Monitoring of air pollution in Skopje in order to determine possible causes

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Abstract – **Brief review of few major air pollutants of Skopje is presented in this article. State automatic monitoring system for ambient air quality measures up to 7 air pollutants. It consists of network of 17 fixed and 1 mobile monitoring stations installed throughout the country. Performed analysis of pollutants' inventory reveals that suspended particles (PM10 and PM2.5) are the most critical air pollutants in Skopje in the last couple of years.**

Keywords – **monitoring, causes, air pollution, Skopje.**

I. INTRODUCTION

The use of oil and oil derivatives, traffic, increasing industrialization and intensification of production inevitably lead to an increase in the concentration of harmful substances in the air. Although in traces, their presence has been shown to have a significant detrimental effect on human health, biosphere and other material goods. There are substances in the air, such as: nitrogen oxides (NO_x), sulphur dioxide (SO_2), ammonia (NH_3), carbon monoxide, particulate matters, heavy metals, hard degradable organic compounds, etc., that have a direct or indirect negative impact if their presence is in concentrations higher than normal.

Nitrogen monoxide (NO) and nitrogen dioxide (NO_2), or general NOx, are the most important nitrogen oxides, that occur as an air pollutant. NO_2 reactive gas is formed by oxidation of nitrogen monoxide (NO). A major source of NO and NO_2 is high temperature combustion process (processes that are carried out in motor vehicles and power plants). The amount of NOx is increased in winter due to intensive use of fossil fuels. The largest amounts of nitrogen oxide emissions in Republic of North Macedonia are emitted during the production of electricity and thermal energy (48%), due to the dominant electricity production with coal as a fuel. Traffic emissions, also, have large share (38%) of total emissions of this pollutant.

Sulphur dioxide, SO_2, is a colourless, toxic gas with sharp and irritant odour, and acidic properties. Its toxic impact on humans occurs at mass concentration in the air of about 6 mg/m^3 or more, causing serious health problems. Today, sulphur dioxide, SO_2, is considered as one of the main pollutants in the atmosphere from anthropogenic sources, and thus intensive measures are taken to reduce its emissions. Considering that electricity production is the main source for SO_2 emissions, its emissions trends vary and depend highly on coal consumption. There are many industries that emit significant quantities of SO_2 in the ambient air: the oil industry emits SO_2 or H_2S during refining of petroleum products, electricity production plants that use coal with high concentrations of sulphur, sulphide smelters, installations for production of paper and pulp. In 2014, the estimated national SOx emissions amounted to 83.141 kilotons, where a key and dominant source with 92%, are the combustion processes from fuels (coal and oil) in power generation.

Suspended particles or particular matter (PM), as one of the most common pollutants in the air is a mixture of solid and liquid particles, suspended in the air with wide range of sizes and chemical structure. They can originate from natural sources (sea salt, desert areas dust, wildfires, volcanic ash pollen) and anthropogenic sources (industrial processes, combustion of fossil and biofuels - vehicles, power plants and households, transport and waste incineration). The most significant share in particles emission (PM2.5 – 51%, PM10 – 35%), according to the conducted inventory of suspended particles, belongs to domestic heating, especially due to incomplete burning wood in old stoves. Recent studies, [1] have shown that key sources of suspended particles emission are heat and electricity production processes (PM2.5 -25%, PM10 - 22%), as well as production processes especially in the area of metallurgy. The reduction in emissions in the recent years, is due to lower consumption of firewood in winter period.

II. EMISSION MEASUREMENTS, LIMIT VALUES AND STANDARDS IN USE

Republic of North Macedonia has an emission inventory reporting obligation, [2], towards the Convention on transboundary air pollution and its eight protocols as well as the European Environmental Agency (EEA). In accordance with the Convention and its protocols, our country is required to annually report data on emissions of the main air pollutants covered by the Convention. According to EU legislation, limit values of air pollution levels are the strictest rules. In a case of exceeding the limit values, measures to reduce the levels of pollutant concentrations must be defined and enforced by the authorities. In addition, for the protection of human health and vegetation, critical levels have been defined, Table I.

TABLE I
LIMIT VALUES OF AIR POLLUTANTS

Pollutant	Averaging period	Limit values	Allowed number of exceedances in a year
Sulphur dioxide, SO_2	1 hour 24 hours	350 $\mu g/m^3$ 125 $\mu g/m^3$	24 3
Nitrogen dioxide NO_2	1 hour 1 year	200 $\mu g/m^3$ 40 $\mu g/m^3$	18 -

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PM10 suspended particles	24 hours 1 year	50 μg/m^3 40 μg/m^3	35 -

In the Republic of North Macedonia, the monitoring of ambient air quality is performed by the Ministry of Environment and Physical Planning, which manages the State Automatic Air Quality System, as well as the Institute of Public Health (IPH) with the Centres for Public Health in Skopje and Veles. Additionally, the air quality monitoring is performed by certain installations that have an obligation in accordance with the requirements of the IPPC permit.

The Ministry of Environment and Physical Planning manages the State Automatic Monitoring System for Ambient Air Quality, which consists of 17 fixed and 1 mobile monitoring station throughout the country, located on following places: 5 measuring stations in Skopje, 2 measuring stations in Bitola, and one measuring station in Veles, Municipality of Ilinden, Kichevo, Kumanovo, Kochani, Tetovo, Kavadarci, Gostivar, Strumica and in the village of Lazaropole, Figure 1, [3].

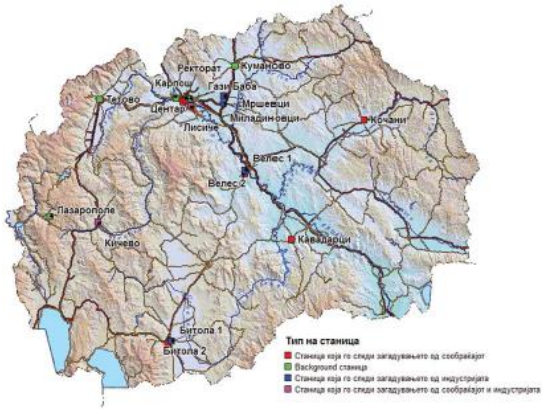

Figure 1. State automatic ambient air quality monitoring system

Automatic air quality monitoring stations monitor the following pollutants: SO_2, NO_2, CO, ozone (O_3), PM10, PM2.5, Benzene, toluene, ethylbenzene, and xylenes (as BTEX).

Within this paper, a comparison of the emissions of SO_2 and PM10 at the level of the entire country and especially for Skopje was made.

SO_2 emissions

Total national SO_2 emissions amounted to 110 kt in 1990. In 2014, emissions decreased for 24% due to decreasing emissions from public electricity and heat production, and amounted to total of 83 kt. In the years 2009 and 2011 emission peaked compared to 2010, due to higher consumption of coal by the major thermal power plant REK Bitola. Shorter operation periods of the second by installed capacity thermal power plant REK Oslomej in the period 2012 – 2013 decreased coal consumption up to 60%, thus reducing SO_2 emissions.

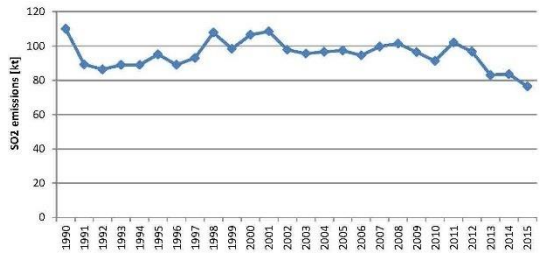

Figure 2. Total national SO_2 emissions for the period 1990-2015

In the period from 2013 to 2014 emissions remained quite stable (-1%), and after 2014 remained at the same level due to the fact that no major changes were carried out. In 2016, SO_2 emissions in Skopje are also the highest in the month of December. Maximal hourly concentrations of SO_2 reaching up to 52 μg/m^3, were registered at monitoring stations in Miladinovci at the end of the second half of December. Figure 3 shows the hourly SO_2 concentrations for Skopje agglomeration region in December 2016, [4, 5].

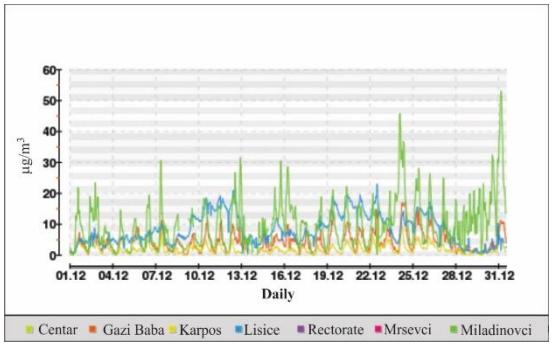

Figure 3. Hourly concentrations of SO_2 for Skopje agglomeration region in December 2016

PM10 emissions

Main emission sources of PM10 in Macedonia for 2014 were residential heating with a share of 36% in total PM10 emissions, industrial processes and product use - ferroalloys production with 33%, energy sector with 20% and agriculture with 7%. Fugitive emissions and waste are minor sources of PM10 emissions. Total national PM10 emissions in 1990 amounted to 48 kt, and in 2014 emissions decreased by 32% reaching 33 kt. Declining emissions from industrial processes are the main reason for this decrease. Low emissions for the years 2001, 2002 and 2009 compared to the other years are related to low emissions from ferroalloys production due to shorter operating hours and produced quantity of ferrosilicon (80-90% decrease compared to 2014). Emissions reduction of 24% was recorded from 2013 to 2014, as a result of a decline in ferroalloys production and decrease in biomass consumption from residential heating. Total national PM10 emissions for the period 1990-2015 are shown in Figure 4.

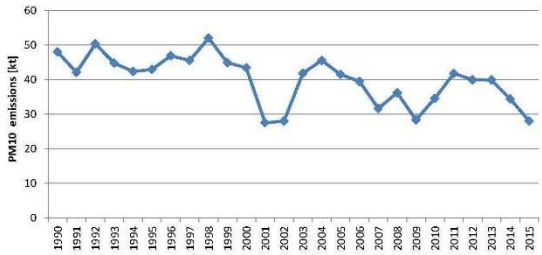

Figure 4. Total national PM10 emissions for the period 1990-2015

Measurements in Skopje showed that the average annual concentration of PM10 was 72,82 μg/m^3 in the municipality of Centar and 57,06 μg/m^3 in the municipality of Karposh. It is noted that the highest measured concentrations of PM10 in Skopje were recorded in winter, [4, 5].

According to measurements for 2016 in Skopje, highest PM10 emissions were observed in the month of December. Enormous hourly concentrations of PM10 that reached over 1000 μg/m^3, are registered at monitoring stations Rectorate and Lisiche, during the second half of December. Figure 5 shows the hourly concentrations of PM10 for December 2016.

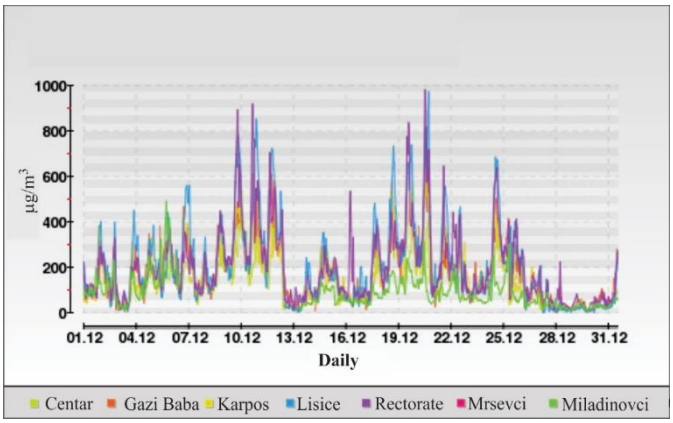

Figure 5. Hourly concentrations of PM10 for Skopje agglomeration region in December 2016

A detailed description of the methods for measuring air pollutants as well as quality control of measurements are given in the European CEN standards, which are accepted in the Republic of North Macedonia. The following table shows the MKC EN standards for measuring the concentrations of pollutants in the air, Table II.

TABLE II
REVIEW OF MKC STANDARDS FOR MEASUREMENT OF POLLUTING SUBSTANCES IN THE AIR

substance	measuring method
SO2	MKC EN 14212:2013 - Ambient air - Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence
NO, NO_2, NO_x	MKC EN 14211:2013 - Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence
PM10	MKC EN 12341:2014 - Ambient air - Standard gravimetric measurement method for the determination of the PM10 or PM2.5 mass concentration of suspended particulate matter
PM2.5	MKC EN 12341:2014 - Ambient air - Standard gravimetric measurement method for the determination of the PM10 or PM2.5 mass concentration of suspended particulate matter
CO	MKC EN 14626:2013 - Ambient air - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy
O_3	MKC EN 14625:2013 - Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry
BTEX	MKC EN 14662-3:2016 - Ambient air - Standard method for the measurement of benzene concentrations - Part 3: Automated pumped sampling with in situ gas chromatography

III. MEASURES FOR REDUCTION OF POLLUTANTS

Having in mind that the Earth is becoming an urban planet and more than 60% of the global population now lives in cities, it is expected that most people will suffer the most severe consequences from pollution in urban areas. In the city of Skopje lives approximately one third of the total population of Republic of Macedonia and the influx of people from the region creates substantial daily migrations. Some activities have been undertaken to implement medium and long-term measures outlined in the National Plan for the ambient air protection, [6]. To improve air quality at the level of Skopje region agglomeration, draft versions of improvement plans are prepared during 2015 and in the first half of 2016. Increasing the share of renewable energy sources in total energy consumption has led to reduction of pollutants emission. In this regard, activities listed in adjustment permits with operational plans of heat production installations are implemented. A study for the gasification of the Skopje region was also prepared. At local level, gasification network is extended with introducing gasification facilities in housing and schools in Skopje. Most of the measures are implemented in the capital because of the highest traffic frequency. Out of this reason, from 1 January 2015, import of vehicles with at least Euro 3 standard is permitted. In the municipality Centar, a measure for speed limit in certain streets even up to 30 km/h is conducted. Namely, a special traffic regime (using the ring road) for trucks whose final destination is not the city of Skopje, is introduced during the winter period. Also, as an experience taken from world capitals such as London, Vienna, Klagenfurt, Linz, Helsinki, Brunek, Stuttgart, Stockholm, Gothenburg and al., application of CaMg $(CH_3COO)_4$ (calcium magnesium acetate) on the roads in the city during the winter season has started. It is used to control and reduce concentrations of PM10 and PM2.5 suspended particles.

IV. CONCLUSION

According to Eurostat data, urban areas in the EU are responsible for 80% of energy consumption [6]. Given the current performed inventory of pollutants in individual sectors/activities in Skopje, it is evident that electricity and heat production, burning firewood for households heating, transport and industrial processes have the greatest contribution to the air pollution. Namely, suspended particles are the most critical pollutant in all previous years. Thus, exceedances above the limit values of suspended particles of size up to 10 μm repeatedly higher than the daily average limit value at all measurement locations especially in winter period are recorded. The national government, together with local and regional authorities, shares responsibility for combating global warming and enormous greenhouse gas emissions, through efficient energy consumption and the use of renewable energy sources [6]. In this regards, certain measures for reduction of pollutants emission have already been introduced in the last few years, [7]. Although the effects from implementation of these measures are difficult to be analysed since their utilization lasted for several days during the entire winter period, it is especially important that their implementation is carried out by cooperation among all the relevant factors between the city and the municipalities. Therefore, it seems that the primary activity to which the most attention should be paid is to raise public awareness, education and change the behaviour / habits of citizens. In addition, increasing of green areas, modernizing and improving efficiency in energy infrastructure, increasing the use of renewable in electricity production, increasing the use of natural gas [8], as well as the development of a better traffic management plan, are actions that should be the primary goals on the agenda for tackling air pollution [4].

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