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Contents

Traffic in the City of Skopje and its impact on air pollution

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Abstract

Today the world is living in a dynamic process of industrialization and urbanization and when we add the strong pressure of the increase of human population to these processes, we can realistically speak of distorted conditions in the sustainable development, accompanied by the extremely strong impact on climate changes.

This pressure is most noticeable in large cities, which at the same time represent major industrial, economic and social centers. Skopje, as the capital city of Macedonia, belongs to the group of cities characterized by these processes.

Traffic is the main artery for communicating and organizing life in the city. Car transport and public bus transport are the main carriers of traffic, complemented with the participation of truck transport in the fields of construction, transport of goods, customs warehouses, etc.

All of this contributes towards traffic having a strong environmental impact, especially on air quality, and Skopje is regularly among the most polluted cities in the world. The number of cars involved in traffic, their year of production and the type of engine they use, fuel quality and road infrastructure only complete the picture of the real impact of traffic on the quality of life, and especially on air pollution.

This situation also affects the social, health and economic conditions in the city.

Keywords: traffic, air pollution, transport, Skopje, sustainable development.

1. INTRODUCTION

The protection of environment and nature in modern social trends is one of the main priorities in the policies of each state. In order to have a thorough approach towards the protection of environment and nature, it is necessary to set up a sustainable system for solving environmental problems, while at the same time covering all areas which have an environmental impact. Knowing the fact that environmental protection presents an interdisciplinary field, its importance is increasingly growing.

The processes of intensive industrialization and urbanization have an impact on disrupted conditions in sustainable development, on the demographic expansion, on climate change, and

on the increasing migration trends, resulting in strong environmental pressures and high levels of its destruction. This pressure is most noticeable in large cities, which at the same time represent major industrial, economic and social centers. Quite often large city centers also represent the largest hot ecology spots in their countries, where air pollution is always a priority. The dynamic processes in the economic development of each country have a great impact on both traffic and on development of road infrastructure. When it comes to the impact of the transport sector on the environment, it primarily implies exhaust gases that pollute the air, reduction of green areas at the expense of road infrastructure reflected primarily through the construction of many roads, parking lots, gas stations with complete infrastructure and auto-service facilities. Skopje, as the capital of Macedonia, also belongs to the group of cities characterized by these processes, and the city is regularly among the most polluted cities in the world.

The fact that traffic accounts for up to a quarter of greenhouse gas emissions at the level of the European Union indicates that this sector has a strong impact on air quality and it is one of the major causes of air pollution in cities. Emissions of pollutants into the air from transport are very harmful to human health and therefore there is an urgent need to reduce them drastically. In view of addressing the problem of air pollution, the European Union adopted the "European Strategy for Low-Emission Mobility" and in 2016 it defined the primary objective that "By 2050, greenhouse gas emissions from transport should be reduced by at least 60% with reference to the level of greenhouse gases in 1990, and reduce them to a minimum, i.e., to have zero greenhouse gas emissions from traffic". **[6]**

2. AIR POLLUTION SITUATION IN SKOPJE

The air pollution situation in Skopje, which is often alarming especially in the winter period, has necessitated a thorough approach to addressing this problem, which in addition to its environmental impact, has a serious impact on human health. For this purpose, a number of documents have been prepared which basically have the strategy of reducing the harmful impact of harmful gas emissions on the air, the causes of this pollution, i.e., the sources of emissions of harmful gases. The Ministry of Environment and Physical Planning, together with the Ministry of Health and the Ministry of Interior are the competent institutions within the Government of the Republic of Macedonia for addressing this problem. The City of Skopje within its competences is active through the Sector for Environmental Protection and the public enterprises in ownership of the City.

The ambient air pollution in Skopje originates from a variety of sources, which are methodologically classified as stationary (point and surface), mobile and fugitive sources. Stationary sources include combustion processes in power transformer plants with power greater than 1 MW, combustion processes in industrial production facilities, other combustion plants with power less than 1 MW, and domestic fireplaces. Heat generating plants are classified as point (high power plants – heating plants and boiler houses with power greater than 1 MW) and surface discharges (boiler houses with power less than 1 MW and domestic fireplaces).**[3]**

LEAP 2 states that according to the data from the Cadastre of air polluters and pollutants for the City of Skopje, 276 business entities (152 non-manufacturing and 124 manufacturing) are registered, which emit pollutants into the ambient air.

According to the same source, the number of discharges or sources in these business entities is 698, with 234 being surface and 464 point sources. This points out to the fact that the number of discharges from power plants is almost twice greater than the number of discharges from

industrial plants, even though the surface volume of industrial facilities located in the four industrial zones (northeast, east, southeast and west of the city) dominates.

Mobile sources include transportation means in the transport sector, as well as mobile machinery in industry, agriculture and forestry.

Important documents addressing the topic of environmental conditions on the territory of the City of Skopje prepared in the period after 2010, and in particular the situation of air pollution, are the Local Environmental Action Plan 2 (LEAP 2), the Study on Heating of the City of Skopje (STUGRES) and the Study on Transport of the City of Skopje (STUTRA).

Using the results of the STUGRES study, within the STUTRA study, a comparative analysis was made about how much of the emissions come from transport, households and power generation sectors. The results show that in 2015 the transport in the City of Skopje participated with 80% in NOx, 20% in CO and 4% in PM 2,5.**[5]**

Although transport contributes the most to NOx emissions, the total measured NO_2 concentrations in 2015 (from all sources) do not exceed the permissible limit values for protection of human health.

3. AUTOMATIC MONITORING OF AMBIENT AIR IN THE REPUBLIC OF MACEDONIA

3.1. Monitoring of ambient air in the Republic of Macedonia

Monitoring of air quality situation is related to the establishment of a monitoring system for monitoring ambient air quality. In the Republic of Macedonia, the Ministry of Environment and Physical Planning is the state body that has competences in this area. To this end, with the support of the international community, primarily through EU-funded projects and programs, JICA (Japan International Cooperation Agency) and other financial and expert institutions, the establishment of the State automatic ambient air monitoring in the Republic of Macedonia has begun.

The design of the State automatic ambient air quality monitoring system was initiated in 1997 with the project: "Study on Air Quality Monitoring System in the Republic of Macedonia", implemented by JICA (Japan International Cooperation Agency). The study covered the whole territory of the country, with a detailed plan for setting up a monitoring system for ambient air quality. At the beginning of the setting up of the monitoring system, the City of Skopje, as the capital of the country, was chosen as a model city and within this project, four monitoring stations were set up at different locations in the city: Karpos, Gazi Baba, Centar and Lisice. The central station was located in the Ministry of Environment and Physical Planning (MoEPP), where data was transmitted hourly by radio telemetry connection.**[7]**

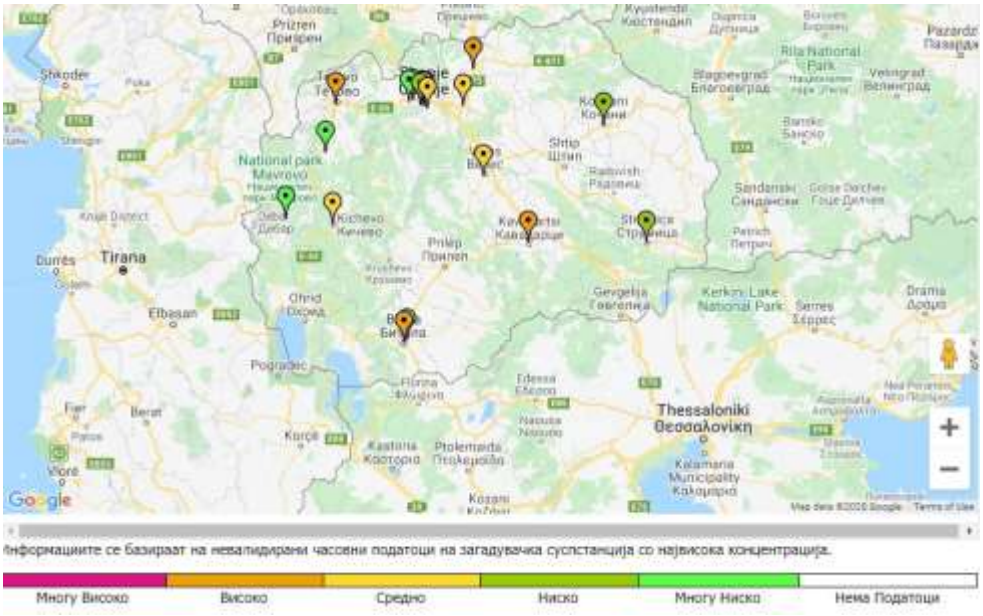

Figure 1 Map of the State automatic ambient air monitoring in the Republic of Macedonia (Source - Ministry of Environment and Physical Planning).

The process of setting up the ambient air quality monitoring system on the territory of the Republic of Macedonia has been carried out in several stages. In December 2002, three monitoring stations were set up, one in Kocani, Kumanovo and Kicevo, and three high volume samplers for measuring suspended particles with up to ten micrometers in size.

In May 2004, six more monitoring stations for ambient air quality were obtained, one mobile station, and one station for monitoring pollution from traffic. Two of these stations were set up in Veles and Bitola, and one in Tetovo and the village of Lazaropole as a rural background station.

In April 2005, a mobile station was set up in Kavadarci, while in Skopje, in the yard of the rectorate of the University “Ss. Cyril and Methodius”, opposite the Court Palace, a new automatic station - Rectorate, was set up to monitor traffic pollution.

In 2008 according to the Memorandum of Cooperation signed on 25.11.2008 between the Ministry of Environment and Physical Planning, the Municipality of Ilinden and the Coordination body of the settlements around the OKTA refinery, the Ministry of Environment and Physical Planning has urgently relocated 2 monitoring stations. Two monitoring stations were temporarily relocated, from Karpos and Centar. The process of relocation of the two monitoring stations from Karpos IV and Centar left a gap in the identification of ambient air quality, especially in the western part of Skopje. Therefore, in 2011, two automatic ambient air quality monitoring stations were purchased that were set up in Centar (at the intersection between “Vodnjanska” and “Vasil Gjorgov” streets) and in Karpos (Elementary School “Petar Pop Arsov”).

A web portal has also been created and developed which publishes on-line measurement data. The link to the web portal is as follows: www.air.moepp.gov.mk. In addition to real-time air quality data, the web portal also continuously publishes the exceeding of limit values, legislation, daily, monthly and annual reports, planning documents related to air, and news.

In 2017, the Ministry of Environment and Physical Planning received a new service vehicle and new measuring equipment that replaced part of the instruments from three monitoring stations in Tetovo, Kumanovo and Bitola 2. In the Municipality of Butel from February 2018 until June 2019, a new mobile station was set up and in June 2019 this mobile station was set up in Gjorce Petrov Municipality, where it will remain until June 2020.

Each year, according to the plan of the Ministry of Environment and Physical Planning, the mobile station will be set up at different locations in those municipalities which are not covered by fixed automatic monitoring stations.

3.2. Monitoring of ambient air in Skopje

Skopje as the capital city is under constant pressure in the field of air pollution. In order to have accurate information on real-time air quality conditions, automatic monitoring stations have been set up in the city, which measure certain parameters.

3.2.1. Automatic monitoring station in Center

Automatic monitoring station in Center was set up in 2011 and it is an urban station for measuring the impact of traffic in downtown Skopje. The station is about 15 meters from the main road with high traffic frequency and about 20 meters from a small intersection, at the beginning of "Vodnjanska" Boulevard leading to the State Hospital. At this station the following pollutants are measured: O_3, NO_2, SO_2, CO, PM_{10}, $PM_{2.5}$ and BTX.

3.2.2. Automatic monitoring station in Gazi Baba

Automatic monitoring station in Gazi Baba was set up in April 1998 and it is located on a hill in the north-west part of Skopje, near the University Complex of the Faculty of Natural Sciences and Mathematics. There is a parking lot 20 meters away from the station. In the Zelezara area, north-west of the station, the metallurgical industry is located 2 km away from the station. The distance from the main road ("Alexander the Great" Boulevard) is 300 meters, while the nearest residential buildings are about 100 meters away. At this station the following pollutants are measured: NO_2, SO_2, CO and PM_{10}.

Figure 2 Automatic monitoring station – Gazi Baba

3.2.3. Automatic monitoring station in Karpos

Automatic monitoring station in Karpos was set up in September 2011 in the school yard of “Nikola Karev” High School. The nearest city roads with low vehicle speed are 20–120 meters away, while the main boulevards are approximately 250 meters away. At this station the following pollutants are measured: O_3, NO_2, SO_2, CO, PM_{10}, $PM_{2.5}$ and BTX.

3.2.4. Automatic monitoring station in Lisice

Automatic monitoring station in Lisice was set up in April 1998. The station is located near the main intersection near the High School "Maria Sklodowska Curie", at a distance of 45 meters to the nearest street and 70 meters from a large intersection. The cement plant is 1,2 km away, and to the southwest of the station there is a quarry which is about 1,8 km away. At this station the following pollutants are measured: O_3, NO_2, SO_2, CO and PM_{10}.

3.2.5. Automatic monitoring station in Rectorate

Automatic monitoring station in Rectorate was set up in 2005 and it is located near a major intersection in downtown Skopje. The urban station for measuring the impact from traffic represents the area with high impact of traffic emissions. At this station the following pollutants are measured: O_3, NO_2, CO, PM_{10} and BTX.

Figure 3 Automatic monitoring station – Rectorate

3.2.6. Automatic monitoring station in Miladinovci

Automatic monitoring station in Miladinovci was set up in December 2008. Miladinovci is a station in the municipality of Ilinden, about 15 km east of Skopje. The station is monitoring the impact of OKTA refinery on air quality. The station is located in a small village about 0,5 km south of the refinery. The surface of the plant is large, with point emission sources (chimneys) located approximately 2 kilometers from the station, but fugitive emissions (from oil tankers) can

be emitted near the station. The M1/E75 highway runs 200 meters east of the station and it is likely that it affects the NO_2 concentrations due to the open and flat surrounding. At this station the following pollutants are measured: O_3, NO_2, SO_2, CO, PM_{10} and BTX.

3.2.7. Automatic monitoring station in Mrsevci

Automatic monitoring station in Mrsevci (operating in the period from 04.12.2008 until 08.2012) is a station located in the municipality of Ilinden, 15 km east of Skopje. The station monitors the impact of OKTA refinery on air quality. The station is located in a small village about 0,5 km north of the refinery. The surface of the plant is large, and the emission point sources (chimneys) are located about 1,2 km from the station. The distance from the M1/E75 motorway is 1,7 km. At this station the following pollutants are measured: NO_2, SO_2, CO and PM_{10}.

3.2.8. Mobile monitoring station - Municipality of Gjorce Petrov

The mobile automatic monitoring station for ambient air quality was relocated in June 2019 from Butel Municipality to Gjorce Petrov Municipality. The mobile station was set up in the yard of the High School "Koco Racin", i.e., in the green area between the streets "Lyhnida" and "Alexander Murtulkov". The distance from the nearest boulevard "Macedonian Army" is about 200 meters, and about 40 meters from the side street "Alexander Murtulkov". In the immediate vicinity of about 10 meters there are trees which are ten meters tall. The first apartment buildings are located 50 meters from the station and the first houses are within 25 meters. The station's location is such that it is expected to register the share of pollution that comes mainly from the combustion of fuels for the heating of administrative buildings and private households in the winter time, as well as the smaller share that comes from traffic pollution. At this station the following pollutants are measured: O_3, NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$.

3.2.9. Mobile monitoring station - Municipality of Butel (from 09.02.2018 until 07.06.2019)

The mobile automatic monitoring station for ambient air quality in the Municipality of Butel was set up for a period of 16 months, starting in February, 2018. The mobile station was located in the yard of "Zivko Brajkovski" Elementary School, i.e., in the green zone between Zivko Brajkovski Primary School building, the Sports Hall and the Kindergarten building "11 Oktomvri", near the partition fence with the Kindergarten and the EVN substation, on the street "Ho Chi Minh", bb., on the east side. The nearest road is about 15 meters away, and about 60 meters from the Sports Hall. At this station the following pollutants are measured: O_3, NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$.

4. The situation of air pollution in Skopje as a result of transport

The impact of harmful gas emissions from road traffic is the largest in urban areas where we have a tight road network and a high frequency of vehicles. Road transport contributes to emissions of nitrogen oxides, carbon monoxide, suspended particles, heavy metals and polycyclic aromatic hydrocarbons. Road emissions also depend on the type and age of the vehicles, the number of kilometers traveled by each vehicle group, and the quality of fuels used by the vehicles. The driving cycle itself also has an impact on emissions; driving in a low-speed urban area usually produces more emissions than driving at a constant speed on a highway. Since 1992, in the European Union the limit values of the exhaust vehicle emissions have been gradually tightened through the so-called Euro-class emissions standards. These standards are constantly being updated and from Euro 0 (no control) to the current Euro 6, they have led to a significant reduction in emissions produced from the vehicles of the new generation.**[4]**

Heavy freight traffic, which includes buses and trucks, produces the largest amount of emissions per vehicle. Vehicles with diesel engines have higher NOx emissions and suspended particles compared to vehicles with petrol engines with built-in catalysts (with Euro 1 class and higher).**[1]** Typically, as the age of vehicles increases, so do emissions, as the catalyst and other systems for processing exhaust gases lose some of their efficiency. Based on the data from the vehicle registry, in 2015 the total number of registered motor vehicles in the country is 436502.

From the transport review in Skopje in 2016 regarding the vehicle fleet and local emissions according to the data from the State Statistical Office - SSO, the Ministry of Interior, as well as from the Ministry of Environment and Physical Planning and the published reports on registered vehicles by type and overview of the vehicle fleet in Skopje for the statistical period (2012-2016), it can be concluded that there is a tendency of constant increase in the number of registered vehicles (15,3% more in 2016 compared to 2012). The largest share in the total number of vehicles is passenger cars (88% in 2016), followed by motorcycles (33% in 2016 compared to 2012) and followed by freight vehicles and passenger cars with an increase of 23% and 14%, respectively. Only the number of buses decreased by 10% in 2016 compared to 2012. According to the data on the number of registered vehicles in 2016, 21,84% of the total number of vehicles registered in the Skopje region are owned by legal entities.

The analysis of the share of different types of vehicles per fuel in this five-year period in the City of Skopje shows an increase in the share of diesel vehicles. The highest increase was noted in diesel passenger cars, which increased by 77% in 2016 compared to 2012, bringing the share of diesel passenger cars from 25% in 2012 to 38% in 2016. In return, the number of petrol passenger cars has dropped by 6%, contributing to reducing their share of 72% in 2012 to 60% in 2016.

The number of freight vehicles using diesel also increased by 62%, while the number of petrol vehicles decreased by 9% in 2016 compared to 2012. The share of diesel/petrol vehicles out of the total number of freight vehicles in 2012 was 54% and 39%, respectively, while in 2016 it had already changed to 71% and 29%. With reference to buses, the number of diesel vehicles decreased by only 3%, while the number of petrol vehicles decreased by 46% in 2016 compared to 2012. Accordingly, the share of diesel buses in the total number of buses increased from 83% in 2012 to 90% in 2016, and the share of petrol buses decreased from 15% in 2012 to 9% in 2016.

The STUTRA study compares the percentage annual increase in the number of passenger cars in Skopje, with the increase in the remaining part of Macedonia (inland Macedonia), as well as with Macedonia as a whole, where it can be seen that the introduction of the import policy for used vehicles does not have such an effect in the City of Skopje compared to the rest of the Republic of Macedonia. The main finding is that new vehicles are being bought in Skopje more than in the rest of the Republic of Macedonia.

If we analyze the emissions of the Republic of Macedonia in the scenario "Just like now" which is the same as "Skopje is suffocating" in the STUGRES study, it can be concluded that 96% of the emissions come from the household sector and only 4% from the transport sector. In 2025 the share of the household sector is expected to be even higher and to amount to 97%, while the share of the transport sector is expected to be reduced to 3%.

The transport sector has the largest share of NOx emissions, which in 2015 was 79%. At the same time, the energy production and household sectors account for 15% and 6%, respectively. As a result of the increase in the average EURO standard, it is projected that the share of the transport sector in NOx emissions in 2025 will be reduced to 65%, while the other two sectors - energy production and households - will grow by 26% and 9%.

The share of the transport sector in CO emissions is lower compared to its share in NOx emissions. In fact, in 2015 transport accounts for 23%, while the household sector accounts for

75% and the energy production sector for 1%. For the same reasons as for NOx emissions, the share of the transport sector will be reduced to 5% by 2025.

5. ACTIVITIES FOR REDUCTION OF AIR POLLUTION IN THE CITY OF SKOPJE FROM THE IMPACT FROM TRAFFIC

In the area of planning documents, the City of Skopje has prepared a Plan for sustainable transport system on the area of the City within the RENAISSANCE project and this plan has been adopted by the City Council of Skopje. With the technical and financial assistance of UNDP, the City of Skopje has prepared a NAMA application, a document for application to obtain funding for realization of activities in the field of traffic, aimed at reducing climate change.
In the part of real projects implemented on the field, the City of Skopje reconstructed, expanded and extended boulevards and built new streets with total length of 48 km, as well as 4 roundabouts, in order to reduce congestion and increase traffic flow.**[2]**
The City of Skopje also operates public transport via JSP Skopje, and has a renewed fleet of new vehicles, with engines EURO 4 and EURO 5, which feature a low level of toxic gas emissions, such as: 200 newly manufactured double-decker closed-top buses and 16 newly manufactured double-decker open-top buses of the Yutong brand, 80 newly manufactured low-floor buses of the LAZ brand, as well as 16 Yutong minibuses, or 312 vehicles in total. There are also new bus stops for public city transport.
Private operators engaged in public bus transport of passengers on the territory of the City of Skopje have also renewed as much as 70-80% of their bus fleet with more eco-friendly vehicles, which meet higher environmental standards compared to the old bus fleet.
With reference to taxi transport, in the process of issuing licenses for taxy transport of passengers, priority is given to eco-friendly vehicles. The maximum number of taxi vehicles that can be used for taxi transport of passengers in the city of Skopje is set at a total of 3,000 taxi vehicles, and with the exception, the maximum number of taxi vehicles can be increased by another 300 taxi vehicles if they are eco-friendly taxi vehicles with low emissions of exhaust gases (hybrid vehicles with combined engine and electric power, natural gas power vehicles and electric power vehicles).
In the area of alternative transport, in recent years the City of Skopje has been working on the completion and connection of bicycle lanes and their signaling.
A bicycle rental system has been introduced at four spots in the city.
For the purpose of raising public awareness, the City of Skopje is continuously celebrating the World-Car-Free Day on September 22, and since 2011 it has joined the European cities which are implementing the European Mobility Week.

6. CONCLUSION

The fact that traffic participates with one quarter of the greenhouse gas emissions at the level of European Union indicates that this sector strongly influences air quality and is one of the major causes of air pollution in cities.

The impact of harmful gas emissions from road traffic is the highest in urban areas where we have a tight road network and a high frequency of vehicles. Road transport contributes to emissions of nitrogen oxides, carbon monoxide, suspended particles, heavy metals and polycyclic aromatic hydrocarbons. Emissions from road transport also depend on the type and age of the vehicles, the number of kilometers traveled by each vehicle group, and the quality of fuels used by the vehicles. Also, the driving cycle itself has an impact on emissions; driving in a

low-speed urban area usually produces more emissions than driving at a constant speed on a highway.

The impact of transport on the environment and especially in the area of air pollution is noticeable but not the highest compared to other pollutants, primarily compared to pollution caused by heating. We should take into account, however, that emissions of pollutants into the air from transport are very harmful to human health and therefore, there is an urgent need to decrease them drastically without any delay.

The general conclusion is that from the numerous analysis of the vehicle fleet of the participants in traffic, the tendency for renewal of passenger cars and part of the buses is evident. The lowest level of renewal of vehicle fleet is found among the heavy freight vehicles. The implementation of the proposed measures to reduce traffic emissions requires a large number of actors to be involved in its realization.

The main objective is to provide a cleaner transport sector with simultaneously positive effects on the economic and social dimension of sustainable development. It is necessary to move towards changing the vehicle fleet by replacing diesel vehicles (as major NOx emitters in transport) with hybrid or electric, which is suggested as a measure in this study. In this regard, certain incentive measures of subsidies from the state for renewal of the vehicle fleet should be further strengthened, which would reduce the emission of harmful gases from vehicles as important environmental pollutants.

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