ENVIRONMENTAL PROTECTION

AIR QUALITY IN R. OF NOTHERN MACEDONIA FROM SUSPENDED PARTICLES

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Abstract: *Air pollution in the country causes serious concerns because the ultimate values, particularly those of the concentrations of suspended particles (defined for the purpose of protection of human health) are multiply exceeded. The situation is the gravest in the biggest urban media, particularly in Skopje and Tetovo. Several sources and reasons for big problems related to air quality have been identified, but they can differentiate in the frames of a city and among different cities. The use of wood for heating of households in the winter period causes serious problems with air quality in densely populated residential areas because most of the households in the country still use wood as a primary source for heating. The road traffic also represents a source of air pollution in the urban media due to the big intensity of traffic and partially due to the old vehicle fleet and inappropriate maintenance of vehicles. The production of energy and industry may also affect air quality at local level, particularly in the vicinity of old industrial facilities that do not have modern systems for reduction of emissions. Presented in this paper, in more details, will be these causes of enormous air pollution in Macedonia that have been of a great concern for the population regarding health and increased mortality rate over the last years.*
Keywords*: pollution, air quality, harmful concentrations, suspended particles*

1. INTRODUCTION

Monitoring of air quality by means of modern methodologies has been carried out for more than 10 years. This paper deals with analysis of trends in air pollution concentration in the period 2005-2015. Certain polluting substances as is sulphur dioxide are clearly characterized by a descending trend of concentrations in the ten-year period. Other polluting substances show a very small descending trend, or their concentrations are at the same level. Concentration of suspended particles is at a high level throughout the entire period, without any significant descending trend.

In compliance with the Law, measures for improvement of air quality must be observed when the ultimate values of concentration of polluting substances referring to human health are exceeded. Successful reductions of emissions in the air require considerable efforts to be put by central and local authorities, companies as well as citizens. To successfully improve air quality, policies on air quality should be harmonized with other policies related to energy, climate and transport at national and local level.

Our country should urgently take actions toward improvement of air quality and beginning of implementation of measures defined in the national and local plans on improvement of air quality. The measures related to reduction of emissions from heating of households and road traffic should have a priority because of the significant effect exerted by these sectors upon the air quality. Further on, the processes of issuance of ecological permits for the installations with the highest emissions in the air should be accelerated.

It is for more than ten years that the European Union has been providing support to the country in respect to strengthening of its administrative capacities in the field of air quality. EU has been providing support to improvement of the network for monitoring of the air quality and chemical laboratories as well as systems for management of data on air quality. The support has been provided through three twinning projects on strengthening of capacities for management of air quality, including also development of legislation related to air quality, improvement of monitoring of air quality, assessments, management of data and reporting as well as inventory of emissions. The current twinning project "Further Strengthening of Capacities for Effective Implementation of Acquis in the field of Air Quality" is focused on further improvement of the capacities of the Ministry of Environment and Physical Planning, the municipalities and the Institute for Public Health. One of the fields on which the current project is focused is preparation of plans for improvement of air quality at local level.

Air quality in the country has been monitored since 1965 by passive taking of samples of certain polluting substances. Later in the 1990-ties, monitoring was modernized and spatially extended to cover the entire territory of the country. The State Automatic Monitoring System for air quality continuously measures the levels of polluting substances in the air in accordance with the EU directives on air quality and the national legislation. The Monitoring programme involves permanent measurement of sulphur dioxide (SO_2), nitric oxides (NO_x/NO_2), suspended particles (PM_{10} and $PM_{2.5}$) carbon monoxide (CO) and ozone (O_3) at seventeen measuring locations in different parts of the country. The evaporable organic compounds

(VOCs), the polycyclic aromatic carbon hydrogen (PAHs) and heavy metals (HM) are measured through short-term measuring campaigns. Also, computations from dispersion modelling have been carried out and applied in assessment of air quality in comparison with the ultimate values.

Starting from autumn 2012, the results from all existing measurements have been publicly available in real time through an internet portal.

Based on the decennial monitoring of the concentrations of polluting substances in the air, it has become well known that air pollution in urban media represents a serious problem for the country. Further on, even in rural areas, the concentrations of polluting substances can be increased, which particularly refers to the ozone and suspended fine particles ($PM_{2.5}$). The national and European standards defined for protection of human health have considerably been exceeded at many places and for a prolonged period of time. The mountainous terrains and the meteorological conditions in the country cause additional challenges in management of air pollution. Additionally, the easy approach to information related to air quality has considerably raised the public awareness and has caused a serious and justified concern about air pollution.

2. SOURCES AND REASONS FOR AIR POLLUTION

There have been identified many sources and reasons for the problem of serious air pollution. The reasons and the main processes may vary within the cities themselves and may be different among cities, however, there is not a single explanation for the presently recorded pollution levels.

One of the key sources of polluting substances in the air which is common for most of the cities is the old and inappropriately maintained vehicle fleet. At national level, approximately half of the cars and busses are old and belong to the category of vehicles with high emissions. The traffic jams and the underdeveloped public traffic, i.e., the absence of public transportation aggravate the situation.

The inefficient combustion in fireboxes and boilers in households along with the use of wood of low quality as a fuel and even use of waste materials give rise to problems, particularly in densely populated residential areas. A considerable part of the households in the country still use wood as the primary source of heat. The dilapidated and limited systems for central heating as well as the high cost of electric power additionally increase the use of solid fuels for heating of households.

The systems for production and distribution of energy are often old, inefficient, unsafe and cause air pollution. The domestic production of electric power mainly depends on lignite of a low quality and old thermal power plants. The combined production of heat and electric power as well as the production of electricity by windmills and hydroelectric power plans is still not sufficiently present in the country. The absence of corresponding waste management and recycling systems increases the amount of waste from households that is combusted in the open air without control. Also, the combustion of agricultural waste may cause problems with air quality at local level.

For the past decades, the limited economic development of the country has caused closing of numerous industrial capacities emitting large amounts of polluting substances in the air. Additionally, after 2006, the remaining industrial production facilities were imposed issuance of ecological permits and processes for estimation of their effect upon the environment, while some of these started to incorporate the best available technologies for reduction of air pollution. However, there are still old production industries without appropriate control of air pollution that pose a risk for their adverse effect upon air quality.

3. FOCUS ON EFFECTIVE ACTIVITIES TOWARD REDUCTION OF POLLUTION SOURCES OF AIR POLLUTION

The decennial system for air quality monitoring has been providing accurate information about the size of the problem wherefore future priorities referring to management of air quality should be directed toward reduction of air pollution. The available data from the monitoring enable monitoring of trends referring to concentrations in the ambient air as well as identification of sources of polluting substances. This is useful in decision making as to where measures for reduction of air pollution are the most necessary and where these would have the greatest effect.

4. POLICIES AND STRATEGIES REFERRING TO AIR QUALITY

The objective of the European policy against air pollution is “to reach level of air quality that does not cause unacceptable effect and risk for the human health and the environment”. In many countries in Europe, additional efforts are necessary to achieve this goal.

The European Community adopted certain policies for limitation of emissions from industry, traffic, energy production facilities and agriculture for the purpose of limiting air pollution, which is responsible for negative effects upon human health and environment. The European directives on protection of air quality and regulation of emissions are contained in a document.

The European Union directives are transposed in the national legislation. The main competent laws are the Law on Environment and the Law on Quality of Ambient Air. The second law regulates in details the following:

- Ultimate and target values related to air quality:
- Ultimate values of emissions from different sources of pollution;
- Management and evaluation of air quality as well as monitoring of emissions into the air;
- Planning of protection of air quality;
- Supervision and responsible authorities for effectuation of the legislation.

As amendment to the primary legislation, a large number of by-law acts have been adopted and have become effective.

In 2012, the Government adopted the first two national strategic documents on protection of air quality. The National Plan on Protection of Ambient Air shows the situation regarding air quality, defines measures for protection and improvement of the quality of ambient air at national level, per sectors (energy, industry, traffic, agriculture and waste) and defines all institutions responsible for the effectuation of the measures in the period 2013-2018.

A National Programme on Gradual Reduction of Emissions of Certain Polluting Substances has been elaborated for the period 2012-2020. This programme identifies measures, at national level, for reduction of emissions of polluting substances in the air like sulphur dioxide, nitric oxides, ammonia, evaporable organic compounds (VOCS), TSP and carbon monoxide. Further on, the programme provides projections referring to national emissions of these polluting substances for the period 2015 – 2020.

In addition to the national plans, plans for improvement of air quality at local level should be prepared for the municipalities where exceedance of ultimate values of polluting substances are observed. These plans contain practical activities that should be taken for the purpose of improvement of the quality of air at local level. So far, plans for the agglomeration Skopje region as well as Tetovo and Bitola municipalities have been prepared.

5. METHODOLOGIES AND DATA USED IN THE ASSESSMENT

Such an assessment is made based on data from monitoring of air quality that have been accumulated for the last ten years, updated inventories of emissions since 1990, results from numerous intensive measuring campaigns and case studies where the dispersion of polluting substances in the atmosphere is mathematically modelled. Also, meteorological data, geographic data and data on the land have been used. Further on, an approximate assessment of sources of pollution has been made by means of statistic modelling of observed concentration of polluting substances.

The effect of certain sources of emissions upon air quality cannot be identified only on the basis of information on emissions. For example, power plants may emit big quantities of polluting substances, but emissions are mainly released into the atmosphere through high chimneys so that the level of effect upon the concentration in the air at the ground surface where people breathe remains minimal. On the other hand, sources like road traffic may emit lesser polluting substances, but since the emissions are released at the ground level, their effect upon the air quality at the height where people breathe may be considerable.

The prevailing weather conditions may also have an influence upon reduction or increase of the concentration of polluting substances. Strong winds may transport polluting substances to a distance of hundreds of kilometres, while in conditions of stable meteorological conditions, the polluting substances may be accumulated around the sources of emissions. A complex terrain and building blocks may additionally contribute to accumulation of polluting substances. Some polluting substances remain in the atmosphere for days and weeks and may be transferred through hundreds of kilometres, while other can be transformed into other substances or may be deposited on the ground for several minutes or hours.

5.1. Monitoring of Air Quality

To evaluate air quality, measurements are made particularly at those places where exceedance of ultimate values is expected. The regulations define the minimum conditions for measurement of air quality. The State Automatic Network for Monitoring of Air Quality consists of 17 stations that permanently measure the quality of air in different parts of the country (Figure 1). This number of stations satisfies the minimum number of monitoring stations at national level and is in compliance with the requirements stated in the national legislation and the European directives. The monitoring stations measure the atmospheric concentrations of the main polluting substances SO_2, CO, NO_2, PM_{10}, $PM_{2.5}$ and O_3, while the information on the levels of pollution is made available to the public and the authorities in real time. This network of monitoring stations is managed by the Ministry for Environment and Physical Planning (MEPP). For the needs of such an assessment, data from monitoring of air quality in the period 2005-2015 have been used.

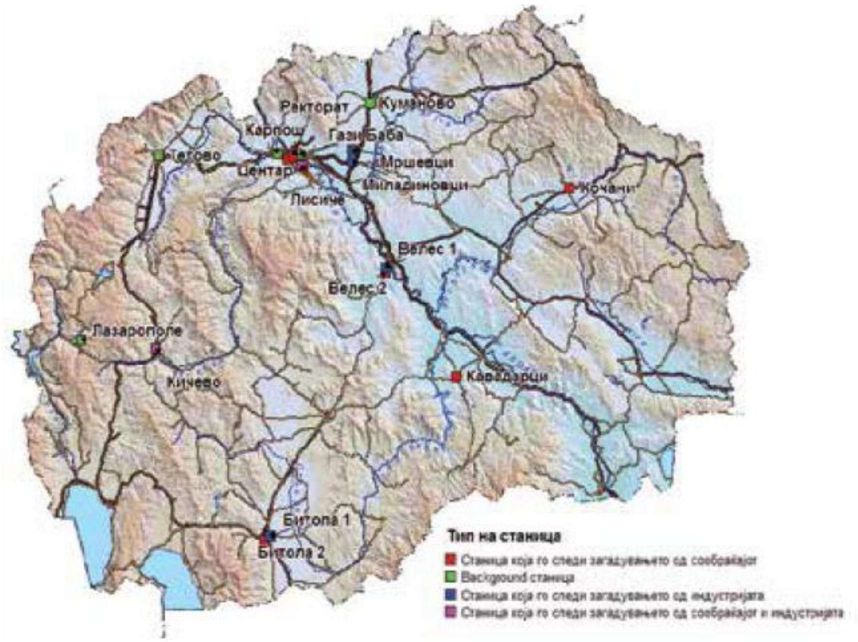

Figure 1. State Automatic Network for Monitoring of Air Quality managed by MEPP
A station for monitoring the traffic jam pollution
Background station
A station for monitoring industrial pollution
A station for monitoring traffic jam and industrial pollution

To obtain reliable results, the monitoring equipment must be regularly maintained and calibrated. Unfortunately, the lack of regular maintenance of the instruments and the lack of spare parts for the instruments that are becoming obsolete has reduced the coverage with data particularly for the last several years.

Irrespective of the existing routine monitoring, the results from the campaigns for measurement of concentrations of heavy metals (HM) and polycyclic aromatic carbon hydrogen (PAHs) have been used in the evaluation. A campaign was organized in the urban background station in Karposh, Skopje, in the period August 2015 to March 2016. The specimens were taken at each tree day period by MEPP, while the chemical analyses were carried out in accredited laboratories in Finland and Serbia. These data were also used for evaluation of potential categories of sources of air pollution by means of statistic modelling by a number of variables (positive factorization matrix).

The results from the measuring campaign involving evaporable organic compounds (VOCs) carried out in Skopje in the period 2011-2012 were also used in the preparations for evaluation.

5.2. Inventories of Emissions

The information on emissions represents an important basis for the national policies toward reduction of emissions. Each year, MEPP prepares an inventory of emissions of polluting substances So_x, NO_x, CO, non-methane evaporable organic compounds (NMVOCs), NH_3, suspended particles, heavy metals and non-degradable organic polluters (POPs). The inventories of emissions are based on corresponding data - rates of activity (for example, fuel consumption, number of products, used consumables, number of cattle, arable land, etc.) and data from performed monitoring of emissions released in the air by big installations. The standard emission factors are taken from the EMER/EEA instructions, 2013. In 2016, MEPP made an evaluation and re-calculation of the inventories for the period 1990-2014.

The results from the inventory of emissions are submitted to UNECE at annual level.

6. SUSPENDED PARTICLES (PM_{10} and $PM_{2.5}$)

Suspended particles, particularly fine particles contain microscopic solid or liquid drops that are so small that they can easily penetrate deep into the lungs and cause serious health problems. The size of the particles, the chemical content and the physical characteristics define the effect of suspended particles upon air quality and human health. Suspended particles also affect climate changes. They partially influence the reduction of temperature since they have a role in the process of formation of clouds and partially contribute to melting of the glaciers (black carbon in snow) which causes warming of the atmosphere.

Suspended particles are classified according to their (aerodynamic) diameter as PM_{10} (particles with a diameter of less than 10 μm) or $PM_{2.5}$ (with a diameter of less than 2.5 μm). Coarser PM_{10} particles also contain within themselves a finer fraction $PM_{2.5}$.

6.1. Sources of Emission of Suspended Particles

There are natural and anthropogenic sources of suspended particles in the atmosphere. For instance, natural sources include sea salt, natural suspended dust, pollen and volcanic ash. Anthropogenic sources are combustion of fuels for energy production, incineration, heating in households and fuel combustion in vehicles. Particularly in cities, important local sources are the road traffic (exhaust gasses from vehicles and dust from roads) as well as combustion of wood or coal for heating of households. The height at which emissions are released is low, almost in the zone where man breathes. Therefore, the effect of these sources upon air quality at the height immediately above ground can be considerable.

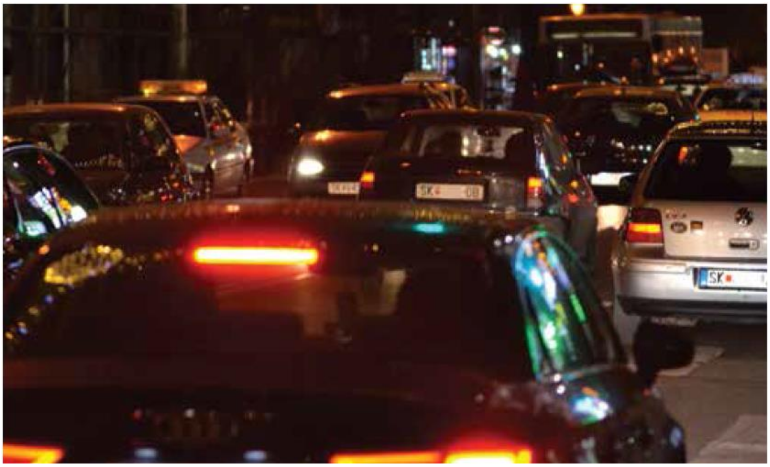

Figure 2. Traffic represents one of the main sources of emissions into the air (Photo: Aleksandar Ristovski).

Suspended particles that are known as aerosols can be categorized as primary or secondary suspended particles. Primary suspended particles are directly emitted into the atmosphere, while secondary particles are formed into the atmosphere after oxidation and transformation of emissions of primary gases (for example, sulphur dioxide turns into sulphates in the suspended particles, or gases like carbon hydrogen turn into secondary organic aerosols). In the course of the heaviest episodes of air pollution, a mixture of primary and secondary suspended particles and reactive gas polluting substances is observed.

The main components of suspended particles into the atmosphere are the secondary sulphates, nitrates, ammonia and organic aerosols, as well as primary sodium chloride, elementary chlorine, elementary carbon, mineral dust and water vapour.

There is a wide spectrum of quantities and chemical contents of suspended particles. Figure 3 shows an illustration of the size of suspended particles from different sources (the largest suspended particles are shown on the left side of the figure). For example, the suspended particles in the emissions originating from traffic and tobacco smoke are very small (below 2.5 μn) in diameter, while the cement dust and pollen are coarser (over 10 μm in diameter). The energy production and industrial emissions generate different size of suspended particles, depending on the production process. The size of suspended particles is very important from health aspect since the finest particles penetrate deep into the human body, causing more serious effect upon health.

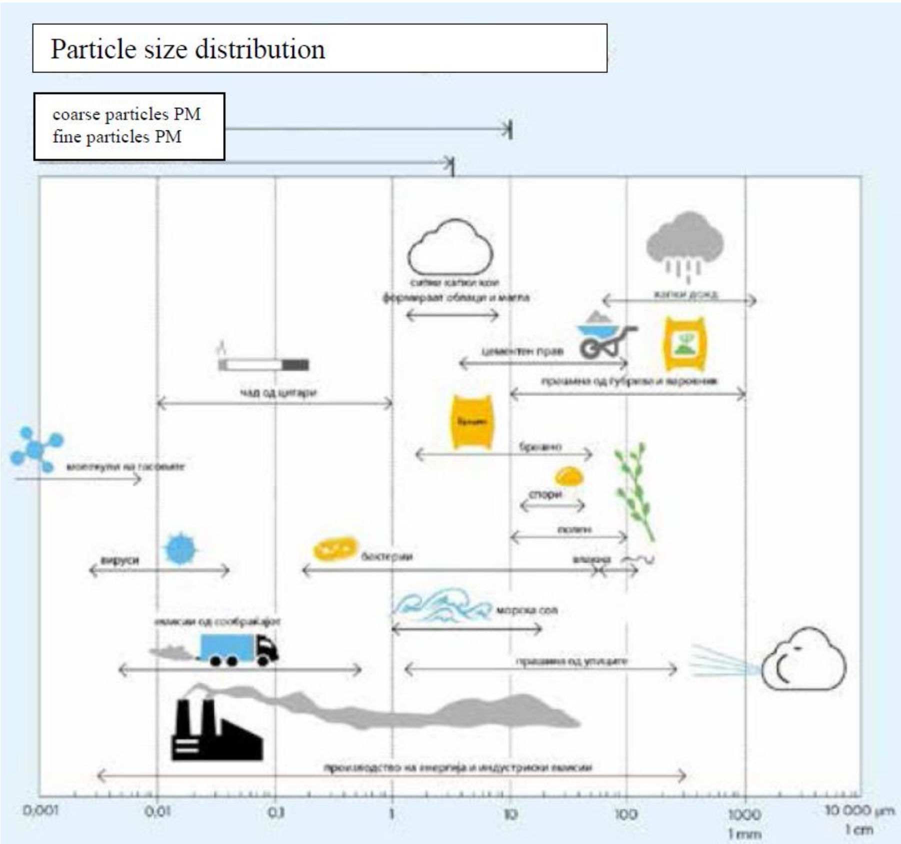

Figure 3. Illustration of different size of suspended particles and examples of their origin.

The annual trends of national emissions of $PM_{2.5}$ and PM_{10} are similar since the sources of these emissions are the same. The total emissions of PM_{10} in 2014 amounted to 33000 tons, while the total emissions of $PM_{2.5}$ amounted to 22000 tons. The variations of annual emissions are mainly due to variation of industrial production (ferrous alloys) and mild winters when the need for heating of households is reduced.

6.2. Standards on Air Quality Regarding Suspended Particles

The ultimate and target values of PM_{10} and $PM_{2.5}$ for protection of human health are defined in the national legislation where the directive on air quality 2008/50/EZ (EU, 2008) is transposed with prolongation of the deadline for reaching of the ultimate value of $PM_{2.5}$ (Table 1). As to RM_{10}, there are ultimate values for the short-term (average daily) and long term (average annual) concentrations. For $PM_{2.5}$, only the ultimate value for long term (average annual) concentration is given. In the country, the average daily ultimate value of PM_{10} (50 μg/m^3) is most frequently exceeded as it is also the case with other European cities and urban areas.

Table 1. Ultimate and target values of PM_{10} and $PM_{2.5}$

Size of fraction	Average period	Value	Comments
Ultimate value of PM_{10}	Average daily value	50 μg/m^3	Not to be exceeded for more than 35 days at annual level
Ultimate value of PM_{10}	Average annual value	40 μg/m^3	
Target value of $PM_{2.5}$	Average annual value	25 μg/m^3	
Ultimate value of $PM_{2.5}$	Average annual value	25 μg/m^3	To be fulfilled until 1st January 2020
Ultimate value of $PM_{2.5}$ *	Average annual value	20 μg/m^3	To be fulfilled until 1st January 2025
Obligations regarding exposure to concentrations of $PM_{2.5}$	Average value from three years	20 μg/m^3	2020
Ultimate value of $PM_{2.5}$ **			To be fulfilled until 2025

*Indicative ultimate value (Phase 2) that will be revised by the Ministry of Environment and Physical Planning in 2018 by consideration of additional information on effects upon human health and environment, technical feasibility and experiences regarding the target value in the EU member countries.

** Reduction of exposure 0 – 20% (depending on the indicator of average exposure in the referent year).

6.3.1. Trend of Concentrations of Suspended Particles (PM_{10} and $PM_{2.5}$) in the Period 2005-2015

The pollution caused by suspended particles was at a high level and was spread all over the urban areas in the country. The average annual concentrations of PM_{10} exceeded the annual ultimate value (40μg/m^3) at all monitoring stations placed in urban areas in the entire period starting with 2005 (Figure 4). Consequently, the average daily value was exceeded at all monitoring stations and throughout all the years, with the exception of the measuring station located in the village of Lazaropole.

The highest annual average concentrations of PM_{10} were measured in Tetovo and Skopje (Lisiche), exceeding 120 μg/m^3. It is not possible to perform a statistic analysis of trends due to a large number of missing data. Still, an evaluation can be made that the concentrations were stable throughout the entire period between 2005 and 2015. The evaluated average value of PM_{10} in the urban locations amounted to approximately 80 μg/m^3.

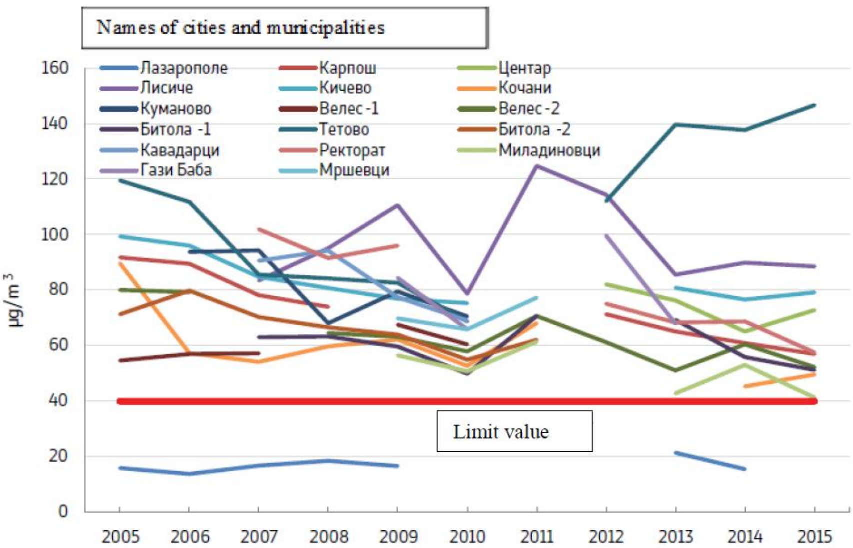

Figure 4. Average annual values of PM_{10} in the period 2005 – 2015.

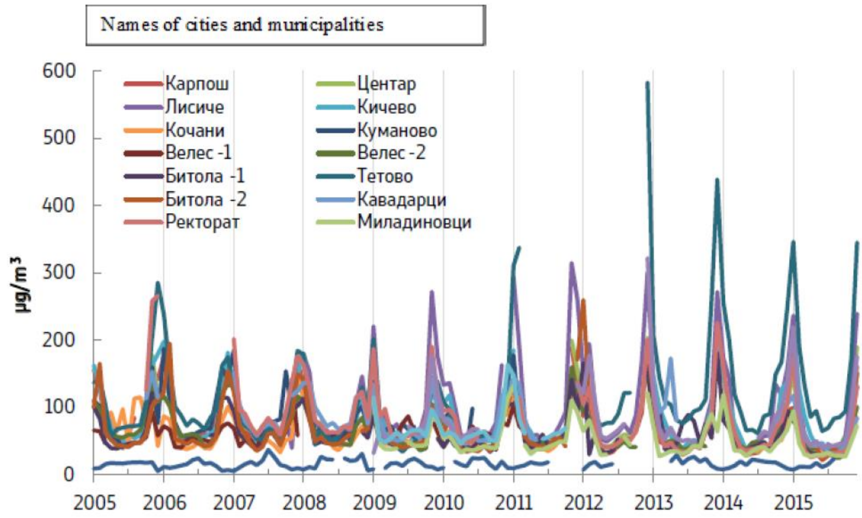

Figure 5. Average monthly values of PM_{10} in the period 2005 to 2015.

The concentrations of PM_{10} in urban media are characterized by pronounced and equal seasonal variations; the concentrations are high in the period December – January (Figure 5). The high concentrations of PM_{10} in the course of winter are related to higher direct emissions (household heating, particularly by use of wood) and also meteorological conditions that limit the dispersion of emissions and alleviate chemical reactions by which secondary particles are created as, for example, exhaust gases from vehicles. In the course of the winter months, smog is typical for the towns in valleys.

In the course of summer, the concentrations of PM_{10} are relatively high: approximately 40-60 μg/m^3 as average daily values. These increased levels of PM are probably related to direct local sources, photochemical formation of particles from reaction gases, regionally dispersed suspended particles from forest and field fires and background concentrations of aerosols. In the rural background station Lazaropole, the average concentrations of PM_{10} vary between 14-21 μg/m^3, but there, the maximum concentrations occur in the course of the summer months.

The average concentrations of suspended particles in the summer months (June – August, the entire study period) amount to 20 μg/m^3, which can be considered average summer background concentrations of suspended particles in this region.

The concentration of fine suspended particles ($PM_{2.5}$) has been measured at two monitoring stations in Skopje since 2012. The average annual value of concentrations amounts to around 40-50 μg/m^3 (Figure 6) which is twice the ultimate value.

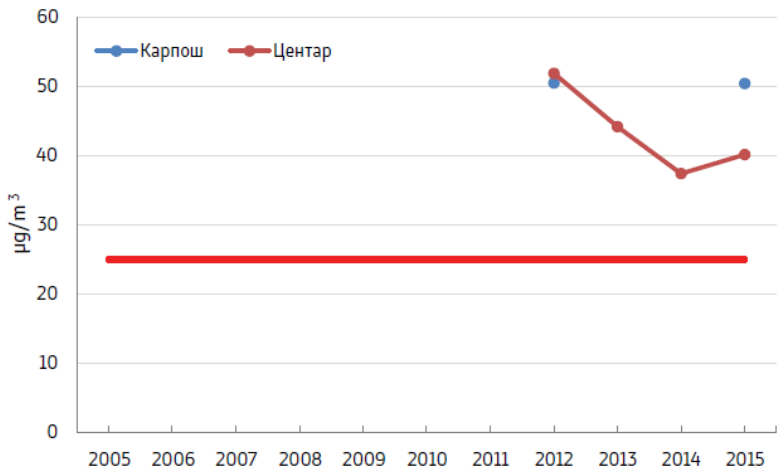

Figure 6. Average value of $PM_{2.5}$ in Skopje in the period 2012 – 2015.

The concentrations of fine suspended particles measured at the monitoring stations in "Centar" and "Karposh" are in correlation. However, the level of concentrations in Karposh is somewhat higher (10%) compared to that measured at the station in "Centar". Comparing PM_{10} and $PM_{2.5}$ concentrations, it can be noticed that a large percentage (approximately two thirds) of particles that can be inhaled belongs to the most dangerous fine fraction.

7. CONCLUSION

As a result of active international cooperation in the course of the past decade, the capacities of air quality management in the country have considerably been strengthened. The present levels of concentrations of polluting substances are well known. There are reliable data on air quality that are accessible for the public and the competent authorities. However, improvement of air quality still needs commitments at a high political level. Policies and strategies referring to air quality are prepared to define the objectives of activities in future.

Reliable long-term data from monitoring of air quality along with tools for evaluation of air quality are used as support to decision making and development of plans for improvement of air quality. Monitoring of air quality is the basis for the evaluation of concentrations of polluting substances along with inventories of emissions, dispersion modelling and analyses for definition of contributions of different sources of pollution.

Suspended particles are the most critical polluting substance in our country that affects human health. The concentrations of suspended particles in our country are high, particularly in the course of the winter months when they considerably exceed the ultimate values defined in the legislation. The main source of suspended particles is household heating. The industry and traffic are also important sources of suspended particles.

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