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INFLUENCE OF VARIOUS FACTORS ON THE PRESERVATION OF AIR QUALITY IN DENSELY POPULATED AREAS

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ABSTRACT
Use of different energy sources, primarily for the purpose of heating and transportation, may have a different impact on air quality in densely populated areas. Fossil fuels, often used for this purposes, depending on type, pollute the atmosphere more or less. Use of fossil fuels that have a significant impact on the environment is motivated for several reasons. These reasons are primarily related to cost of energy generating products, unavailability of less polluting energy sources, unavailability of adequate technologies and the lack of environmental awareness. Frequently, just in case of excessive values of air pollutants in a particular area, local population considers the causes of air pollution and gives it the importance. In this respect, mostly, there is no environmental awareness of people on the global scale. For this study, data on average daily values of air quality in the Sarajevo Canton in the last five years are used. The paper provides a critical approach to the impact of these factors, numerical justification for the application of certain energy sources, and different scenarios were analyzed with the goal of improving the air quality, in both, the micro scale and impact on the global scale.
Keywords: air pollution, pollution sources, fossil fuels, natural gas, coal

1. INTRODUCTION
The reported deaths of 4000 people caused by London smog in 1952 was the catalyst for the introduction of the UK and world wide regulation of air pollution control. In 1986 the EC stated that several of traditional cases of air pollution, such as smoke and particulates, where now under control in the European Community (EC1987). This improvement in local urban air quality is due to the replacement of coal in industry and households by natural gas, oil and nuclear power. In Bosnia and Herzegovina, such as in other low income countries in Eastern Europe, little progress has been made. While coal is still a significant energy source, the pollution potential of large coal power plants has been reduced by the introduction of wet/dry scrubbers to the exhaust gases prior to emission. Significant air pollutants still exist in the urban air environment due to the transportation or heating purposes.
There are many aspects of environmental problems: economical, political, psychological, medical, scientific, and technological. Understanding and solving such problems often involves certain quantitative aspects, in particular the acquisition and analysis of data. In our case, we have possibility to get relevant information and data on natural gas consumption (hourly, daily, by consumer, by profile), compare this with temperatures and air pollutant concentration in urban area of the Sarajevo Canton. These analyses allow us to finally get certain conclusions.

2. INFLUENCE OF DIFFERENT FACTORS ON AIR POLLUTION

When a gaseous or particulate emission is released into the atmosphere, in form of vehicle exhaust, industrial stack or other sources, its fate is almost impossible to predict. This is so because of the complex factors that influence its subsequent pathways. The influencing factors are primarily:

- Sources
- Meteorological
- Processes

Our society is based on utilization of energy generated from fossil fuels. Using less polluting fossil fuels, emissions of air pollutants can be largely decreased. The fuel such as natural gas seams to be ideal solution until renewable energy sources replace the fossil fuels.

3. NATURAL GAS VS COAL

In this section, our aim is to investigate the influence of natural gas and coal on air pollution considering meteorological factors. For comparison of the parameters of combustion-related pollutants of solid fuels and natural gas, let us consider the combustion of coal and natural gas of equivalent power of 1 GW, which corresponds to installed power on the gas system of the Sarajevo Canton. Calculation is done for two extreme scenarios: the current situation in which the greater part of the Sarajevo Canton has the natural gas network and hypothetical situation in which, at current energy needs, coal is used for heating instead of natural gas.

In calculation of quantities of combustion-related pollutants for these two fuels, the estimation is that the average level of efficiency of fire-box for coal is approximately 60% and for gas boilers approximately 90%. Calculation is done for natural gas composition: carbon dioxide 0,1%; nitrogen 0,6%; methane 98%; ethane 1%; propane 0,2%; butane 0,1% and coal: moisture 8%; ash 7,7%; carbon 77%; hydrogen 3%; nitrogen 1,25%; sulphur 1%; oxygen 2,05%. Detailed calculations are given in [1] and values of annual emissions are given in Table 1.

Table 1. Comparative calculated values of annual combustion-related emissions for natural gas and coal in the Sarajevo Canton

Burning product	Annual emissions using natural gas, t	Annual emissions using coal, t
Particulates	0	$76 \cdot 10^3$
Sulphur dioxide	0	$25 \cdot 10^3$
Carbon dioxide	$1.650 \cdot 10^3$	$3.500 \cdot 10^3$
Nitrogen dioxide	$12 \cdot 10^3$	$50 \cdot 10^3$

These results are obtained for two extreme cases, but the real situation is somewhere between. The goal is to have at least first situation or better due to utilisation of renewable energy sources. In urban areas, the various factors can influence the first or second situation. The concentration of the air pollutants, as mentioned before, can vary depending on weather conditions (temperature, inversions, wind speed etc.) in urban areas where pollutants are emitted.

4. DEMONSTRATION OF WIND INFLUENCE ON POLLUTANT CONCENTRATIONS USING BOX MODEL

If we consider an urban area such as the Sarajevo Canton with a population of 400.000 and 100.000 vehicles, trafficking within a 100 km^2 area with an average travel distance of 10 km and with average time to travel this distance 2 h. Assume each vehicle emits 0,01 g/km of NO_2. We use Box model to determine the concentration of NO_2 due to the traffic in function of time regarding the speed of wind. It is based on the mass conservation of a pollutant in a box. If there is only pollution entering the box from city emissions and the initial concentration in the box is zero we can write [2]:

$$C(t) = \frac{q_s \cdot L}{U \cdot H}\left(1 - e^{(-Ut)/L}\right)$$

The evolutions of pollutant concentration with wind speed are shown on figure 1. Considering this model one can see if the speed of wind is decreasing the concentration tends to be linear dependent on the pollution rate with the time. When the speed of wind is increasing, after certain period of time the concentration of the pollutant tends to be constant, due to the rate of pollution leaving this space. For

all other pollutants heaving greater or lower emission rate, the shape of the curve is identical and proportional to the emission rate per kilometre.

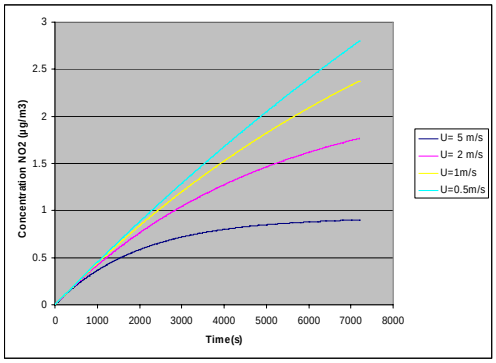

Figure 1. Evolution of NO_2 concentration with wind speed

Emissions from traffic have significant contribution to the entire concentration of pollutants. Finally, we use this model for the specific purpose to calculate concentrations of air pollutants apart from the winter and to compare this with measured concentrations in subsequent sections.

5. VARIOUS FACTORS THAT CONTRIBUTE TO AIR POLLUTION

Daily concentrations of air pollutants during two months, January and April, are shown in the next graphics, serving such as an example of two characteristic pollution periods. One can see that in January, as a winter month, the concentrations are higher then in April. In winter, due to the heating purposes, emissions are higher and combining with inversions, the concentrations of air pollutants can be severely high. Characteristics for January are that for some days in period of inversions, the concentrations are too high exceeding limit values. In periods out of winter, the pollution is associated with the traffic and industry exhaust that is shown in example of daily concentration for April.

The concentrations primarily depend on weather conditions and not only on the emission rate in that region. It means that concentration depends on wind speed and direction and atmospheric stability. Regarding to the global scale the high concentrations of air pollutants in certain urban areas can be representative indices how utilisation of fossil fuels such as coal pollute the atmosphere.

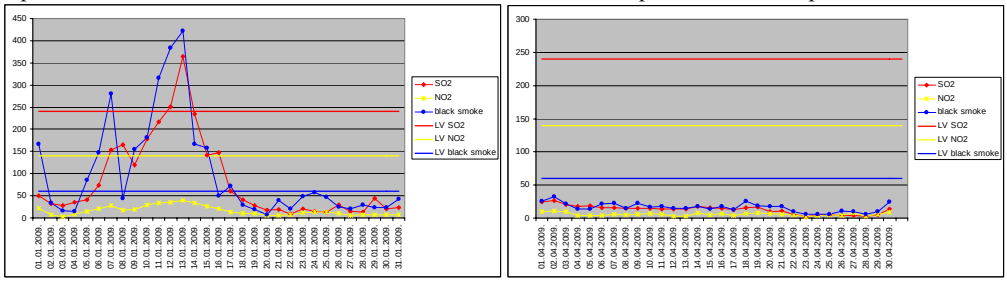

Figure 2. Daily concentrations of air pollutants in January and in April 2009

It is important to see how important is the emission in urban areas using coal. Concentrations of all pollutants have similar behaviour and when concentration of one pollutant is increasing, concentrations of other pollutants is also increasing. Analyzing the concentrations of pollutants in April one can see that they are nearly constant due to presence of wind that corresponds to the calculations given by box model in previous section. Analyzing gas consumption and concentrations of pollutants one can see that with lower ambient temperature the consumption of natural gas is proportionally higher and the emissions are higher due to increased utilisation of all types of fuels for heating (coal, fire wood, heating oil, etc). To avoid this or to lower the consumption with temperature, primarily is recommended to work on energy efficiency and especially on building insulation.

6. CONTRIBUTION OF DISTANT POLLUTION SOURCES

Beside the sources inside the urban area, the distant pollution source, even hundreds of kilometres away, such as coal thermal power plant, can influence the concentration of pollutants in this area. In the case of the Sarajevo Canton, proximity of the thermal power plant Kakanj of approx. 30 km influences the air quality. The concentration of a pollutant plume at any x, y, z location can be computed from the diffusion equation.

$$C_{(x,y,z)} = \frac{Q}{2\pi\sigma_y\sigma_z U}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)\right]\exp\left[-\frac{1}{2}\left(\frac{z}{\sigma_z}\right)\right]$$

Where σ_y, σ_z are diffusion coefficients in m, as functions of downwind distance x [3]. Coordinate system x = 0 at stack, y = 0 at plume centre line, z = 0 at ground level. Q is any property per unit time, e.g. kg/s and C is that property per unit volume, e.g. kg/m³. Using the Briggs formulation [4] to calculate the plume rise and diffusion equation it is possible to calculate the concentration of SO_2 in Sarajevo city due to the emission of the mentioned thermal power plant. Actually, the power of this thermal power plant is 450 MW, supposing that the load factor is 72.5 % and efficiency of 40%. The stack height is 300 m. Taking into account that the coal has 1% of sulphur content and net heating value of 30 MJ/kg, in presence of wind with the speed of 10 m/s from the northwest, we get the concentrations $C(SO_2)$ = 8.1 μg/m³ in Sarajevo from this power plant. Beside the other polluting sources this source contributes to the overall air pollution in the city. The calculated value of the concentration of SO_2 corresponds to the findings of the Federal Hydrometeorological Institute of Bosnia and Herzegovina. Also, in function of wind direction the exhaust gas from this power plant dramatically pollute the rural areas in radius on 50 km [5].

7. CONCLUSIONS

Winter concentrations of air pollutants (SO_2, NO_2) are the highest due to heating purposes. Weather conditions, such as temperature inversion, influence high concentrations of air pollutants. During this period of inversions (stability) the true impact of the air pollution can be seen not only in micro scale but also in the global scale. Emissions of CO_2 as a greenhouse gas to the atmosphere cause effects of global warming on global scale. It means that beside the local pollution of air and its effects on local habitants, global warming is more important to consider for development of local environmental and energy politics. The prices of fossil fuels significantly influence emissions of air pollutants even on global scale. Also, accessibility to natural gas networks increases the number of consumers which in turn decreases the emissions of pollutants and improves air quality. In this paper the contribution of other pollution sources such as transport and distant pollution sources are given, which conforms to measured concentrations of pollutants in air.

Studied case is typical case in low income countries in Eastern Europe rich with coal where the utilisation of coal is still inefficient. Use of less polluting fossil fuels, use of advanced technologies for more efficient coal utilisation and finally renewable energy sources are final objectives for the development of the energy sector. Every investment in this sector in the future must take this into account as well as the concerns for the environment.

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