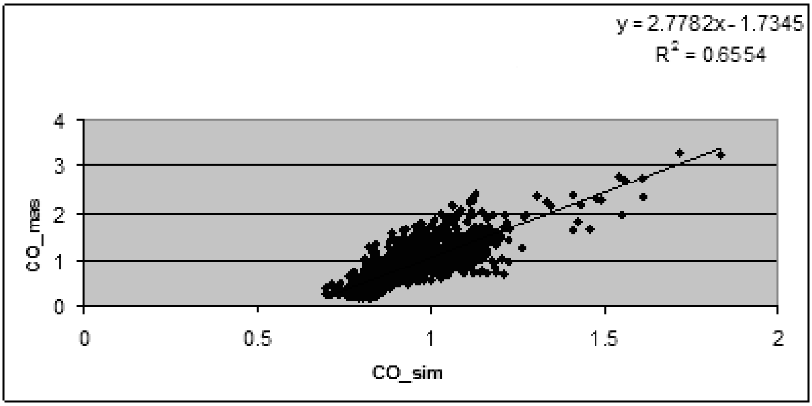

Fig. 9. A good correlation between simulated and measured data ($R^2 > 0,5$)

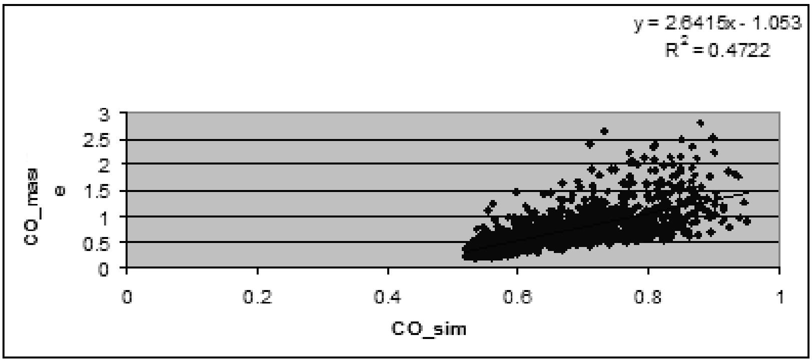

Fig. 10. A weak correlation between simulated and measured data ($R^2 < 0,5$)

The values of the fractions of predicting (FA2) must be between 0,5 and 2.

8. The model's parameterization

The correlation between the simulated and measured data could be improved if the errors are corrected. The input data are very important for the quality of output data. In the input data there are a few parameterization mathematical relationships which could be improved. The model must be run with the new inputs. The results must be compared as it can be seen in the graph below (Raducan, 2008a)

If the values of the correlation coefficients are higher, the parameterization has improved the model outputs and it is validated for that set of data. This parameterization must be tested for many others sets of data in the same location and if it works properly, than it can be used within that street canyon. Also, the parameterization must be tested from time to time, using real data.

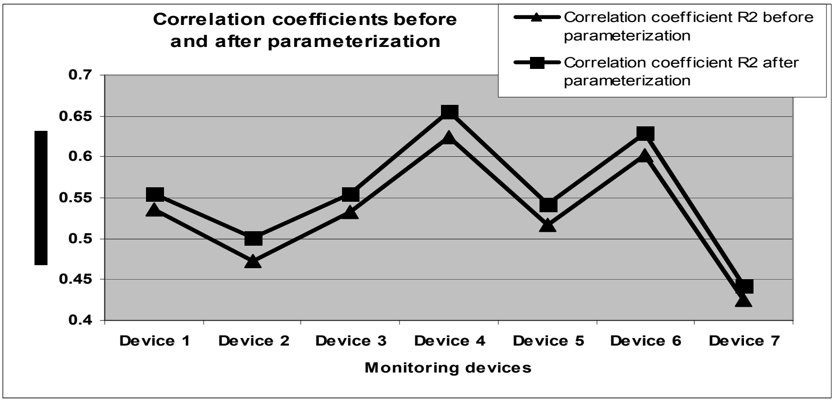

Fig. 11. A comparison between two sets of model outputs, before and after a parameterization; the model was run in 7 points in the street canyon

In many studies with OSPM, the results are compared with those obtained with other models to improve physical concepts of the model parameterization. Yet, the numerical models do not describe well enough some important phenomena and they require various parameterization relationships. These relationships are very important in the case when the wind is weak and the turbulence produced by traffic has a great influence.

It is noted that OSPM has been successfully applied to analysis of data obtained from routine monitoring in order to predict trends in traffic emissions (Palmgren et al., 1999).

Because OSPM, as software, does not require significant resources of the computer system, several years' data were processed within a few minutes.

9. Conclusions

The aim of the study has been enriching and understanding how to make an analysis of the urban air pollution.

A complex analysis of urban air quality must contain an observational part that examines the concentrations of pollutants recorded in the street and a dispersion modeling part.

First, the monitored pollutants must be established. Also, the monitoring devices must be chosen and the location in the urban area. Then, from the multitude of pollutants dispersion models, the most appropriate must be chosen (could be more then one model in order to compare the models output data).

Data analysis is done taking into account both the measured concentrations in the street, and emissions, traffic, weather conditions and topography, all being related to one another. The best way to compare data is to use some types of graphs to highlight the features that interest us.

The results should be stated clearly, visibly and after careful and thorough analysis. It is preferable to highlight both the results and shortcomings after a practical study. The latter could become research topics for those who made that study but also for other researchers.

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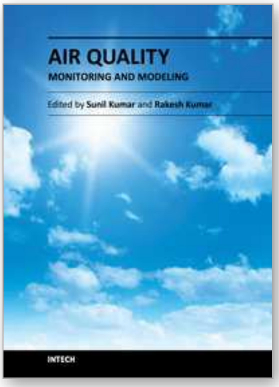

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The book reports research on relationship between fungal contamination and its health effects in large Asian cities, estimation of ambient air quality in Delhi, a qualitative study of air pollutants from road traffic, air quality in low-energy buildings, some aspects of the Sentinel method for pollution problem, evaluation of dry atmospheric deposition at sites in the vicinity of fuel oil fired power, particles especially PM 10 in the indoor environment, etc.