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Preliminary assessment report

Improved preliminary assessment report of air quality for sulphur dioxide, nitrogen dioxide, nitrogen oxides, carbon monoxide, particulate matter, and ozone in Republic of Macedonia

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Abstract

On the basis of the difference of air quality, data population, numbers and density, seven zones and one agglomeration have been defined in the Preliminary assessment report for establishment of zones and agglomeration in the Republic of Macedonia, prepared within CARDS 2004 project in 2006 [1]. Within this report recommendations for the further improvement and revision of this document were given.
In this direction in the frame of the twining project "Improvement of air quality" in Republic of Macedonia, activities were undertaken for further improvement of the preliminary assessment of air quality. This report has been improved, revised and updated with air quality processed data for the period 2006-2007, emission data from the Cadastre [2] and the CORINAIR inventory for 2004 data [3]. Furthermore OKTA modeling results for sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen oxides (NOx), have been presented. Modeling results can be used in future as tools for prediction and simulation of air quality taken into account the available air quality data.
This improved preliminary assessment refers to the basic pollutants as follows: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen oxides (NOx), particulate matter ≤ 10 micron (PM10), carbon monoxide (CO) and ozone (O_3)**.** The air quality has been assessed in the context of limit values, upper and lower assessment thresholds and long term objectives respectively in accordance with the Decree on limit values of the levels and types of pollutants in ambient air and alert thresholds, terms for limit values achievement, limit value margins of tolerance, target values and long-term targets in which the EU Air quality directives have been implemented [4].
Depending on the air quality in relation to the assessment threshold levels and the long term objectives in the Daughter directives, data on population and density, two zones and one agglomeration have been defined.
The monitoring requirements in the daughter directives have been compared with the current station configuration and numbers of different types of stations. It was concluding that 2 new stations in suburban area will have to be set up for ozone; two new stations should be set up for particulate matter and nitrogen dioxide respectively in urban background area.

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1. Introduction

Republic of Macedonia as a signer of the pact for association and stabilization among other things foresees approaching, transposing of the European regulation within the air area. Ministry of environment and physical planning (MEPP) prepared frame Ambient Air Quality Law [5], according to the Framework Directive 96/62/EC and the Decree on limit values of the levels and types of pollutants in ambient air and alert thresholds, terms for limit values achievement, limit value margins of tolerance, target values and long term targets [4]. There is an on-going preparation of few sub-legislation Acts in consent with the EU regulations.

Even though Republic of Macedonia is not an EU Member State, it undertakes the obligations according to the Council Directive 96/62/EC on Air Quality Assessment and Management, where the Member States are required to assess air quality throughout their territory. The requirements for assessment methods depend on the nature of the area and the levels of air pollution, in relation to limit values and assessment thresholds as defined in Daughter Directives.

Regarding the establishment of zones and agglomerations, a legal act “Lists of zones and agglomerations of air quality in R. Macedonia” have been prepared. This document is in phase of legal adoption and will enter in force in the first quartile of 2009. First preliminary assessment of zones and agglomeration in Republic of Macedonia was prepared in 2006 under the CARDS (Community Assistance for Reconstruction, Development and Stabilization) 2004 project [1].

According the recommendations given by the CARDS 2004 project, within this report we will describe the results of the improved preliminary assessment of the air quality of sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter, carbon monoxide and ozone, taken into account air quality data from the period 2005-2007.

This report consists of the six following chapters:

Chapter 2 describes the geographical characteristics of Republic of Macedonia with emphasis on the Administrative - territorial classification and inhabitants.

Chapter 3 deals with the requirements and elements of the EU air quality directives, zones with the assessment regimes and measurement methods used in this report. Information from three main assessment methods has been used: air quality measurements, emission inventories, and modeling. Information on measurement methods concentrates on continues measurements, conducted by State automated air quality network. Regarding emissions inventories, data are provided from CORINAIR (Core inventory for air pollution) [3] and Cadastre [2]. Results received from the application of the UDM-FMI (Urban dispersion modeling-Finish Meteorological Institute) model (given by the Finnish partner) in few real cases are presented in figures given in this report. UDM-FMI model is used for calculation of air pollution levels from the emissions, and for comparing the results with measurements.

In chapter 4, available data processed with the main assessment methods for each pollutant will be presented and discussed. In Chapter 5, new zones and agglomerations have been defined, and the monitoring requirements in the EU daughter directives have been compared with the current stations configuration. Examination of the assessment threshold levels to determine the regime for assessment strategy is discussed for each investigated substance within Chapter 6. Chapter 7 presents the conclusions and recommendations in brief.

The current report will need updating and supplementing in the coming years, as experience in this area develops further and several years of air quality data is available.

2. Geographical characteristics of Republic of Macedonia

2.1 Physical - geographical characteristics

Republic of Macedonia is a country located in the central part of the Balkan Peninsula between 40^{o} 50’ and 42^{o} 20’ and between 20^{o}27’30’’and 23^{o}05’. R. Macedonia has borders with Albania from west (191 km), Greece from south (262 km), Bulgaria from East (165 km) and with Serbia from north (231 km). The total length of the border is 849 km, and total area of 25.713 km2.

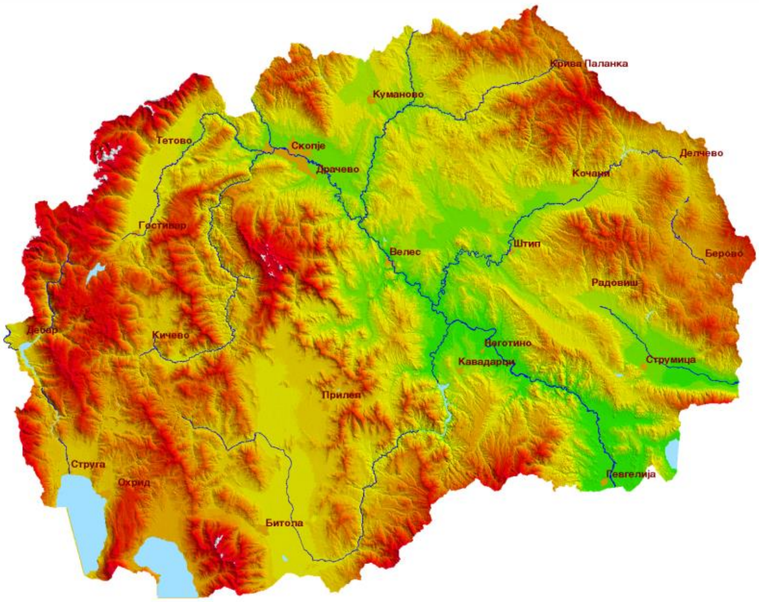

Figure 1: ***Geographic map of Republic of Macedonia***

2.2 Administrative - territorial classification and inhabitants

Macedonia is a country with total of 2.036.855 inhabitants (information from 2005) and average inhabitant density of 78.6 inhabitants / km^{2} from which 60% inhabit the urban areas. The big share of the inhabitants live in the bigger cities as follows: Skopje - 467.257 inhabitants, Bitola - 86.408, Kumanovo - 103.205, Prilep- 73.351 and Tetovo - 70.841(2002 statistical data), the irregular set up of the industrial capacities and the inadequate communal infrastructure create serious problems in securing the quality in the environment.

The demographic, economic, social situation and the characteristics of the environment show significant differences between the city and the rural areas. The industrialization and urbanization process have had positive influence on the development of the cities and the nearby villages and negative influence on the distant hill and mountain villages [2].

According to the Law on territorial organization of the local self government [6], Republic of Macedonia consists of 84 municipalities: 33 municipalities with premises in a city and 41 municipalities with premises in a village. The City of Skopje as separate unit of the local self government consists of 10 municipalities (Figure 2).

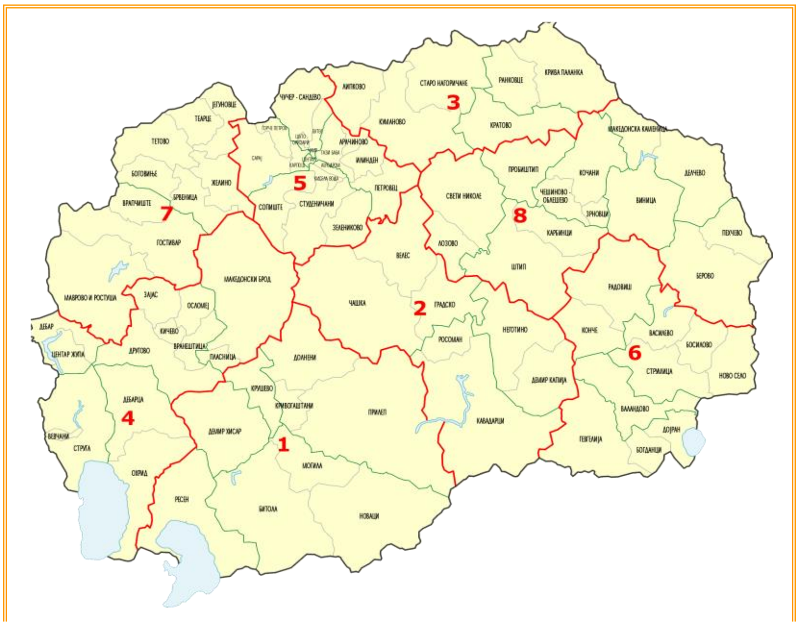

Figure 2: ***Regional allocation of Republic of Macedonia***

According to the latest statistical allocation (NUTS - Nomenclature of Statistical Territorial Units of Republic of Macedonia), the municipalities in the Republic of Macedonia are grouped into 8 statistical regions (Figure 2) as follows:

- Pelagonija (Region 1)
- Vardar (Region 2)
- North East (Region 3)
- South West (Region 4)
- Skopje (Region 5)
- South East (Region 6)
- Polog (Region 7)
- East (Region 8)

Table 1: ***Number of inhabitants per region****

Year	Pelagonija	Vardar	North East	South West	Skopje	South East	Polog	East	Total
2000	244115	133817	204774	223792	572163	173737	303131	170821	2026350
2001	244039	134019	204913	224575	576087	174257	305423	171569	2034882
2002	238055	133074	203312	221340	576857	171115	304072	172332	2020157
2003	237653	133177	203352	221914	580498	171603	305651	172925	2026773
2004	237156	133297	203105	222414	583891	171979	307250	173452	2032544
2005	236594	133283	202522	222626	587262	171997	308774	173797	2036855

*Statistical yearbook of Republic of Macedonia, 2006

3. Methods and data sets used in the preliminary assessment

Three main assessment methods or tools can be used singly or in combination for preliminary air quality assessment:

- air quality measurements;
- air emission inventories;
- air pollution modeling

All three methods or tools provide information with inherent uncertainty. By uncertainty we mean a quantitative measure of the most likely possible deviation of the value from the "true" value.

Air quality measurements are used to explore air quality, particularly at those places where exceedances are to be expected, and/or emission information is inadequate. Regarding preliminary assessment the air quality data (2005-2007) from continues measurements are used. Data from the indicative measurements can be used in complementary manner. Apart from sampling and analysis, errors may introduce major uncertainties if data are not validated, stations are not representative meaning that air quality in the surroundings differs substantially from air quality at the station, or that concentrations vary appreciably in time while the measurements have only limited time coverage.

Air emission inventories provide comprehensive information on sources and their emissions and emission fluxes in the entire zone. These methods enable a first estimate of areas at risk of exceeding limit and target values can be incomplete or may be based on inaccurate or inappropriate emission factors or activity figures.

Air pollution modeling serves to relate air quality to emissions in a quantitative sense, and provides a better basis for describing areas of exceedances in the entire zone. It also provides additional essential information for the management of the air quality in the zone, as required under the EU directives for air quality. Modeling may produce uncertain results either due to uncertainty in input such as meteorological quantities or emission data, or because of improper description or calculation of atmospheric processes and the resulting concentrations. Generally, the accuracy of the results derived from the UDM-FMI when compared to air quality measurement data has been good in cases where reliable input data has been available.

3.1 Air quality measurements

3.1.1 Margin of tolerance

The margin of tolerance is a new concept in European Commission legislation on air quality. Despite its name it is not derogation from a limit value. It provides a trigger for action in the period before the limit value must be met. As Figure 3 shows, the margin of tolerance is added to the limit value when the legislation setting the limit value comes into force. It is reduced each year to reach zero on the date by which the limit value must be met. It is important to understand that concentrations do not have to be kept below the margin of tolerance. Nor do they have to be reduced each year by the same amount as the margin of tolerance. The purpose of the margin of tolerance is simply to identify the zones with the worst air quality (Group 1 of Figure 3). Member States must prepare detailed action plans for these areas showing how the limit value will be met by the attainment date. Group 2 identifies the zones with better quality and Group 3 with good air quality (Figure 3).

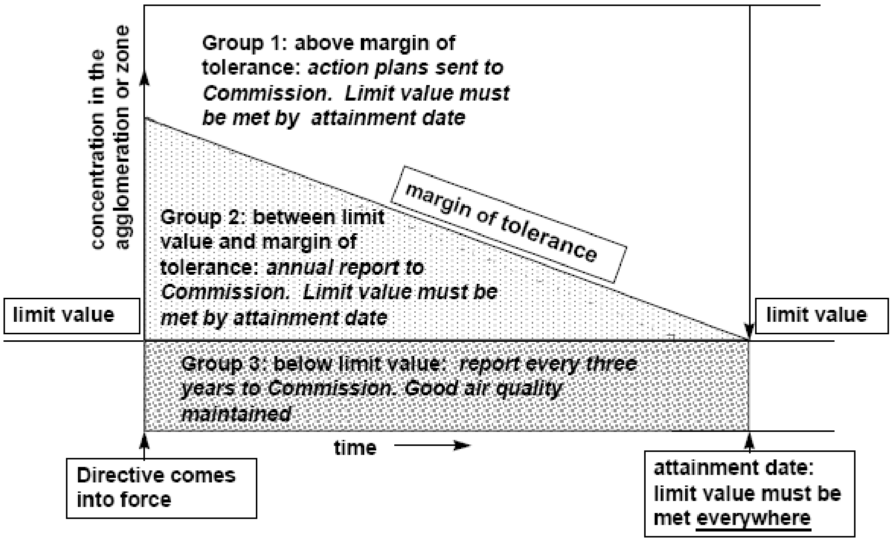

Figure 3: Schematic diagram of how reports to the Commission relate to exceedance of the limit value plus the margin of tolerance

In R. Macedonia secondary legislation - Decree on limit values of the levels and types of pollutants in ambient air and alert thresholds, terms for limit values achievement, limit value margins of tolerance, target values and long-term targets enter into force on 01.01.2007 [4]. Within this Decree in Annex 1(A ,B)[4], the limit values of separate pollutants and the dates when they should be reached are present in tables (see also Annex II Tables 16-21 of this report). In the guidelines prepared for this decree, it is explained how the concentration of the pollutants should be reduced each year by the same amount of the margin of tolerance to reach zero on the date by which the limit value must be met. Within this report the margins of tolerance are not taken into account for the air quality assessment because the Decree [4] entered into force in 2007, and it was not essential for 2005-2006 air quality data. In order to process the data in same manner, margin of tolerance was not taken into account in this report, but when this report will be updated and supplemented in the coming years, assessment and setting of the zones will be effected by the margin of tolerance set into the Decree [4]. Accordingly within this report we have taken into account more severe limit values for the pollutants which should be met in 2012.

3.1.2 Zones and assessment regime

Zones are primarily units for air quality management, but the directives also specify assessment requirements per zone. The air pollution levels are evaluated in order to establish the requirements for continuous assessment methods in zones. These requirements depend on how far air quality levels are below a limit value. For each pollutant two thresholds are set in: the upper assessment threshold (UAT) and the lower assessment threshold (LAT), (see Annex II, Tables 22-25 of this report) which are also given in Annex 2 in the Rulebook on criteria, methods and procedure for evaluating the ambient air quality [7] (see Annex II). The thresholds are lower than the limit value and are defined as percentages of the limit value. The assessment requirements in a zone depend on whether, in the preceding years, an assessment threshold is exceeded anywhere in the zone. In the first year of implementation of the Daughter Directive the assessment regime depends on the results of the Preliminary Assessment If the UAT of a certain pollutant is exceeded, the most intensive assessment requirements apply for this pollutant; if LAT is exceeded, but UAT is not, slightly less intensive assessment requirements are prescribed; if the levels are everywhere below LAT the least intensive requirements apply. So, exceedance of the limit value does not determine the assessment requirements; it triggers air quality reporting and management actions. See Figure 4.

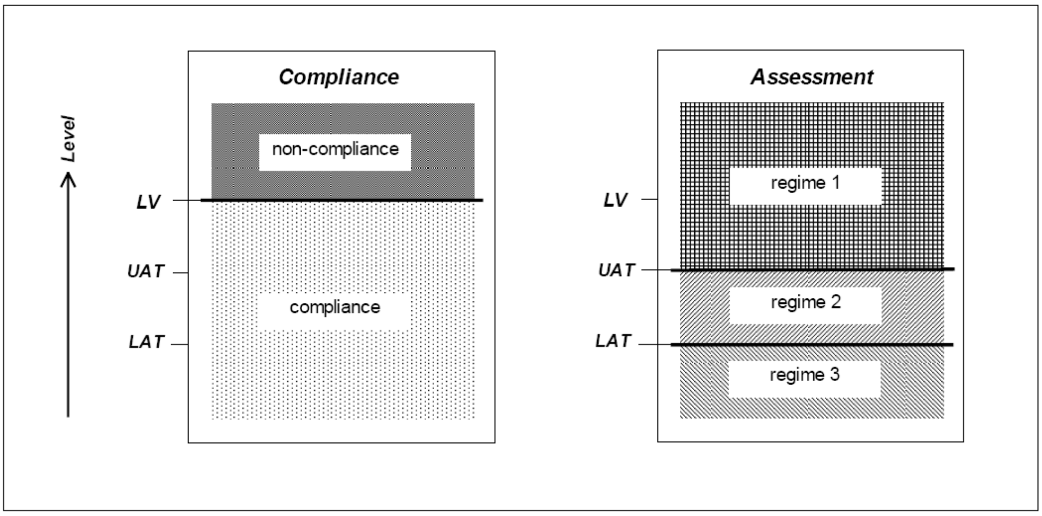

Figure 4. ***Implication of exceedance of the limit value, the upper assessment threshold and the lower assessment threshold for compliance judgement and assessment requirements in a zone***

Table 2 summarizes the assessment requirements for the three assessment regimes and the assessment requirement for each of them.

Table 2 *Air quality assessment and pollution levels*

Maximum pollution level in agglomeration or zone	Assessment Requirements*
Regime 1: Greater than the upper assessment threshold	High quality measurement is mandatory. Data from measurement may be supplemented by information from other sources, including air quality modeling.
Regime 2: Less than the upper assessment threshold but greater than the lower assessment threshold	Measurement is mandatory, but fewer measurements may be needed, or less intensive methods may be used, provided that measurement data are supplemented by reliable information from other sources.
Regime 3: Less than the lower assessment threshold	
a.In agglomeration, only for pollutants for which an alert threshold has been set	At least one measuring site is required per agglomeration, combined with modeling, objective estimation, and indicative measurements.
b.In non-agglomeration zones for all polutants and in all types of zone for pollutants for which no alert threshold has been set	Modeling, objective estimation, and indicative measurements alone are sufficient.

Air quality assessment means any method used to measure, calculate, predict or estimate the level of a pollutant in the ambient air. The complimentary data from air quality need to be measured. As can be seen from Table 2 air quality will be assessed with continuous measurements in zones where the concentrations exceed the upper assessment threshold agglomerations. Air quality will be assessed with combinations of measurements and modeling in zones where the concentrations are between the upper and lower assessment threshold.

Air quality can be assessed using modeling or objective assessment in zones where the concentrations are lower than lower assessment threshold [8].

3.1.3 Air quality measuring networks

In R. Macedonia the monitoring of the ambient air quality is performed by automated, fixed monitoring stations and by manual sampling on several measurement locations. The measurements are performed by the following institutions: Ministry of environment and physical planning (MEPP), Republic Health Institute (RHI), Hydro meteorological institute (HMA) as shown in Table 3.

Table 3 ***Automatic and manual measuring networks (MEPP, RIHP, HMA) and type of parameters measured***

Institutions		Number of measurement locations	Air quality parameters	Meteorological parameters
MEPP		15 stations	CO; SO_2; NOx; O_3; PM10;	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation,
		10 samplers	PM10 and Heavy metals	
HMI		9 measurement locations in Skopje and 10 in other cities	SO_2 and smoke	
RHI	IHP-	7 measurement	SO_2 and smoke	

	Veles	locations		
	IHP-Skopje	3 measurement locations	SO_2 and smoke	

Methods which are used for the measurement of different parameters by different networks are summarized in Table 4.

Table 4 ***Methods used for measurement of different air quality parameters***

Air quality parameters	Network	Measurement method
SO_2	MEPP	MKS EN 14212:2005 Ambient Air Quality – Standard method for the measurement of concentrations of sulfur dioxide by ultraviolet phluoroscence
SO_2	HMI, RHI	Reflectometry, Standard British method – acidimetric, West – GAEKE method
Black smoke	HMI, RHI	Reflectometry, Standard British method-photometry
NO, NO_2, NOx	MEPP	MKS EN 14211: Ambient air quality – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminiscence
PM10	MEPP	Beta Attenuation: X -Ray Absorption in Matter in accordance with MKS EN 12341:1998 Air quality – Determination of the PM10 fraction of suspended particulate matter – reference method and field test procedure to demonstrate reference equivalence of measurement methods
CO	MEPP	MKS EN 14626:2005 Ambient Air Quality – Standard method for the measurement of concentrations of carbon monoxide by nondispersive infrared spetroscopy
O_3	MEPP	MKS EN 14625:2005 Ambient Air Quality – Standard method for the measurement of concentrations of ozone by ultraviolet photometry

Type and number of type of station are given below. Table 5 shows the amount of different types of stations in the Republic of Macedonia.

Table 5 ***Types and number of stations in the Republic of Macedonia***

Type of station	Type of area	Automated stations	Manuel stations	Total number of stations
Traffic	Urban	7	9	16
Traffic	Suburban		3	3
Industrial	Urban	5	7	12
Industrial	Suburban	1	1	2
Background	Suburban	1	3	4
Background	Rural	1		1
Background	Urban		13	13

Total		14	36	50

In this report only data from the automated monitoring stations are taken into account, since the measurement methods of the manual stations are not in accordance with the Annex 3 of the Rulebook on criteria, methods and procedures for evaluating the ambient air quality [7].

On the following figure, Distribution of automated air quality monitoring stations in Republic of Macedonia is presented.

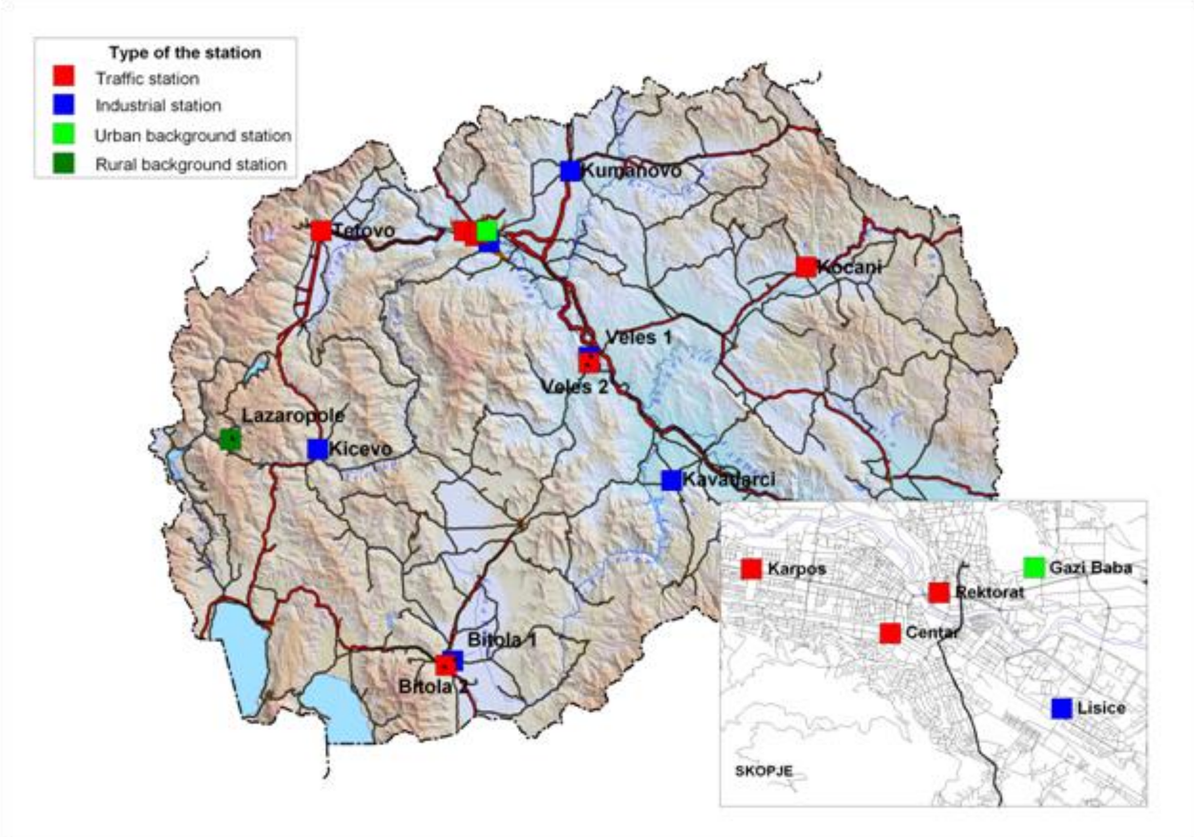

Figure 5 ***Distribution of automated air quality monitoring stations in Republic of Macedonia***

Measured pollutants, type and location of the station, start of station operation, type of area and characterization of zone in which the station is located are presented in Annex I of this report.

Data collection and validation system of the automated air quality network

Central station collects all of the data from the automated monitoring stations every hour, by modem connection. These data are collected with ISO (International Standard Organization) Generator and inserted into SQL (Structured Query Language) Base. Data from SQL Base are gathered by MEPP collector and inserted into the Data base, which is used for validation of the data. Analyzed data in this report has not been corrected even though the calibration of the instruments has been performed.

3.2 Air emission inventories

Data from two sources: In this chapter we have presented CORINAIR-methodology emission inventory [3] and Cadastre [2] database are presented in this chapter. The data for the identified objects of pollution are presented in tones per year for separate pollutants for which measured data exists. For the major pollution sources measurements have been undertaken. The Cadastre data [2] are given on a national level per statistical region. The data gained from the Cadastre are presented according to the national methodology for identification of polluters and pollutants, so we can not guarantee that are compatible with EU data. Data classified per several main duties in the country are presented without appropriate classification per sectors, while by implementing the CORINAIR methodology [3] and using the SNAP nomenclature this issue is corrected and the presented pollution is classified per sectors and duties. In 2007, the CORINAIR methodology has been prescribed as National methodology for preparation of emission inventory for identification of the pollution per duties [9]. This gives an overview of the inappropriate identification of the origin of the pollution on national level per sectors and duties.

3.2.1 CORINAIR emission inventory

A standard methodology, harmonized at the European level, has been developed and applied in the CORINAIR project and documented in the EMEP (Emission monitoring programme for Europe) / CORINAIR Atmospheric Emission Inventory Guidebook (EMEP/CORINAIR, 1996) [10]. Within this project a complete, consistent and transparent emissions database for all of the European territory for the base years 1990 and 1994 is available. Member States may have more detailed and up-to-date emission inventories for particular zones. If however, no specific emission inventory for the zone under study is available such an inventory can be derived from the most recent CORINAIR inventory available, using the methodology described in this chapter.

The CORINAIR database can be used directly to calculate background concentrations, resulting from emissions outside the region under study.

An emission source nomenclature that includes anthropogenic and natural sources is needed. The SNAP97 (Selected Nomenclature for Air Pollution, version 1997) developed by the EEA (ETC (European topic centre) /AE (Air Emissions)) and EMEP is the most complete and detailed list presently available. The SNAP sectors are given the following table bellow:

Table 6 ***SNAP nomenclature***

SNAP sector	Name
1	Combustion in energy and transformation industry
2	Non-industrial combustion plants
3	Combustion in manufacturing
4	Production processes
5	Extraction and distribution of fossil fuels and geothermal energy
6	Solvent and other product use
7	Road transport
8	Other mobile sources and machinery
9	Waste treatment and disposal
10	Agriculture
11	Other sources and sinks

In R. Macedonia the first CORINAIR inventory was prepared by the consulting company Tehnolab within project founded by Regional CARDS 2002. In this project the technical personnel from MEPP was involved. During the period August 2005 – January 2006, the Company Tehnolab prepared an air emission inventory for Reublic of Macedonia for 2004 as national database in electronic form. They have also prepared report on the data sources, applied procedures, used emission factors and implementation of QA/QC (Quality Assurance/Quality Control) activities. The data for the year 2004 needed for the preparation of the emission inventory was processed according to the CORINAIR methodology and for the first time was sent to EEA (European Environmental Agency) and CLRTAP (Convention on Long-Range Transboundary Air Pollution). In this preliminary assessment report we have used emission data for 2004, calculated according CORINAIR methodology per SNAP sector.

3.2.2 CADASTRE

In accordance with the obligations stated in the Law on environment [11] and the Law on ambient air quality [5], a Cadastre for air polluters and pollutants is in accordance with the program of MEPP for establishment of integrative and efficient system of measures for management of air quality.

, The total emission of pollutants in the air for 2004 presented in the Cadastre is coming from the following sources:

- Stationary sources
- Mobile sources (traffic)
- Diffuse sources

The presented data in the Cadastre refer to 84 Municipalities in R. Macedonia which are organized in 8 statistical regions.

The following measured pollutants are comprised in the Cadastre, according to the characteristics of the source: SO_2, NOx, CO, VOC and TSP.

Emissions from Stationary sources

Cadastre database contains data of 1.660 registered business entities that release pollutants in the air, from which 1042 are from non-productive (for example, schools, hospitals etc.) and 618 from productive (production of heat and power energy, mine processing etc.) duties. 2.758 registered exhausts of all recorded stationary sources release pollutant emission in the air.

Emissions from residential sources - household fireboxes

The household fireboxes are categorized as collective stationary sources of pollution of the air where the air pollutant emission results from the use of wood and heating coal. As a product from the combustion of those energy-releasing materials, the following pollutants are emitted in the air: SO_2, NOx, CO and TSP. Main emissions from small scale burning are suspended particulates and CO, and suspended particulates and SO_2 from heating coal.

The emission of the pollutants in the air is determined according to the data for the wood and coal consumption in R. Macedonia and according to the number of households from the last census of the population.

Emissions of air pollutants from mobile sources

The road traffic is one of the biggest mobile sources of air pollution. The remaining mobile sources (railway traffic, air traffic and lake traffic) are negligible compared to the total air pollution from mobile sources.

The air pollution from road traffic is a consequence from the use of liquid energetic materials (benzene, diesel, Liquefied petroleum gas (LPG) that after their combustion in the vehicles the following emissions are released: SO_2, NOx, CO, CO_2 (carbon dioxide), total suspended particles (TSP), and volatile organic compounds (VOC). The most important emission emitted from the road traffic is nitrogen oxide and CO.

The analyses of the amount of air pollutants from traffic in R. Macedonia are done according to calculations based on data for the number and the structure of the registered vehicles in R. Macedonia, as well as according to the consumption, the types and the amount of motor fuels. Empiric factors are used in the calculations according to the guidelines given in the Emission Inventory Guide book-Road Transport SNAP code 0701 [10] harmonized to the conditions in R. Macedonia.

Fugitive emissions of air pollutants

The fugitive emissions are defined as emissions that are released in the atmosphere from sources like chimneys, process outlets or ventilation outlets, canals and other outlets that have so called directed or controlled emission of air pollutants. The external or internal operational activities can be fugitive emission sources (in transport, manipulation, loading, unloading, open storage spaces, gas stations etc.). The fugitive emissions might be caused by leakages of pollutants in solid, liquid and gas condition, vaporization from certain equipment parts (ventilation pumps, valves etc.) The fugitive emissions may cause minor or bigger disruption of the ambient air quality.

3.3 Introduction modeling

Air pollution modeling may be seen as a method for providing information on air quality on the basis of what we know of the emissions, and of the atmospheric processes that lead to pollutant dispersion, transport, chemical conversion and removal from the atmosphere by deposition. Models have become a primary tool for analysis in most air quality assessments mainly for the following mentioned reasons.

A figure of the air quality in a larger area may be obtained - in contrast to the limitations in the spatial coverage of air quality measurements.

The relation between air concentrations and the emissions causing these can be made explicitly and quantitatively by modeling, which is most important for supporting air quality management. Models are the only available tool if the impact on air quality of possible future sources or of alternative future emission scenarios is to be investigated.

Air pollution models can be used in a complementary manner to air quality measurements, regarding the strengths and weaknesses of both analysis techniques. Modeled information is necessarily uncertain due to deficiencies in our knowledge of emissions and atmospheric processes. This disadvantage may be largely off set by validation of models with the help of measurements, or by assessing air quality by combination of information from modeling and measurements. In fact, if a concentration map is to be made on the basis of measurements, model results provide essential information for interpolation. The use of interpolation in assessments of air quality measurements alone is to be recommended only if emission information cannot be made available or if acceptable models cannot be found, and if monitoring data with sufficient spatial and temporal coverage are available [8].

3.3.1 Model - UDM-FMI

The UDM-FMI is a local scale dispersion model developed and applied for regulatory purposes at the Finnish Meteorological Institute. This local scale air pollution dispersion model has been developed to be used for assessing the dispersion of atmospheric emissions from single or multiple point sources. The dispersion model is based on Gaussian plume equations for various stationary source categories (point, area and volume sources). The Gaussian plume equations can be mathematically derived from the atmospheric diffusion equation in case of homogenous and stationary turbulence.

The dispersion module of the system utilizes input emission data, pre-processed meteorological data and geographical data. The model is based on the steady-state hypothesis, where emission rates and meteorological conditions are assumed to remain constant during each model time-step (one hour). The hourly air concentrations for each pollutant in emission inventory are computed in grid points usually covering a rectangular area for the whole period of meteorological data. The input emission data consists of part describing the some details of the emission sources and then the emissions of the sources for each hour of the period, which usually covers one calendar year. The emission time series must be consistent with the meteorological time series. Emission source and emission time series records are given in the report [12].

4. Results

4.1 Sulphur dioxide (SO_2)

4.1.1 Emissions

Annual mean of the SO_2 concentrations calculated from the available data in the period 2002-2006 are presented in Figure 6.

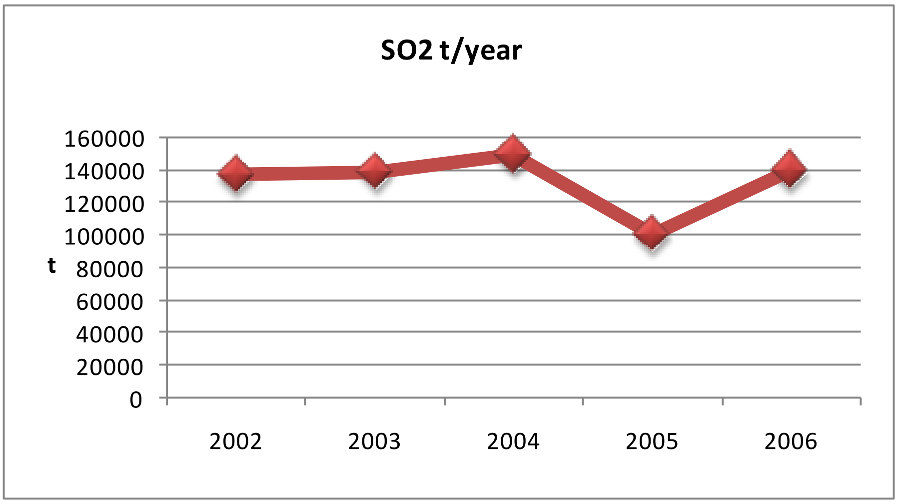

Figure 6 ***Trend of SO_2 emissions***

The total quantity of SO_2 emission on national level from the period 2002 to 2006 shows almost no change for the years 2002, 2003 and 2004, while for 2005 there is a rapid drop and for 2006 there is a significant increasing of the yearly emission amounts. With the trend analysis and in context of the current situation of the major combustion capacities in the Republic of Macedonia these trends are probably conditioned by the status of the separate blocks of REK - Bitola i.e. whether they are operative or not in the combustion of the lignite in the electrical energy production

Figure 7, shows the percent share of the SO_2 according to the SNAP nomenclature (see Table 6).

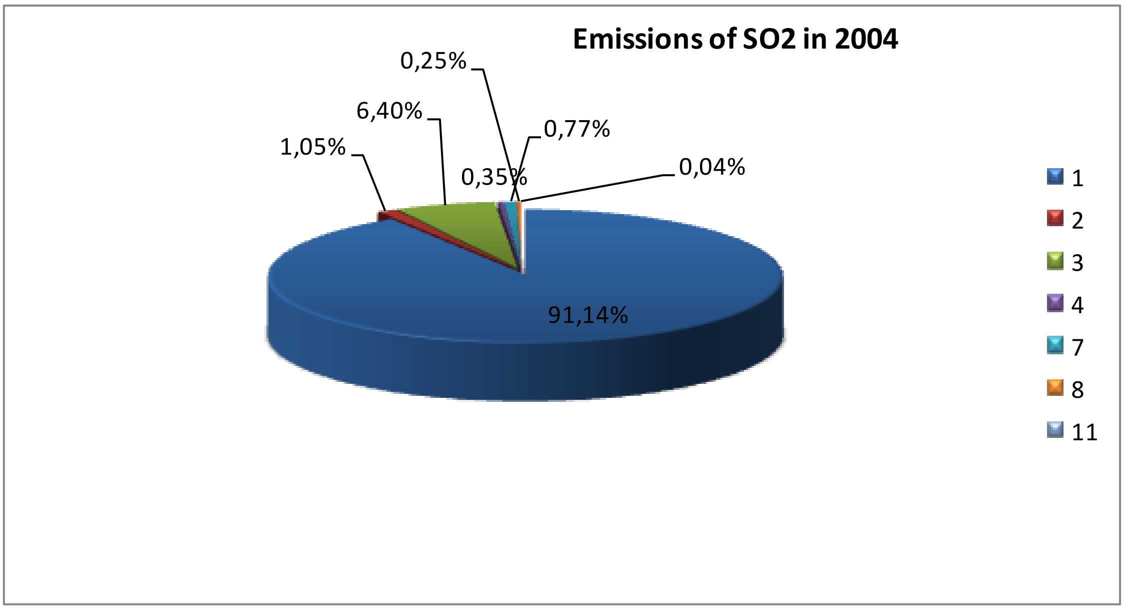

Figure 7 ***Emissions of SO_2 in 2004 by SNAP sectors***

According to the data above it can be noticed that the biggest percent of 91.14 % of sulphur dioxide belongs to the first sector which is transformation and energy production. In our country there are energy production facilities that produce electrical energy by using low quality lignite (brown coal) that consists certain percent of sulphur and by using heavy oil that releases SO_2 in its combustion process. This is the reason for the great percentage of SO_2.

The results calculated from 2004 SO_2 Cadastre data are shown on followings figures and tables. Point source emissions from year 2004 from the Cadastre are given on the following map.

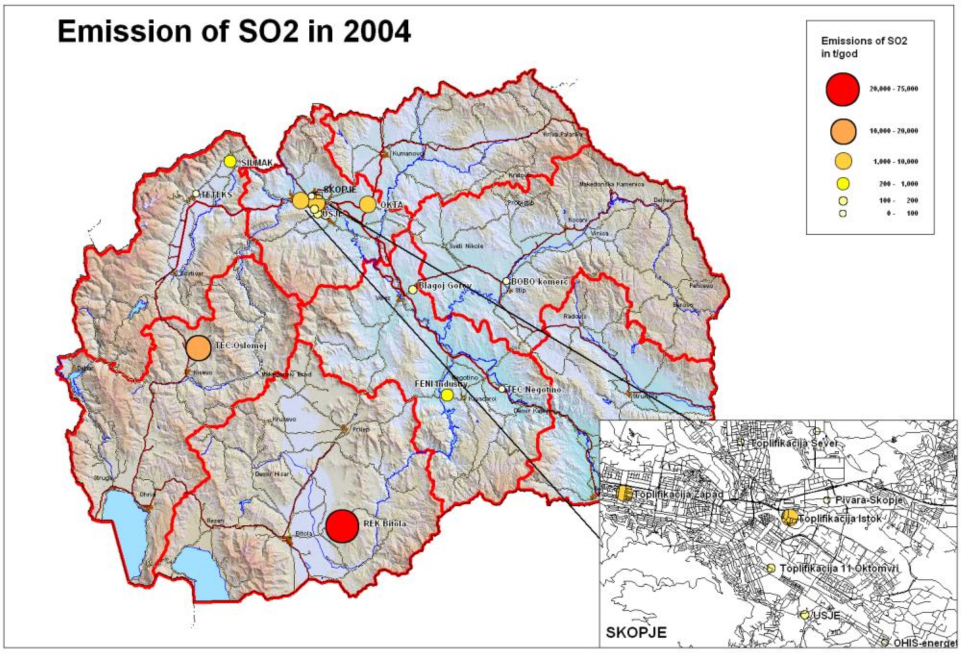

Figure 8 ***Emissions of SO_2 from major point sources in 2004 from Cadastre data***

On this map all great energy producers are shown. REK Bitola and TEC Oslomej are great combustion companies that produce electrical energy by using lignite. With their operation these big companies contribute to the pollution of the environment (air) by releasing great amounts of SO2. On Skopje map two major companies can be noticed. These companies produce heat energy for heating the households during the winter period and are one of the biggest air polluters.

In order to explain better the SO_2 emission sources, we have used the data from the Cadastre, presented on the next figure expressed in percents for stationary sources, households, traffic and fugitive emissions.

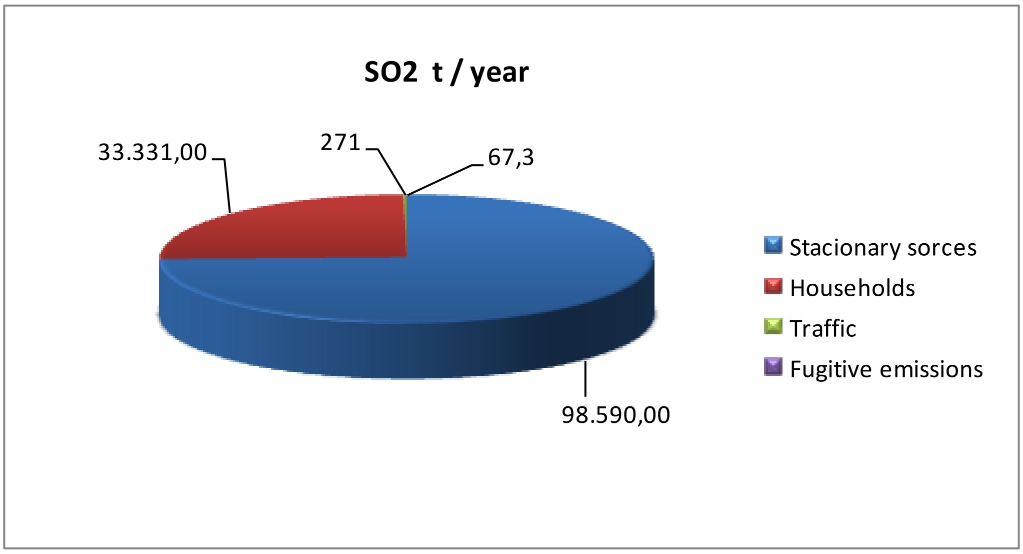

Figure 9 Emission of SO_2 by different type sources

The largest portion of SO_2 is produced by stationary sources. Most probably the large percent is due to the combustion of the low-quality and low-calorie brown coal with approximately 2 % sulphur. The brown coal is used for production of electrical power in two large capacities in R. Macedonia that belong to large combustion sources according to their installed power.

4.1.2 Measured concentrations

Measured concentrations compared to limit value for protection of human health

The data are recorded over period 2005-2007. Data from 14 stations are presented and analyzed. Type of each station is presented in the Table 5.

Six stations are industrial type of stations, six of them are traffic stations, one is a background rural and one is urban background station. For the period 2005-2007, data was available from nine stations. Data for two years was available from four measurement stations and one year for one measurement station.

The measurement method used to measure SO_2 is based on UV-fluorescence, which are the reference method mentioned in the Rulebook on criteria, methods and procedures for evaluating the ambient air quality [7].

The devices have been calibrated 2−6 times during the year. Over 40 % of the data had time coverage over 90 % for hourly values and about 5 % had time coverage less than 50 %. According to the results, major part of the SO_2 measurement data is beyond acceptable time coverage. According to the Annex 2 of the Rulebook criteria, methods and procedure for evaluating the ambient air quality [7], the minimum time coverage for indicative measurements is 14 % and for fixed measurement 90 %.

Limit values of the levels of concentrations, margins of tolerance and terms for achievement of the limit values are given in Table 16, Annex II of this report. The hourly mean limit value for SO_2 of 350 µg/m³ may not be exceeded more than 24 times a year. The measurements show that hourly values were exceeded more than 24 times in period 2006-2007 only in Centar and Karpos stations in capital town Skopje. The second threshold level for the protection of human health is the daily mean of 125 µg/m³ SO_2. This value may not be exceeded more than three times per year. More than three exceedances of daily mean (125 µg/m³) were measured in Karpos and Centar stations during 2006 and in Centar station in 2007. The highest levels measured in Karpos are closely connected with heat production, and heating in non-productive institutions (schools and administrations) in Karpos and the SO_2 exceedances in Centar stations are due to emissions from household heating and frequent traffic.

We have defined the following classification of the stations type labeled with different colors:

(red)	Traffic station
(blue)	Industrial station
(dark green)	Rural background station
(light green)	Urban background station

For the protection of ecosystems, a limit value of 20 μg/m³ SO_2 for the yearly and winter means is defined in Table 15 of Annex II of this report. Annual averages of SO_2 and winter averages of SO_2 are shown on Figures 10 and 11.

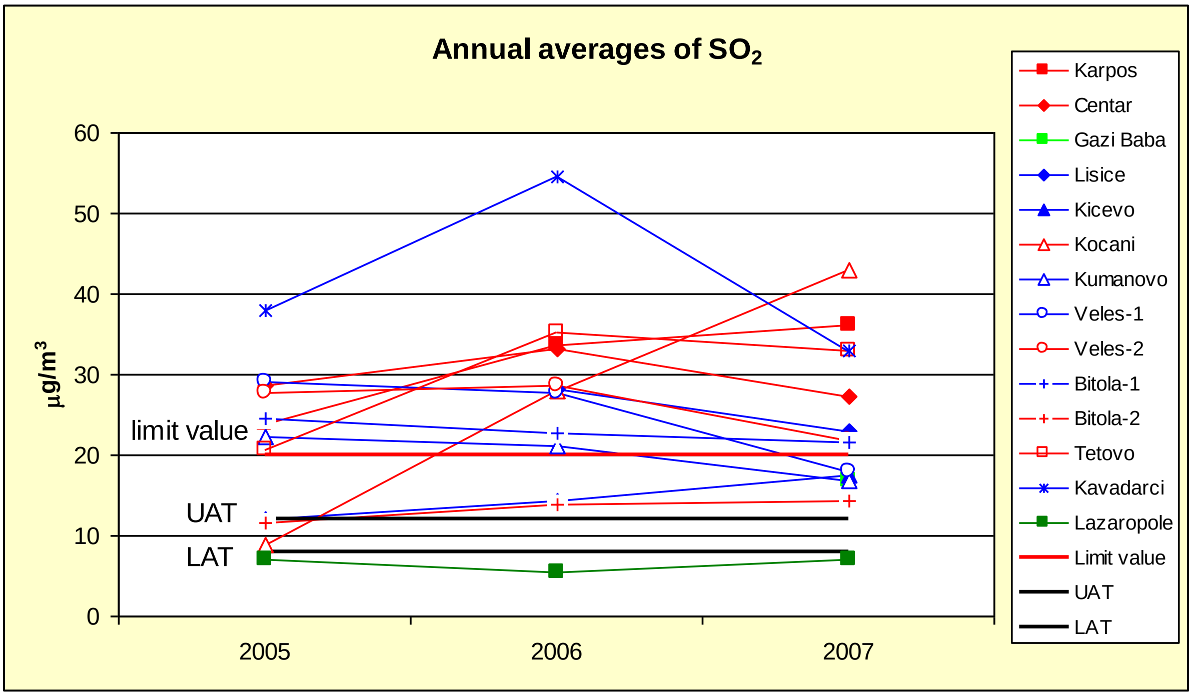

Figure 10 ***Annual averages of SO_2***

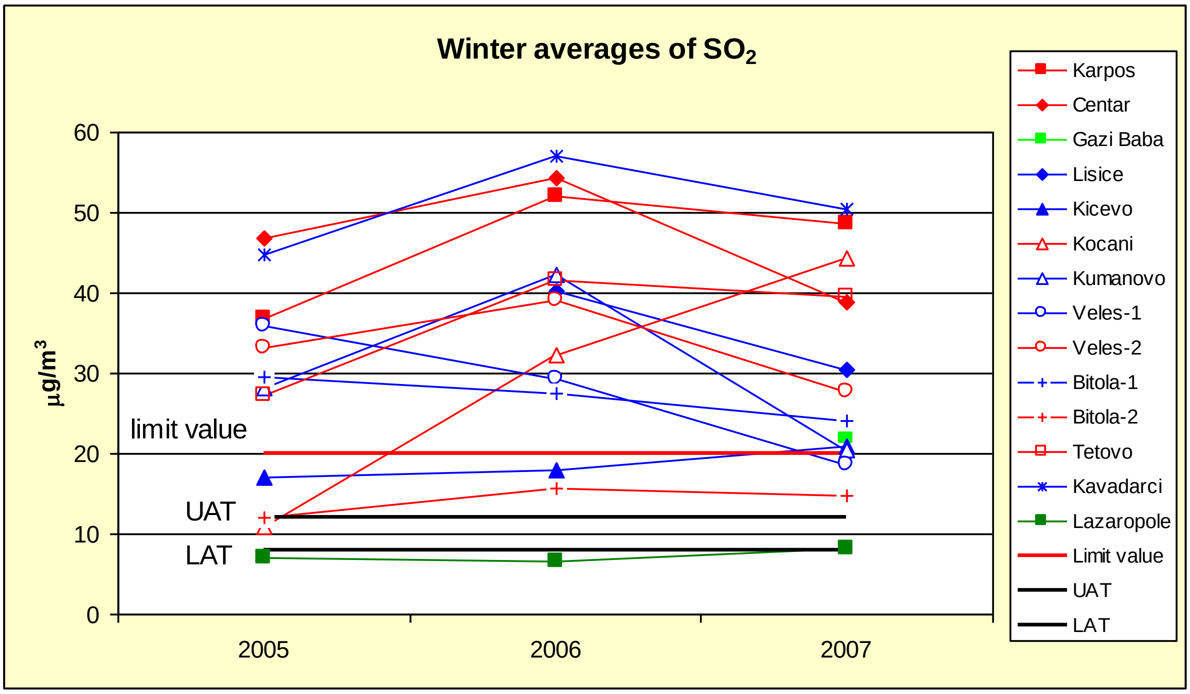

Figure 11 ***Winter averages of SO_2***

Limit value for the annual and winter average is exceeded everywhere except Lazaropole, Kicevo and Bitola-2. From the figures given above we can notice that the winter average of SO_2 is higher than the annual average on all measurement places. This is closely connected to the frequent traffic as well as the higher capacity of the heating production plants in the winter period.

Measured concentrations compared to assessment thresholds

UAT (12 $\mu g/m^3$) and LAT (8 $\mu g/m^3$) for yearly and winter mean (Table 21 in Annex II of this report) are exceeded everywhere (see Figure 10). The daily limit value given for protection of health was exceeded during the assessment period (2005-2007) at two measurement stations in Skopje (Karpos and Centar). In addition, the upper assessment threshold (UAT) was exceeded in Skopje and Kavadarci (Figure 12). At the other stations used in the assessment, the concentrations were lower than the UAT, in other words with small exceptions more then three excedances have not been noticed. While analyzing the three year period (Figure 13), it can be seen that lower assessment threshold (LAT) was exceeded more than three times in all measurement stations except in measurement stations Bitola-2, Kicevo and Lazaropole.

For sulphur dioxide, lower assessment threshold levels for the daily mean are exceeded in the capital Skopje, Bitola and Kavadarci located close to the industries (electrical energy production, treatment of iron and nickel). Exceedances of the assessment threshold levels for the daily mean observed in Kumanovo and Tetovo are due to frequent traffic and residential heating.

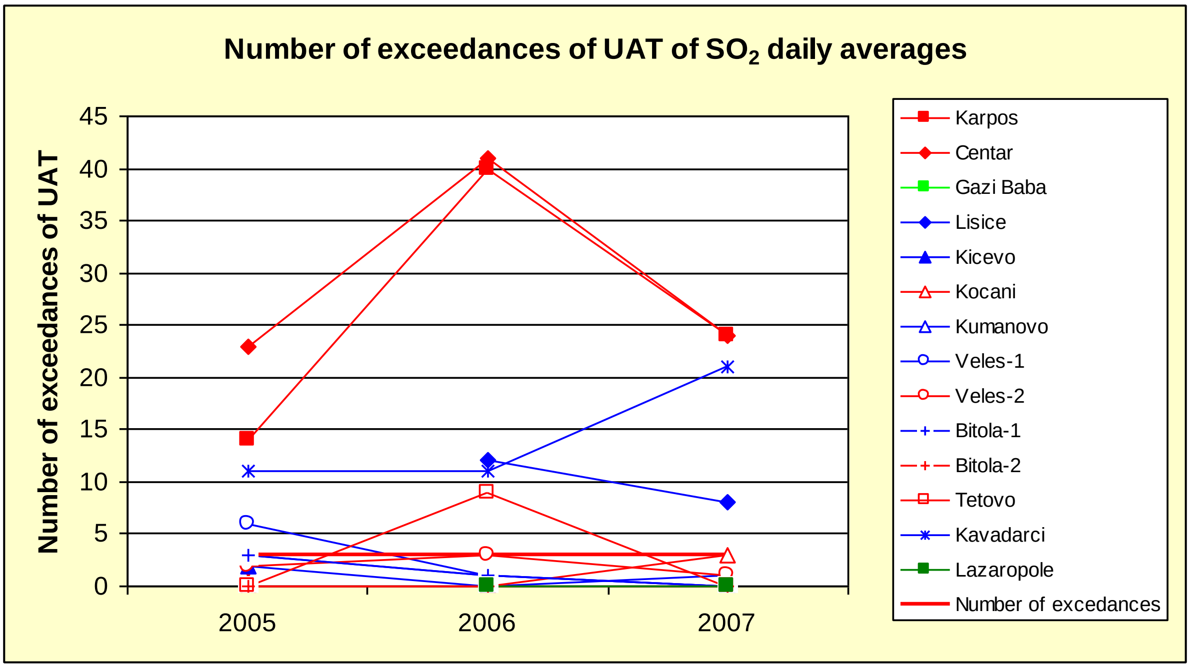

Figure 12 ***Number of exceedances of UAT of SO_2 daily averages***

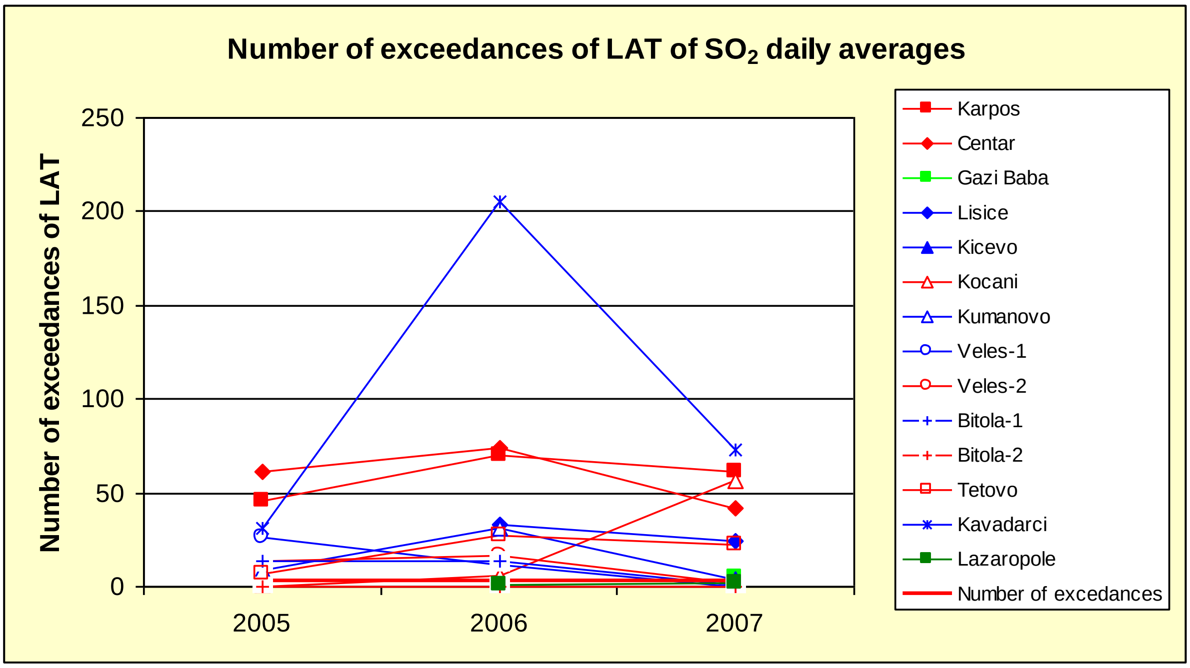

Figure 13 ***Number of exceedances of LAT of SO_2 daily averages***

4.1.3 Dispersion modeling

In this report results received from the application of mathematical atmospheric dispersion model (UDM-FMI) developed in the Finnish Meteorological Institute model are presented. This local scale air pollution dispersion model has been developed to be used for assessing the dispersion of atmospheric emissions from single or multiple point sources.

In this study, two pollutants from Okta oil refinery were considered, namely SO_2 and NOx. The concentrations expressed in µg/m3 were calculated for 5041 receptor points surrounding 7 x 7 km area around the oil refinery. The hourly concentrations were calculated for each receptor point for each hour of the year 2005. From the hourly concentration time series the model calculated statistical parameters that can be compared to limit or guideline values for air quality.

Meteorological time series for dispersion modeling are compiled by interpolating the weather data to the site of application with a straightforward distance-weighted interpolation.

For this study the synoptic weather observations of the year 2005 from the weather station in Skopje airport were used. According to the meteorological data the most frequent wind directions in the area are north and northeast (19 % each of all wind directions). The proportion of light winds (speed category under 2 m/s) is 4592 % depending on the direction sector. The proportion of fresher winds (wind speed over 6 m/s) is greatest in the north and southeast sector.

For the model calculations an hourly emission time series for SO_2 emissions of the year 2005 were created. The emission and technical data was collected from the Cadastre database. The emissions from two sources were included in the calculations. The SO_2 emission and other technical data used in the modeling are shown in the Table 7.

Table 7 ***Emission of SO_2 and other technical data used in the modeling***

Parameters	Stack 1	Stack 2
Average SO_2 emissions (g/s)	48,4	14,3
Annual SO_2 emissions (t/a)	1417	418,8
Outflow of gases (Nm^3/h)	173,13	40945
Temperature of gases(C)	185	200
Height of the stack (m)	150	80
Inner diameter of the stack (m)	4,05	3,05
Hours of operation (h/a)	8136	8136

The highest modeled sulphur dioxide concentrations caused by the atmospheric emissions from Okta oil refinery are shown in the Table 8. These values are the highest concentrations calculated to single points for the period 2005. The concentrations are significantly lower most of the time on these and other receptor points.

According the results of the model calculations the highest SO_2 annual average of the study area is 1.5 µg/m³ (limit value 20 µg/m³). The 4th highest SO_2 daily average concentration is 10.3 µg/m³ (limit value 125 µg/m³) and the 25th highest SO_2 hourly concentration 44.3 µg/m³ (limit value 350 µg/m³).

Table 8 ***The highest SO_2 concentration of the study area***

Input values	Limit value	SO_2 (µg/m³)
Annual average	20	1.5
Highest daily average		22.8
4th highest daily average	125	10.3
Highest hourly average		78.8
25th highest hourly average	350	44.3

In Figure 14 the highest concentrations of SO_2 are compared to the air quality limit values. SO_2 concentrations caused by the Okta oil refinery emissions are at the most 8 % of the limit value for SO_2 annual average concentration, 8 % of the limit value for SO_2 4th highest daily average concentration and 13 % of the limit value for SO_2 25th highest hourly concentration limit value.

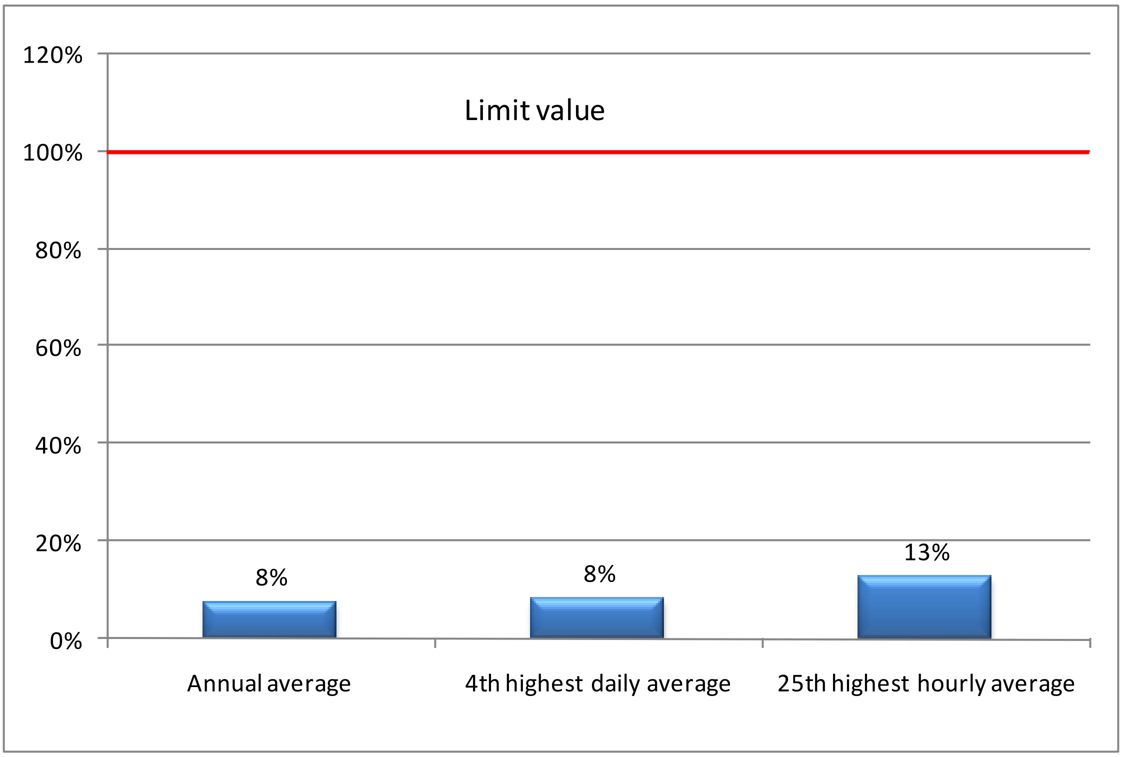

Figure 14 ***The highest SO_2 concentrations compared to air quality limit values***

As the main stack of the oil refinery is high (150 meters) the concentrations on the ground in the vicinity of the plant will be quite low and the maximum concentration occurs from approximately one kilometre to several kilometers from the stack position.

According to the dispersion modeling calculations the most probable direction of the highest ground surface concentrations would be to the southwest or northwest of the plant location. According to the dispersion model results, the concentrations due to emissions of the oil refinery used in the modeling study are sufficiently low on the ground surface to meet the EU air quality limit values.

Results of dispersion calculations for SO_2 are presented as isopleths in Figures 15-17. Quantities presented in the isopleths presentations are those comparable to the EU limit values for SO_2. Locations of maximum concentrations are presented with white stars [11].

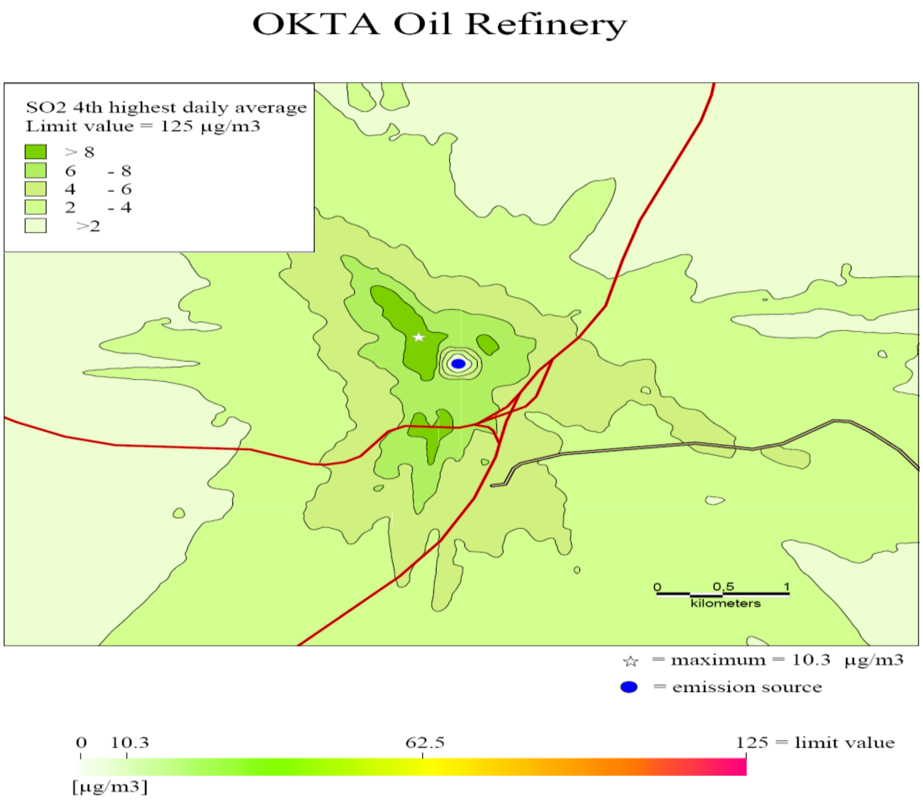

Figure 15 ***4th Highest daily average SO_2 concentration / µg / m^3***

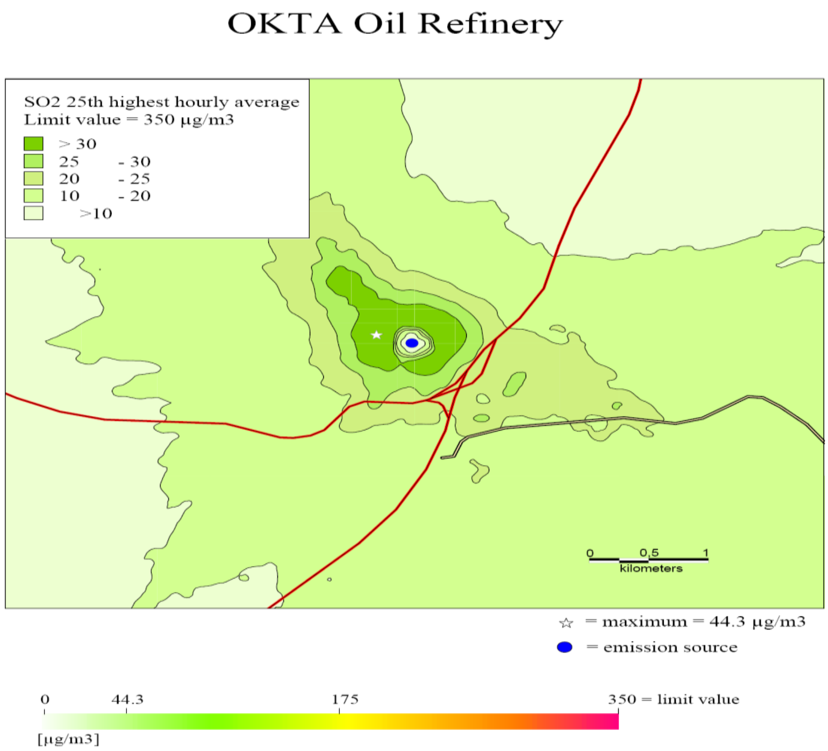

Figure 16: ***SO_2 25th hourly concentration / µg / m^3***

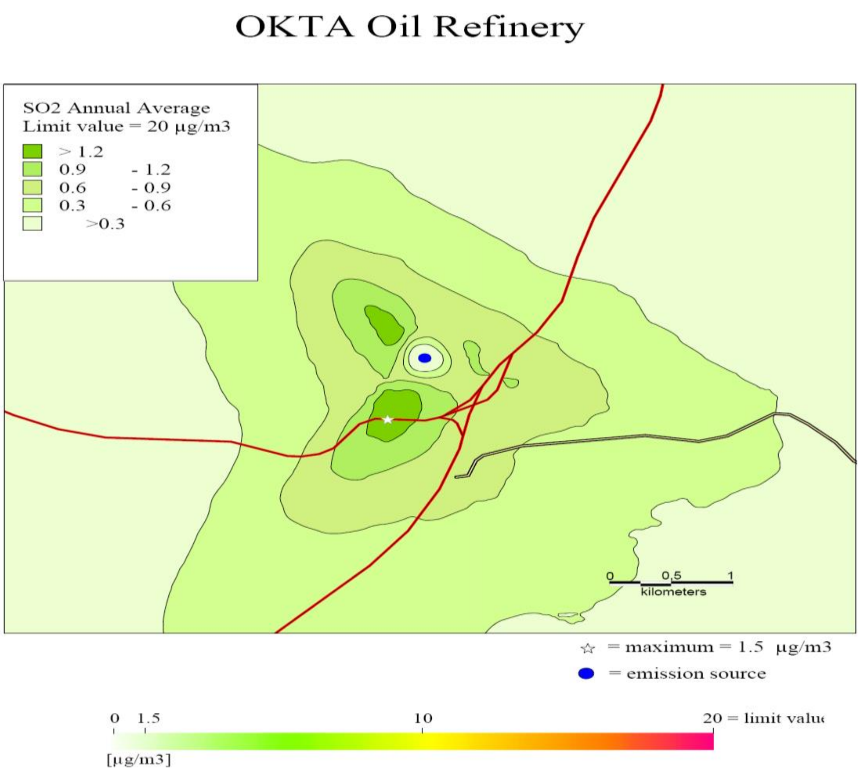

Figure 17: ***Annual average SO_2 concentration / μg /m^3***

4.2 Nitrogen dioxide (NO_2) and nitrogen oxides (NO_X)

4.2.1 Emissions

Annual mean of NO_2 concentrations calculated from the available data in the period 2002-2006 are presented in Figure 18.

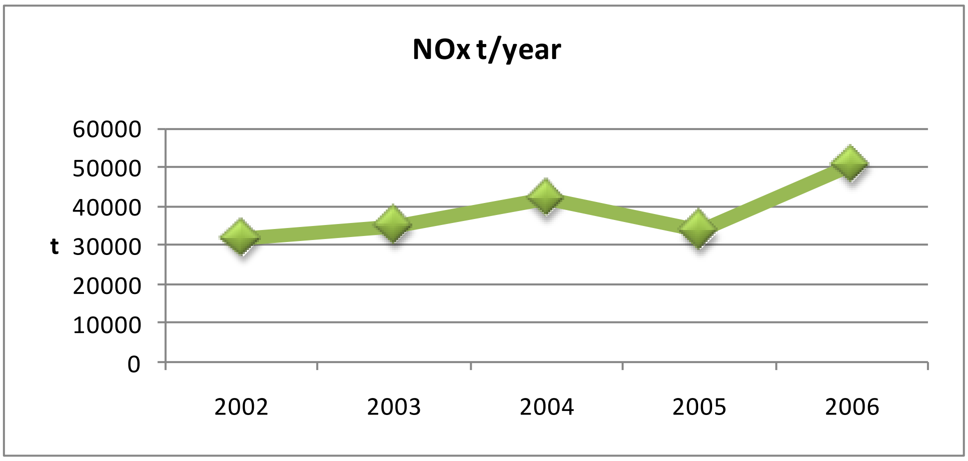

Figure 18 ***Trend of NOx emissions***

The trend of the emissions of NOx shows slight increase for the period 2002 to 2004 and certain decrease for 2005, while in 2006 there is a significant increase of the trend line. The increasing trend for 2006 is equivalent to the increasing trend for the sulphur dioxide emissions, which shows that combustion of greater coal amounts increases the amount of nitrogen oxides. Also, the increasing of the number of vehicles with inappropriate fuel combustion because of the old age structure of the vehicles should not be neglected in the overall increase of the nitrogen oxide emission.

The percentage of NOx emissions according the SNAP nomenclature from the emission inventory are presented on Figure 19.

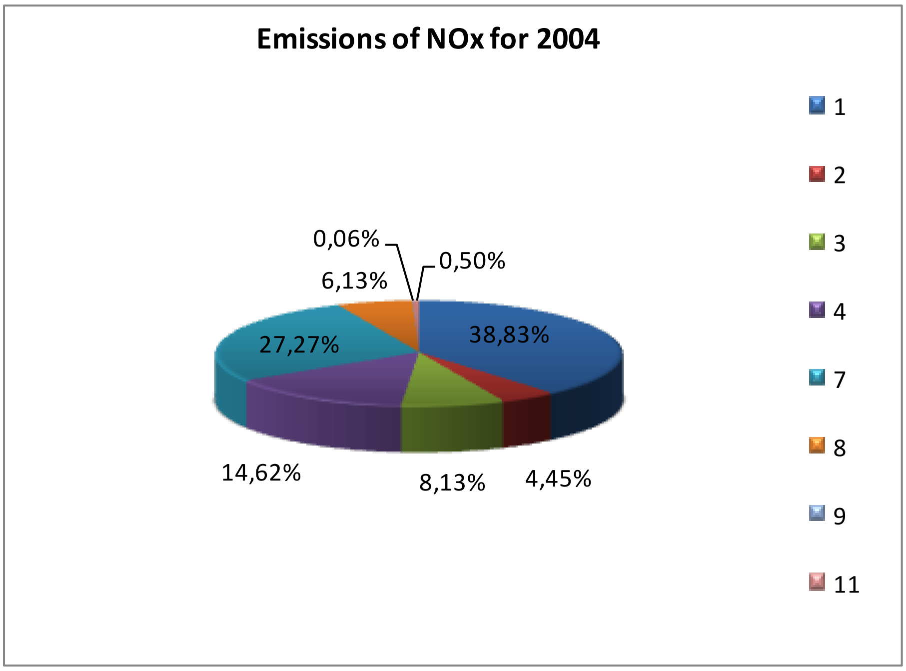

Figure 19 ***Emission of SO_2 by different type sources***

The first sector represents the energy production where during the combustion processes that are incomplete, great amount of NOx is released, keeping in mind the usage of the low quality fuel. The transport is the SNAP sector 7 that contributes by releasing great amount of NOx due to the old vehicles that do not have complete fuel combustion. As a result of the high traffic frequency the distribution of the pollution with nitrogen oxides is greater in the urban areas as well as along major roads. Point source emissions from year 2004 from the Cadastre are given on Figure 20.

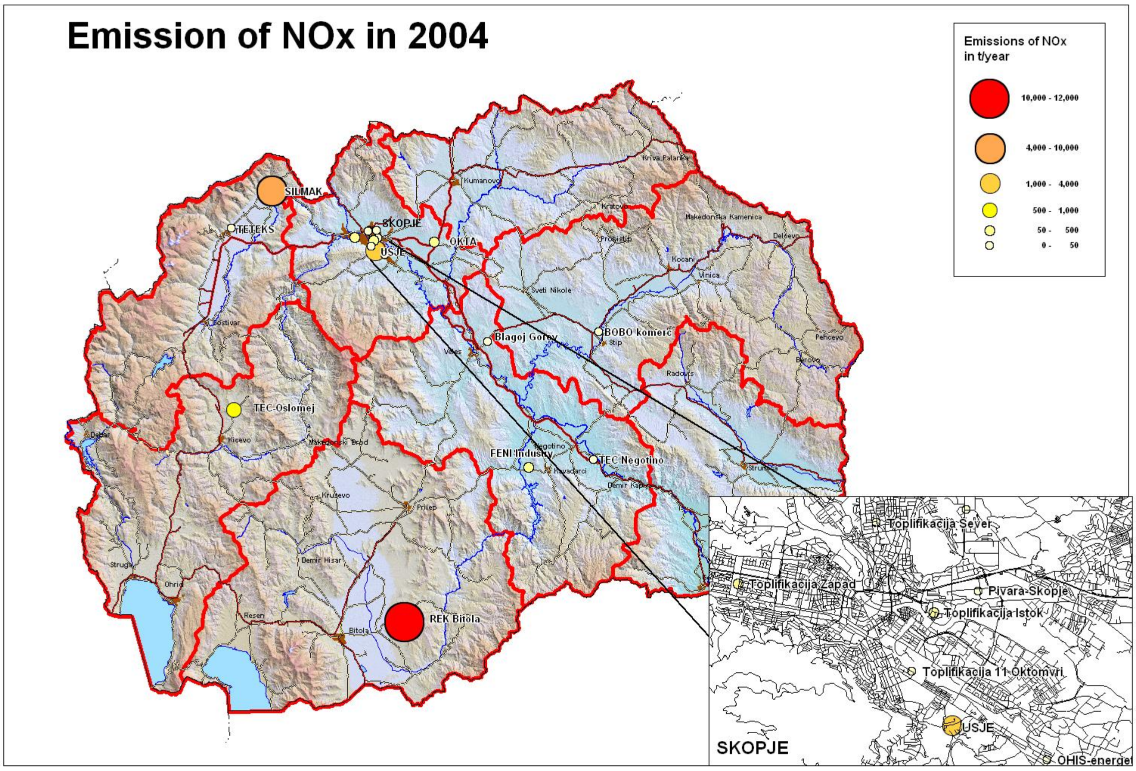

Figure 20 ***Emissions of NO_X from major point sources in 2004 from Cadastre data***

The figure shows that largest emission of NOx belongs to the energy sector during electricity production and it is distributed mostly in the Southwest region where the largest electricity production facilities using brown coal are located. During the combustion of the brown coal, due to its bed quality, the emissions contain large amounts of nitrogen oxides.

Figure 21 shows that the largest portion in the total emitted amount of NOx yearly is from stationary sources and from traffic emissions. This is due to the combustion of low quality brown coal during electricity production and combustion of low quality fuels in the traffic.

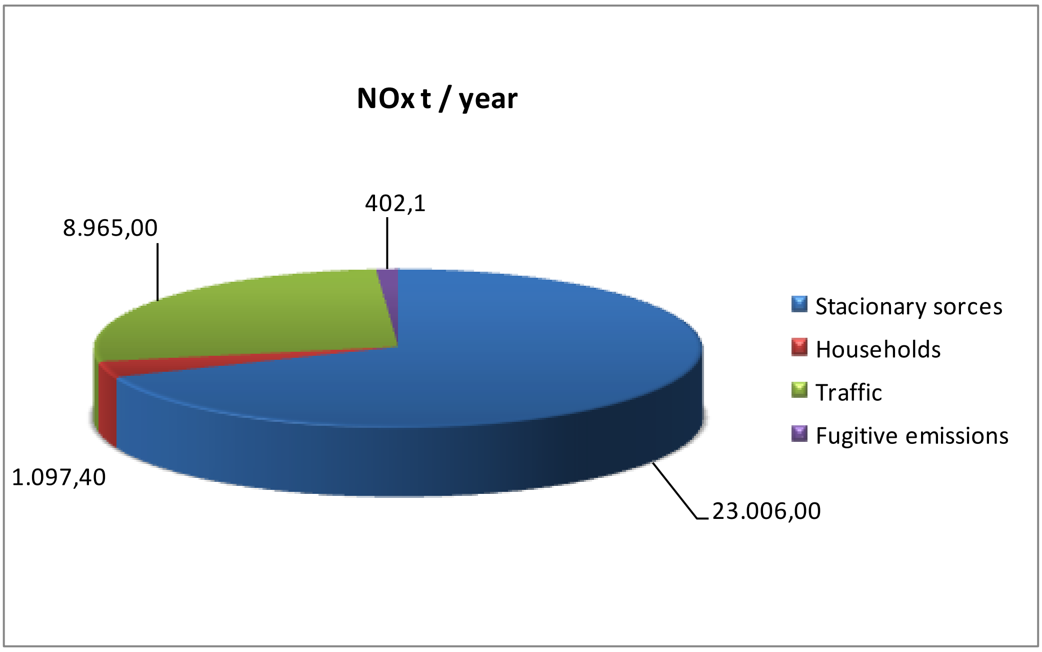

Figure 21 ***Participation of emission sources in the NOx emissions***

4.2.2 NO_2 measured concentrations

Measured concentrations compared to limit value

The data are recorded over period 2005-2007. Data from 14 stations are presented and analyzed. Type of each station is presented in the Table 5.

Five stations are industrial type of stations, seven of them are traffic stations, one is a background rural and one is urban background station. For the period 2005-2007, data was available from seven stations. Data from two years was available from three measurement stations and one year for five measurement stations.

The measurement methods used to measure nitrogen oxides is based on chemiluminescence's, which is the reference method mentioned in the Annex 3 of the Rulebook on criteria, methods and procedures for evaluating the ambient air quality [7].

The devices have been calibrated 2−6 times during the year. Over 5 % of the data had time coverage over 90 % for hourly values, and about 20 % had time coverage less than 50 %. According to results major part of the NO_2 measurement data is beyond acceptable time coverage. According to the Annex 2 of the Rulebook [7], the minimum time coverage for indicative measurements is 14 % and for fixed measurement 90 %.

Limit values of the levels of concentrations, margins of tolerance and terms for achievement of the limit values are given in Table 17 of Annex II within this report.

An hourly mean limit value of 200 μg/m³ NO_2 for the protection of human health may not be exceeded more than 18 times a year. The measurements show that hourly values were exceeded more than 18 times only in 2006 at Rektorat station in Skopje. This station is located on crossroad with high density traffic.

The second threshold level for the protection of human health is the annual limit value of NO_2 (40 μg/m³).

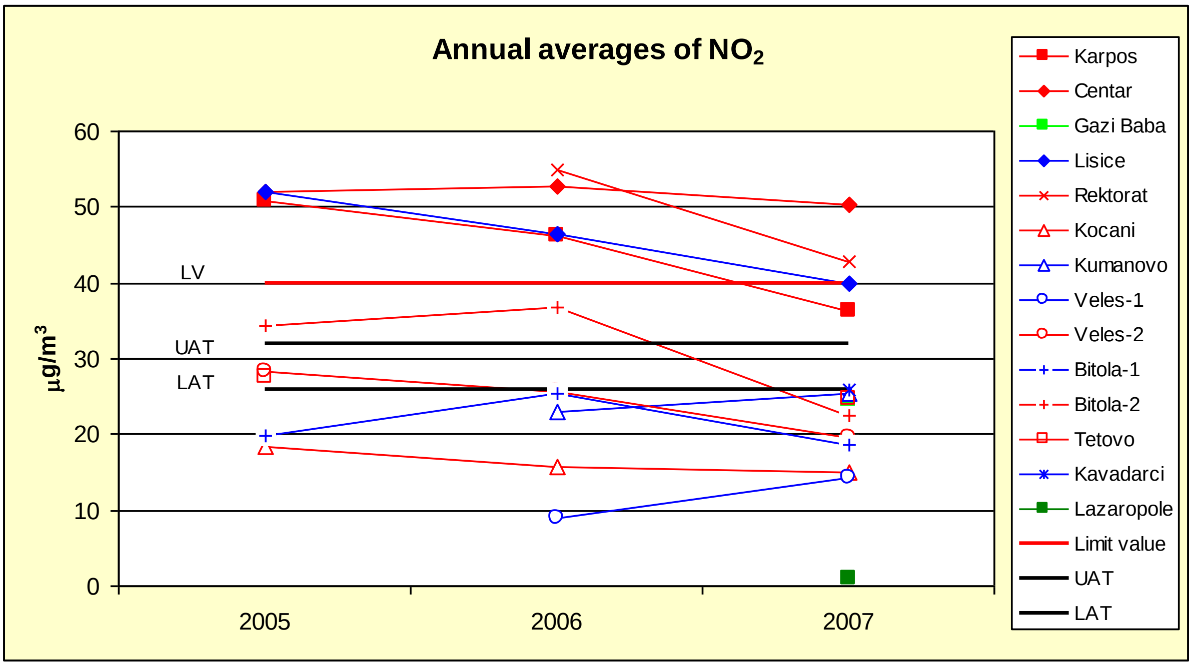

Figure 22 ***Annual averages of NO_2***

As can be seen from Figure 22 annual limit value of NO_2 was exceeded in Skopje (Karpos, Centar, Lisice and Rektorat) over the analyzed period. NO_2 concentrations are highest in Skopje, especially in morning and evening rush hours due to the traffic emissions. The largest city of Republic of Macedonia, Skopje is vulnerable to episodes of high pollutions as the mountains surroundings prevent the pollutions from dispersing to outlying areas. This high emission originates also from power plants.

Measured concentrations compared to assessment thresholds

Examination of measured levels to assessment threshold levels (Table 23 of Annex II) for the limit value for the yearly mean (32 and 26 µg/m³, respectively) shows the upper assessment threshold level in Skopje and Bitola-2 for the period 2005-2006 have been exceeded. In other stations however, no exceedance of the upper assessment threshold level was observed. Limited exceedance of the lower assessment threshold level, but not of the upper assessment threshold level was observed in Tetovo and Veles-2 station in 2005. Figures 23 and 24 shows the number of excedances of UAT and LAT of NO_2 hourly data.

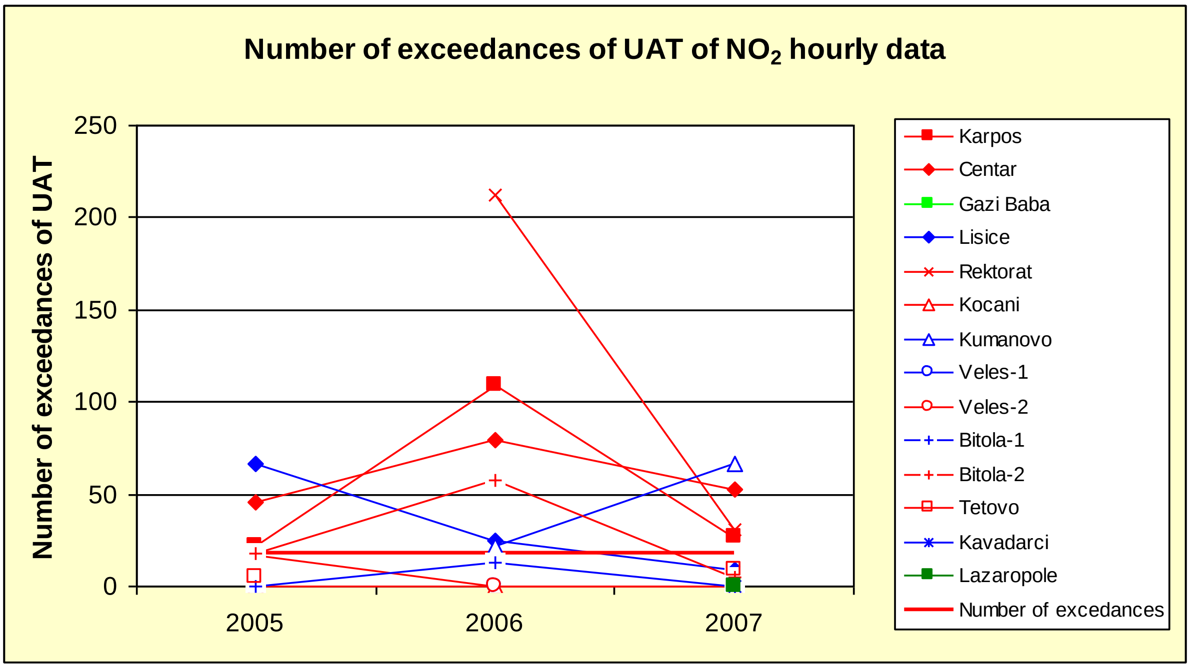

Figure 23: ***Number of exceedances of UAT of NO₂ hourly averages***

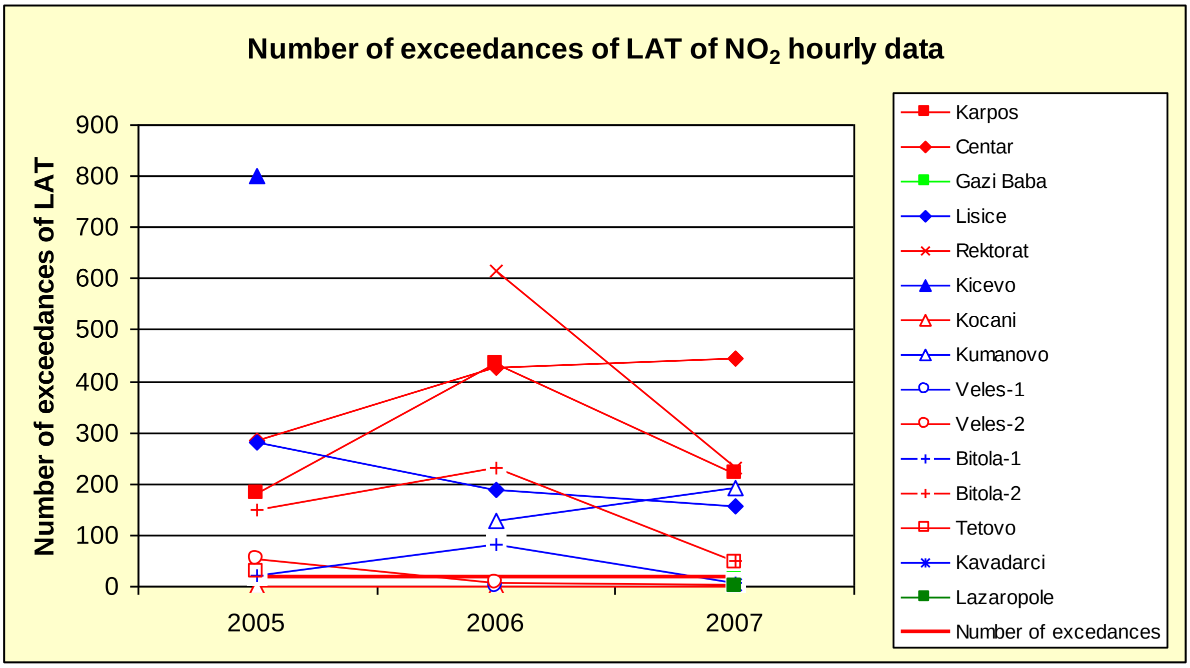

Figure 24: ***Number of exceedances of LAT of NO_2 hourly averages***

NO_2 levels were related to assessment threshold levels of limit values for the hourly means (100 and 140 μg/m³, respectively). This UAT and LAT may not be exceeded more than 18 times per year. The upper assessment threshold level for limit values for the hourly mean were exceeded in the capital Skopje, Kumanovo (2006-2007) and Bitola-2 (2006) station. The NO_2 emissions most probably originate from traffic especially in Skopje and Kumanovo where the traffic characteristics are frequency of heavy vehicles and trailers. Exceedances of the lower assessment threshold level have been observed everywhere except Kocani, Kavadarci and Lazaropole . In Veles excedances of LAT were observed only in 2005 at Veles-2 station.

4.2.3 Dispersion modeling

For the model calculations an hourly emission time series for NOx emissions of the year 2005 for Okta stationary source were created. The emission and technical data was collected from the Cadastre database. The emissions from two sources were included in the calculations. The emission and other technical data used in the modeling are shown in the Table 9.

Meteorological time series for used in the dispersion modeling of NOx was already described above for SO_2 model (see paragraph 4.1.3).

Table 9: ***Emission of NOx and other data of Okta oil refinery used in model calculation***

Input data	Stack 1	Stack 2
Average NOx emission (g/s)	6.93	3.07
Annual NOx emission (t/a)	202.8	89.9
Outflow of gases (Nm^3/h)	173,13	40945
Temperature of gases(C)	185	200
Height of the stack (m)	150	80
Inner diameter of the stack (m)	4,05	3,05
Hours of operation (h/a)	8136	8136

Results of dispersion calculations are presented in Figures 26 and 27. Quantities presented in the isopleths presentations are those comparable to the EU limit values for NO_2. Locations of maximum concentrations are presented with white stars.

The highest modeled nitrogen oxides caused by the atmospheric emissions from Okta oil refinery are shown in the Table 10. These values are the highest concentrations calculated to single points for the period 2005. The concentrations are significantly lower most of the time on these and other receptor points.

The highest NO_2 annual average concentration of the study area is 0.03 µg/m³ (limit value 40 µg/m³) and the highest NOx annual average concentration 0.3 µg/m³ (limit value 30 µg/m³). The 19th highest NO2 hourly concentration 1.0 µg/m³ (limit value 200 µg/m³).

Table 10: ***The highest NOx concentration of the study area***

Parametars	Limit value	NO_2 and NOx concentration (mg/m^3)
Annual average (NOx)	30	0,3
Annual average (NO_2)	40	0,03
Highest daily average (NO_2)		0,6
Highest hourly average (NO_2)		2,6
19th highest hourly average(NO_2)	200	1

In Figure 25 the highest concentrations of NO_2 and NOx are compared to the air quality limit values. NO_2 concentrations are at the most 0.08 % of the limit value for NO_2 annual average concentration, 1 % of the limit value for NOx annual average concentration and 0.5 % of the limit value for NO_2 19th highest hourly concentration limit value.

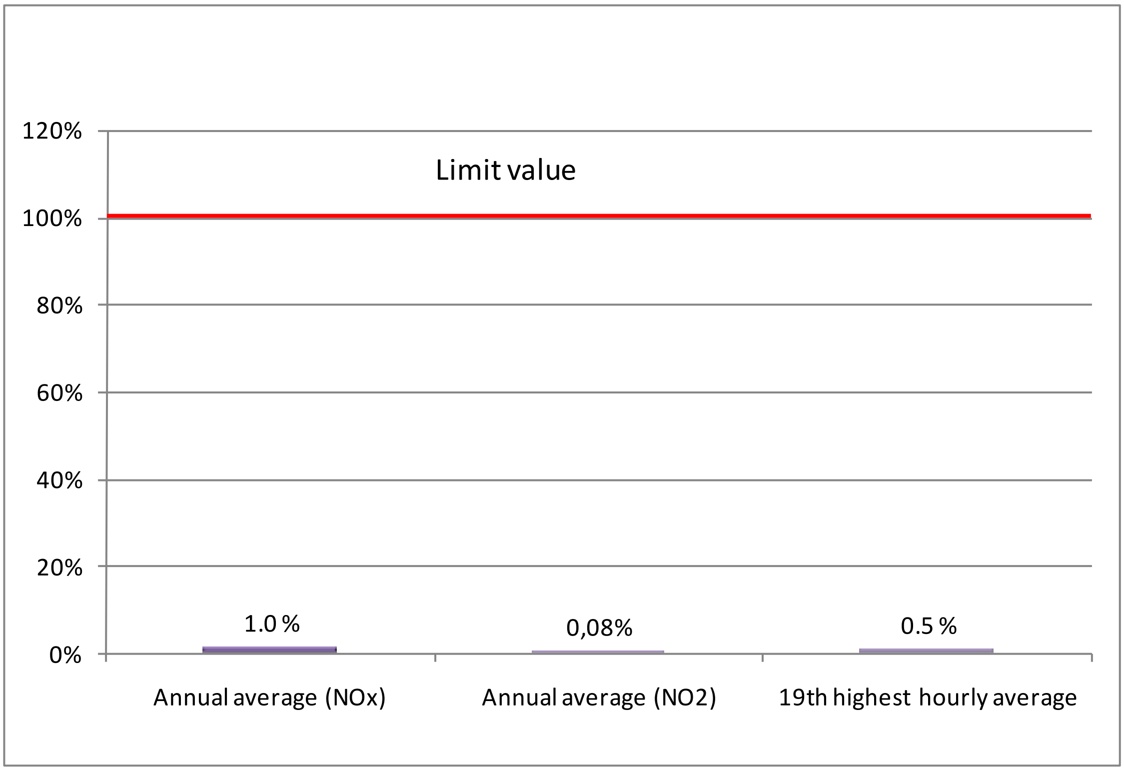

Figure 25: ***The highest NOx concentrations compared to air quality limit values***

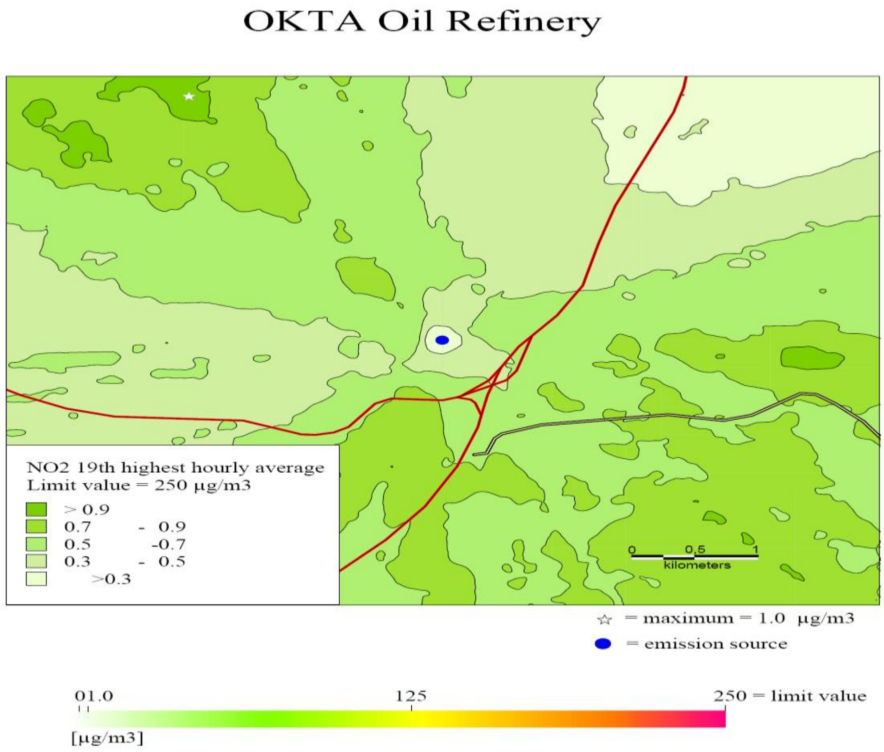

Figure 26: ***19th highest hourly NO_2 concentration $\mu g/m^3$***

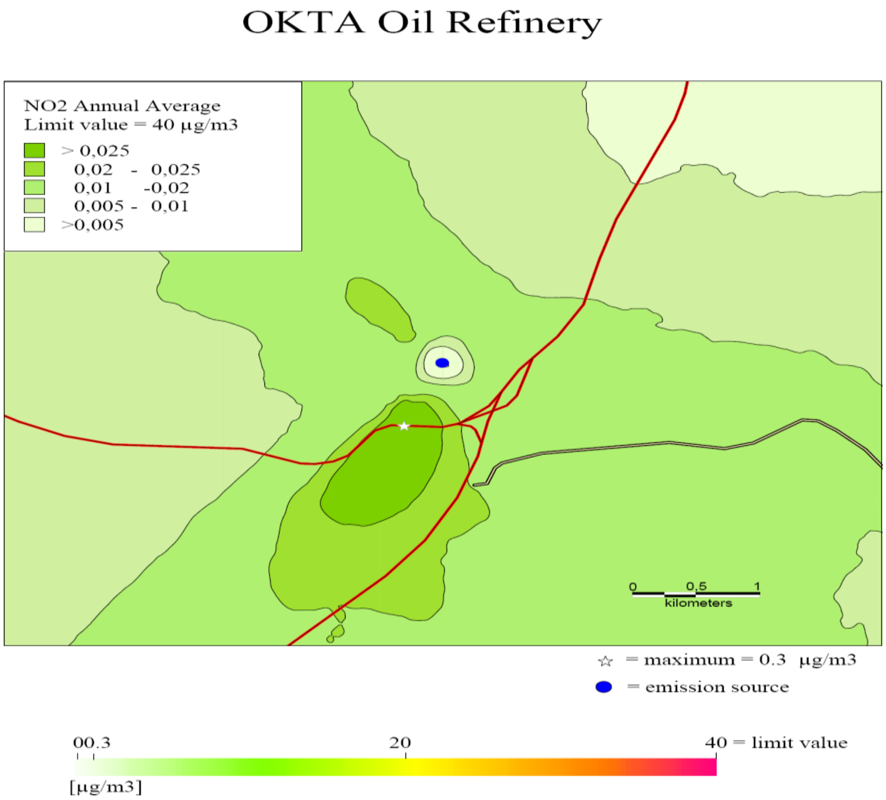

Figure 27: ***Annual Average of NO_2 concentration $\mu g/m^3$***

As the main stack of the oil refinery is high (150 meters) the concentrations on the ground in the vicinity of the plant will be quite low and the maximum concentration occurs from approximately one kilometre to several kilometers from the stack position. According to the dispersion modeling calculations the most probable direction of the highest ground surface concentrations would be to the southwest or northwest of the plant location. According to the dispersion model results the NO_2 and NOx concentrations due to emissions of the oil refinery used in the modeling study are sufficiently low on the ground surface to meet the EU air quality limit values.

4.3 Particle matter ≤ 10 micron (PM10) and total suspended particulate (TSP)

4.3.1 Emissions

Trend of the annual mean TSP concentrations calculated from the available data in the period 2002-2006 is shown on Figure 28.

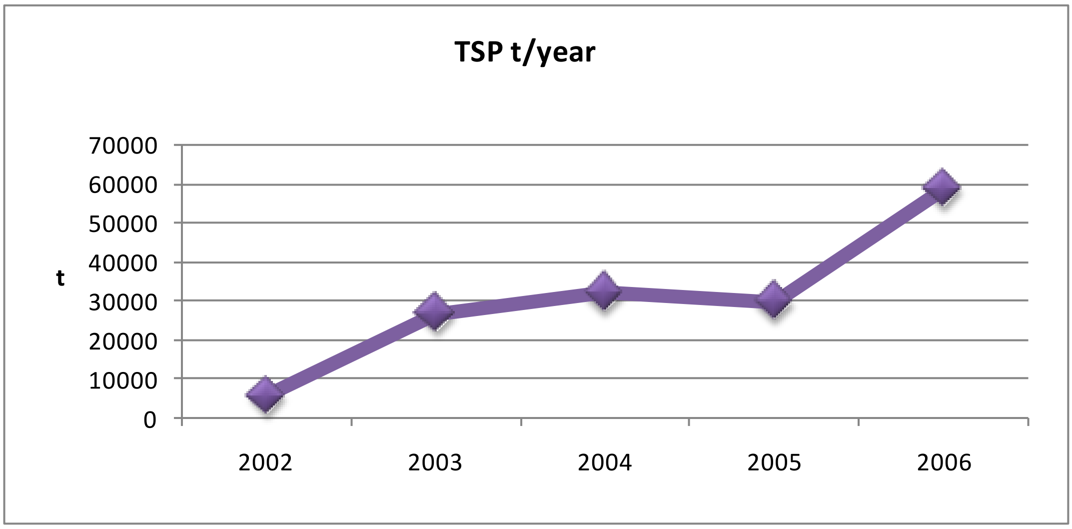

Figure 28: ***Trend of TSP emissions in the period 2002-2006***

The trend analysis of the emissions of total suspended particles shows that in the period 2002-2006 there is a continuous increase of the emission amounts per year. This is in correlation with the increasing trend of the other pollutants, and it is mainly due to the emissions from separate point sources (Silmak) and also as a result of usage of low quality fuel. Lower emissions of this pollutant during period 2001-2003 are due to the fact that this factory was closed. Reopening of this factory and higher production contribute to higher concentration of TSP in 2004-2006 period.

The percentage of TSP emissions according the SNAP nomenclature from the emission inventory is presented on Figure 29.

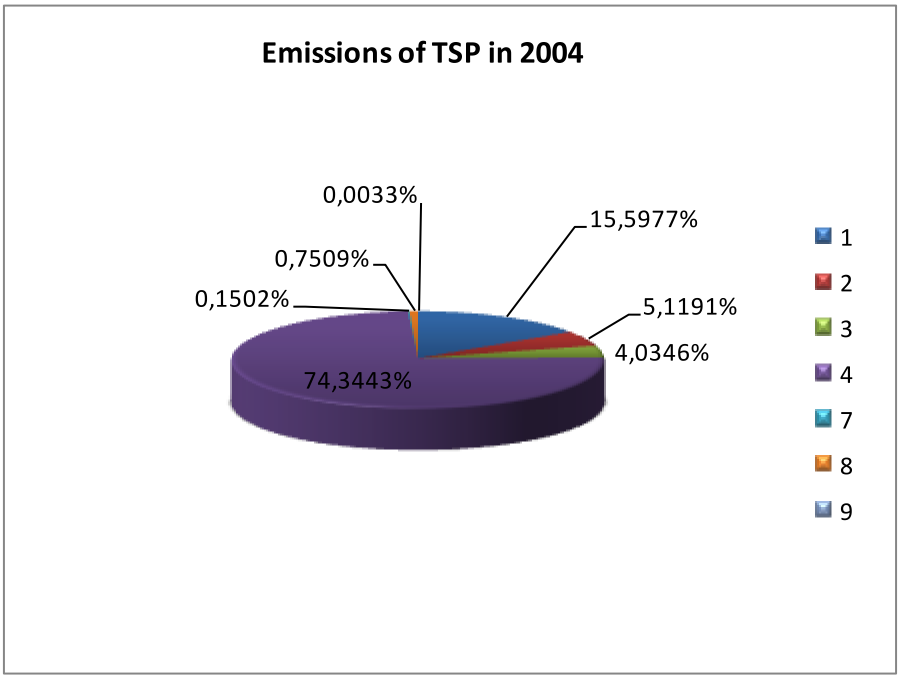

Figure 29: ***Contribution of TSP emission in 2004 per SNAP sector***

The biggest portion from the TSP emissions in the air according to SNAP nomenclature is identified in Sector 4 – Production and the energy sector. The first sector represents the energy production where during the combustion processes of brown coal TSP is emitted.

The largest amount of TSP emissions comes out from the production of Ferro - Siliceous alloy. This can be shown on the following map where Point emission source data from year 2004 from the Cadastre are presented.

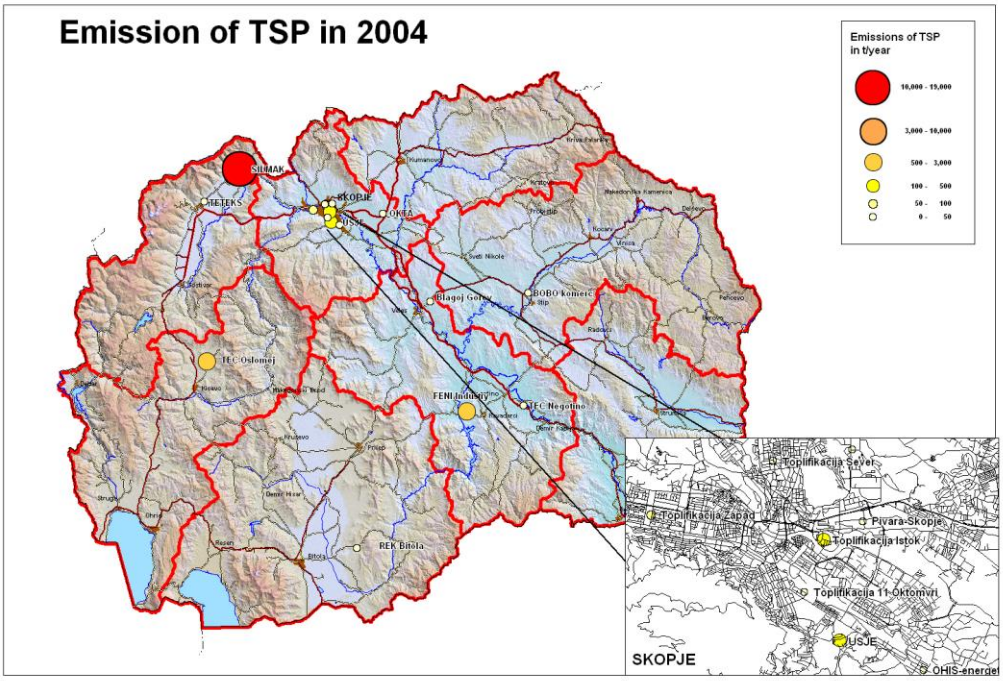

Figure 30: ***Emissions of TSP from major point sources in 2004 from Cadastre data***

The next figure confirms the fact that the stationary sources as well as the fugitive emissions are the largest emitters of particulates in the air. The traffic portion is very small and it is mostly due to the usage of liquid diesel fuel.

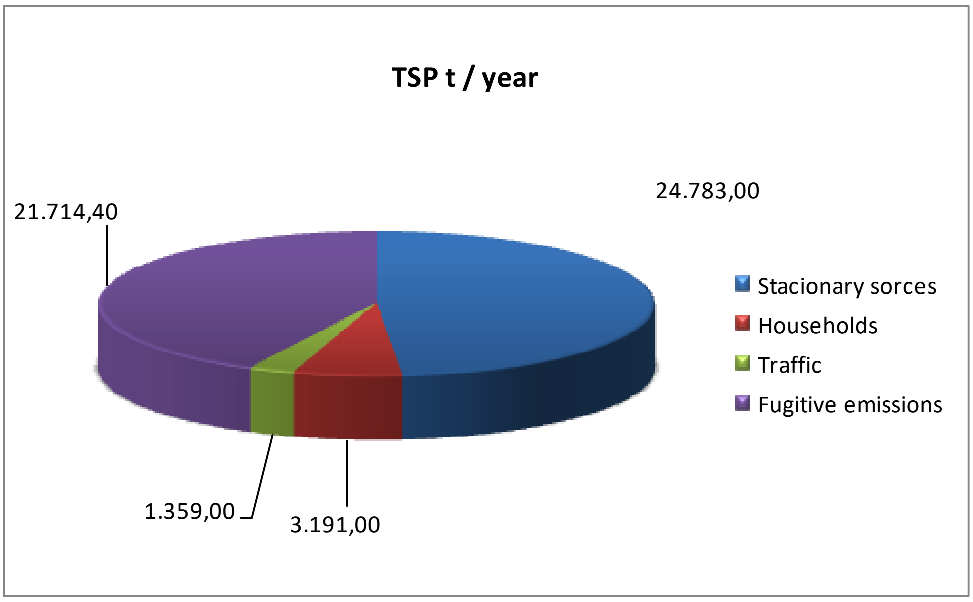

Figure 31: ***Participation of different sources in the TSP emissions***

4.3.2 PM10 measured concentrations

Measured concentrations compared to limit values

The data are recorded over period 2005-2007. Data from 14 stations are presented and analyzed. Type of each station is presented in the Table 5.

Seven stations are industrial type of stations, six of them are traffic stations, and one is a background rural. For the period 2005-2007, data was available from nine stations. Data from two years was available from two measurement stations and one year for three measurement stations.

The measurement methods used to measure PM10 are based on continues measurements with Beta Attenuation: x-Ray Absorption in Matter. The devices have been calibrated 2−6 times during the year. Around 30 % of the data had time coverage over 90 % for hourly values, and about 16 % had time coverage less than 50 %. According to the results, major part of the PM10 measurement data is beyond acceptable time coverage. According to the Annex 2 of the Rulebook [7], the minimum time coverage for indicative measurements is 14% and for fixed measurement 90%. For PM10, examination to limit values takes place against daily and yearly means.

Daily mean (50 $\mu g/m^3$) for the measurement period is exceeded everywhere except in Lazaropole for more than 35 days.

The annual averages of PM10 concentrations for period 2005-2007 is presented on following figure.

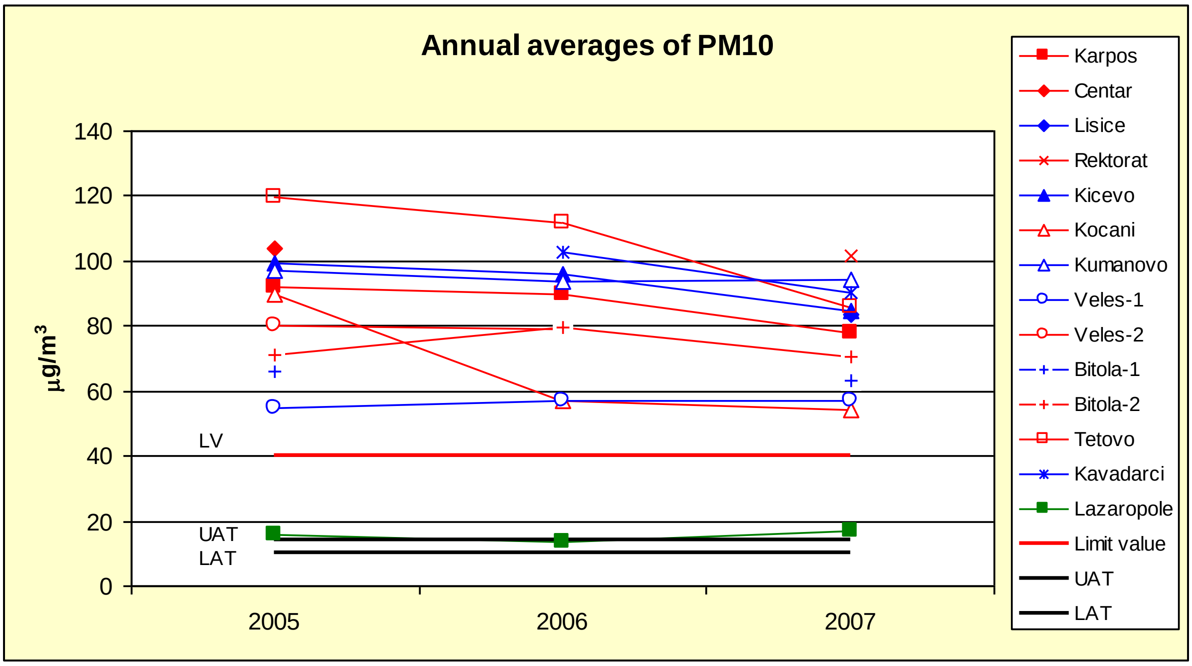

Figure 32 ***Annual averages of PM10***

As it can be seen from Figure 32, the annual limit value of 40 μg/m³ (Table 18 of Annex II) was exceeded everywhere except in Lazaropole. PM10 originates from motor vehicle exhaust gases and as dust rising from unpaved surfaces. High particulate emissions are also generated from small scale wood combustion in residential heating. Particularly, toxic chemicals are emitted through uncontrolled burning of household waste (i.e. backyard burning) which is common in Republic of Macedonia. The highest values of PM10 are registered in the winter period. During calm cold winter days, the meteorological situation called inversion causes episodes of high concentrations of this pollutant.

Measured concentrations compared to assessment thresholds

For PM10, examination to assessment threshold levels for limit values takes place against daily and yearly means. The respective assessment threshold levels are 30 μg/m³ and 20 μg/m³ (daily mean) and 14 and 10 μg/m³ (yearly mean). Examination of measured levels to assessment threshold levels for the limit value for the yearly mean shows that the upper assessment threshold level for the period 2005-2006 have been exceeded everywhere except Lazaropole, and the lower assessment threshold have been exceeded in all measurement stations.

UAT and LAT for daily limit value (Table 24 of Annex II) may not be exceeded more than 7 times a year. The number of exceedances shows that daily values were exceeded more than 7 times everywhere including Lazaropole.

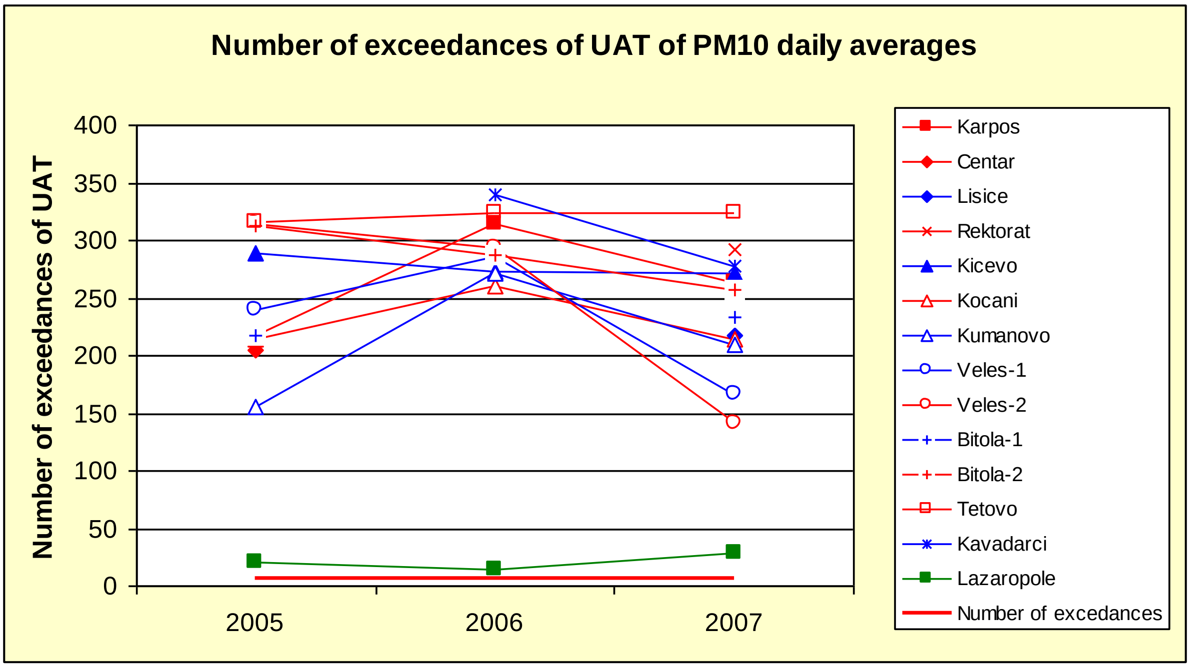

Figure 33 ***Number of exceedances of UAT of PM_{10} daily averages***

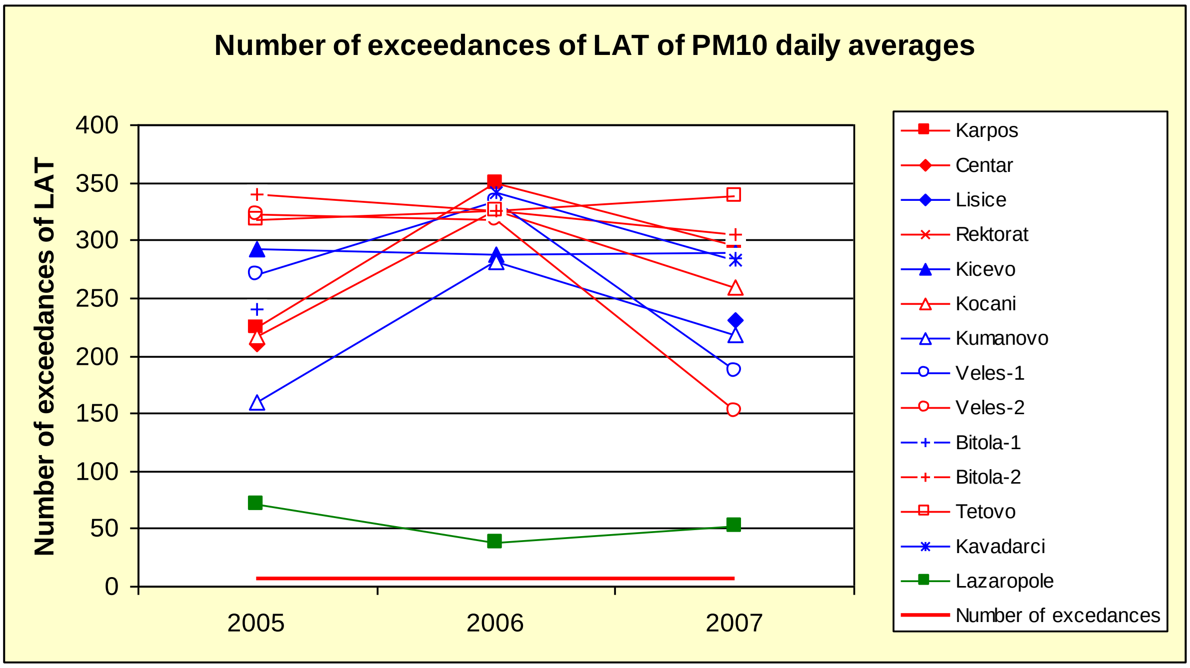

Figure 34 ***Number of exceedances of LAT of PM_{10} daily average***

4.4 Carbon monoxide (CO)

4.4.1 Emissions

The trend analysis of the emissions of carbon monoxide (Figure 35) shows that in the period from 2002 to 2006 there is a continuous increase of the emission amounts per year. This is in correlation with the increasing trend of the nitro oxides and it is expected. Mainly this trend is due to the inappropriate combustion especially of the vehicle fuels. Also, the work of the boilers is increased, especially of those that use heavy oil or other fuels. Similar is the effect of the transport as result of usage of low quality liquid fuels. Also there is an increasing of the old vehicle import that has low ecological standards.

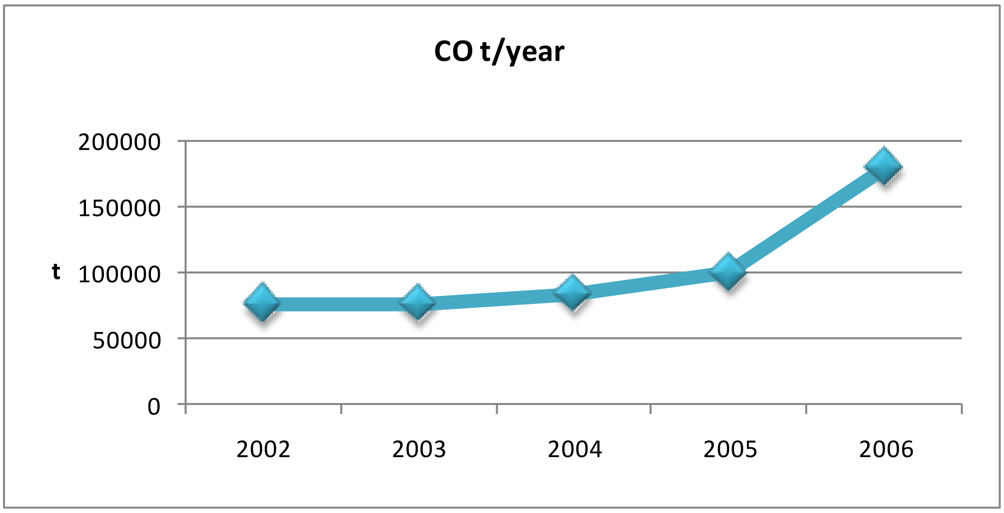

Figure 35 ***Trend of CO emissions in the period 2002-2006***

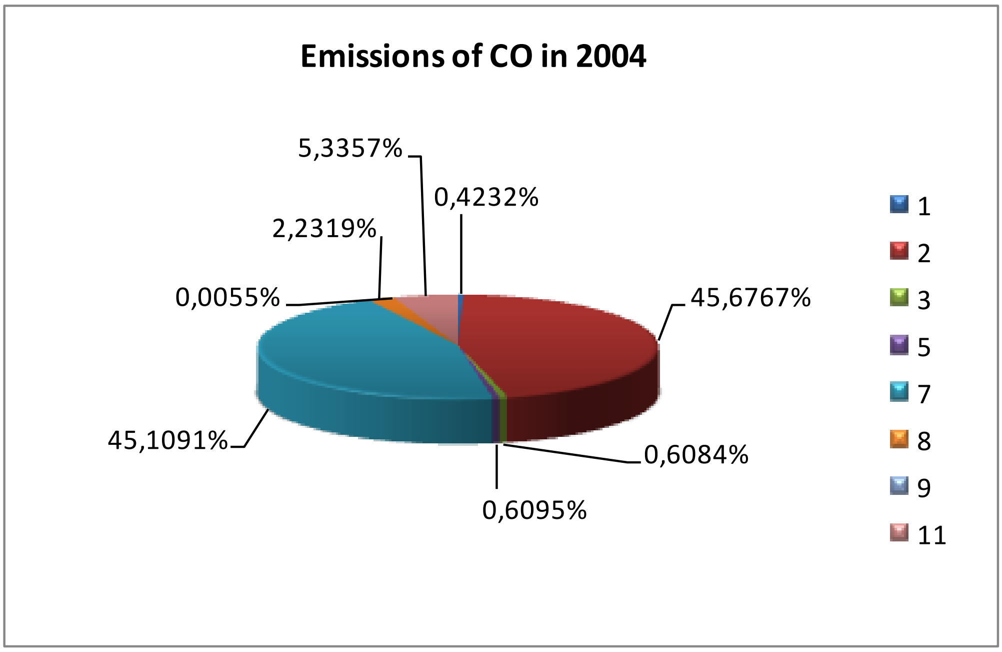

Figure 36: ***Contribution of CO emission in 2004 per SNAP sector***

The greatest impact in the CO emissions pollution have sectors 2 and 7 that are related to the non-industrial combustion sources (for example uses of coal for the heating of different non productive institutions like schools, hospitals) and the transport.

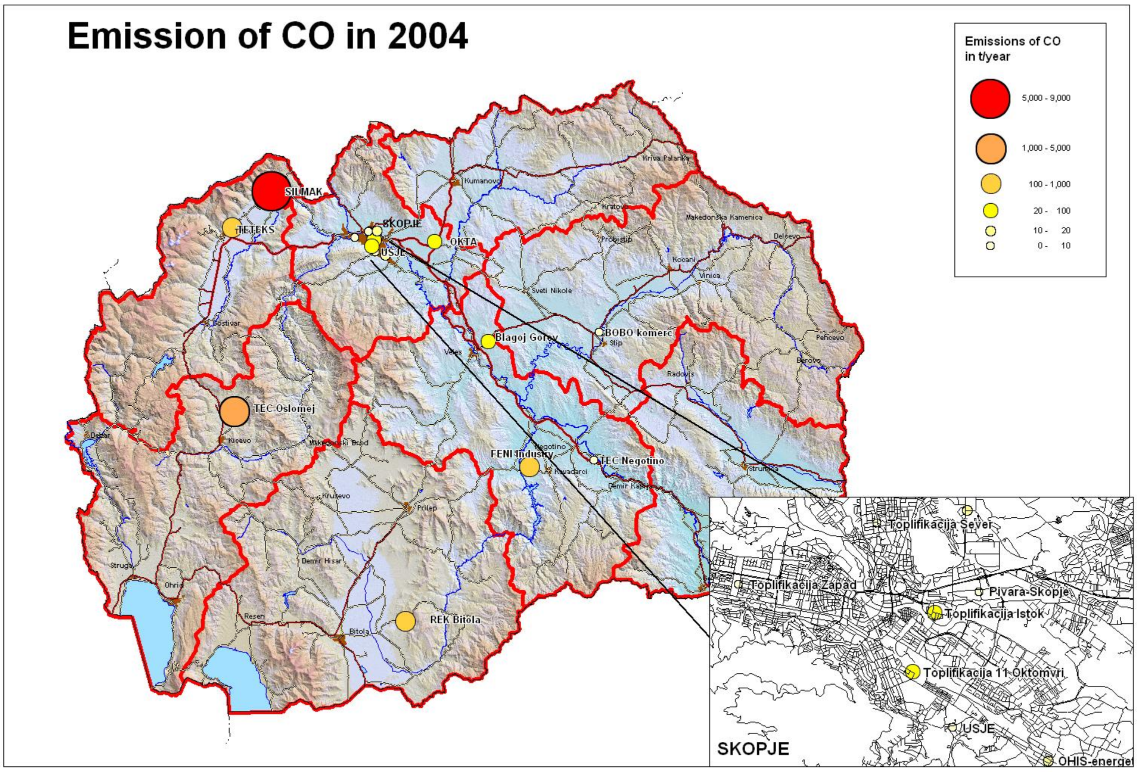

Figure 37: ***Emissions of CO from major point sources in 2004 from Cadastre data***

The analysis on the map shows that the largest amount of emissions from stationary sources is recorded during the electricity production – brown coal combustion.

The following figure confirms the fact that the CO emission come from household heating during the winter period (most probably wood burning), from traffic and from stationary sources.

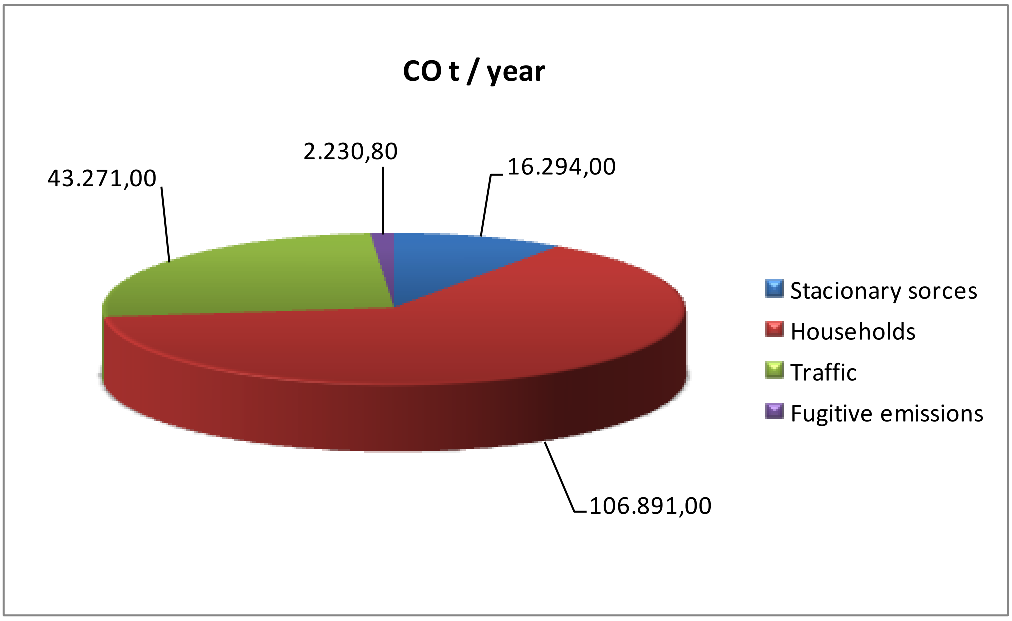

Figure 38: ***Participation of different sources in the CO emissions***

4.4.2 Measured concentrations

Measured concentrations compared to limit value

The data are recorded over period 2005-2007. Data from 14 stations are presented and analyzed. Type of each station is presented in the Table 5.

Seven stations are industrial type of stations, six of them are traffic stations, and one is a urban background station. For the period 2005-2007, data was available from twelve stations. Data for two years was available from two measurement stations and one year for one measurement station.

The measurement methods used to measure CO are based on non-dispersive infrared absorption. The devices have been calibrated 2−6 times during the year. Around 24 % of the data had time coverage over 90 % for hourly values, and about 1 % had time coverage less than 50 %. According to the results major part of the CO measurement data is beyond acceptable time coverage. According to the Annex 2 (2) of Rulebook [7], the minimum time coverage for indicative measurements is 14 % and for fixed measurement 90 %.

Maximum 8-hour daily limit value for protection of human health for CO is 10 mg/m^3(Table 19 of Annex II). For the analyzed period exceedances of the limit value were observed in Skopje and Bitola-2 station. Exceedances of this pollutant in the biggest cities in R. Macedonia are due to emission of CO through motor vehicle exhaust systems and other combustion processes.

Measured concentrations compared to assessment thresholds

For CO, examination to assessment threshold levels for limit values takes place against 8-hour daily limit value. The respective assessment threshold levels are 7 for UAT and 5 mg/m³ for LAT (Table 25 of Annex II).

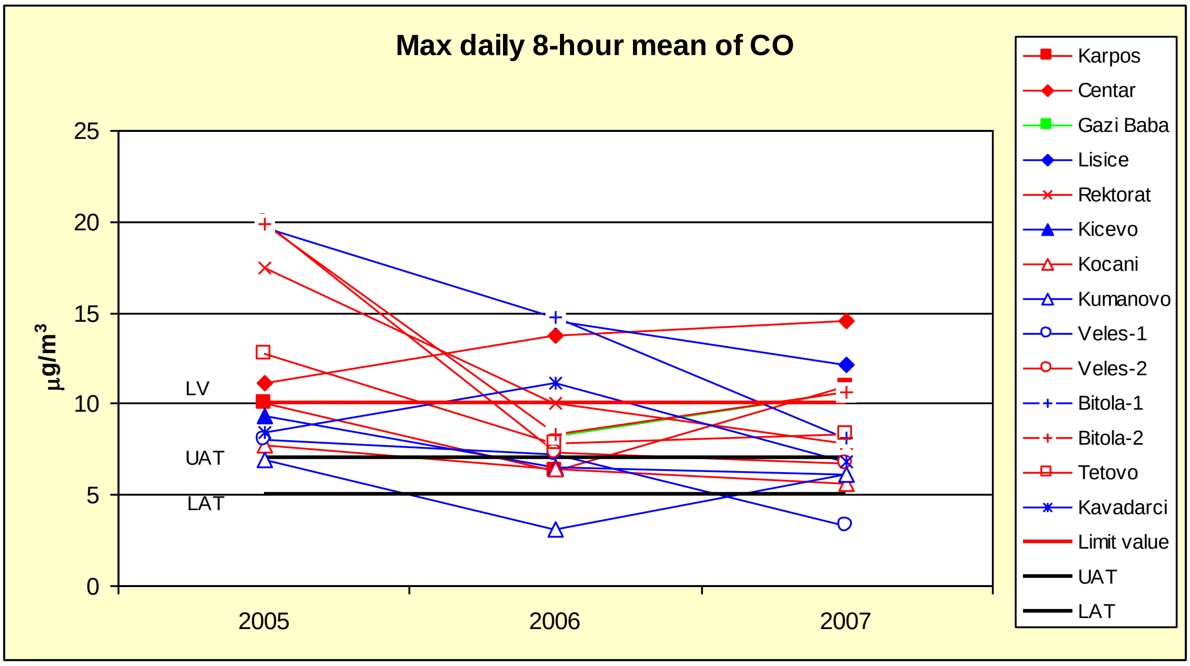

Figure 39: ***Max daily 8-hour mean of CO***

Exceedances of LAT and UAT must be determined on the basis of concentrations during the previous five years where sufficient data are available. In our case the assessment was preformed for threshold for the previous three years. For the whole analyzed period data were not available only for three stations (Gazi Baba, Rektorat and Kavadarci). The upper assessment threshold was continuously exceeded during the three years period in Skopje stations (Centar and Lisice) and in Bitola and Tetovo. The lower assessment threshold was exceeded everywhere during the period of previous three years where sufficient data are available.

4.5 Ozone

4.5.1 Measured concentrations

Measured concentrations compared to target values, long term objectives, information and alert threshold

The data are recorded over period 2005-2007. Data from 14 stations are presented and analyzed. Type of each station is presented in the Table 5.

Seven stations are industrial type of stations, six of them are traffic stations, and one is an urban background. For the period 2005-2007, data was available from 13 stations.

The measurement methods used to measure O_3 are based on photometric UV Absorption. The devices have been calibrated 2−6 times during the year. Around 40 % of the data had time coverage over 90 % for hourly values, and about 2 % had time coverage less than 50 %. According to the results major part of the O_3 measurement data is beyond acceptable time coverage. According to the Annex 2 (3) Rulebook [7], the minimum time coverage for indicative measurements is 14 % and for fixed measurement 90 %.

Target value for protection of human health for O_3 (Table 20 of Annex II) is 120 $\mu g/m^3$ and cannot be exceeded more than 25 days in one calendar year, with averages calculated for the period of three years. For the analyzed period exceedances of the target value were observed in Tetovo, Bitola, Veles, Kumanovo and Lazaropole. Target value for protection of vegetation for ozone O_3 is 18000 $\mu g/m^3$ h average value calculated in the course of five years. Exceedances of target value for protection of vegetation were observed in the same measurement locations as for the target value for protection of human health.

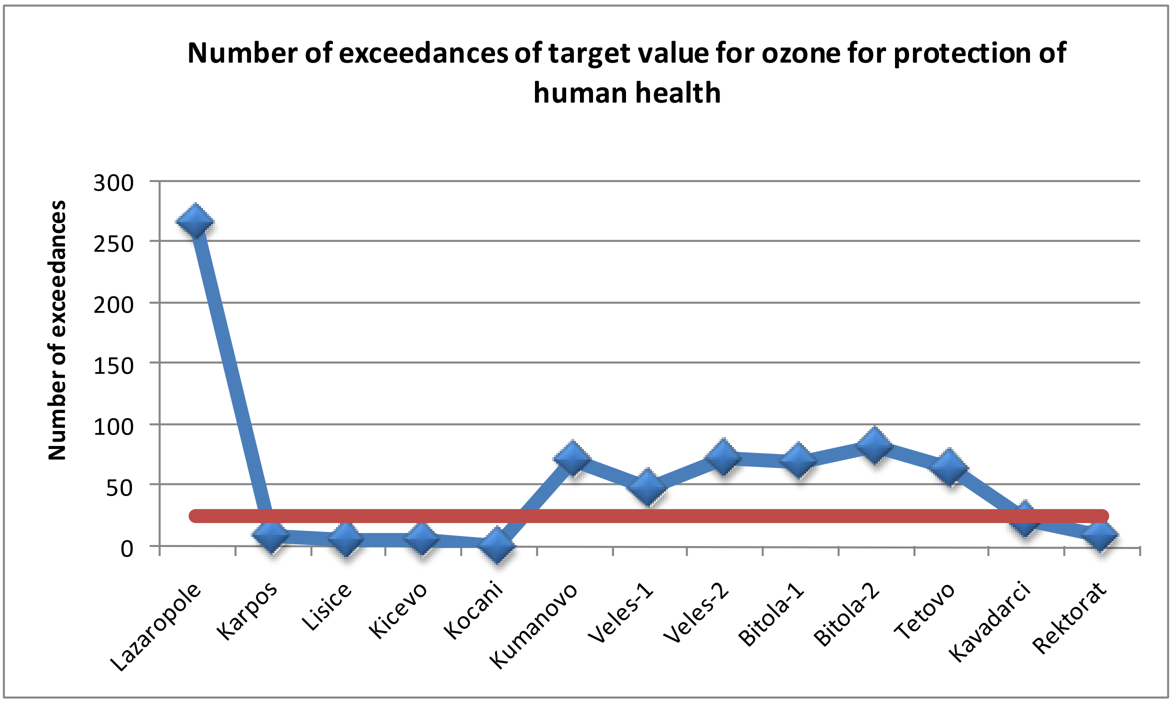

Figure 40: ***Number of exceedances of target value for ozone of human health protection***

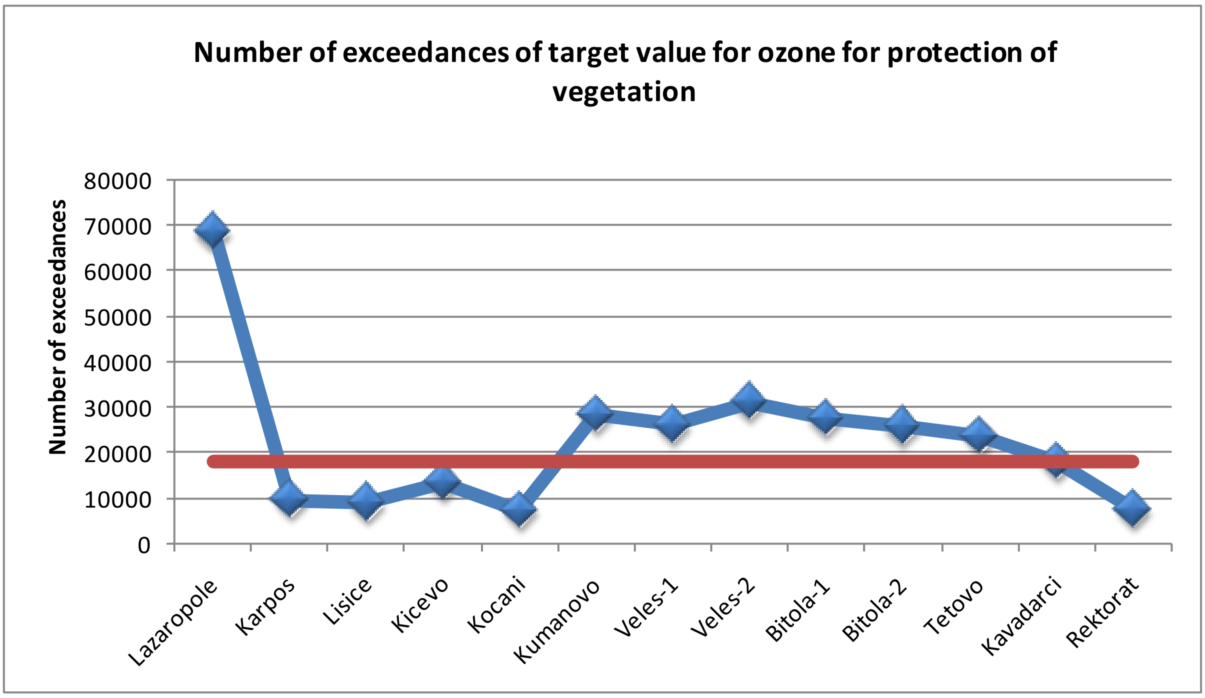

Figure 41: ***Number of exceedances of target value for ozone for the protection of vegetation***

The long-term objectives for ozone concentrations in ambient air are determinated for protection of the human health and protection of the vegetation (Table 21 of Annex II). The maximum ozone daily 8 hour average value during one calendar year for protection of human health is 120 μg/m^3. AOT40 value for protection of vegetation calculated from the hourly values in the period May-July is 6000 μg/m^3 h.

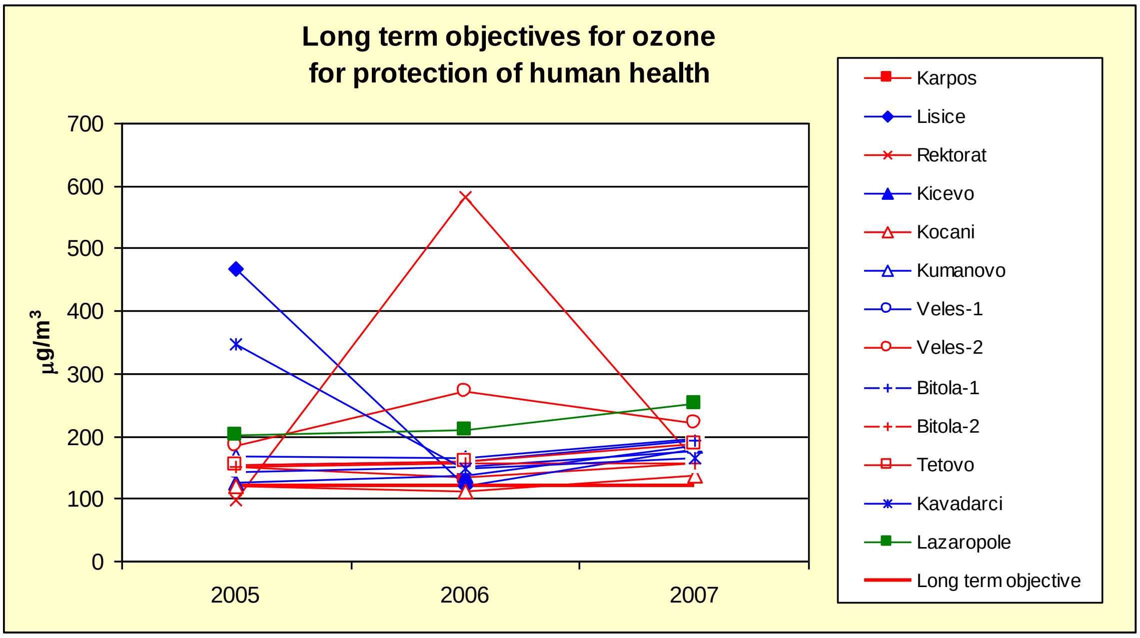

Figure 42: ***Long term objectives for ozone for protection of human health***

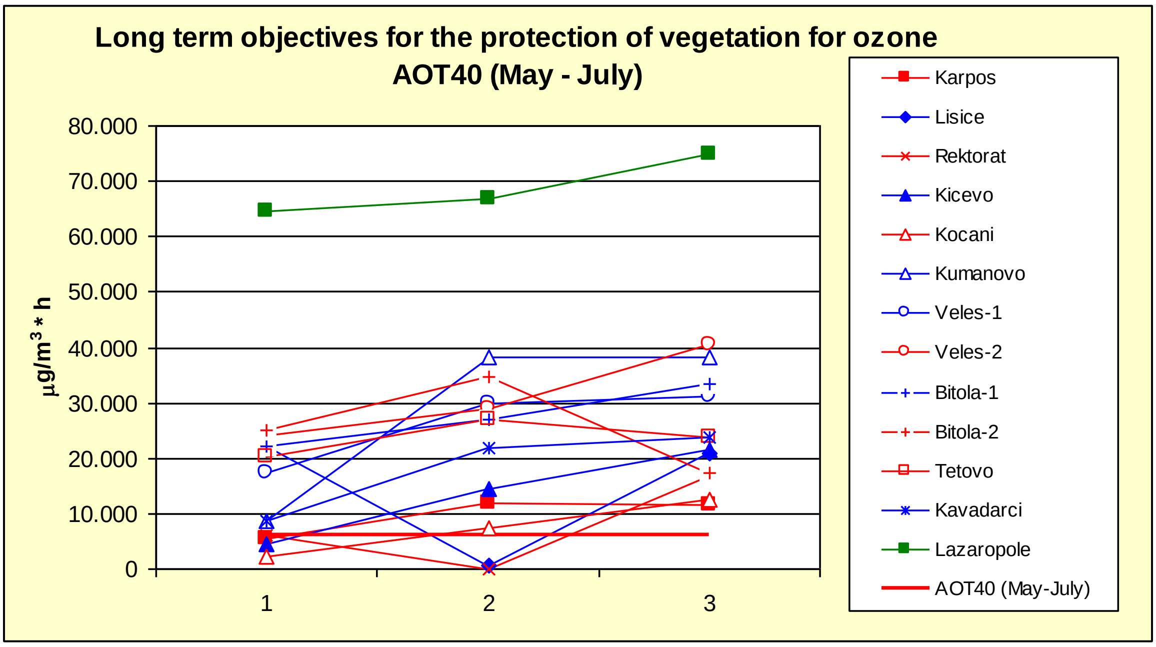

Figure 43: ***Long term objectives for the protection of vegetation for ozone AOT40***

As can be seen from Figure 42 and 43, long-term objectives for ozone concentrations in ambient air for protection of human health was exceeded everywhere. The AOT40 value for protection of vegetation was exceeded everywhere in the analyzed period except in 2006 in Lisice and Rektorat and 2005 in Kicevo and Kocani.

Regarding information threshold (180 µg/m^3) and alert threshold (240 µg/m^3) exceedances of these values were observed in Lazarople especially in summer periods. Higher concentrations of ozone in this rural area are due to the higher concentrations of hydrocarbons emitted from the forests, which participate in the photochemical reactions for ozone formation.

5. Zones and agglomerations

According to CARDS 2004 proposal, seven zones and one agglomeration were designated according to the administrative distribution of the following statistical regions borders. Nevertheless, the Air quality situation did not support this zoning easy to designate Good solution for Air Quality Management (action plans have to cover small areas, easy to set responsibilities) because of the considerable heavy measurement and reporting obligations.

In the frame of the Twinning project, the new proposal for establishment of zones and agglomerations in Republic of Macedonia have been given and accepted.

According to this proposal two zones and one agglomeration were defined in Republic of Macedonia on the basis of the differences in the air quality.

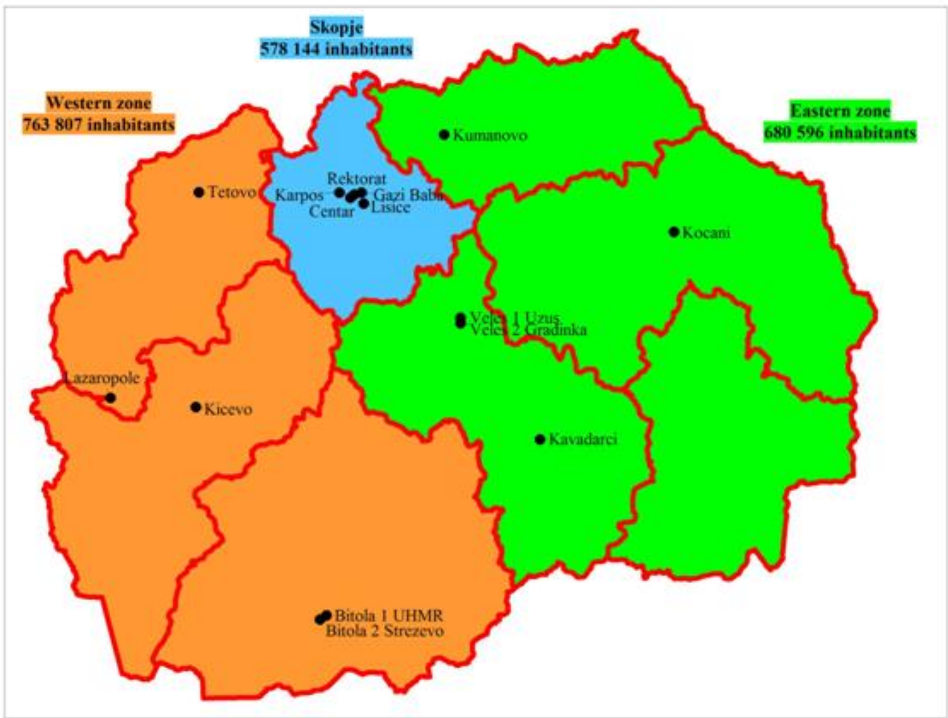

Figure 44: ***Zones and agglomeration in Republic of Macedonia***

The zones are defined as: Western zone (South west, Polog and Pelagonija statistical region) and Eastern zone (North east, South east, Vardar and East statistical region) and one agglomeration Skopje (Skopje statistical region).

Table 11: ***Basic data per zone***

Zone	Number of business entities	Population	Area/m^2	Density / number of inhabitant per m^2
Eastern zone	789	680596,00	13182,51	51,63
Western zone	595	763807,00	10476,30	72,91
Skopje-agglomeration	276	578144,00	1717,70	334,25

It can be seen from Table 11 that the Eastern zone represents the largest area, with highest population, but Skopje agglomeration has a high population density with a lot of urban areas in a relatively small surface area. Nevertheless, attention should be paid explicitly to these areas, because of the large number of people living in urban locations.

The minimum and current number of stations per pollutant and per zone is given on the following tables:

Table 12: ***Current number of stations per pollutant and per zone***

Zone	Inhabitants	SO_2	NO_2	NOx	PM10	CO	O_3
Skopje	578 144	4	5	5	5	5	3
Eastern	680 596	5	5	5	5	5	5
Western	763 807	5	5	5	5	4	5
	Total	14	**15**	**15**	**15**	**14**	**13**

Table 13: ***Minimum number of stations per pollutant and per zone***

Zone	Inhabitants		SO_2	NO_2	NOx	PM10	CO	O_3
		health	**ecosystem**	**health**	**ecosystem**			
Skopje	578 144	2	0	2	0	2	2	2
Eastern	680 596	2	1	2	1	2	2	2
Western	763 807	3		3		3	3	2
	Total	**7**	**1**	**7**	**1**	**7**	**7**	**6**

On the basis of number of stations required for the number of inhabitants, minimally one station will have to record city background levels and minimally one will have to focus on traffic for the cases where the concentration of particulate matter or nitrogen dioxide in one zone or agglomeration is found above the upper assessment threshold level. This applies to all zones and agglomerations for particulate matter and nitrogen dioxide. Regarding ozone at least 1 station should be located in suburban areas, where the highest exposure of the population is likely to occur. In agglomerations at least 50 % of the stations should be located in suburban areas.

The current station set will therefore have to be extended according to the following scheme for the proposal:

- Skopje agglomeration: the agglomeration gets 1 station in suburban areas for ozone measurements;
- the Eastern zone gets 1 urban background stations for particulate matter and nitrogen oxide and 1 station located in suburban area for ozone measurements;
- The Western zone gets 1 urban background stations for particulate matter and one for nitrogen oxide.

Taken into account this proposal, totally 2 new stations (urban background) for nitrogen dioxide, PM10 and ozone are needed.

Nevertheless, the given number of monitoring stations serves as an indication when using only measurements to describe the air quality. In this sense, they can be considered as minimum numbers. Every country is free to set up more than this number of monitoring stations.

Adding additional instruments, like models, to describe air quality can, however, lead to a reduction in the given number of monitoring stations. The use of models can also contribute to a more accurate description of air quality in urban areas. UDM –FMI model was used for simulation of air quality only in Skopje agglomeration. Some examples were shown in the previous chapter.

The recommendation is to use good quality emission and other technical input data is essential for achieving reliable results from the modeling. However, it is essential that the input data is checked before modeling by an emission expert to decrease the possibility of errors in the data.

6. Discussion

Chapter 4 has supplied data on the quality of SO_2, NO_2, NOx, CO, O3, PM10, and TSP in air in Republic of Macedonia. These results can be used as an aid for appointing a regime to the assessment of the air quality in the zones and agglomerations, also mentioned in Chapter 5. However, besides monitoring data, the emission trends and emission data from the Cadastre [2] and the CORINAIR [3] in Republic of Macedonia could be considered as well.

In the future when the modeling technique is further developed, this source of information may also be used in creating a definition of an assessment regime for a zone or agglomeration. The regime classification used in this chapter is outlined in 3.1.2.

Table 14: ***Assessment regime in zones and agglomerations***

Agglomeration/Zone	SO_2	NO_2	PM10	CO	O_3
Agglomeration					
Skopje	1	1	1	1	1
Zone					
Eastern	1	1	1	1	1
Western	1	1	1	1	1

6.1 Sulphur dioxide (SO_2)

Regarding SO_2, Skopje agglomeration and the two defined zones have been assigned assessment regime 1, based on the measuring data.

In Chapter 4.1.2 measurements of sulphur dioxide from 2005-2007 were tested against the upper and lower assessment thresholds of the limit value for the daily mean. The upper assessment threshold level (where exceedance is allowed for a maximum of six days in three years) was found to be exceeded at Skopje agglomeration on the following monitoring stations Karpos, Centar and Lisice. In the eastern zone UAT was exceeded more than 6 times in Veles-1 and Kavadarci stations. These stations function to measure the pollution of the local industrial sources. In the western zone the upper threshold level is exceeded only in Tetovo station, but the LAT is exceeded in all industrial stations like Tetovo, Bitola-1 and Kicevo. No exceedances have occurred in Lazaropole. This station functioned as a rural background monitor and should therefore not be seen as a representative regional monitoring station.

According to the emission data (Fig.9) it can be noticed that the biggest percent of 91.14 % of sulphur dioxide belongs to the first sector which is transformation and energy production. The major sources in Skopje agglomeration are heating plant Toplifikacija-West, oil refinery OKTA and traffic. Because of the smaller area of the agglomeration, substantial number of people per 1 km^2 (see Table 11), are exposed to SO_2 emissions derived from large stationary sources.

In the western zone, sulphur dioxide levels expressed in t/year are higher due to the presence of local sources REC Bitola and TEC Oslomej. In this zone, higher concentration levels are found in the surroundings of the stationary sources caused by their increasing influence. Major sources in the Eastern zone are TEC Negotino and Feni industry-Kavadarci.

6.2 Nitrogen dioxide (NO_2) and nitrogen oxides (NOx)

As can be seen from Table 14, regarding NO_2, Skopje agglomeration and the both zones have been assigned assessment regime 1, based on the testing of air quality measuring data and experts' judgment.

In section 4.2,2 the monitoring data for nitrogen dioxide between 2004 and 2006 have also been tested on the lower and upper assessment threshold level values of the limit value for the hourly mean (100 and 140 $\mu g/m^3$). The upper threshold level is exceeded more than 36 times in all Skopje stations, except Gazi Baba for which there is no good data coverage for the three years period. In the eastern zone UAT was exceeded only in Kumanovo and in the western zone in Bitola-2 traffic oriented station. The lower threshold level is exceeded in Bitola-2 and Tetovo stations situated in western zone and at Veles-2 station in eastern zone. Clearly, the increased levels of NO_2 are measured in the urban areas along the traffic arteries.

In section 4.2.2 a test was also carried out on the lower- and upper threshold level values of the limit value of the yearly mean (32 and 26 $\mu g/m^3$). The monitoring results show that the limit value exceeded in all Skopje stations. The lower threshold level was exceeded in Bitola-2 station in the Western zone. No exceedance has occurred in the Eastern zone.

Regarding NOx largest portion in the total emitted yearly amount of NOx is from stationary sources and traffic. NOx is distributed mostly in the Western zone where the largest electricity production facilities using brown coal are located. In Skopje agglomeration 3262 t/year nitrogen oxides (2004 Cadastre data) are emitted mostly from stationary sources and traffic. In the Eastern zone NOx emissions are mainly caused by wood processing, incomplete combustion, domestic heating and traffic in urban areas.

6.3 Particulate matter ≤ 10 micron (PM10) and total suspended mater (TSP)

In section 4.3.2 the first test on PM10 is carried out on the assessment threshold level for the limit value of the daily mean. Threshold levels are 30 and 20 $\mu g/m^3$ and exceedance may not take place more than 14 times in three years. Considerable exceedance of the upper assessment threshold level takes place at all stations in the agglomerations and the zones. This is why all zones and agglomerations fall under assessment regime 1.

A second test is carried out on assessment threshold levels for the yearly mean. The threshold levels are 14 and 10 $\mu g/m^3$, respectively. These threshold values are very strict, as they are based on indicative limit values meant for 2012, being a yearly mean of 20 $\mu g/m^3$. Limit value of the yearly mean is exceeded in all stations except Lazaropole where the upper threshold level is exceeded. All zones and agglomerations fall under assessment regime 1. For PM10, the levels are lowest in the Eastern zone and highest in the Western zone.

TSP emissions in both zones are unevenly distributed and are mostly concentrated around bigger combustion and production sources. In the Western zone highest emissions of this pollutant are concentrated around stationary sources for ferrosilicon production and electricity production..

The main sources of TSP for the present air pollution levels in Eastern zone are traffic, wood combustion and wood industry.

Monitoring PM2.5 has to date not been implemented in the Republic of Macedonia. Such measurements can be made since all existing monitoring stations have possibility to measure PM2.5. In order to create a representative picture of the PM2.5 levels in our country some of the PM10 monitoring stationneed to be reallocated for PM2.5 measurements.

6.4 Carbon monoxide (CO)

Testing for maximum daily 8-hour mean takes place on assessment of the UAT and LAT of 7 and 5 µg/m³ respectively. An assessment threshold will be deemed to have been exceeded if it has been exceeded during all three separate years. In Skopje agglomeration and Western zone the limit value and UAT are exceeded. In the Eastern zone UAT is exceeded few times during two separate years in Kicevo and Veles-2 station and during one year in the other stations. Although the carbon monoxide concentrations are lower, taken into account MS experts' advises this zone has been assigned assessment regime 1 as well.

In the Western zone highest CO emissions are found around stationary sources for ferrosilicon production and electricity production.

In Skopje agglomeration and Eastern zone CO emissions are due to incomplete fuel combustion in small industry capacities.

6.5 Ozone (O_3)

Monitoring data for ozone between 2005 and 2007 have also been tested on the long term objective for protection of human health and long term objective for protection of vegetation AOT40 respectively. The extensive analysis demonstrates that concentrations are found to be above long term objectives for all stations. Assessment regime 1 is allocated to all the zones and agglomeration.

7. Conclusions and recommendations

The current air quality in the Republic of Macedonia for sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter, carbon monoxide and ozone is assessed in the context of the limit values, the margins of tolerance and the assessment threshold levels according to the Decree [4].

First preliminary assessment of air quality was prepared within CARDS 2004 project [1]. Seven zones and one agglomeration were designated according to administrative distribution following statistical regions borders. This zoning was easy to designate since it represent good solution for air quality management (action plans have to cover small areas, easy to set responsibilities). Nevertheless, the air quality situation did not support this zoning, and on the other hand considerable heavy measurements and reporting obligations originate from this type of assessment.

The Preliminary assessment of air quality was further improved within component 3 in the twining project using main assessment methods: air quality measurements and air emission inventories. Air pollution modeling was introduced and implementation of UDM-FMI for assessing the dispersion of atmospheric emissions of NO_2, NOx and SO_2 from Okta refinery was presented. Modeling results were not used for the description of air quality because the modeling was introduced on separate point source on limited area (7 x 7 km) and 2004 Cadastre input emission data have been used.

According to air quality situation (2005-2007 available data) and emission distribution in different areas, using the main assessment methods (air quality measurements and air emission inventories) two zones (Eastern and Western zone) were defined. Data on population, numbers and density, have been used to define Skopje agglomeration. Privileges of the new zoning are: less costly and easier to fulfill measurement and reporting obligations, action plans have to cover bigger areas and less monitoring stations should be set up, compared with CARDS 2004 zoning proposal. Regarding Air quality management, i.e. designation of responsible authorities might be more difficult.

Depending on the air quality in relation to the assessment threshold levels in the air quality daughter directives, there were three determination regimes possible for assessing air quality. Regime 1, where the concentration is found above the highest/upper assessment threshold level; Regime 2, where the concentration is found between the upper and lower assessment threshold levels and Regime 3, where the concentration is found below the lower assessment threshold level. Taken into account of air quality situation, results of testing UAT, LAT, limit values and long term objectives, emission distribution and experts judgment, Regime 1 was defined for all investigated pollutants in the two zones and agglomeration Skopje.

Minimum requirements given in the daughter directives for the number of monitoring stations for protection of human health and ecosystem of all investigated parameters are fulfilled in each zone and Skopje agglomeration (See Table 12 and Table 13). However, two new stations in suburban area will have to be set up for ozone, and two new stations should be set up for particulate matter and nitrogen dioxide respectively in urban background areas. These stations need to be located in areas with lower population density, e.g. with natural ecosystems, forests, far removed from urban and industrial areas and away from local emissions in order to have more accurate description of air quality. The given number of monitoring stations serves as an indication when using measurements data to describe air quality.

More representative information on the air quality in future can be established with:

- Further improvement of quality of measurement data (correction of data taken into account, field calibration, better data coverage);
- Improved quality and coverage of emission data (traffic, small scale wood burning);
- Adding more instruments, like models, to describe air quality can, however, lead to a reduction in the given number of monitoring stations. The use of models can also contribute to a more accurate description of air quality in urban areas.
- Additional measurement campaigns performed to assess air quality;
- Different environments (i.e. urban background areas near residential areas, rural residential areas, traffic influenced areas outside cities (along motorways), rural background areas) covered with monitoring stations;
- Use of mobile station and passive sampling for indicative and short term measurements champagne;

Preliminary assessment report should initiate the work to prepare plans and programs to improve air quality. For the preparation of plans and programs co-operation between authorities in all levels is needed. The preliminary assessment report after reliable data available for five years period needs to be revised.

Acknowledge

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ANNEX I

Table 15 ***Air quality monitoring network of MEPP***

Name	City/place	Pollutants measured	Meteo parameters	Type of station	Type of area	Characterization of zone
Karpos	Skopje	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Traffic	Urban	Residential/Commercial/Industrial
Center	Skopje	SO_2, CO, NO, NO_2, NO_X, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Traffic	Urban	Residential/Commercial
Gazi Baba	Skopje	SO_2, CO, NO, NO_2, NO_X, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Background	Suburban	Commercial
Lisice	Skopje	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Industrial	Urban	Residental/Commercial/Industrial
Rektorat	Skopje	CO, NO, NO_2, NO_X, O_3, PM10		Traffic	Urban	Residental/Commercial
Kicevo	Kicevo	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Industrial	Urban	Residental/Industrial
Kumanovo	Kumanovo	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Industrial	Urban	Residential/Commercial/Industrial
Kocani	Kocani	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Traffic	Urban	Residental/Commercial
Lazaropole	v.Lazaropole	SO_2, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Background	Rural	Natural
Veles 1 Uzus	Veles	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Industrial	Urban	Commercial/Industrial

Veles 2 Gradinka	Veles	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Traffic	Urban	Residential/Commercial
Bitola 1 UHMR	Bitola	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Industrial	Suburban	Commercial/Industrial
Bitola 2 Strezevo	Bitola	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Traffic	Urban	Residential/Commercial/Industrial
Tetovo	Tetovo	SO_2, CO, NO, NO_2, NO_X, O_3, PM10	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Traffic	Urban	Residential/Commercial
Kavadarci	Kavadarci	SO_2, CO, NO, NO_2, NO_X, O_3, PM10,	Temperature, Pressure, Humidity, Wind direction, Wind velocity, Global radiation	Industrial	Urban	Residential/Commercial/Industrial

ANNEX II

I The limit values and assessment thresholds

Limit values of the levels of concentrations, margins of tolerance and terms for achievement of the limit values are given in the following tables

Table 16 ***Limit values for Sulfur dioxide (SO_2)***

	Average calculation period	Limit value	Margin of tolerance	Date by which the limit value should be achieved
1. Hourly limit value for human health protection per hour	1 hour	350 μg/m³, not exceeded by more than 24 times in the course of a calendar year	150 μg/m³ (43%) at the day of application of this Decree, and by equal annual percentage each 12 months afterwards in order to reach 0% by 1 January 2012	1 January 2012
2. Daily limit value for human health protection	24 hours	125 μg/m³ not exceeded by more than 3 times in the course of a calendar year	None	1 January 2012
3. Limit value for ecosystems protection	Calendar year and winter (1 Octomber -31 March)	20 μg/m³	None	1 January 2012

Table 17 ***Limit values for Nitrogen dioxide(NO_2) and Nitrogen oxides (NO_x)***

	Average calculation period	Limit value	Margin of tolerance	Date by which the limit value should be achieved
1. Hourly limit value for human health protection per hour	1 hour	200 μg/m³ NO_2, not exceeded by more than 18 times in the course of a calendar year	100 μg/m³ (50%) at the day of application of this Decree, and by equal annual percentage each 12 months afterwards in order to reach 0% by 1 January 2012	1 January 2012
2. Annual limit value for human health protection	Calendar year	40 μg/m³ NO_2	20 μg/m³ (50%) at the day of application of this Decree, and by equal annual percentage each 12 months afterwards in order to reach 0% by 1 January 2012	1 January 2012

3. Annual limit value for vegetation protection	Calendar year	30 μg/m³ NO_x	None	1 January 2012

Table 18 *Limit values for Particle matter ≤ 10 micron (PM_{10})*

	Average calculation period	Limit value	Margin of tolerance	Date by which the limit value should be achieved
Phase 1				
1. Daily limit (24 hours) value for human health protection	24 hours	50 μg/m³ PM_{10} not exceeded by more than 35 times in the course of a calendar year	25 μg/m³ (50%) at the day of application of this Decree, and by equal annual percentage each 12 months afterwards in order to reach 0% by 1 January 2010	1 January 2010
2. Annual limit value for human health protection	Calendar year	40 μg/m³ PM_{10}	20 μg/m³ (50%) at the day of application of this Decree, and by equal annual percentage each 12 months afterwards in order to reach 0% by 1 January 2010	1 January 2010
Phase 2[1]				
1. Daily (24 hours) limit value for human health protection	24 hours	50 μg/m³ PM_{10} not exceeded by more than 7 times in the course of a calendar year	To be derived from data and be equivalent to the limit value in Phase 1	1 January 2012
2. Annual limit value for human health protection	Calendar year	20 μg/m³ PM_{10}	10 μg/m³ (50%) on 1 January 2010, reduction by equal annual percentage each 12 months in order to reach 0% by 1 January 2012	1 January 2012

[1] Indicative limit values should be revised in the context of further information on health and environmental effects, technical feasibility and experience in application of limit values in Phase 1.

Table 19 *Limit values for Carbon monoxide (CO)*

	Average calculation period	Limit value	Margin of tolerance	Date by which the limit value should be achieved
Limit value for human health protection	Maximum 8 hours daily average concentration	10 mg/m³	6 mg/m³ (60%) at the day of application of this	1 January 2012

			Decree, and reduction by equal annual percentage each 12 months afterwards in order to reach 0% by 1 January 2012	

Table 20 *Target values for Ozone (O_3)*

	Parameter	Target value for 2010(a)
Target value for human health protection	Maximum 8-hours daily average concentration [(b)].	120 μg/m^3, not to be exceeded by more than 25 days in each calendar year with an average value measured for a period of three years [(c)]
Target value for vegetation protection	AOT40, calculated from 1 hourly values from 1 May to 31 July	18000 μg/m^3 h average value calculated in the course of five years[(c)]

AOT40 expressed in (μg/m^3 x hours) shall mean the sum of the difference between daily concentrations higher than 80 μg/m^3 (= 40 billionths) and 80 μg/m^3 in the course of the analyzed period, by using 1 hour values measured every day between 8 o'clock in the morning and 8 o'clock in the evening according to the Central European time.

Table 21 *Long-term targets for Ozone(O_3)*

	Parameter	Long-term target
Long-term target for human health protection	Maximum daily 8 hours average concentration in the course of one calendar year	120 μg/m3
Long-term target for vegetation protection	AOT40, calculated from 1-hour average values from May to July	6000 μg/m3

II Criteria for establishing the upper and lower assessment threshold

Upper assessment threshold is the level under which combination of modeling methods and techniques for assessment of ambient air quality may be used;
Lower assessment threshold is the level under which only modeling techniques for objective assessment of ambient air quality may be used;

Upper and lower assessment thresholds are given in the tables bellow

Table 22 ***Assessment thresholds for Sulphur dioxide (SO_2)***

	Health Protection	Protection of the Eco System
Upper assessment threshold	60% of the 24-hour limit value (75 μg/m^3) not to be breached more than three times in any calendar year)	60% of the limit value for winter (October 1 to March 31) (12μg/m^3)
ess	40% of the 24-hour limit value (50 μg/m^3) not to be breached more than three times in any calendar year)	40% of the limit value for winter (October 1 to March 31) (8 μg/m^3)

Table 23 ***Assessment thresholds for Nitrogen dioxide(NO_2) and Nitrogen oxides(NO_x)***

	Hourly limit values for human health protection for NO_2	Annual limit values for human health protection for NO_2	Annual limit values for vegetation protection for NOx
Upper assessment threshold	70% of the limit value (140 μg/m^3, not to be breached more than 18 times in any calendar year)	80% of the limit value (32 μg/m^3)	80% of the limit value (24 μg/m^3)
Lower assessment threshold	50 % of the limit value (100 μg/m^3, not to be breached more than 18 times in any calendar year)	65% of the limit value (26 μg/m^3)	65% of the limit value (19,5 μg/m^3)

Table 24 ***Assessment thresholds for Particle matter ≤ 10 micron (PM_{10})***

The upper and lower thresholds for assessing the particular matter (PM_{10}) are based on indicative limit values until January 1, 2010.

	24 hour average	Annual average
Upper assessment threshold	60% of limit value (30 μg/m^3) not to be breached more than seven times in any calendar year	70% of the limit value (14 μg/m^3)
Lower assessment threshold	40% of limit value (20 μg/m^3) not to be breached more than seven times in any calendar year	50% of the limit value (10 μg/m^3)

Table 25 ***Assessment thresholds for Carbon monoxide (CO)***

	Eight hour average
Upper assessment threshold	70% of the limit value (7 μg/m^3)
Lower assessment threshold	50% of the limit value (5 μg/m^3)