Slovak
Hydrometeorological Institute

Ministry of Environment
of the Slovak Republic

AIR POLLUTION

IN THE SLOVAK REPUBLIC

1999

Bratislava 2001

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C O N T E N T

AMBIENT AIR

EMISSIONS

APPENDICES

1.1 REGIONAL AIR POLLUTION AND QUALITY OF PRECIPITATION

Regional air pollution is a pollution of a boundary layer of a rural country at a sufficient distance from local industrial and urban sources. Boundary layer of the atmosphere is a mixing layer extending itself from the Earth surface up to the height of about 1 000 m. In regional positions, the industrial emissions are more or less evenly vertically dispersed in the entire boundary layer and ground level concentrations are smaller than those ones in cities.

Pollutants coming from combustion processes such as sulphur dioxide, oxides of nitrogen, hydrocarbons or heavy metals, play an important role in a regional scale. Residence time of these pollutants in the atmosphere is several days and thus they may be transported in the atmosphere over a distance of several thousand kilometres from the source. The products of oxidation from primary gas pollutants, for instance sulphates, may reach the central troposphere by vertical transport, where they are involved in the global circulation.

Since 1950, the regional air pollution in Europe has been risen parallel with the emissions of pollutants from power generation, industry, heating and transport. The construction of high stacks showed to have a negative impact in the environment, as these prolonged the residence time of pollutants in the atmosphere. Acidity of precipitation, as well as the concentrations of secondary pollutants, such as ozone, hydrogen peroxide and others, have been risen in the atmosphere as a result of uncontrolled emission development. At present, ozone and acid precipitation are considered to be the two main stress factors for the forest and agriculture ecosystems in Europe.

Unfavourable development along with the alarming growth of ecological damages did enhance an international co-operation. The UN ECE Convention on Long Range Transboundary Air Pollution (CLRTAP) was signed in 1979. Since its entry into force in 1983 the Convention has been extended by eight protocols: Protocol on Long-term Financing of the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) (Geneva, 1984), Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 Per Cent (Helsinky, 1985), Protocol Concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes (Sofia, 1988), Protocol Concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes (Geneva 1991), Protocol on Further Reduction of Sulphur Emissions (Oslo, 1994), Protocol on Heavy Metals (Aarhus, 1998), Protocol on Persistent Organic Pollutants (Aarhus, 1998), Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg, 1999). Commitment to the first sulphur Protocol represented 30% reduction of European sulphur dioxide emissions by 1993 as compared to 1980. The Slovak Republic has fulfilled this commitment. Reduction of European emissions has already manifested in a decrease of acidity in precipitation over the territory of Slovakia. In compliance with the second sulphur Protocol, the European sulphur dioxide emissions should be reduced 60% by 2000, 65% by 2005 and 72% by 2010, as compared to 1980. According to the last sulphur Protocol the Slovak Republic should reduce 80% its sulphur dioxide emissions by 2010 as compared to 1980, those of oxides of nitrogen 42%, ammonia 37% and volatile organic compounds 6% as compared to 1990.

Implementation of the Co-operative Programme for Monitoring and Evaluation on Long Range Transport of Air Pollutants in Europe (EMEP - Environment Monitoring and Evaluation Programme) is a part of the Convention. In the sense of the Convention, the EMEP is mandatory to all European countries. Its goal is to monitor, model and evaluate the long range transport of air pollutants in Europe and elaborate foundations for the strategy to reduce European emissions. MSC-W (Meteorological Synthesising Centre-West) - Norwegian Meteorological Institute in Oslo, CCC (Chemical Coordinating Centre) - NILU (Norwegian Institute for Air Research) in Kjeller, and MSC-E (Meteorological Synthesising Centre-East) - Institute for Applied Geophysics in Moscow are three international co-ordinating centres within EMEP. The EMEP monitoring network (Figure 1.1) comprises approximately 100 regional stations and 4 selected stations in the territory of Slovakia, belonging to the national network of regional stations of the Slovak Hydrometeorological Institute, are at the same also a part of EMEP network. The programme of measurements in EMEP stations has been gradually extended. Measurements of sulphur compounds in air and analysis of precipitation have been enhanced to include measurements of suspended particles, oxides of nitrogen, ammonium ions in suspended particles and ozone. In 1994 the measurement of volatile organic compounds (VOCs) have started to be carried out under the auspices of CCC - NILU. The 6th phase of EMEP had started in 1995 and does include also the measurements of heavy metals (HMs) and persistent organic compounds (POPs). Measurements of POPs within EMEP are carried out in a very few countries and for the time being upon the voluntary basis.

Results of measurements from regional network of stations in Slovakia are used also in other monitoring programmes such are GAW/BAPMON (Global Atmosphere Watch/Background Air Pollution Monitoring Network) under WMO and UNEP/GEMS (United Nations Environment Programme/Global Environment Monitoring System).

The level of regional air pollution is not assessed according to the primary ambient air quality standards, but according to the secondary ambient air quality standards and deposition limits, thus upon a long-term impact on the environment. Clean Air Act No 309/91 Coll. does include the category of secondary ambient air quality standards and deposition limits, but these have not been adopted in the Slovak Republic till now.

The determination of secondary ambient air quality standards, or ecological limits is based upon the conception of critical levels and critical loads.

Critical level (CL) is the highest concentration of pollutant which ecosystem may tolerate without being injured. Critical levels differ themselves for individual pollutants and individual ecosystems. In the Draft Manual for Mapping Critical Levels/Leads, UN ECE, 1990, the following critical levels are suggest

Pollutant	**Ecosystem**	**CL** [μg.m^{-3}]	**Period**
SO_2 - S	Forest	10	annual average
	Natural vegetation	10	
	Agricultural crops	15	
NO_x - N	All categories	9	annual average
O_3	All categories	50 60 150	9 až 16-h average (1.4.-30.9.) 8-h average 1-h average

According to the Directive of European Community (1992), the critical ozone level for protection of vegetation was indicated to be 200 $\mu g.m^{-3}$ as 1-hour average and 65 $\mu g.m^{-3}$ as 24-hour average.

Executive body of Working Group on Effects within the framework of the Convention had proposed following cumulative critical levels for ozone:

- **Critical level for agricultural crops**, expressed as cumulative exposure of concentrations above 40 ppb. This index of exposure AOT40 (accumulated exposure over a threshold of 40 ppb) is calculated as a sum of the differences between 1-hour ozone concentrations in ppb for each daylight hour within 9.00 and 16.00 in which the concentration is over 40 ppb and average global radiation intensity 50 $W.m^{-1}$ or more during the period of three months May, June and July. AOT40 of 3 000 ppb h corresponds to a 5% yield crop loss.
- **Short term critical level for agricultural crops and natural vegetation** AOT40 is 500 ppb h, cumulated within five subsequent days under low (water) vapour pressure deficit and 200 ppb h, cumulated within five subsequent days under high (water) vapour pressure deficit conditions. These values are related to the daylight hours
- **Critical level for forest ecosystems**: AOT40 is 10 ppm h. This cumulative exposure is calculated for 24 hours of a day, during a period of six months, when the trees are most sensitive to ozone.

Critical load is ecological deposition limit and represents maximum permissible deposition of pollutant in ecosystem. Critical load is expressed in the mass of pollutant over the area unit per time unit (e.g. $g.m^{-2}.year^{-1}$, $kg.ha^{-1}.year^{-1}$, or $equivalent.ha^{-1}.year^{-1}$). It is a function of ecosystem sensitivity. Total deposition is composed of dry, wet and hidden deposition. Dry deposition represents interception of gases and particles on the surface, mainly by vegetation. Wet deposition represents substances in rainwater and hidden deposition is interception of droplets from clouds and fogs on the surface of vegetation predominantly, mainly in mountains. Dry deposition is calculated upon regional concentration of respective substance and behaviour of the surface; wet upon annual concentration of respective substance in rainwater and annual totals of precipitation amount; hidden upon the differences between values from rain gauges placed under the tree canopy and those ones at free area.

The territory of the Slovak Republic is ecologically mid-sensitive to sulphur deposition. The value of critical sulphur load over the territory of Slovakia represents 1-3 g $S.m^{-2}.year^{-1}$, or 10-30 kg $S.ha^{-1}.year^{-1}$. However, the real sulphur deposition exceeds these values within the last decade. Despite of the fact, that European sulphur dioxide emissions have decreased 30%, the values of total sulphur deposition are higher than the critical load. Typical values of sulphur deposition expressed in g S $m^{-2}.year^{-1}$ for the lowlands and mountain positions of Slovakia in 1999 were following:

Sulphur deposition	Danube lowlands	Mountain position (> 1 500 m)
Dry	1.1	0.3
Wet	0.5	1.4 (1.9)[+]
Hidden	0.1	0.7 (0.9)[++]
Total	**1.7**	**2.4 (3.2)**

Critical load	**1.0 - 3.0**

[+] *With regard to the correction of negative error in amount of precipitation measurements in mountains*

[++] *upper level of estimate at hidden deposition*

A detailed assessment of critical loads (ecological sensitivity of the territory) and determination of target loads in Slovakia for sulphur, nitrogen, actual acidity, heavy metals and some other pollutants have not been completed yet. These data are needed for Environment Impact Assessment (EIA) on long range transport of air pollutants as well as the EIA studies of the new large air pollution sources.

1.2 NATIONAL NETWORK OF REGIONAL STATIONS IN THE SLOVAK REPUBLIC

At the beginning of 1999, there were 7 stations in operation in the Slovak Republic to monitor regional air pollution and chemical composition of precipitation. But due to the financial reasons two stations were shut down, station Milhostov to May 31, 1999 and station Mochovce to December 31, 1999. Location and elevation of the individual stations are indicated in Figure 1.2 and 1.3. Apart from the above mentioned, chemical composition of precipitation is regularly analysed from suburban station Bratislava - Koliba, in elevation 286 m.

Regional stations

Chopok Meteorological observatory of the Slovak hydrometeorological institute, located on the crest of the Low Tatras, 2 008 m above sea level, 19°35'32" longitude, 48°56'38" latitude. Measurements started in 1977. Since 1978 the station has become a part of EMEP network and GAW/BAPMoN/WMO network.

Mochovce Meteorological observatory of the Slovak hydrometeorological institute, approximately 4 km north from nuclear power plant Mochovce, in an abandoned place, 260 m above sea level, 18°27'22" longitude, 48°17'22" latitude. Measurements have been running since 1982.

Topoľníky Pump station Aszód on small Danube, 7 km south-east from village Topoľníky, in plain terrain of the Danube lowlands, 113 m above sea level, 17°51'38" longitude, 47°57'36" latitude. Only family houses of employees of the pump station are situated nearby. Measurements have been carried out since 1982.

Milhostov Meteorological observatory of the Slovak hydrometeorological institute, approximately 6 km from Trebišov, in the East-Slovakian lowlands, 104 m above sea level, 21°44'05" longitude, 48°40'05" latitude. Station has been in operation since 1983.

Liesek Meteorological observatory of the Slovak hydrometeorological institute on east-west side of Roháče mountain, nearby the village Liesek, 692 m above sea level, 19°40'46" longitude, 49°22'10" latitude. Measurements started to be carried out in 1988. Since 1992 the station has become a part of EMEP network.

Stará Lesná Station is situated in the zone of Astronomic institute of the Slovak Academy of Sciences on south-east edge of TANAP (National Park of the Tatra), 2 km north from village, 808 m above sea level, 20°17'28" longitude, 49°09'10" latitude. Station started the measurements in 1988. Since 1992 the station has become a part of EMEP network.

Starina Station is situated in the zone of drinking water reservoir Starina, 345 m above sea level, 22°15'35" longitude, 49°02'32" latitude. Nearby only the building of watershed Bodrog and Hornád is situated. Station started to operate in 1994. The same year the station has become a part of EMEP network.

Measurement programme

Ambient air	**Gas components**	SO_2, NO_x, HNO_3 - 24-hour averages
		O_3 - continuous registration by analyser
		VOCs C_2-C_6 10 –15 minute sampling 2x weekly at 12.00 noon
	Atmospheric aerosol	SP mass concentration - 1, 3 or 7 day sampling interval
		Pb, Cu, Zn, Mn, Cr, V, Ni, Cd - monthly averages
		SO_4^{2-}, NO_3^- - 24- hour averages
Precipitation	**Daily precipitation**	pH, conductivity, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, F^-, PO_4^{3-}
	Monthly precipitation	pH, conductivity, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, Zn^{2+}, Mn^{2+}, Fe^{2+}, Al^{3+}, F^-, PO_4^{3-}

Methods of sample collection and determination

Ambient air

	Collection	**Determination**
SO_2	filter W41 impregnated by KOH	IC - Dionex
NO_x	after oxidation into NaOH and guajacol absorption solution	spectrophotometrically, spectrophotometer Unicam - modified Saltzman method
HNO_3	filter W41 impregnated by KOH	IC - Dionex
O_3	registration by TE analyzer	principle - UV absorption
VOCs C_2 - C_6	stainless steel canister	GC-Chrompack + FID
SP	filter Sartorius	gravimetrically
Heavy metals - Pb, Cu, Zn, Mn, Cr, V, Ni, Cd	filter Sartorius	after digestion in MW-oven by AAS Varian in flame, or graphite atomiser
SO_4^{2-}	filter W40	ITP from water solution
NO_3^-	filter W40	ITP from water solution

Precipitation		
pH	wet only" - rain gauges WADOS or "bulk" - PE bucket	pH meter ORION, glass electrode
conductivity		conductometer WTW
SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, K^+ Na^+, Mg^{2+}, Ca^{2+}, PO_4^{3-}, F^-		IC - Dionex
Zn^{2+}, Mn^{2+}, Fe^{2+}, Al^{3+}		AAS - Varian, in flame or graphite atomiser

1.3 ASSESSMENT OF MEASUREMENT RESULTS IN 1999

SO_2, sulphates

Regional concentrations of sulphur dioxide (Table 1.1, Figures 1.4, 1.8, 1.11, 1.15, 1.19, 1.23 and 1.27) ranged between 1.12 µgS.m^{-3} (Chopok) and 4.38 µgS.m^{-3} (Topoľníky), in 1999. As compared to 1998, the values of sulphur dioxide were higher on majority of the stations. Upper value of this concentration range represents 44% of the critical level of sulphur dioxide (critical level for forest and natural vegetation is 10 µg S.m^{-3} and for agricultural crop 15 µg S.m^{-3}). In 1999 the concentrations of sulphates in atmospheric aerosols were smaller in stations Chopok, Starina a Liesek, in stations with lower altitude Mochovce, Milhostov, Topoľníky the concentrations were higher and in Stará Lesná the same as those ones in the previous year (Table 1.1, Figures 1.5, 1.9, 1.12, 1.16, 1.20, 1.24 and 1.28). Regional level of sulphates at Chopok was 0.47 µg S.m^{-3}, at all other stations higher than 1 µg S.m^{-3}, in Milhostov and Mochovce the highest ones, 1.84 µg S.m^{-3} and 1.74 µg S.m^{-3}, respectively. Sulphates contributed to the total mass of suspended particles by 10-19% (Figures 1.31-1.37). Concentration ratio of sulphates to sulphur dioxide, expressed in sulphur, presents interval 0.31-0.62, corresponding to the regional level of pollution.

NO_x, nitrates

Regional concentrations of oxides of nitrogen at regional stations, expressed in nitrogen varied within the range 0.9-3.05 µg N.m^{-3} (Table 1.1, Figures 1.6, 1.13, 1.17, 1.21, 1.25 and 1.29). The smallest annual average value was recorded at Chopok 0.9 µg N.m^{-3}, higher one at Starina 1.46 µg N.m^{-3}, Stará Lesná 1.57 µg N.m^{-3}, Liesek 1.99 µg N.m^{-3} and values above 3 µg N.m^{-3} at lowland stations Topoľníky a Milhostov. The highest concentrations of oxides of nitrogen in

Topoľníky 3.01 μg N.m^{-3} and in Milhostov 3.05 μg N.m^{-3} represent 30% of critical level (Critical level of nitrogen dioxide is 9μg N.m^{-3} for all ecosystems). Trend of oxides of nitrogen is not possible to assess in a reliable way due to complex transformation cycle of different nitrogen compounds. Nitrates occurred predominantly in form of particles (Table 1.1. Figures 1.7. 1.10. 1.14. 1.18. 1.22. 1.26 and 1.30). Concentrations of nitric acid (Table 1.1) are lower at stations Chopok, Stará Lesná and Liesek as compared to aerosol nitrates, however at Starina the level of nitric acid and aerosol nitrate is at the same level. Though both these forms of nitrogen are collected on filters and measured separately, CCC EMEP does require report their sum, because phase division is dependent upon temperature and humidity of air. Nitrates contributed to the total mass of atmospheric aerosol 5-17% (Figures 1.31-1.37). Concentration ratio of total nitrates (HNO_3+NO_3) to NO_2 expressed in nitrogen represented the range 0.23-0.36.

Suspended particles, heavy metals

Concentrations of total suspended particles ranged from 13.8 to 47.0 μg.m^{-3} in 1999 (Table 1.1). Most of the stations showed smaller concentrations of suspended particles as compared to 1998. These annual average differences accounted only for a couple of μg N.m^{-3}. In Table 1.1 and in Figure 1.38 are listed the concentrations of heavy metals in regional stations in 1999. As compared to 1998, the concentrations of manganese, cadmium, nickel and chromium were higher on the majority of the stations and vice versa lead, zinc and vanadium reached in the most of the stations smaller concentrations. Higher concentrations of zinc at Chopok were caused probably by local effects. The share of the sum of metals measured in suspended particles (lead, zinc, copper, manganese, cadmium, nickel, vanadium and chromium) varied within 0.2-0.7% (Table 1.1, Figure 1.31-1.37). Trend in majority of metals is downward, with the most outstanding manifestation at lead. This fact has been linked with the gradual lead decreasing in petrol since 1982 and production of lead-free petrol only at present time.

Ozone

In Figures 1.39-1.42 annual course of ozone concentrations at 4 regional stations Chopok, Stará Lesná, Starina and Topoľníky are depicted. Longest time series of ozone measurements is in station Stará Lesná. The measurements of three other stations begun to be carried out later, in 1994. In 1999 the annual average ozone concentration at Chopok reached 90 μg.m^{-3}, at Starina 59 μg.m^{-3}, at Stará Lesná 65 μg.m^{-3} and at Topoľníky 53 μg.m^{-3}. Measurements of ozone and exceedances of critical levels are completely assessed in Chapter 3 Atmospheric Ozone.

Increase in ozone concentrations was observed within 1970-1990, on average 1 $\mu g.m^{-3}$ annually. After 1990 the increase slowed down or stopped in compliance with other European observations. This trend does correspond to the European development of ozone precursors.

VOCs C_2-C_6

VOCs C_2-C_6, or the so-called light hydrocarbons, started to be sampled in autumn 1994 in station Starina. Starina is one of small number of European stations, included into EMEP network with regular sampling of volatile organic compounds. They are then measured and assessed according to the EMEP method elaborated by CCC-NILU. Their concentrations ranged within one order of magnitude from decimals of ppb up to several ppb (Figures 1.43 and 1.45). Among the VOCs measured, ethane is most abundant. Remarkable was the presence of isoprene, releasing itself out of a near forest growth. More complex assessment of VOCs needs longer time series. Measurements of identical samples carried out in the Slovak Hydrometeorological Institute and in NILU showed high degree of agreement. Also the measurements carried out within the AMOHA (Accurate Measurements of Hydrocarbons in the Atmosphere) project, organised by NPL (National Physical Laboratory) in United Kingdom and IFU (Fraunhofer Institute) in Germany, the final result of which will be European directive for optimum sampling and assessment of hydrocarbons, are in agreement with the requirements of NPL and IFU.

Precipitation

Natural acidity of precipitation in balance with atmospheric carbon dioxide is 5.65 pH. Atmospheric precipitation are considered to be acidic if the sum of anions is higher than the sum of cations and the value of pH is smaller than 5.65. Precipitation contains mainly sulphates, nitrates and chlorides as anions, but in a smaller amount also anions of weak mineral and organic acids. Sulphates contribute to the acidity 60-70%, while nitrates 25-30%. Share of chlorides, weak mineral and organic acids is small. Chlorides are almost exclusively a part of neutral salts, predominantly of marine origin. Among cations the dominant is ammonium, ions of calcium, magnesium, sodium and potassium. Ammonium is special case because in soils it may be oxidised to nitric acid.

Chemical analysis document a slight decrease of acidity in 1999 as compared to 1998. Figure 1.47 gives the amount of precipitation in 1999 varying from 589 mm up to 1185 mm in dependence on location of the individual stations. Interval of pH values in monthly precipitation ranged between 4.5-6.1 (Table 1.2, Figure 1.48). Annual course of sulphates, nitrates and pH upon the basis of daily measurements is depicted in Figures 1.53-1.58. Time series and trend of pH values within a long-time period indicate clearly the decrease in acidity (Figure 1.46). Values of pH are in a good coincidence with the pH values according to EMEP maps. Concentrations of dominant sulphates, but also nitrates in precipitation have significant influence on mineralisation. Values of conductivity (Table 2.1, Figure 1.49) were slightly smaller as in previous year. Decrease in sulphates corresponds to SO_2 emission reduction since 1980.

All other components in precipitation (Table 1.2, Figures 1.50-1.52) did not prove any significant trend, slight decrease was observed in heavy metals. Critical load of wet deposition has not been indicated yet. USA and Canada indicated the value of wet sulphur deposition 0.7 g $S.m^{-2}.year^{-1}$ as the target load for forests. This value was exceeded over the territory of Slovakia in 1999.

Station	**Wet sulphur deposition** [g $S.m^{-2}.year^{-1}$]
Chopok	1. 38
Mochovce	0. 60
Topoľníky	0. 55
Milhostov	0. 23*
Starina	0. 67
Stará Lesná	0. 70
Liesek	0. 72
Bratislava	0. 66

** for a period of 5 months only*

According to the measurements of EMEP the Slovak Republic is situated on the south-east boundary of a territory with the highest regional air pollution and acidity of precipitation in Europe. Development of a regional air pollution and chemical composition of precipitation corresponds to the development of European emissions

Fig. 1.1 **Network of EMEP monitoring stations in 1997**

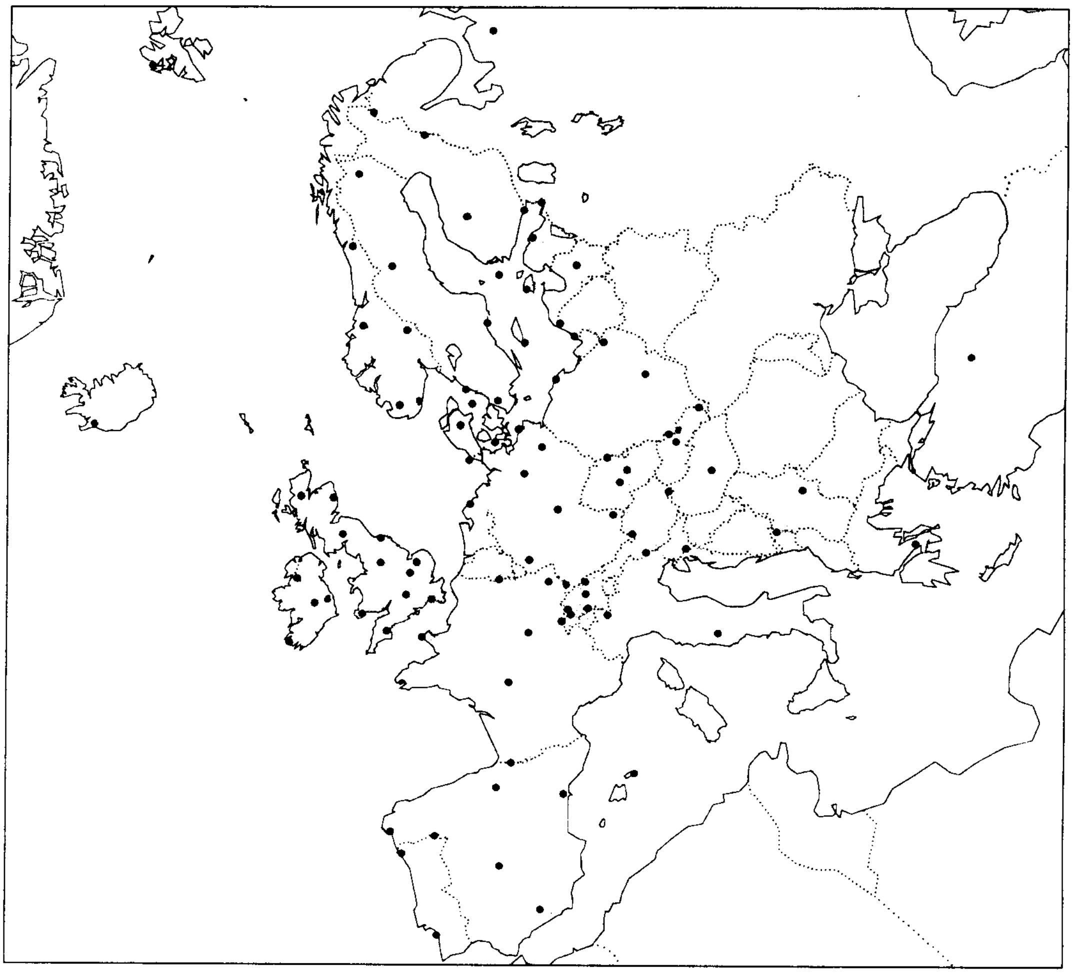


Fig. 1.2 **Network of regional stations in the Slovak Republic**

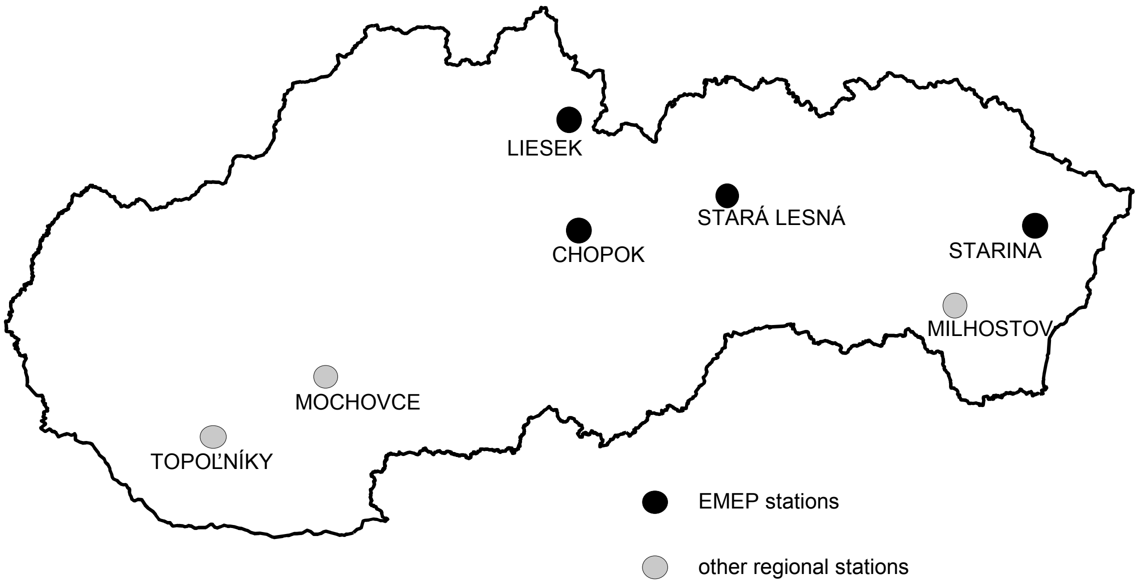
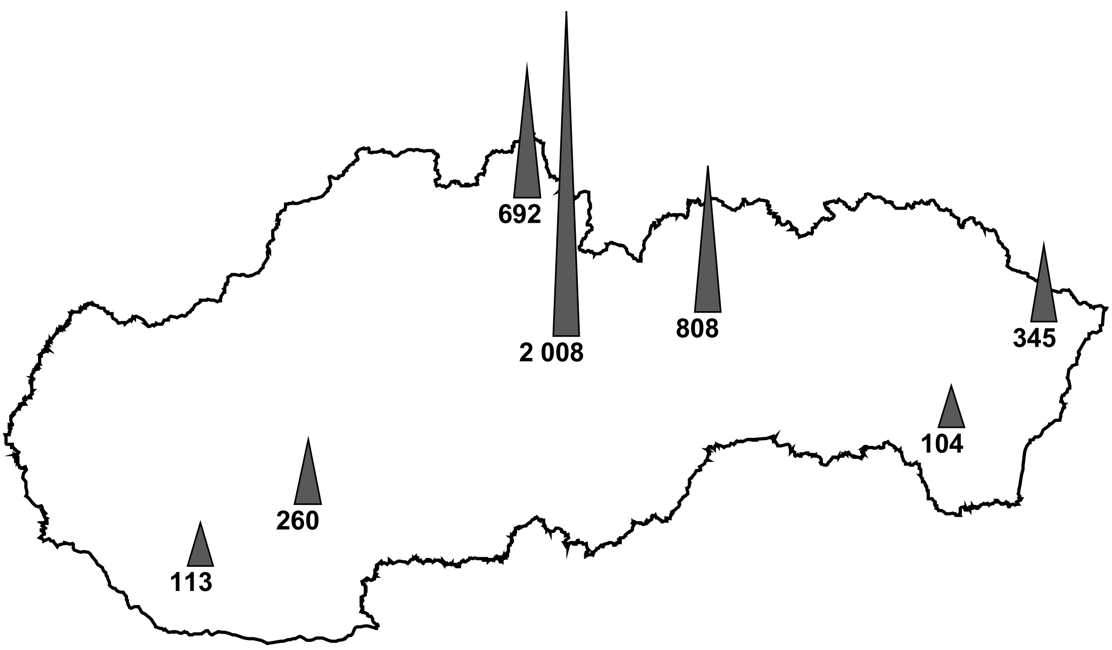


Fig. 1.3 **Altitude of regional stations [m]**



Tab. 1.1 Annual average concentrations in ambient air - 1999

	SP µg/m³	SO_2-S µg/m³	NO_2-N µg/m³	HNO_3-N µg/m³	SO_4^{2-}-S µg/m³	NO_3^--N µg/m³	O_3 µg/m³	Pb ng/m³	Mn ng/m³	Cu ng/m³	Cd ng/m³	Zn ng/m³	Ni ng/m³	V ng/m³	Cr ng/m³
Chopok	13.8	1.12	0.90	0.08	0.47	0.19	90	2.4	1.6	2.8	0.3	87.8	2.1	0.1	2.6
Mochovce	36.9	4.31	-	-	1.84	0.89	-	16.6	10.9	4.5	0.6	51.0	4.6	1.3	1.7
Topoľníky	26.2	4.38	3.01	-	1.68	1.01	53	17.1	8.0	6.2	0.6	54.3	4.9	2.1	3.6
Milhostov*	47.0	4.29	3.05	-	1.74	1.10	-	23.6	9.0	4.8	0.8	25.7	2.3	2.2	1.8
Starina	20.5	3.04	1.46	0.32	1.14	0.21	59	14.6	5.6	5.0	0.7	94.7	6.2	0.6	2.0
Stará Lesná	22.1	1.71	1.57	0.07	1.06	0.30	65	15.6	6.0	3.8	0.5	36.6	1.7	0.3	1.6
Liesek	30.9	4.10	1.99	0.06	1.26	0.53	-	15.5	21.9	24.1	0.6	111.5	3.0	0.7	4.3

Tab. 1.2 Annual weighted means in monthly precipitation - 1999

	Precip. mm	pH	Conduct. µS/cm	Na^+ mg/l	K^+ mg/l	Mg^{2+} mg/l	Ca^{2+} mg/l	Zn µg/l	Fe µg/l	Al µg/l	Mn µg/l	Cl^- mg/l	NH_4^+-N mg/l	NO_3^--N mg/l	SO_4^{2-}-S mg/l	PO_4^{3-} mg/l
Chopok	1185.3	4.5	24.17	0.23	0.21	0.069	0.36	40	42	25	5.2	0.36	0.68	0.47	1.17	0.04
Bratislava	697.8	5.1	22.11	0.27	0.22	0.098	0.76	15	26	30	4.2	0.77	0.72	0.54	0.94	0.02
Mochovce	689.1	4.9	18.53	0.15	0.18	0.067	0.54	13	22	22	3.7	0.22	0.47	0.41	0.87	0.05
Topoľníky	715.3	5.1	15.09	0.12	0.24	0.090	0.56	10	10	19	3.8	0.32	0.38	0.41	0.77	0.02
Milhostov*	174.7	6.1	29.73	0.22	0.20	0.103	0.68	15	26	46	11.2	0.57	1.67	0.69	1.33	0.07
Starina	761.5	4.8	23.78	0.25	0.24	0.065	0.35	15	17	24	3.3	0.27	0.56	0.45	0.88	0.05
Stará Lesná	702.5	4.8	21.83	0.21	0.24	0.065	0.35	13	21	20	3.9	0.32	0.55	0.42	1.00	0.04
Liesek	853.4	4.7	19.33	0.25	0.30	0.073	0.33	103	17	23	4.9	0.37	0.66	0.40	0.84	0.05

** for a period of 5 months only*

Tab. 1.3 Annual average concentrations of VOC [ppb] in ambient air - 1999

	etane	etene	propane	propene	i-butane	n-butane	acetylene	butene	pentene	i-pentane	n-pentane	isoprene	n-hexane	benzene	toluene
Starina	3.149	1.664	1.370	0.226	0.438	0.676	1.337	0.308	0.351	0.484	0.449	0.157	0.098	0.584	0.605

CHOPOK

monthly average concentration

Fig. 1.4

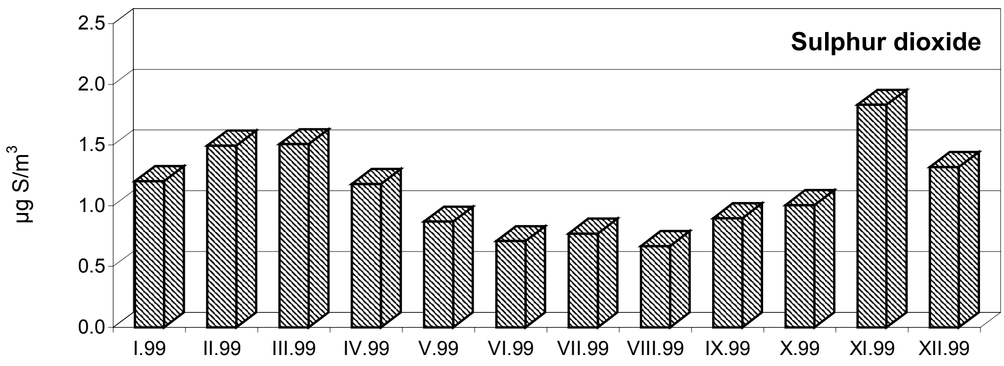


Fig. 1.5

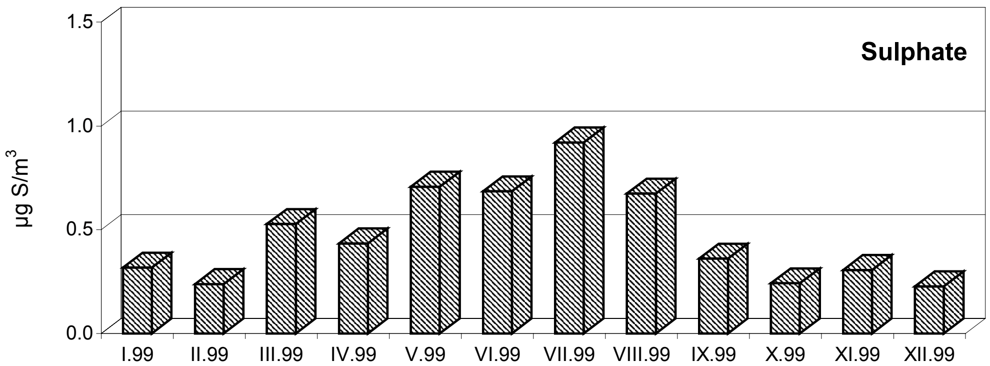


Fig. 1.6

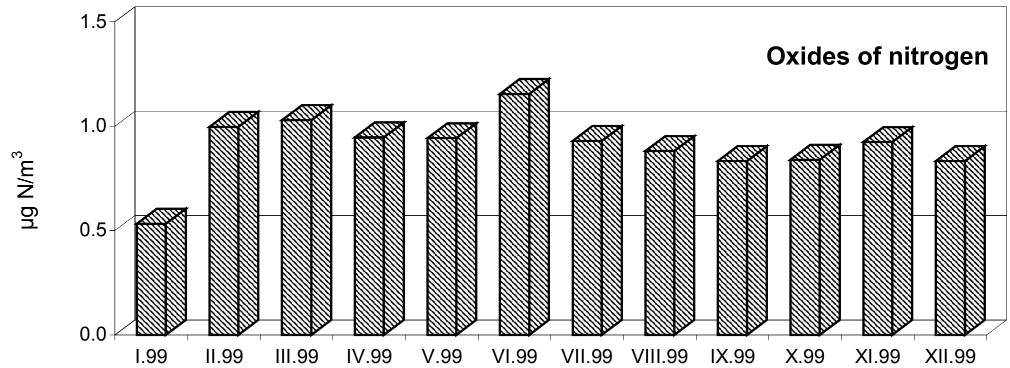
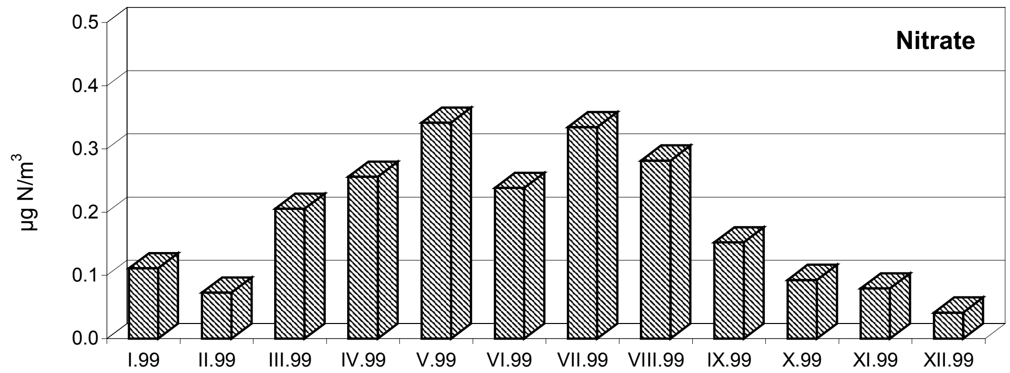


Fig. 1.7



MOCHOVCE

monthly average concentration

Fig. 1.8

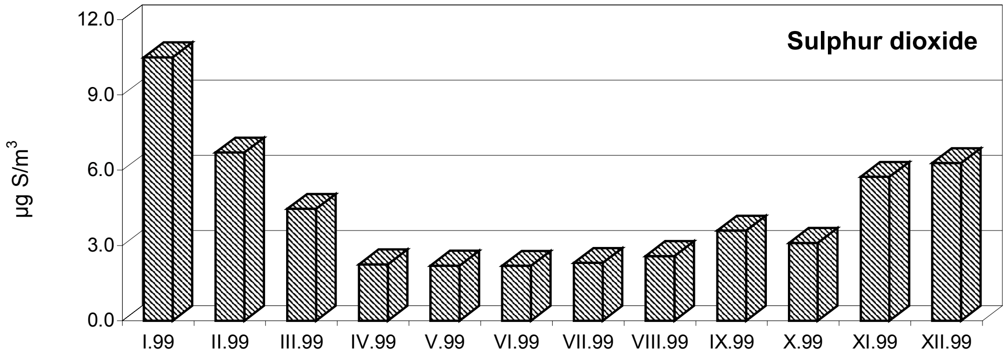


Fig. 1.9

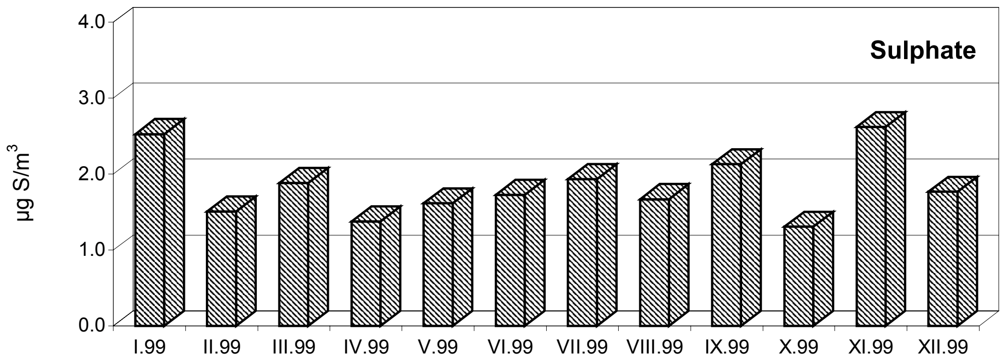
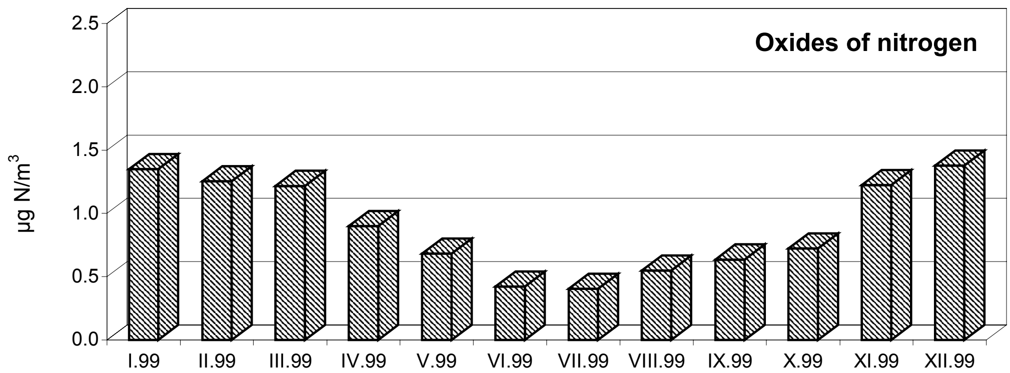


Fig. 1.10



TOPOĽNÍKY

monthly average concentration

Fig. 1.11

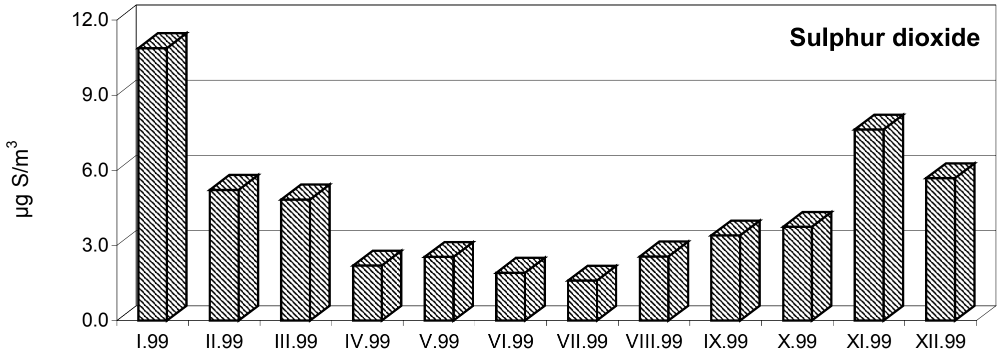


Fig. 1.12

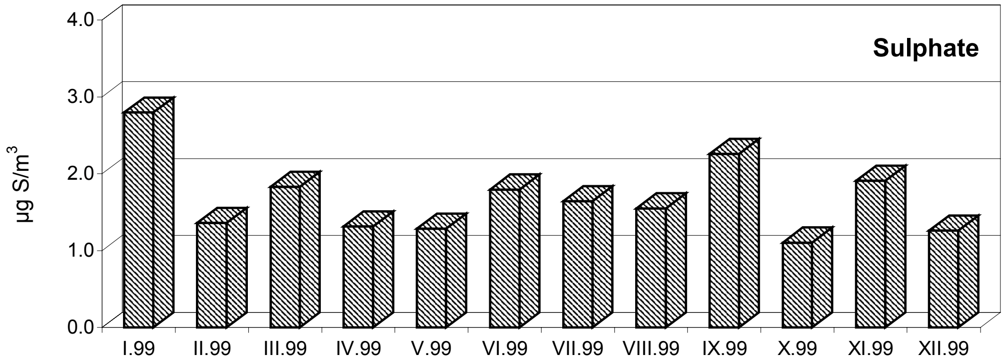


Fig. 1.13

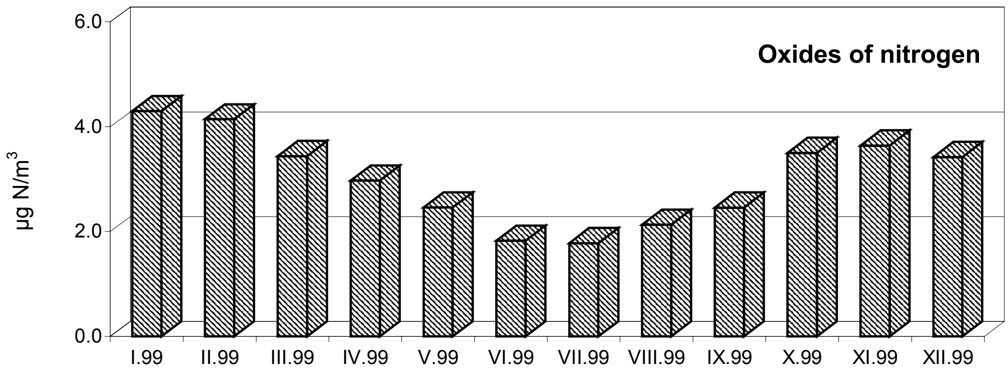
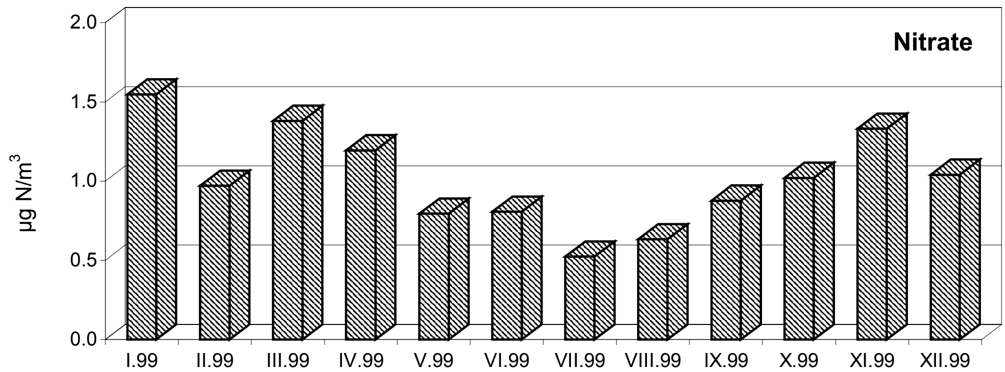


Fig. 1.14



MILHOSTOV

monthly average concentration

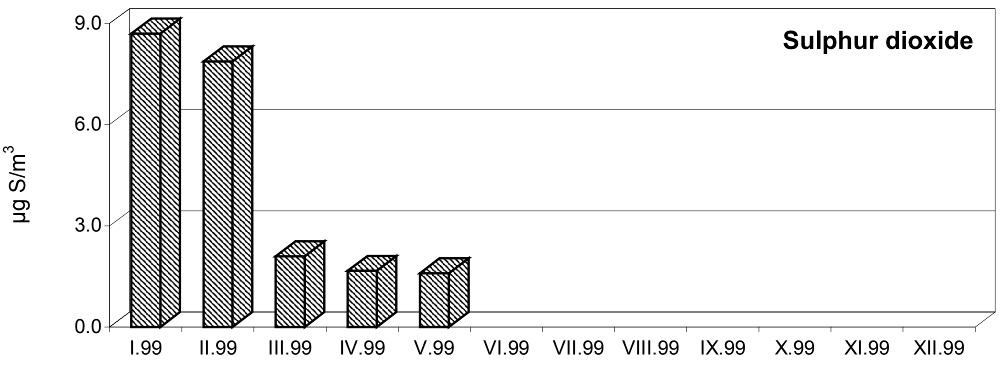


Fig. 1.15

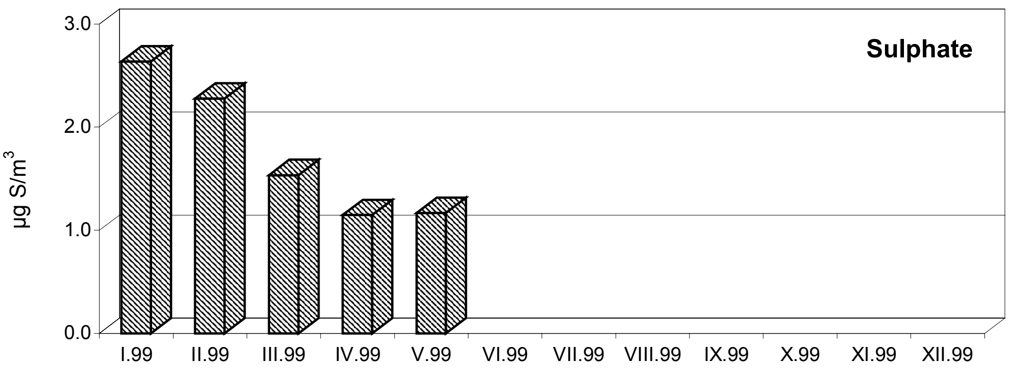


Fig. 1.16

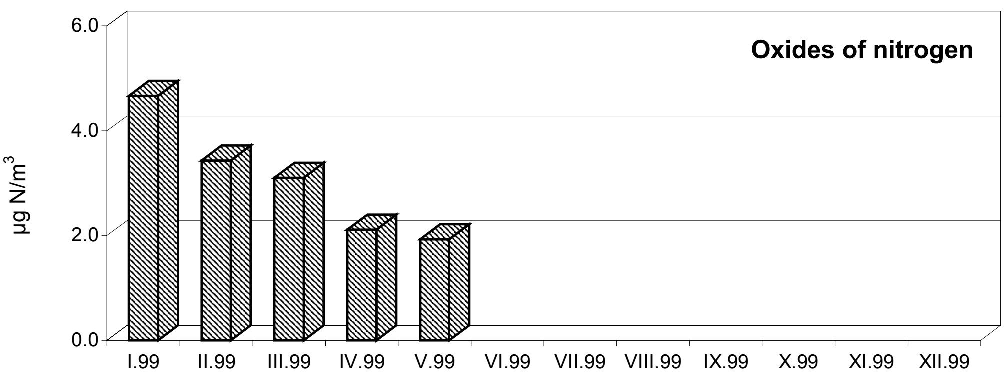


Fig. 1.17

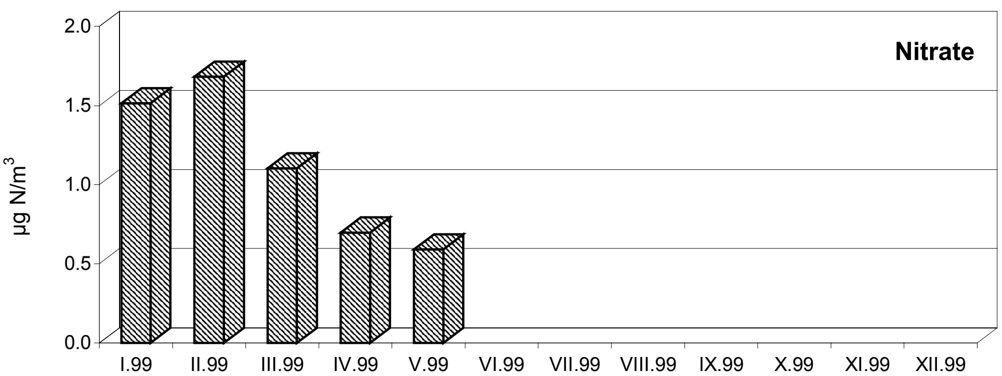


Fig. 1.18

STARINA

monthly average concentration

Fig. 1.19

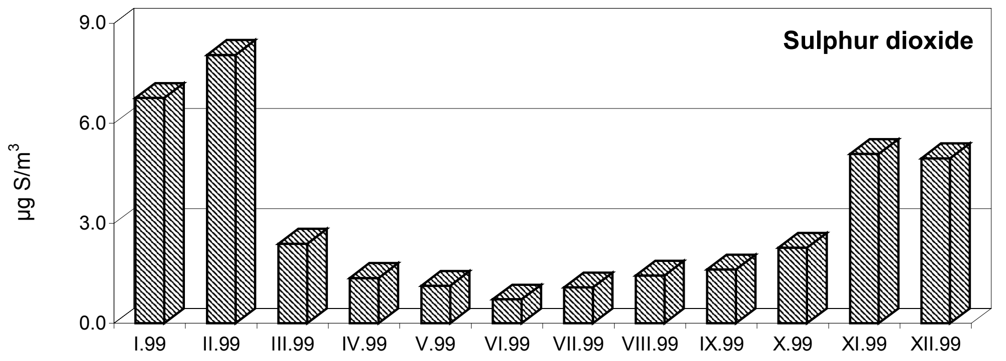


Fig. 1.20

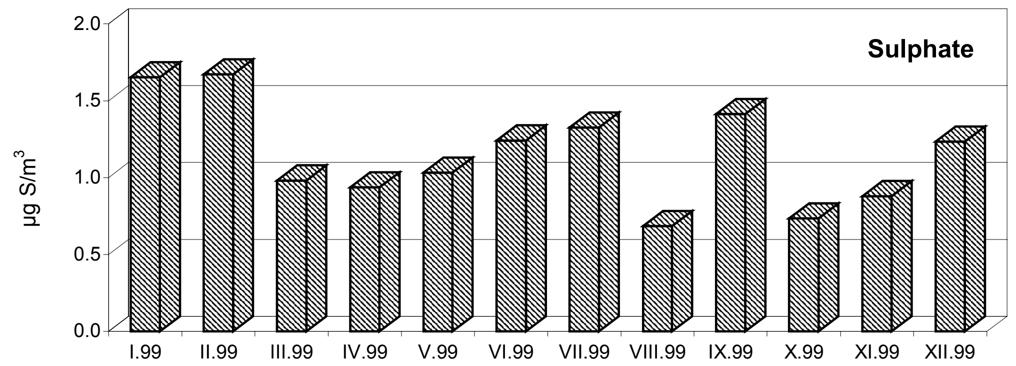


Fig. 1.21

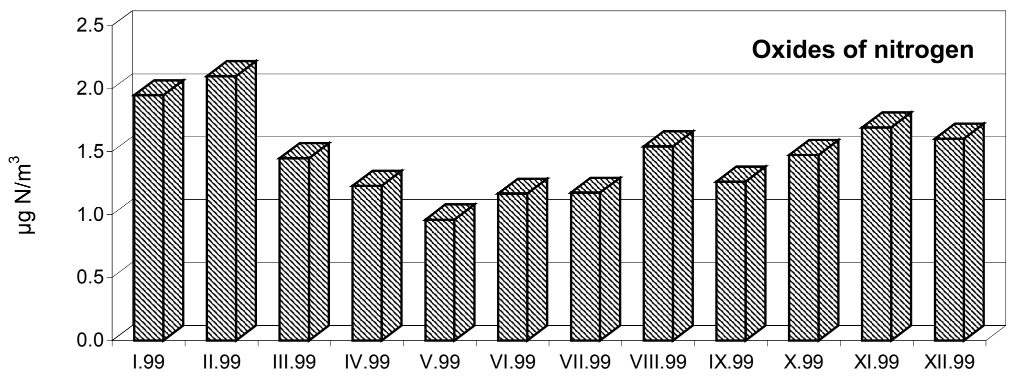
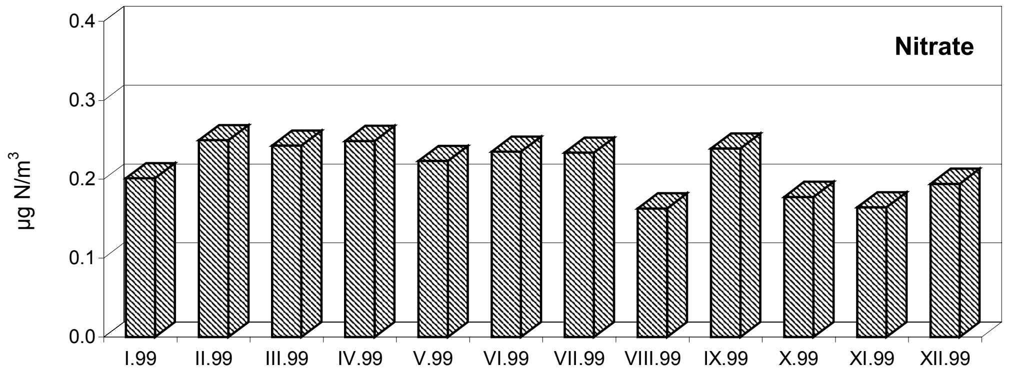


Fig. 1.22



STARÁ LESNÁ

monthly average concentration

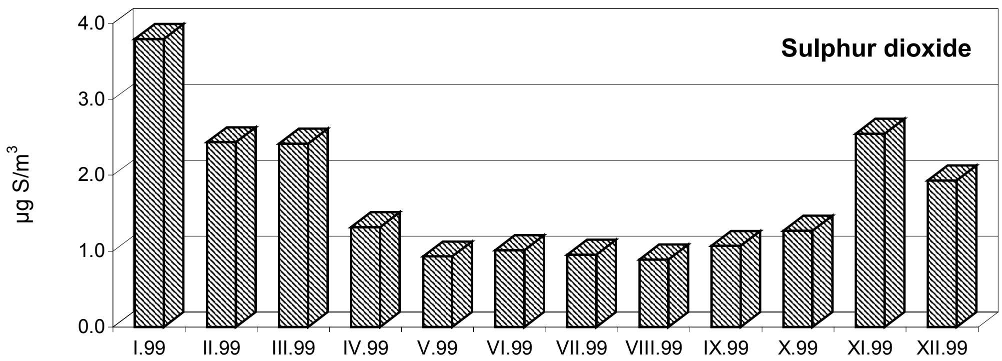


Fig. 1.23

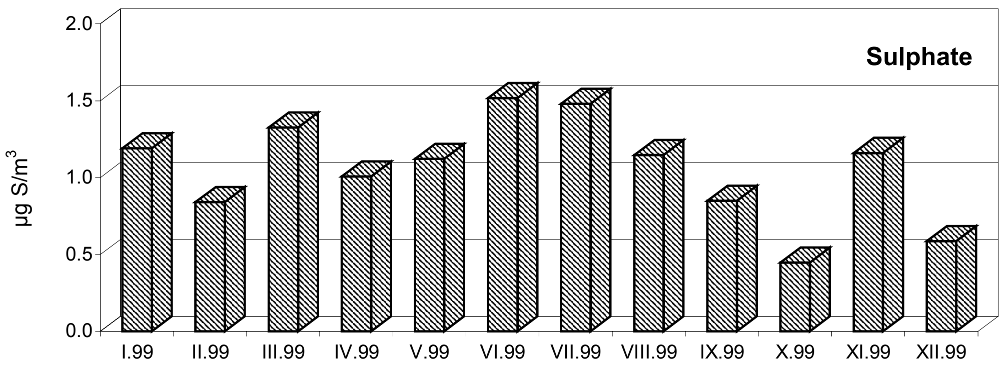


Fig. 1.24

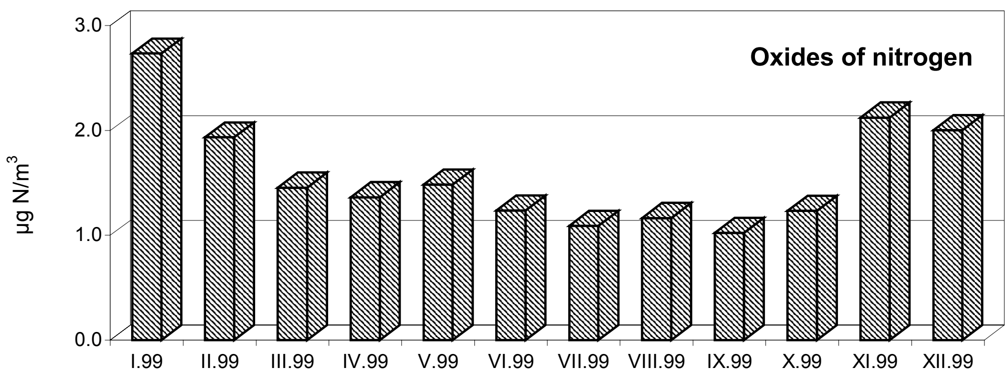


Fig. 1.25

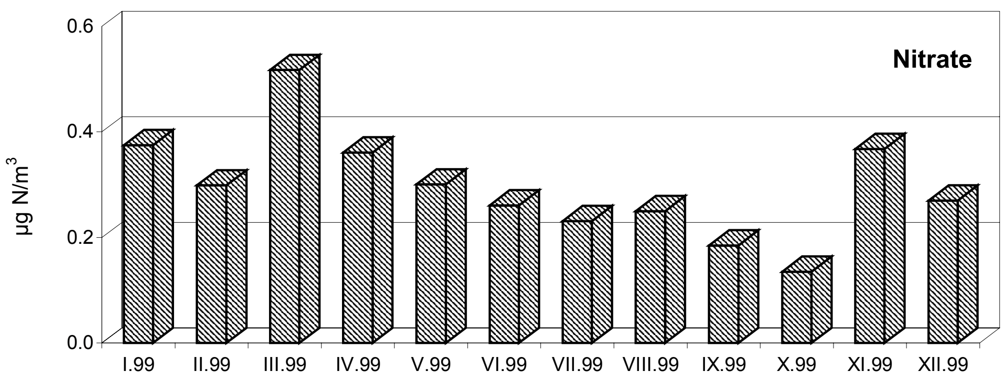


Fig. 1.26

LIESEK

monthly average concentration

Fig. 1.27

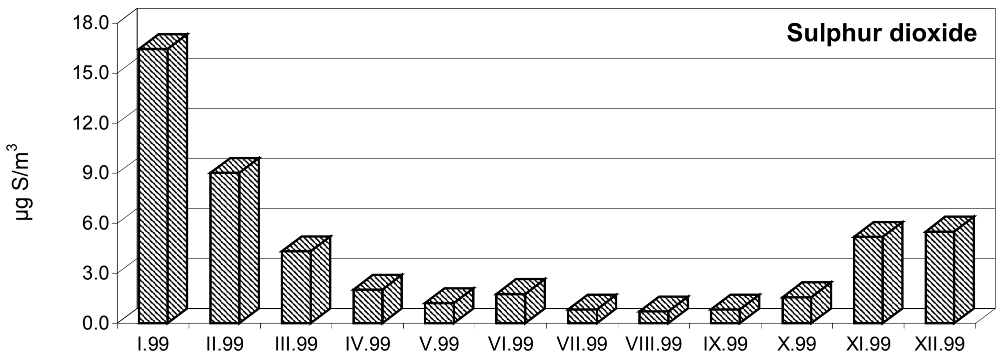


Fig. 1.28

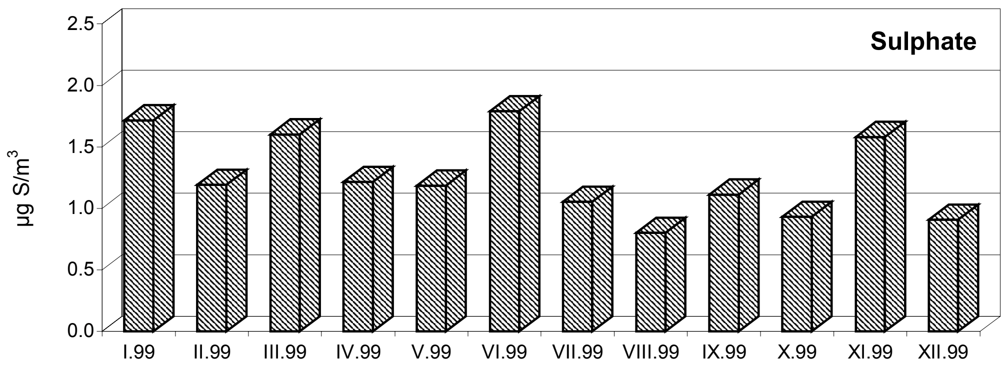


Fig. 1.29

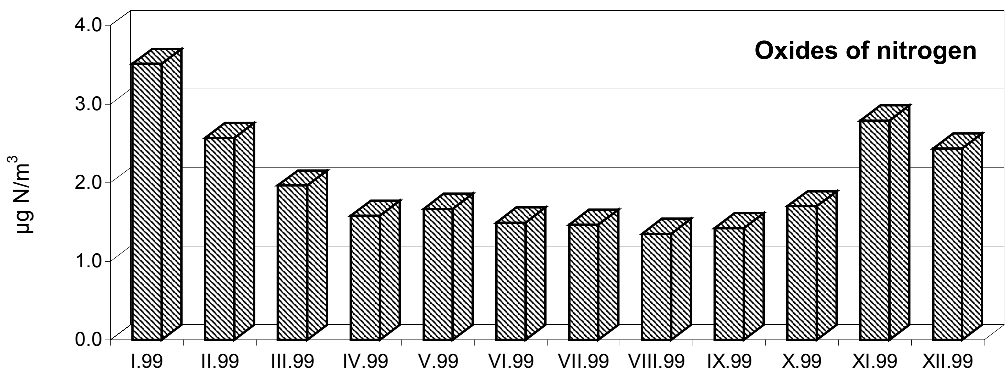
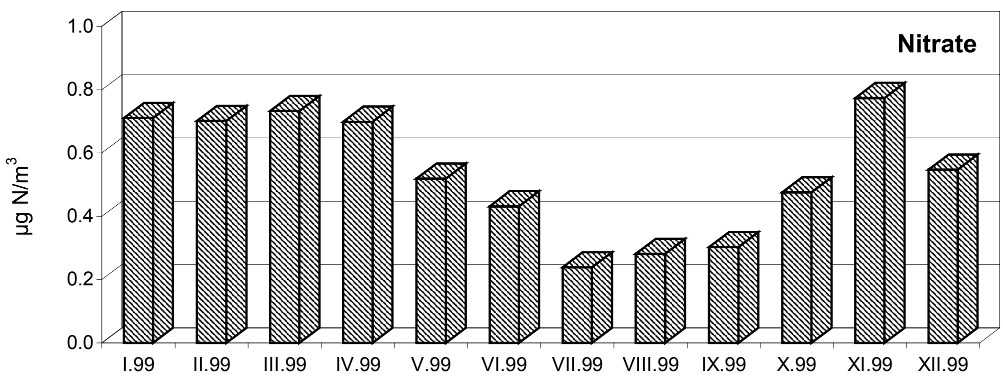


Fig. 1.30



Composition of aerosol and proportional share of heavy metals

Fig. 1.31

Chopok - 1999

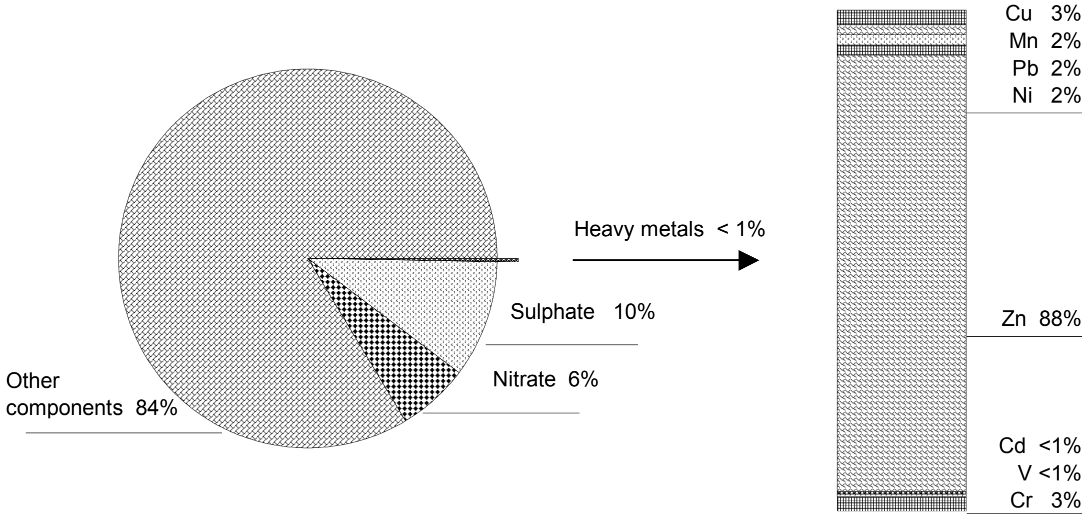
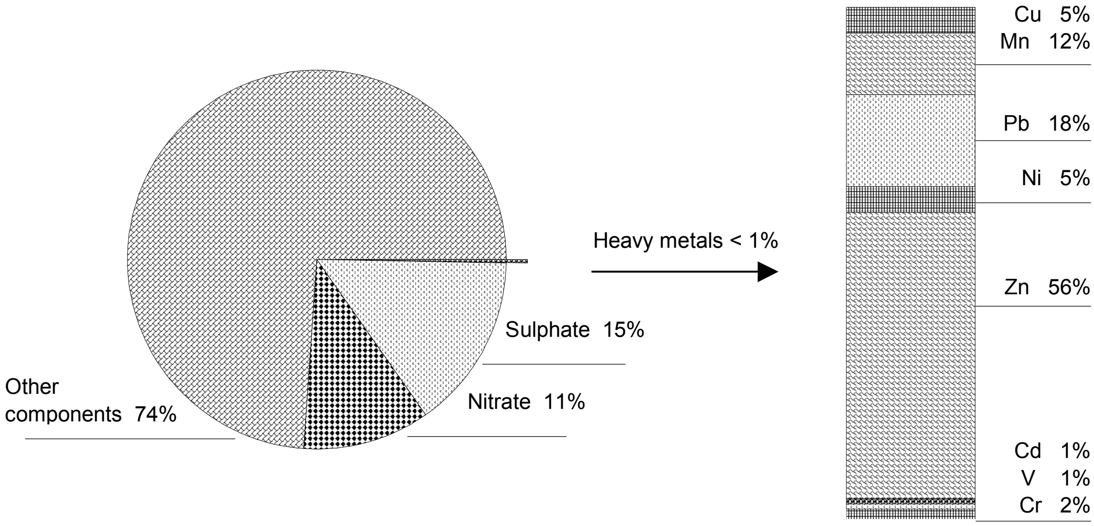


Fig. 1.32

Mochovce - 1999



Composition of aerosol and proportional share of heavy metals

Fig. 1.33

Topoľníky - 1999

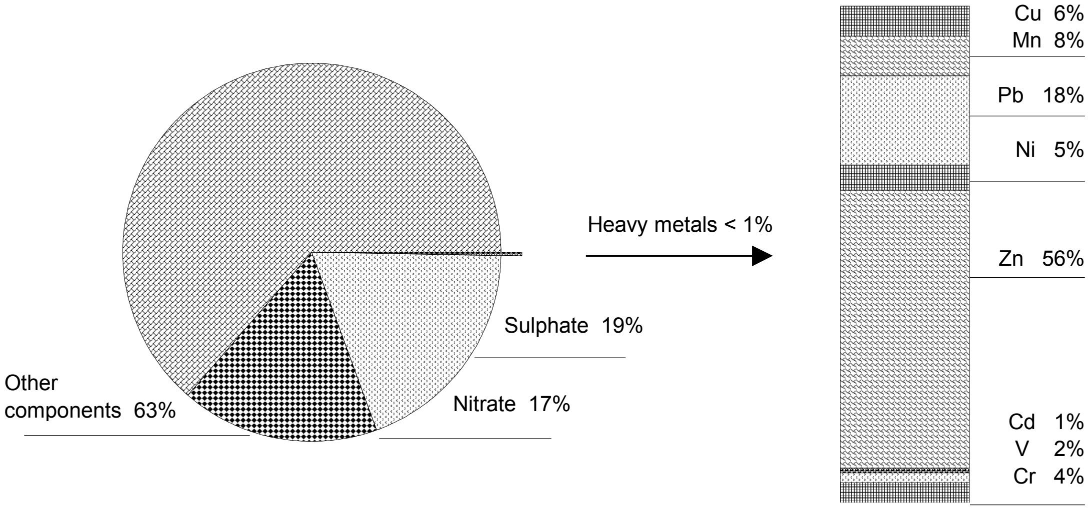
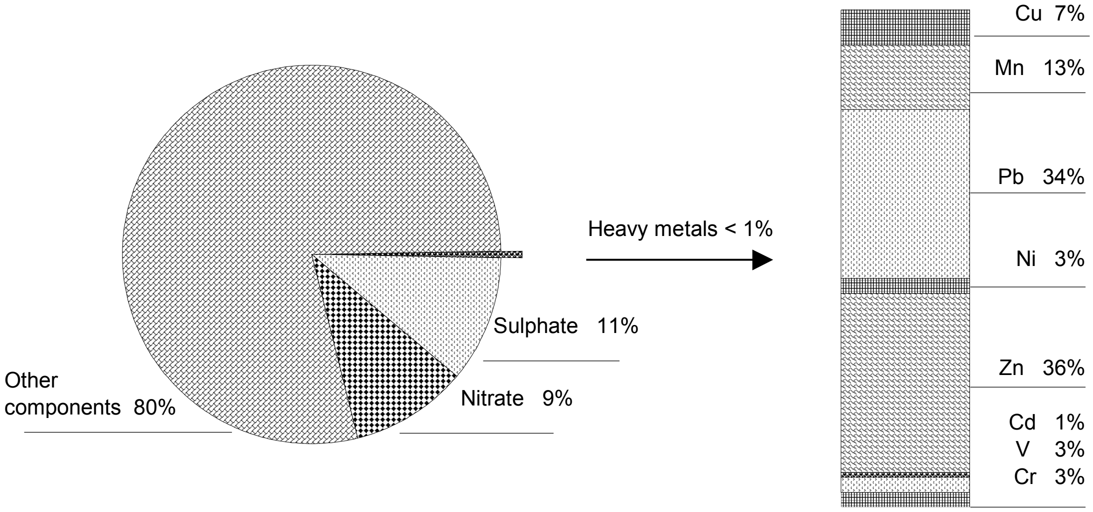


Fig. 1.34

Milhostov - 1999



Composition of aerosol and proportional share of heavy metals

Fig. 1.35

Starina - 1999

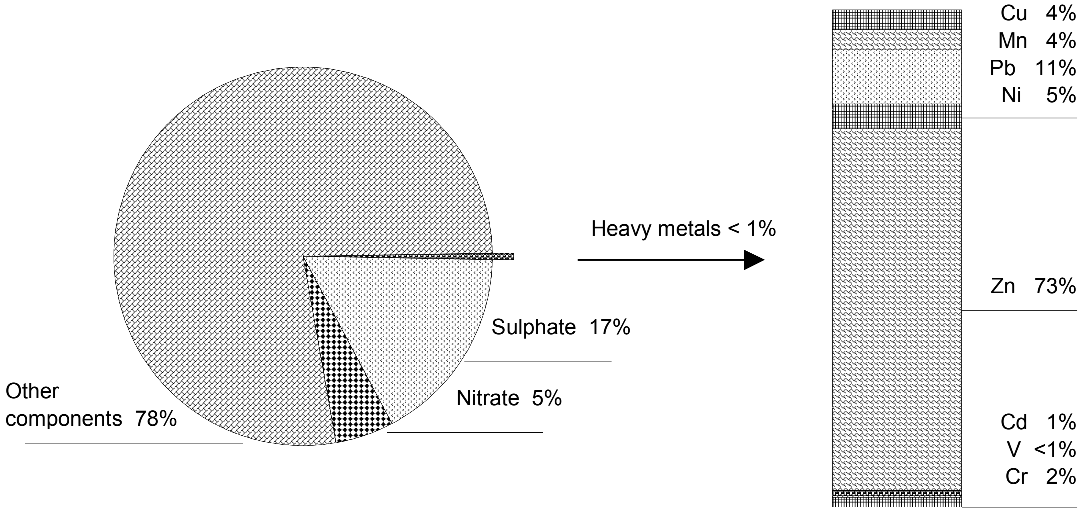


Fig. 1.36

Stará Lesná - 1999

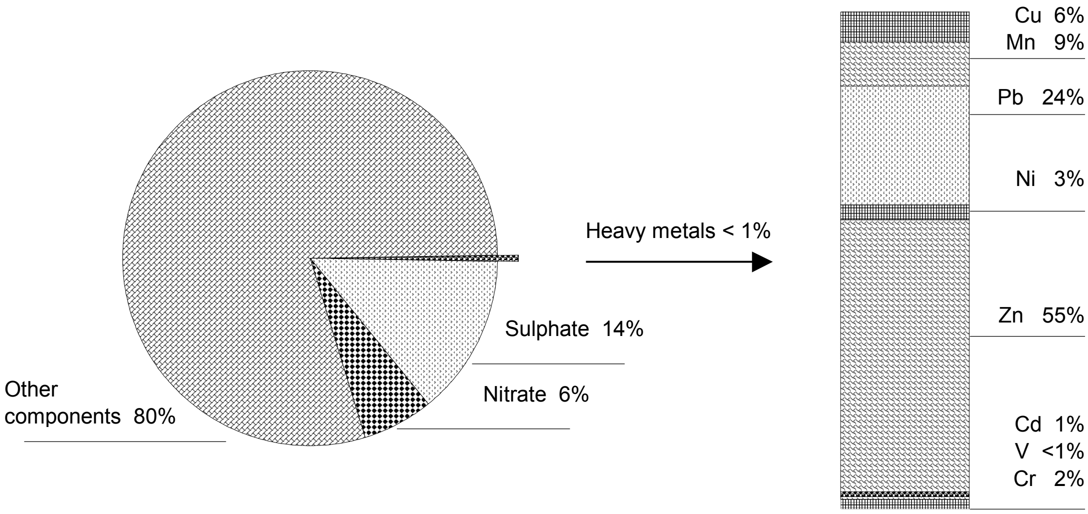


Fig. 1.37

Liesek - 1999

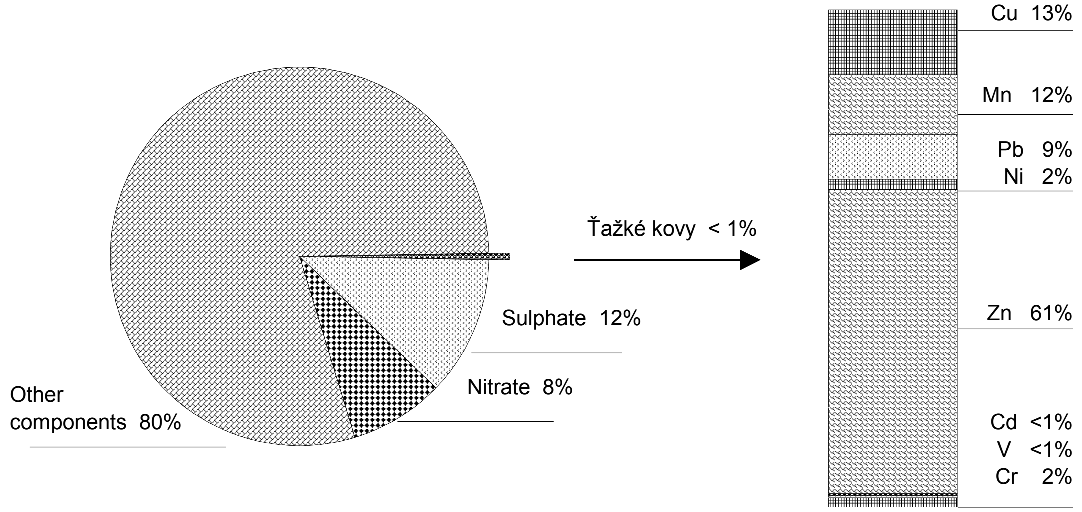
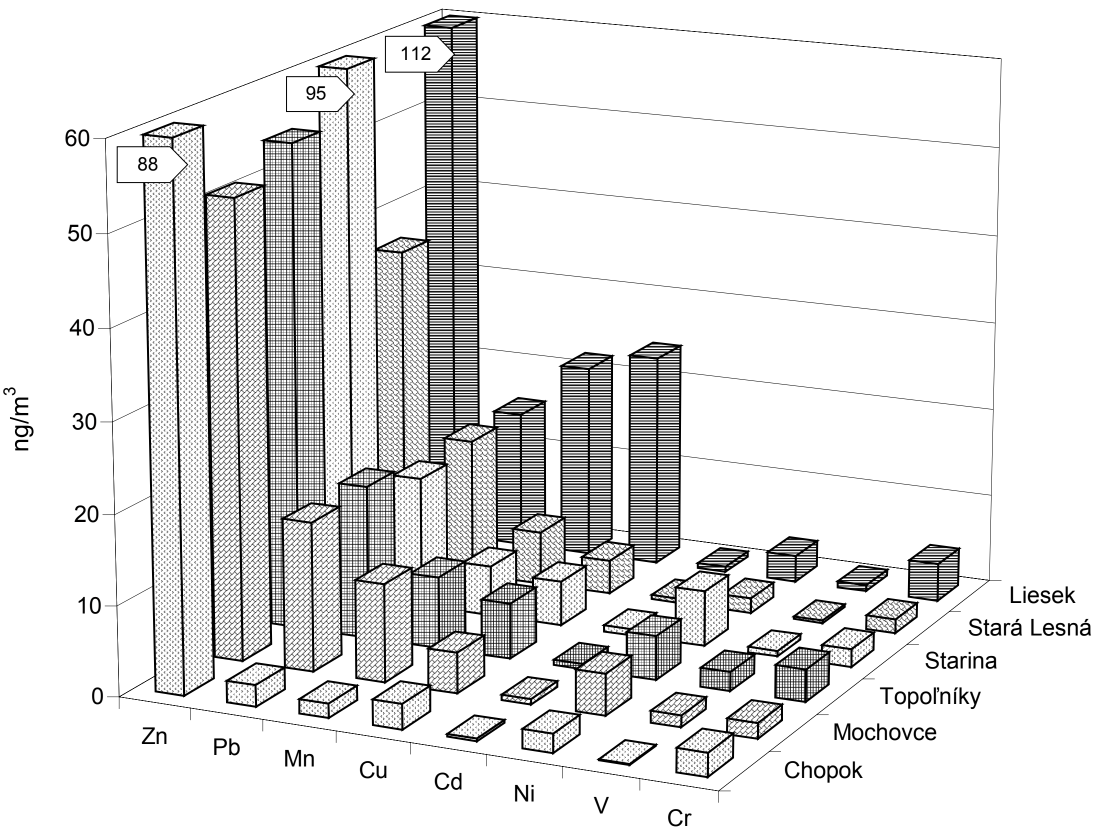


Fig. 1.38

Heavy metals in ambient air - 1999



Ground level ozone - 1999

Fig. 1.39

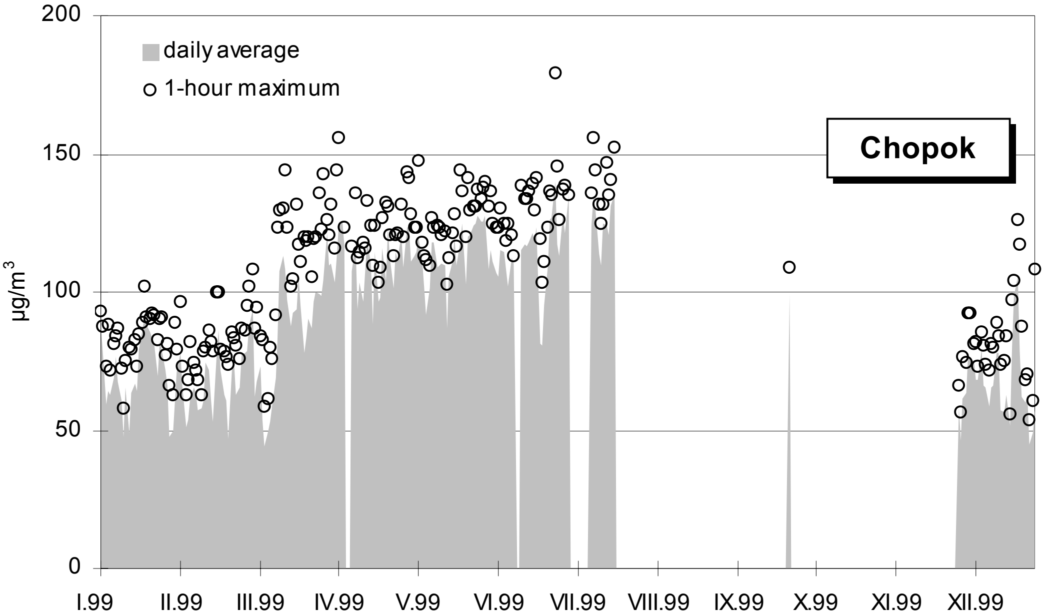
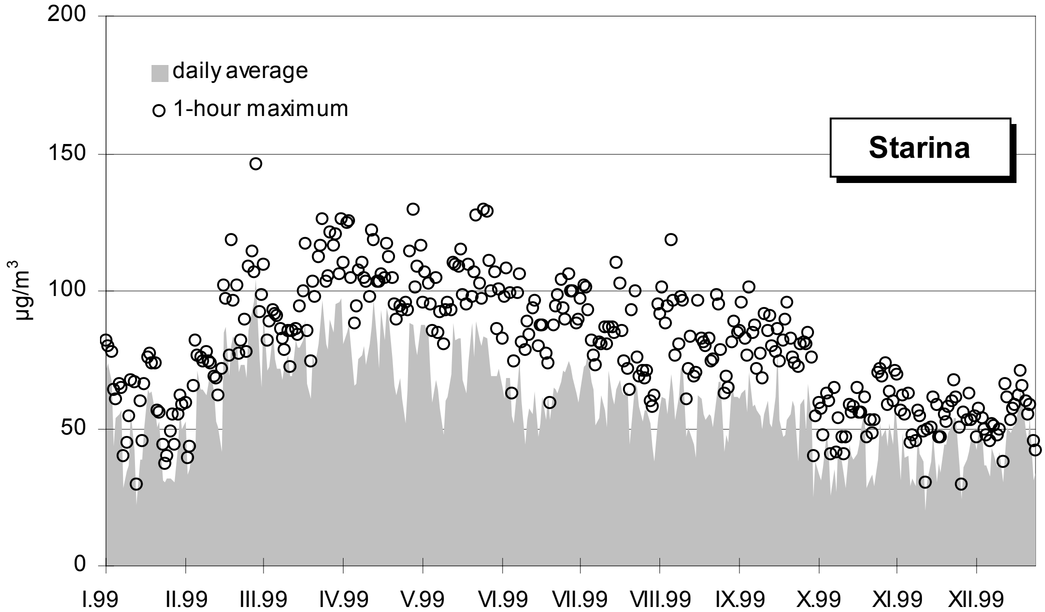


Fig. 1.40



Ground level ozone - 1999

Fig. 1.41

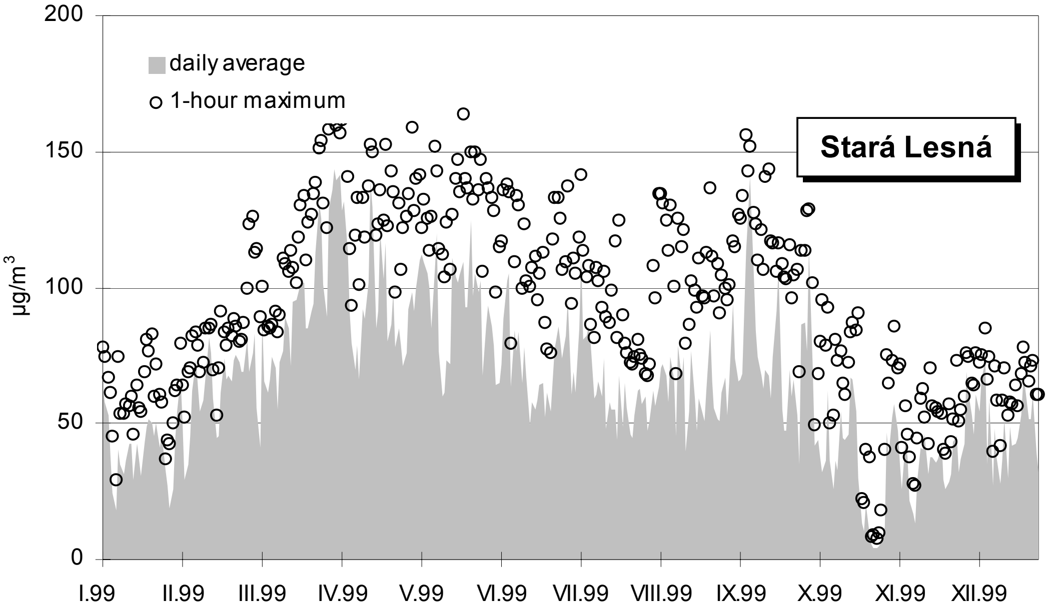


Fig. 1.42

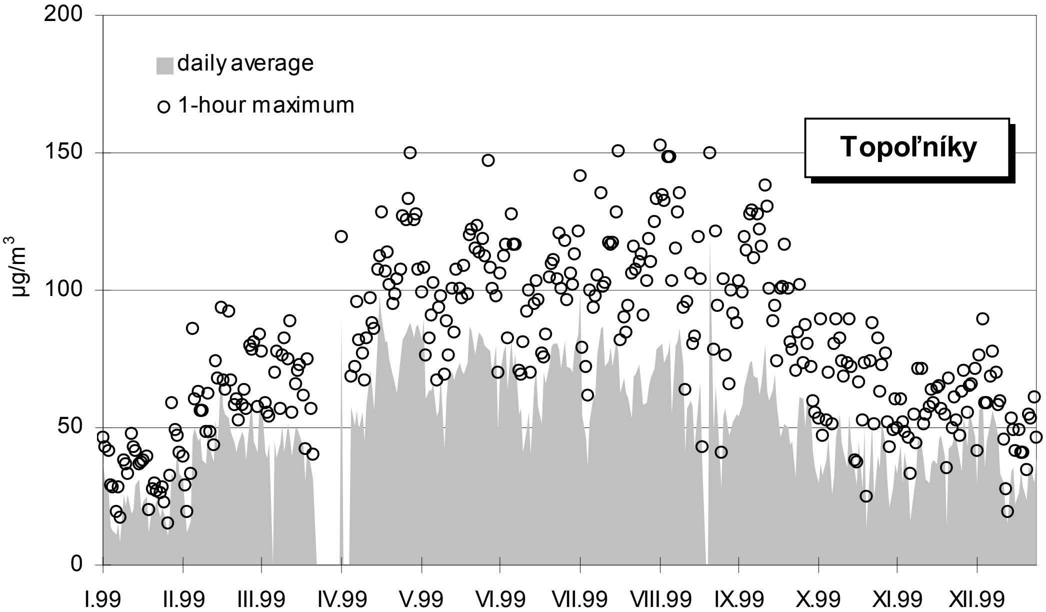


Fig. 1.43

VOCs - Starina - 1999

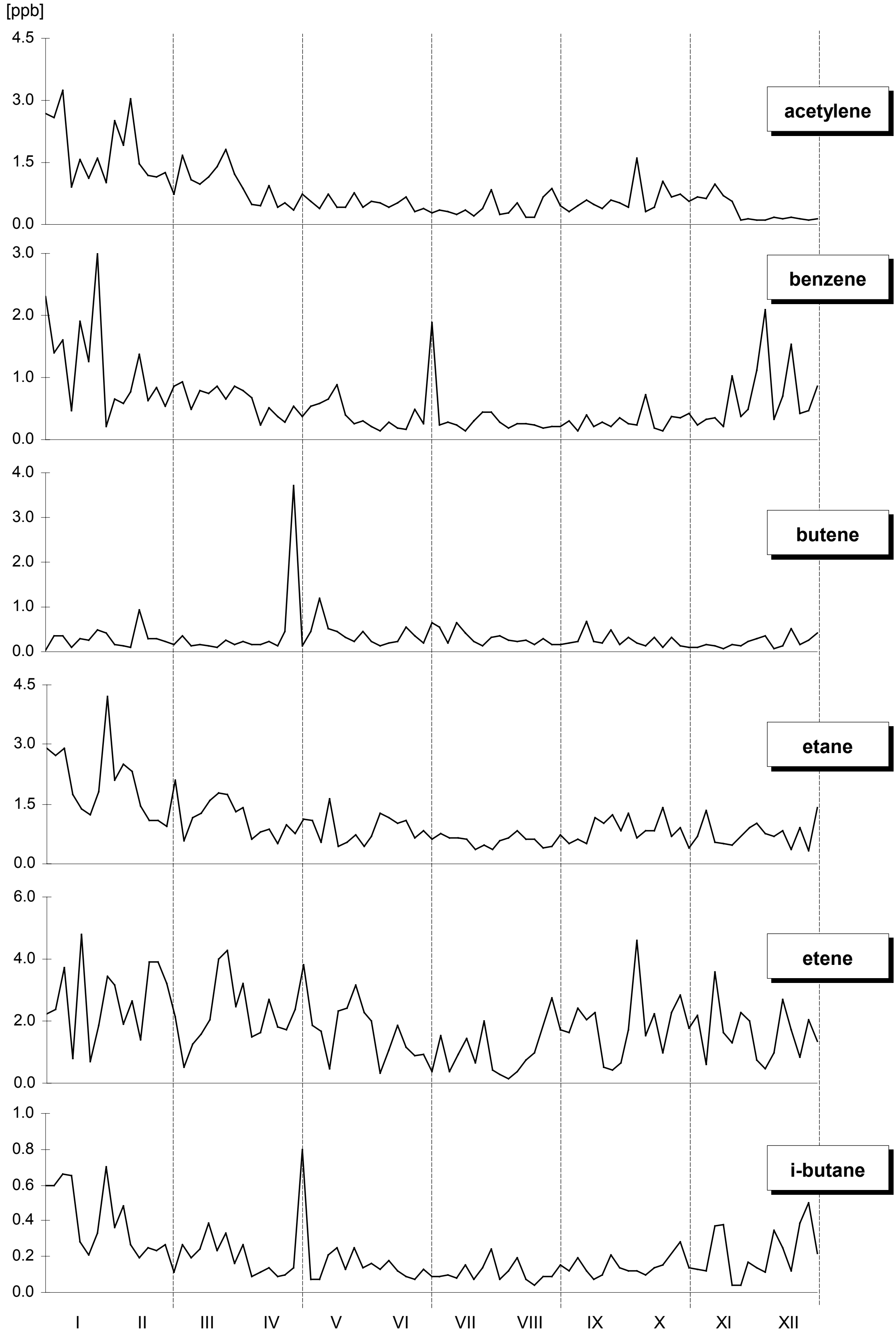


Fig. 1.44

VOCs - Starina - 1999

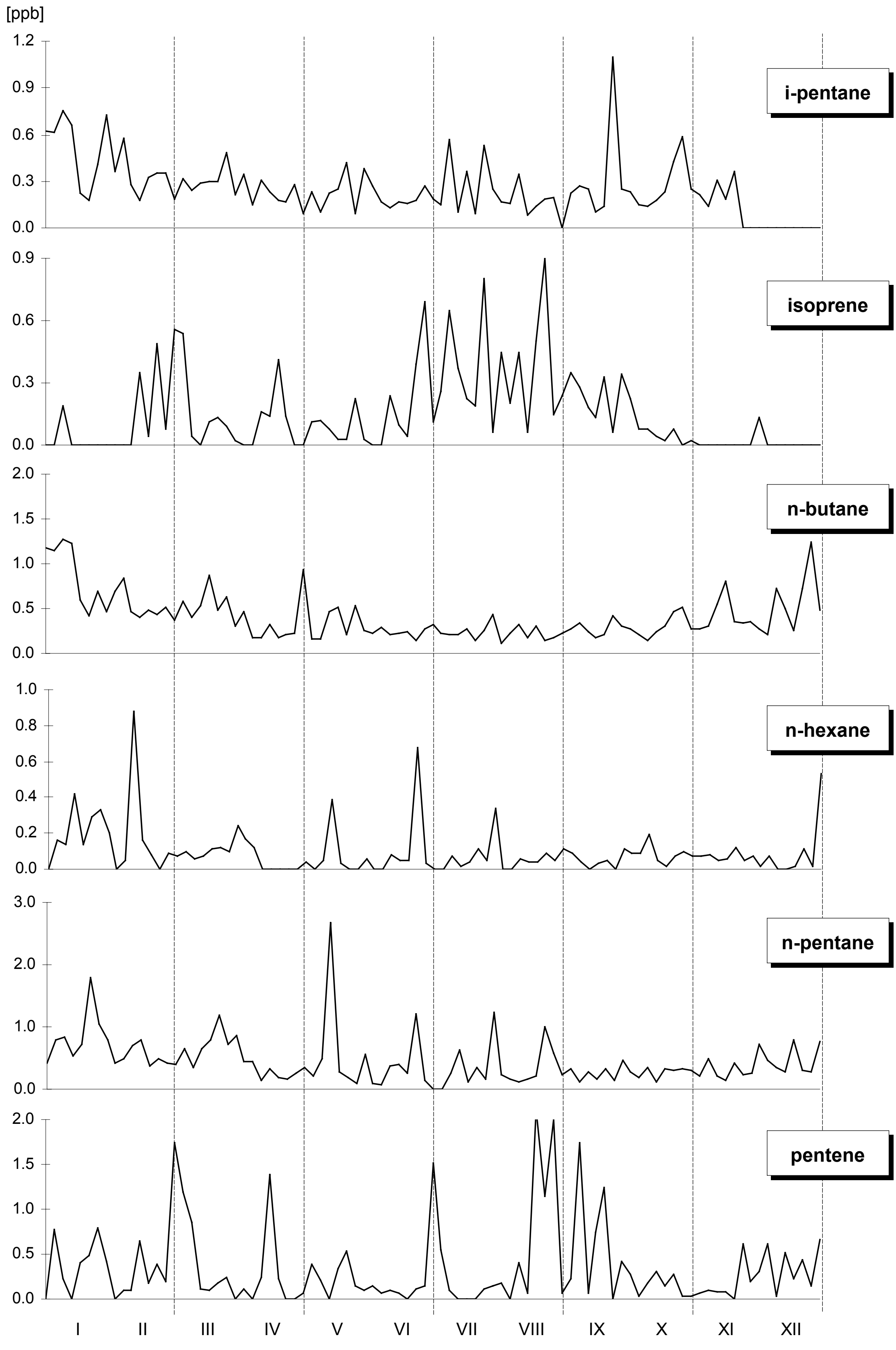


Fig. 1.45

VOCs - Starina - 1999

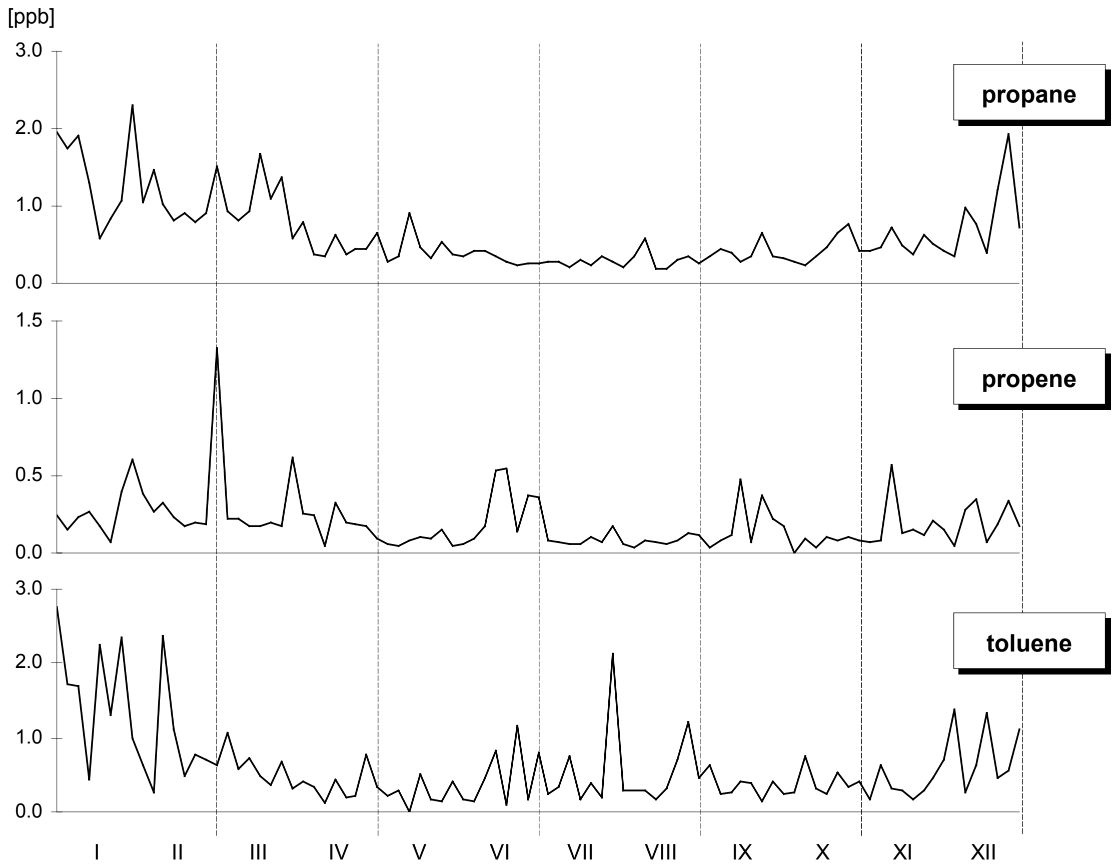
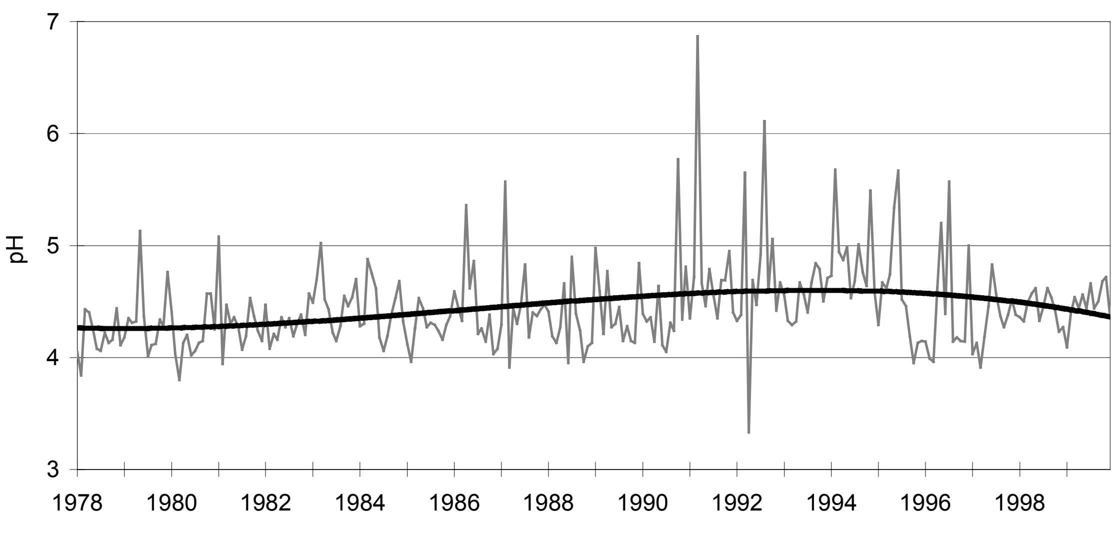


Fig. 1.46

pH in precipitation - Chopok



Monthly precipitation – 1999

Fig. 1.47 **Precipitation amount [mm]**

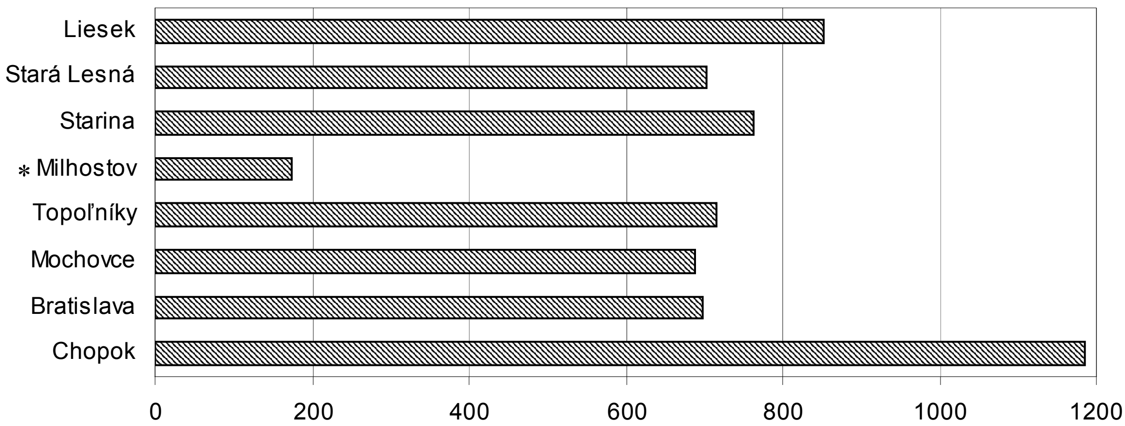


Fig. 1.48 **pH of precipitation**

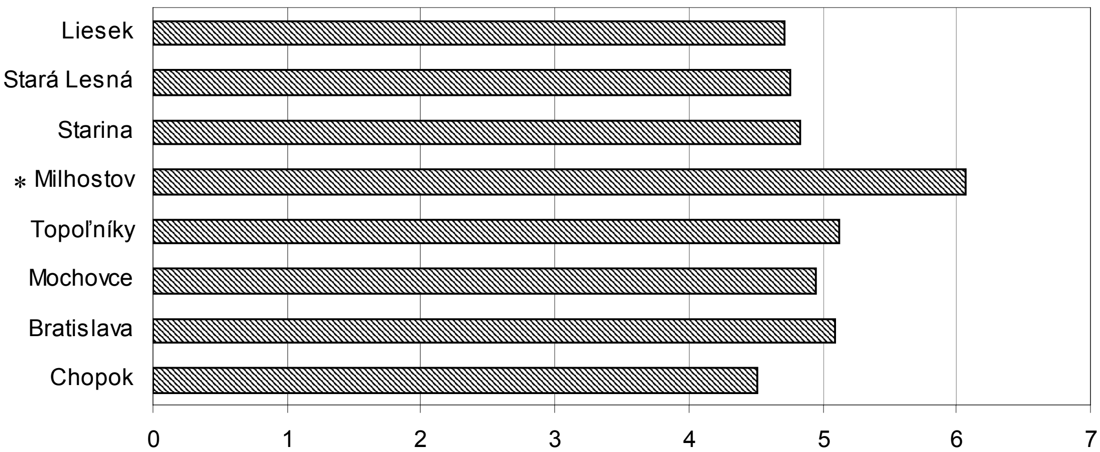
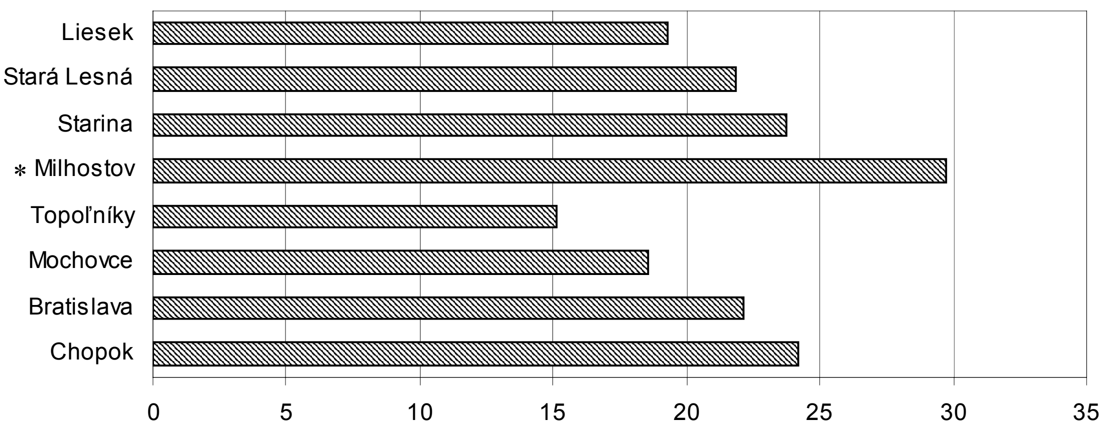


Fig. 1.49 **Conductivity of precipitation [µS/cm]**



** Station Milhostov operated for a period of 5 months only*

Fig. 1.50 **Cations in monthly precipitation**

Annual weighted means - 1999

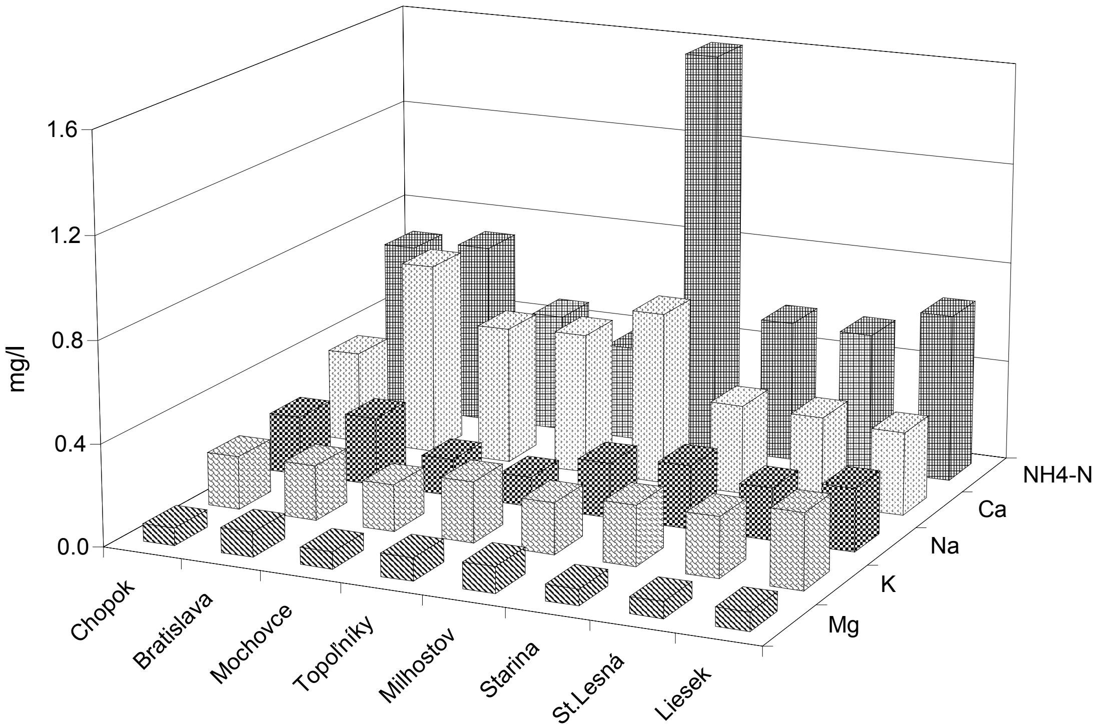


Fig. 1.51 **Anions in monthly precipitation**

Annual weighted means - 1999

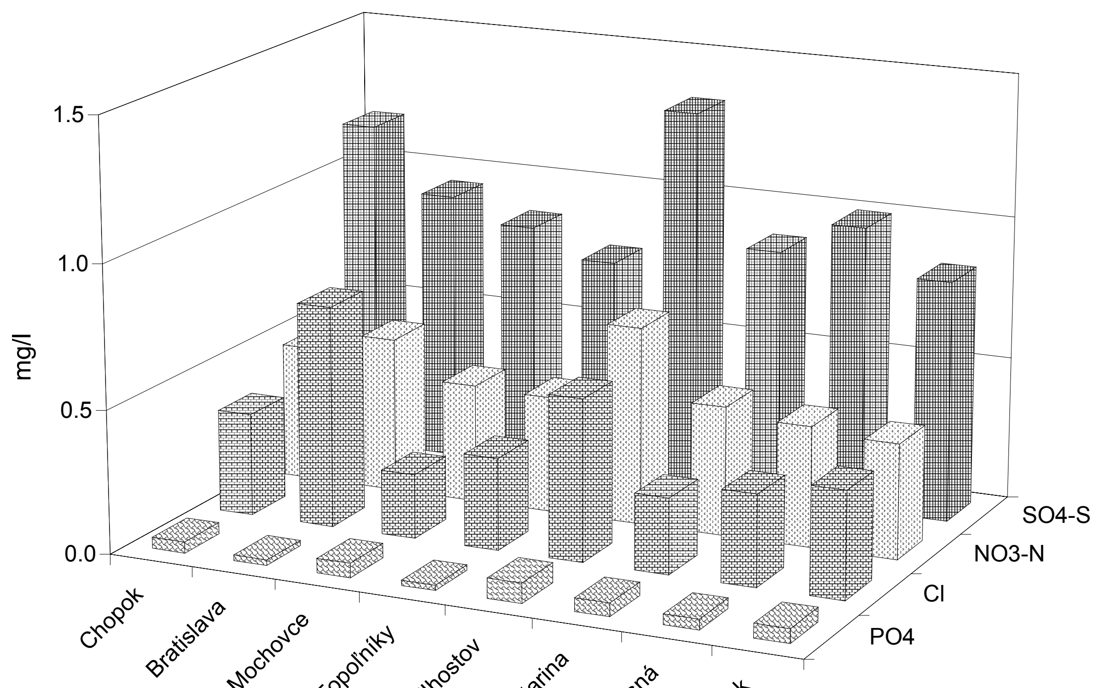
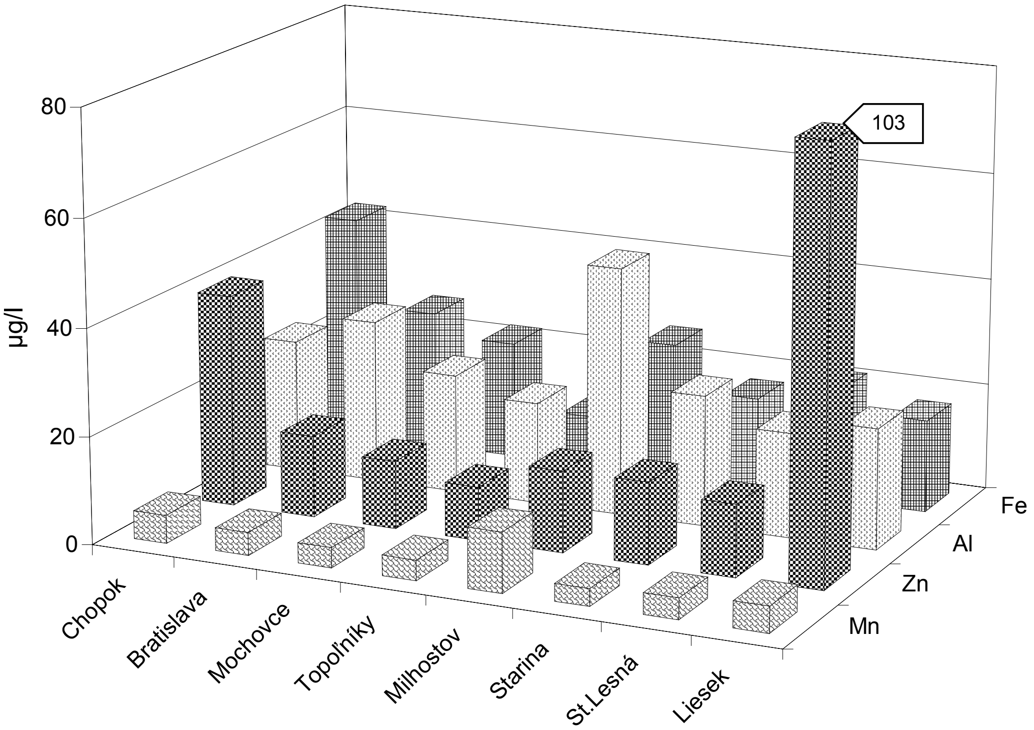


Fig. 1.52

Metals in monthly precipitation

Annual weighted means - 1999



Daily precipitation – 1999

Fig. 1.53

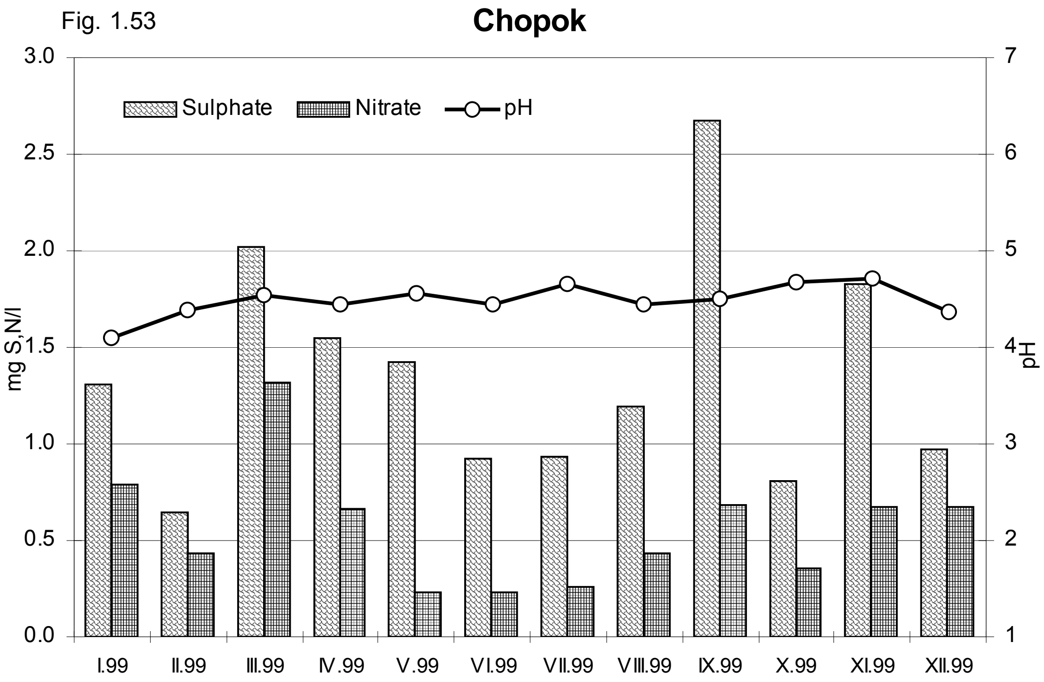
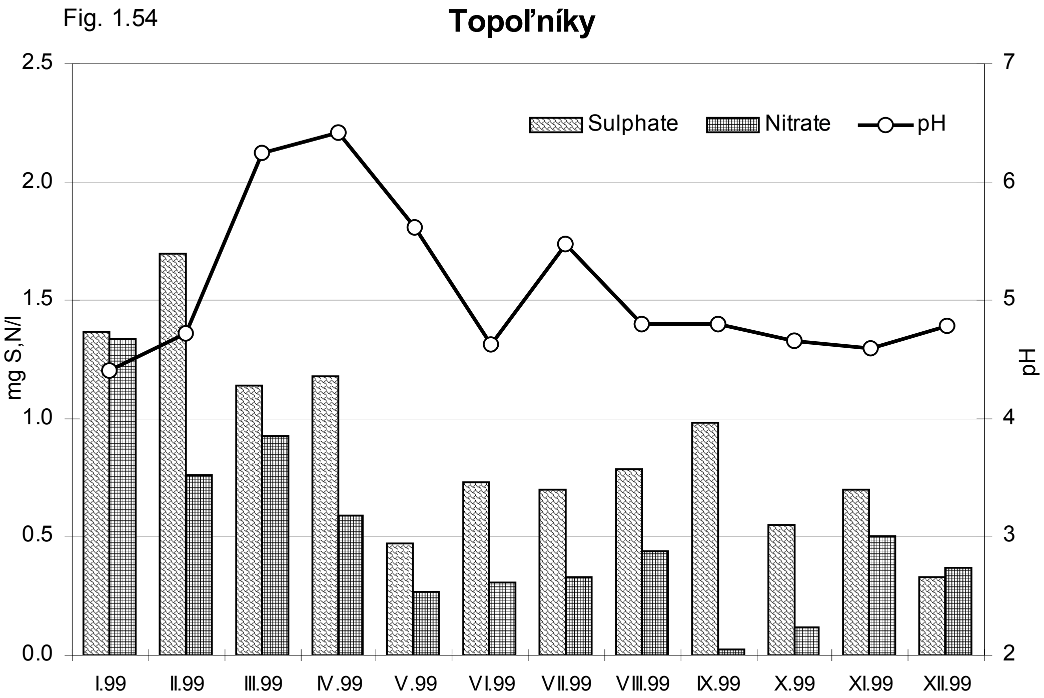


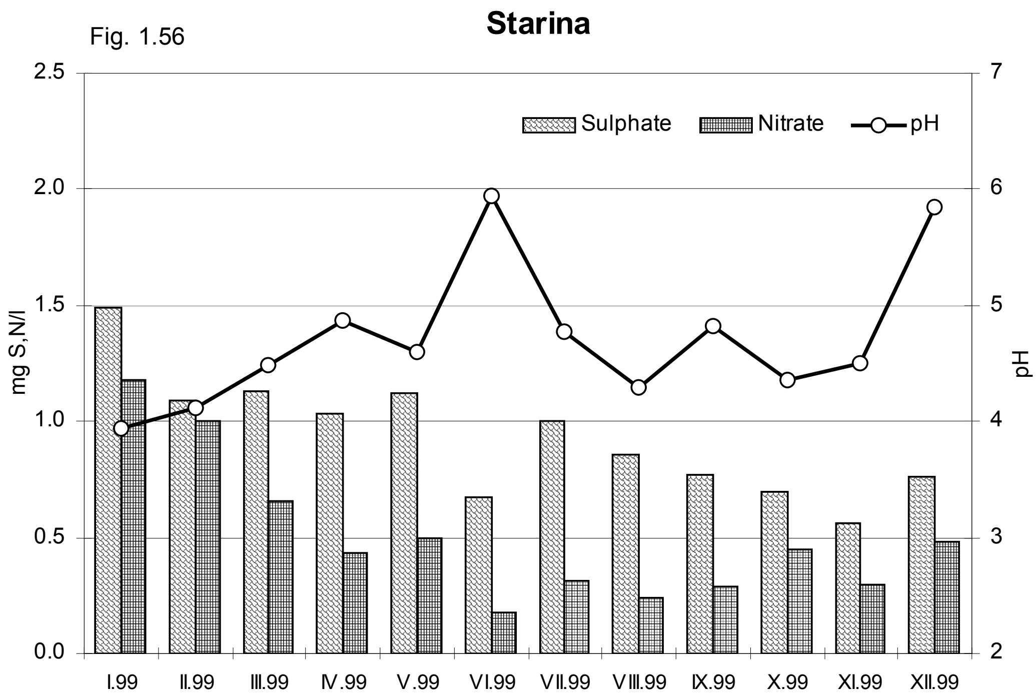
Fig. 1.54



Daily precipitation – 1999

Fig. 1.55

Fig. 1.56



Daily precipitation – 1999

Fig. 1.57

Stará Lesná

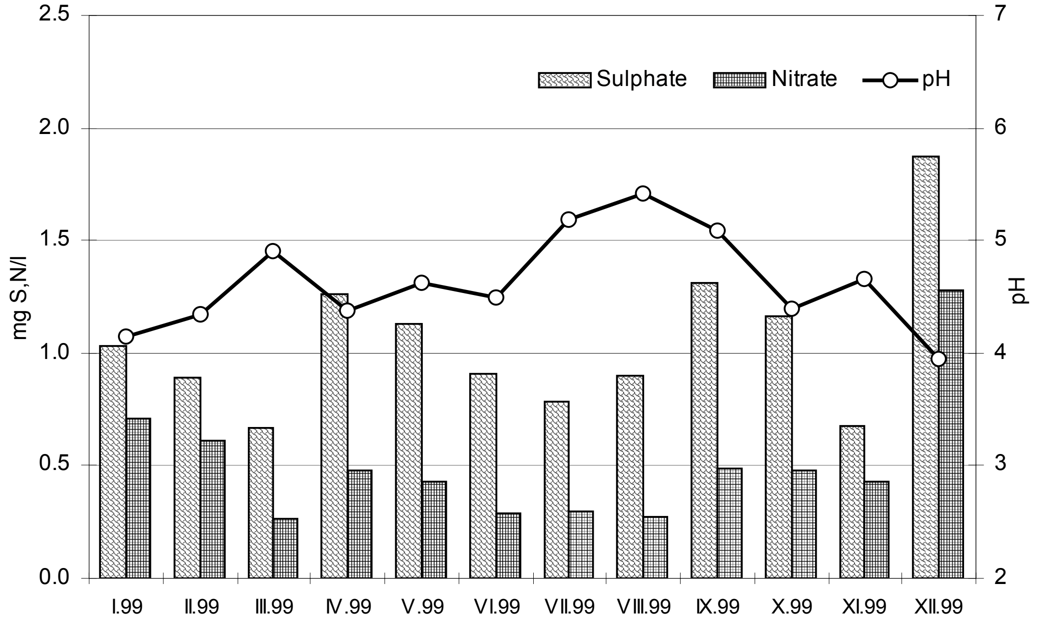
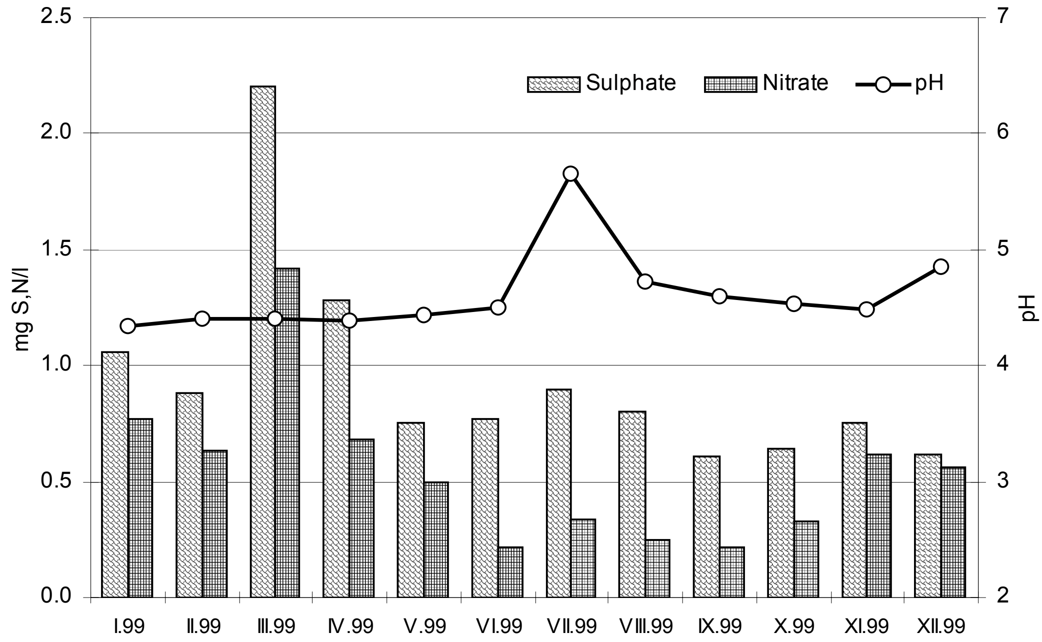


Fig. 1.58

Liesek



2.1 CHARACTERIZATION OF AIR POLLUTION MONITORING AREAS

Bratislava

Bratislava spreads out at the area of 370 km^2 along both banks of the Danube, at the boundary-line of Danube plain of the Little Carpathians and the Bor lowlands in elevation of 130-514 meters. Wind patterns of this area are affected by the slopes of the Little Carpathians, which do interfere into the north part of the city. Geographical effects enhance the wind speed from prevailing directions. The ventilation of the city is favourably affected by high wind speeds, reaching over 5 $m.s^{-1}$ on annual average. In regard to prevailing north-west wind, the city is situated favourably to major air pollution sources, which are concentrated at relatively small area between south and north-eastern periphery of Bratislava. The main share in air pollution is from chemical industry, power generation and car transport. Secondary suspended particles, the level of which depends upon meteorological factors, land use and agricultural activities and characteristics of surface, are significant secondary source of air pollution in the city.

Banská Bystrica

The town is located in the Bystrické valley, which is by the north part of the Zvolenská basin surrounded by the Starohorské hills from north, by the Horehronské valley from north-east and by the Kremnické hills from south-east. According to the climate classification this location does belong within Slovakia to the moderately warm, moisture region with cool winter. Annual average temperature is 8°C. Prevailing wind is from north and north-east, of average speed 2.1 $m.s^{-1}$ and approximately 33% occurrence of inversion in valley positions. Air pollution is affected by the cement and wood processing industries releasing emissions of suspended particles, but also by a large number of local heating sources. Heavy traffic does contribute to the high level of air pollution in the town centre, as well.

Ružomberok

Location of the city does comprise the area of western part of the Liptovská basin, on the confluence of rivers Váh, Revúca and Likavka. Mountains Veľká Fatra does constitute the border in the west, the Chočské mountains in the north and the Low Tatras in the south. From climate point of view this location is characterised as cooler, of annual average temperature 7.1°C. The most frequent wind blows from the west, of the average speed 1.6 $m.s^{-1}$. Air pollution by classical pollutants is due to the operation of heating plant technology. North Slovakian pulp and paper processing plants are the largest industrial source of air pollution. Considerable share in this pollution is caused by the small local sources, as well. Mixture of predominantly organic-sulphur compounds, leaking episodically from the technology of pulp production causes specific air pollution.

Žiar nad Hronom

The area of the Žiarska basin is closed from more sides, bordered by the Pohronský Inovec in the south-west, by the Vtáčnik and the Kremnické hills in the west up to the north and by the Štiavnické hills in the east up to the south-east. The area is characterised by the very unfavourable meteorological conditions in regard to the level of air pollution by industrial emissions in ground level layer. Annual average of wind speed in all directions is 1.8 $m.s^{-1}$, the value approximately 3-times lower than that one in Bratislava (5.2 $m.s^{-1}$). The east and north-west wind directions do occur there most frequently within year. The major share in air pollution is due to the aluminium production and power generation.

Horná Nitra

This area does include a part of the Horná Nitra basin from Prievidza to Bystričany. Direction of wind is affected considerably by geography and orientation of the basin. The most frequent winds occur there from north and north-east directions. Low value of annual wind speed 2.3 $m.s^{-1}$ does refer to the unfavourable conditions for emission dispersion and transport. Dominant share in air pollution of this area is due to the power generation. To a lesser extent the emissions from sources of chemical industry and local heating do contribute as well. The low quality of fuel sources for power generation does contribute to air pollution in this area to a great extent. The coal in use does contain apart from sulphur also arsenic.

Žilina

The town itself is spread in the valley of central Váh river, in the basin of central Považie. The Žilina's basin is classified as the basin situated moderately high. From the east the Little Fatra mountains do intervene into the area, from the south the White Carpathians and from the north-west the mountains Javorníky. According to the climate characteristics the area does belong to the moderately warm region. In the area of a basin, the relative humidity of air is higher and also the number of foggy days is the highest one throughout the year. Slight windiness of average wind speed 1.3 $m.s^{-1}$ and occurrence of calm up to 60% do characterise this area. From the standpoint of potential air pollution, the wind conditions in the Žilina's basin are very unfavourable and thus relatively smaller sources of emissions do lead to the high level of air pollution in ground level layer. Air pollution by classical pollutants is due to the local heating plant of the Slovak Power Plants, but local chemical operations and mainly heavy traffic in the town centre do participate in it as well.

Martin

Town Martin is situated in the Turčianska basin on confluence of rivers Turiec and Váh, surrounded by the mountain ranges Veľká and Malá Fatra. The area of basin located between high mountains has unfavourable climatic conditions from standpoint of pollutant emission dispersion. Frequent occurrence of inversions, low average wind speed 2.8 $m.s^{-1}$ and high relative humidity contribute to higher concentrations of oxides of nitrogen, oxides of sulphur and suspended particulate matter. To the largest emission sources belong heavy engineering, local heating plants of the Central Slovakian power plants and car transport.

Jelšava

Jelšava is situated in the area, which lies in the southern part of the Jelšava's mountains, bordered in the north-east by the massive Hrádok, in the south-west by the Železnické foothills and in south by the Jelšava's kras. The terrain is relatively broken along the central stream Muráň, oriented in the north-west – south-east. Air circulation is indicated by the direction of the valley of river Muráň. Annual average wind speed is relatively low, only 2.5 $m.s^{-1}$. The frequent occurrence of surface inversions during the nights is due to the broken mountain terrain. Two massives, Skalka and Slovenská skala, bordering the valley, also contribute to the occurrence of inversions. Major share in air pollution is from the Slovak magnesite plants Jelšava and Lubeník, situated in the north-west from the town and small local heating systems, predominantly gasofied.

Hnúšťa

The area is situated in the valley of Rimava river. Along quite narrow valley, the individual mountain ranges of relatively great elevation are extended. Short-term measurements do confirm the expected low wind speeds of about 1.5 $m.s^{-1}$ on average and considerable high occurrence of calm. The area is polluted mainly by the chemical production in Hnúšťa and Magnesite plant in Hačov.

Košice

The city Košice spreads out in the valley of the Hornád river and its surroundings. According to the geographical classification it does belong to the zone of inner Carpathians. From south-west, the Slovenský Kras does intervene into this area, in the north the Slovenské Rudohorie and in the east the Slánske hills spread out. Among these mountain ranges, the Košice's basin is situated. Mountain ranges configuration does affect the climate conditions in this area. Prevailing wind from the north is distinguished by the relatively higher wind speeds, on average 5.7 $m.s^{-1}$. Annual average wind speed from all directions is 3.6 $m.s^{-1}$. The major share in air pollution of this area is caused by heavy industry, mainly engineering industry, non-ferrous and ferrous metallurgy. Energy sources, among which the city heating plants and local boiler rooms do emit lesser amounts of pollutants.

Prešov

Prešov lies in the north promontory of the Košice's basin. Surrounding mountains of the Šariš's highland and the Slánske mountain range do reach the altitude of 300-400 m above sea level. The highest hill Stráža, in the north out of the town, does protect the town towards the invasion of cool Arctic air. The town lies on the slope turned to the south and thus the cool air runoff is provided, which does settle under the calm at the bottom of the basin. In course of a year the northern air circulation does prevail and is also the strongest. The next maximum of air circulation does belong to the south direction. Good ventilation of the town is provided by the widening of a valley itself in the confluence of the Sečkov into Torysa. Major share in air pollution of the town is caused by the town boiler rooms, mainly lacking separation technique, traffic, as well as secondary suspended particles.

Krompachy

Krompachy are located in the valley system of a good developed local air circulation. South part of the town lies in the valley of the Slovinský brook. Surrounding elevations do reach up to 350 m. North part of the town lies in the valley of the river Hornád. This valley is east-west oriented. Air circulation is indicated by the orientation of a valley. Annual average wind speed is low, achieving 1.4 $m.s^{-1}$. Main share in air pollution is due to the Non-ferrous metal works Krompachy, situated north-east and due to local heating systems.

Strážske

Strážske is located in the east out of the Vihorlat, in the north part of the East-Slovakian lowlands, in the place of the so-called Brekovská gate, where air circulation speed is strengthened, mainly from the north quadrant. Average wind speed is 3.4 $m.s^{-1}$. Wind speed is distinguished by distinctive daily course to have a minimum during night hours. Local chemical industry is the main source of air pollution in this area.

Vranov nad Topľou

Vranov lies in the valley of the river Topľa, which does pass into the East Slovakian lowlands. Location is bordered in the west by the Slánske hills and in the north by the wide zone of the Carpathians. Air circulation is given by the north-west orientation of the valley Topľa. The main air pollution source of the area is the local wood processing industry and local heating systems.

Humenné

Humenné lies in the valley of river Laborec, which is protected in the north by a wide zone of the Carphatians and in the south by the mountain range Vihorlat. The valley is north-east oriented. In regard to the complexity in geography, the prevailing wind direction is not unambiguously definitely formed. The occurrence of calm is relatively high. Local chemical industry does present the main air pollution source in this area.

2.2 CHARACTERIZATION OF AUTOMATIC MONITORING STATION LOCATIONS

West Slovakia

Bratislava - Mamateyova

Station is located 4 km in the south, out of the city centre, in the housing estate of prefab built-up area, very close to moderately busy road. Among the major sources of air pollution do belong traffic, power sources and petrochemical complex Slovnaft, Ltd. The last mentioned contributes to city air pollution mainly under the east wind direction.

Bratislava - Trnavské mýto

Location is considered to be the centre of a territory under control. The station is situated nearby a busy crossroad Šancová street - Vajnorská street. As far as the emissions from traffic are concerned, this location does belong to the extremely polluted one.

Bratislava - Kamenné námestie

Station is situated in the city centre, close to supermarket TESCO, in the area of heavy car traffic. Its position represents the old part of the city, which is not fully gasofied. Location is polluted by major sources, mainly by Slovnaft, Ltd., under the south-east wind direction.

Central Slovakia

Banská Bystrica - Nám. slobody

Station is placed in the city centre, 100 m from local busy traffic communication, at a distance of 50 m from one and two storey housing estate built up area. Station is located in a valley part of the city with worsened dispersion conditions.

Ružomberok - Riadok

Station is located in the garden of an elementary school, close to the low traffic communication. In surrounding the low built-up area of family houses prevails. Major pollution source the Slovakian pulp and paper processing plants Ružomberok is situated north-east from monitoring station.

Žiar nad Hronom

Station is placed at a boundary-line of the 4-storey house built-up area and open space, passing down, out of the station. Meteorological station is next of the monitoring station.

Prievidza

Station is located in the town centre, at the area close to the 4-storey residential houses and buildings of similar height. Near the station, the slight traffic road goes.

Handlová

Station is placed in the predominantly one-family house built-up area. Among the major emission sources do belong power sources and industry.

Bystričany

Station is situated in the zone of the water reservoir substation, at the area planted out by the fruit-trees. Power plant Nováky (ENO) is in a distance of 1.5 km far from the monitoring station.

Žilina - Veľká Okružná

Station is located in the town centre of a moderately dense built-up area of 1-5-storey buildings, in a distance of 10 m out of the busy traffic road.

Žilina - Vlčince

Station is placed in the north-east part of the town, in the housing estate Vlčince, about 0.7-1.5 km far from industrial town zone. Position is open in all directions and representative for the wind speed and wind direction measurements.

Martin

Station is placed in the area of an elementary school in the town centre, very close to the pedestrian zone and approximately 200 m from a busy traffic communication. It is surrounded by 2-storey buildings from one side and by a free zone of the sport school area from other sides.

Jelšava

Station is situated close to the historical town centre, approximately 50 m from the main road. It is surrounded by low serial built up area open to the dominant pollution source of this location, the Slovakian magnesite plants. Station is situated in a valley position of slight windiness (1.9 $m.s^{-1}$) and increased occurrence of inversions.

Hnúšťa

Station is situated in the north edge of the town, approximately 100 m far from state road No. 531, in an open area.

East Slovakia

Košice - Štúrova

This station represents the city centre. It is placed in an open area, in the centre of the Osloboditeľov square, between the car park and symbolic cemetery. Roads of inner circle, in a distance of about 15 m north and 50 m south out of the station, go in east-west direction. There is, in the vicinity of the station, no significant pollution source.

Košice - Strojárenská

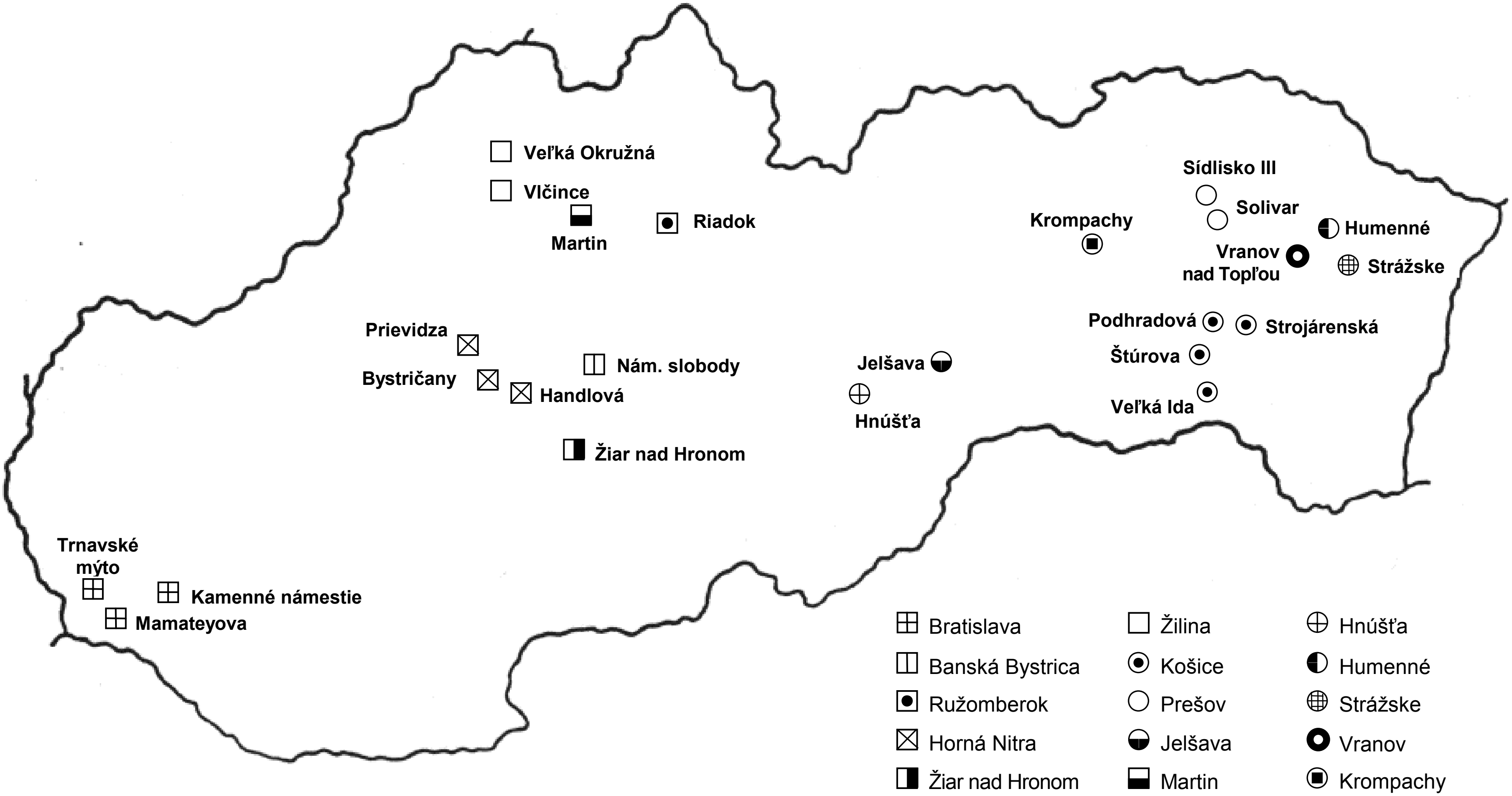
This station represents the north part of historical city. It is located next of the town hall, in a densely built-up part of the city, about 50 m far from the surrounding buildings. Approximately 15 m is the distance of a station from the road of inner circle. Under the south wind, the location is exposed to the exhaust gases coming from traffic in Moyzesova street.

Košice - Podhradová

Station is located in the grounds of the Slovak Hydrometeorological Institute, in a relatively open area, in the north edge of the housing estate Podhradová and the city itself. Under the south air circulation, when the dispersion conditions are mostly worsened, the location is exposed to a considerable extent.

Košice - Veľká Ida	Station is located in the south-east part of the municipality Veľká Ida, nearby the East Slovakian iron works (VSŽ), in a relatively open area. The station has been purchased by the VSŽ in order to control the effect of this works on ambient air quality in the municipality.
Prešov - Sídlisko III	Station is placed in an open area, near supermarket, at the boundary-line of a new housing estate and north -west part of the historical town centre. Nearby, approximately 50 m, the main road to Levoča goes. The town boiler room using solid fuel is about 1000 m north from the station.
Prešov - Solivar	Station is located in the south-east part of the town in an open zone of a thin low built up area in a vicinity of cross-road Solivarská and General Petrov streets.
Krompachy	Station is located in the valley of the Slovinský potok, in the west edge of the town, out of the busy roads, 2 km south-west out of the Ferrous metal plant Kovohuty Krompachy. Surrounding built-up area comprises the multi-storey houses. It is a valley position with the increased occurrence of inversion.
Strážske	Strážske is situated in an open area, in the west edge of a town, in the housing estate with a local boiler room, approximately 1km east - south-east out of the Chemko Strážske plant. In a vicinity of the station no busier roads go.
Vranov nad Topľou	Station is placed in the town centre, in front of the Civic house, approximately 2 km north-west out of the plant Bukóza Vranov. Alongside the main road, in a distance of about 30 m out of the station, is the surrounding built-up area, represented by the 3- and 4-storey residential houses.
Humenné	Station is located in the south part of a town centre at the border of a pedestrian zone of minimum car transport (parking 50-100 m from AMS). Surrounding objects are connected to the central heating. The most important air pollution source - Chemes Humenné is located approximately 2 km west from AMS.

Fig. 2.0 **Location of automatic air pollution monitoring stations in the Slovak Republic**



Tab. 2.1 Geographical co-ordinates of monitoring stations

Area	**Station**	**Longitude**	**Latitude**	**Altitude** [m]
Bratislava	Mamateyova	17°08'05"	48°07'43"	136
	Trnavské mýto	17°07'45"	48°09'32"	136
	Kamenné námestie	17°07'00"	48°08'45"	139
Banská Bystrica	Nám. slobody	19°09'30"	48°44'12"	343
Ružomberok	Riadok	19°18'27"	49°04'32"	485
Žiar nad Hronom	Žiar nad Hronom	18°51'07"	48°35'17"	263
Horná Nitra	Prievidza	18°37'30"	48°45'11"	269
	Handlová	18°45'32"	48°44'00"	437
	Bystričany	18°31'00"	48°40'02"	251
Žilina	Veľká Okružná	18°44'18"	49°13'12"	390
	Vlčince	18°46'20"	49°12'40"	368
Martin		18°55'26"	49°04'03"	396
Jelšava		20°14'18"	48°37'48"	255
Hnúšťa		19°57'12"	48°35'04"	315
Košice	Štúrova	21°15'47"	48°43'01"	199
	Strojárenská	21°15'17"	48°43'37"	200
	Podhradová	21°14'45"	48°45'17"	248
	Veľká Ida	21°10'34"	48°35'31"	207
Rudňany		20°41'17"	48°52'47"	523
Prešov	Sídlisko III	21°13'54"	49°00'03"	245
	Solivar	21°15'59"	48°58'43"	255
Krompachy		20°52'24"	48°55'04"	385
Strážske		21°49'48"	48°52'21"	134
Vranov nad Topľou		21°41'26"	48°53'12"	128
Humenné		21°53'08"	48°54'35"	160

2.3 DATA QUALITY AND PROCESSING OF MEASUREMENT RESULTS

Measurements of ambient air concentrations by continuous instruments do perform the highest technical level of ambient air pollution control. The results of measurements are being used at the approval of new air pollution sources, at ambient air protection planning within the frame of smog alert systems, as well as at ordinary checking of condition if permissible ambient air standards are exceeded.

The tests of analysers are carried out regularly by zero gas and calibration gas of the known concentration. Measurement spans are tested in the laboratory by an external calibrator, which does enable to change the concentrations. Testing of analysers does comprise the checking of all parameters recommended by the producer in compliance with the international standards. The composition of calibration gas must be constant during the entire process of testing. Supplying lines for calibration gases have to be made of borosilicate glass or teflon. When calibration gas is rarefied, it is necessary to use zero gas, which does not contain the ingredients evolving the response of analyser. It is necessary to take into account the possible interferences. To use ambient air as the zero air, the primary chemical cleaning is needed, or synthetic air of corresponding composition and purity may be used. Testing of linearity does include at least 7 calibration points within the measuring range. The data acquired are assessed by the method of the least squares. The testing on interfering gases must not evolve the bigger deviations as the producer of instrument does appoint.

To process a huge amount of data, the graphical presentation was chosen and significant statistical characteristics as well as the ambient air quality indices are given in the tables.

Daily average concentrations and maximum half-hour concentrations in respective day are presented in each graph. Values of pollutants having identified ambient air quality standards AQS_d and AQS_s, are marked in graphs.

Annual average concentrations, calculated upon the daily average concentrations as arithmetic mean, 95-percentiles for daily and half-hour concentrations, daily maximum and short-term concentrations, measured in respective year, are given in the table appendices.

For selected locations, the concentration roses were processed for suspended particles, oxides of nitrogen and sulphur dioxide. Wind speed and wind direction data from meteorological stations were also used for the assessment, as the monitoring stations are not equipped with the anemographic sensors.

Frequency and pollution duration time was processed individually according to the special ambient air quality standards for signal purposes: Attention, Warning and Regulation.

Air pollution indices were assessed according to the method of the Ministry of environment of the Slovak Republic. The Table "Air pollution indices" does provide information about the share of respective pollutants (SO_2, NO_x and suspended particles) in total air pollution index in individual areas.

To compare polluted areas, air pollution indices (API) were assessed taking three pollutants SO_2, NO_x and suspended particles (S_i) into consideration.

Three ways how to express API are distinguished:

API_y - long-term (annual) air pollution index
API_s - short-term air pollution index
API_d - daily air pollution index

The indices are defined as follows:

$$\mathbf{API_y} = \sum_{i=1}^{3} [\text{annual average concentration} / AQS_y]_{Si}$$

$$\mathbf{API_s} = \sum_{i=1}^{3} [95 \text{ percentile}_s / AQS_s]_{Si}$$

$$\mathbf{API_d} = \sum_{i=1}^{3} [95 \text{ percentile}_d / AQS_d]_{Si}$$

Classification of air pollution degrees according to the indices (API_y, API_s, API_d):

API range	0.0 - 0.4	0.5 - 0.9	1.0 - 1.4	1.5 - 2.0	over 2.0
Air pollution degree	favourable	slight	moderate	unhealthy	very unhealthy

Tab. 2.2 Technical parameters of measuring instruments

Pollutant measured	Principle of measurement	Range of measurement [mg/m³]	Detection limit [µg/m³]	Producer	Type
SO_2	UV-fluorescence	0...2.6	2.6	TEI	Model 43A
	UV- fluorescence	0...1.3	1.3	Monitor Labs	ML 9850
H_2S	UV- fluorescence	0...1.4	1.4	TEI	Model 340
NO, NO_2, NO_x	Chemiluminescence	0...1.9	0.9	TEI	Model 42
	Chemiluminescence	0...1	< 0.9	Monitor Labs	ML 9841
CO	GFC	0...72.5	< 72.5	TEI	Model 48
	GFC	0...72.5	< 114.5	Monitor Labs	ML 9830
O_3	UV-photometry	0...2	4	TEI	Model 49
	UV-photometry	0...1	2	Monitor Labs	ML 9811
SP	Beta-absorbtion	0...3.3	10	ENVIRONMENT SA	MPSI 100
	Beta-absorbtion	0.005...20	5	FAG	FH 62 I-N
	Beta-absorbtion	0.001...1	10	VEREWA	F 703
	TEOM	0.005...1	5	Rupprecht &	1400
		0.005...1	5	Patashnick	1400ab

Remark: All concentrations of measured pollutants are expressed in µg.m^{-3} at standard conditions (298°K and 101.3 kPa)

Tab. 2.3 List of pollutants monitored in Slovakia

Area	Station	SO_2	NO_x	SP	O_3	CO	H_2S
Bratislava	Mamateyova	*	*	*	*	*	*
	Trnavské mýto	*	*	*		*	
	Kamenné námestie	*	*	*			
Banská Bystrica	Nám. slobody	*	*	*	*	*	
Ružomberok	Riadok	*	*	*	*		*
Žiar nad Hronom	Žiar nad Hronom	*	*	*	*		
Horná Nitra	Prievidza	*	*	*	*		
	Handlová	*	*	*			
	Bystričany	*	*	*			
Žilina	Veľká Okružná	*	*	*		*	
	Vlčince	*	*	*	*		*
Martin		*	*	*	*		
Jelšava		*	*	*	*		
Hnúšťa		*	*	*	*		
Košice	Štúrova	*	*	*	*	*	
	Strojárenská	*	*	*			
	Podhradová	*	*	*	*		
	Veľká Ida	*	*	*	*	*	
Prešov	Sídlisko III	*	*	*			
	Solivar	*	*	*	*	*	
Krompachy		*	*	*			
Strážske		*	*	*			
Vranov nad Topľou		*	*	*			
Humenné		*	*	*	*		

NO_x

Fig.2.1

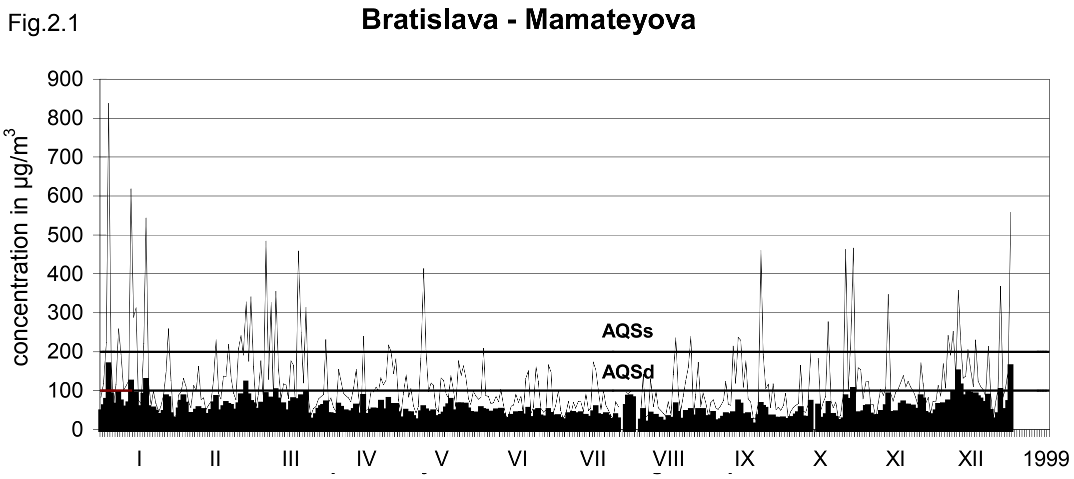


Fig.2.2

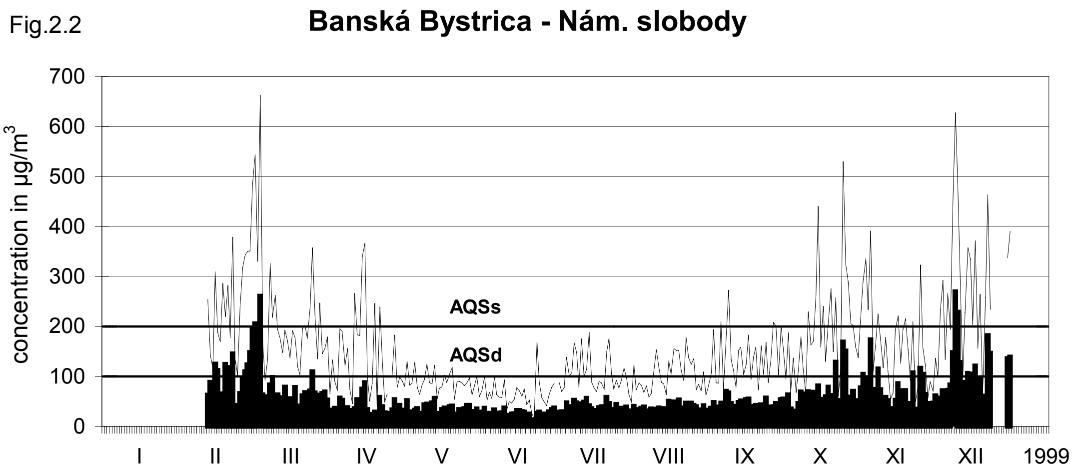
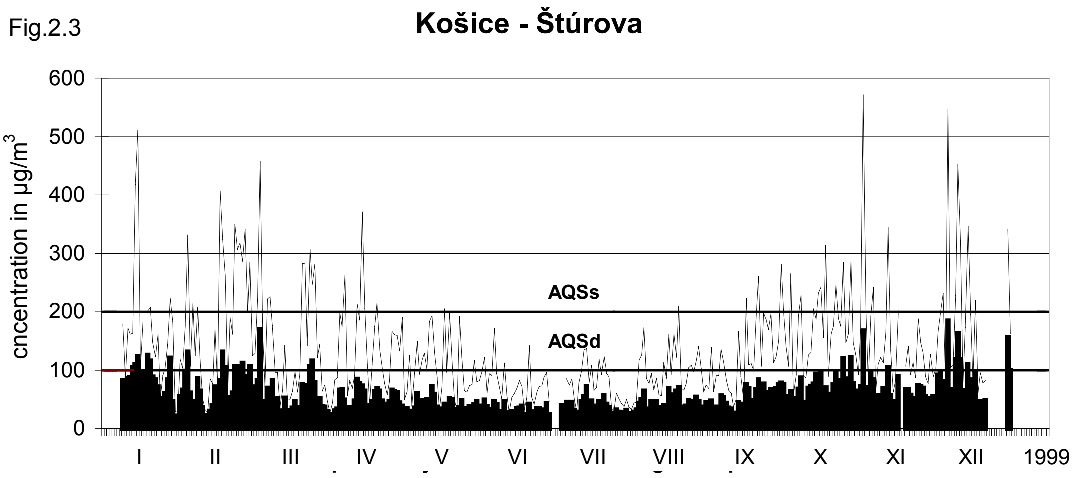


Fig.2.3



■ daily average concentrations — maximum short-term concentrations

SO_2

Fig.2.4

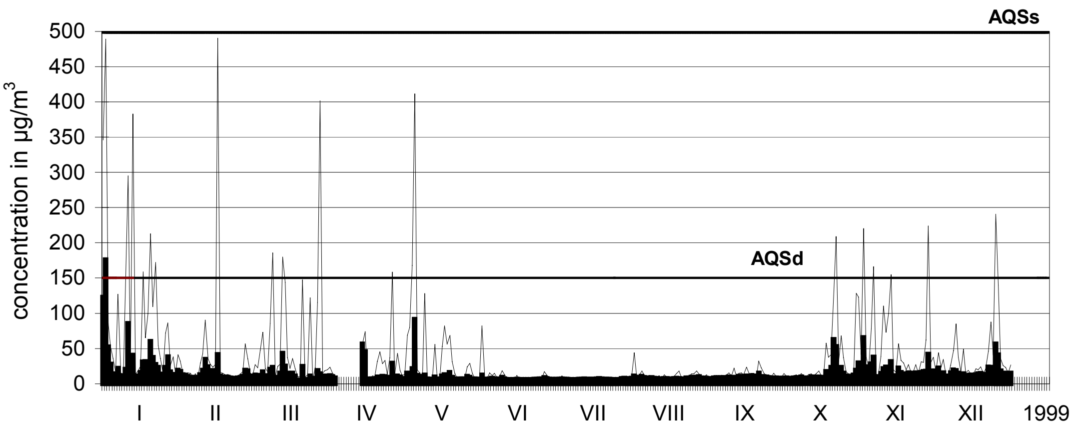


Fig.2.5

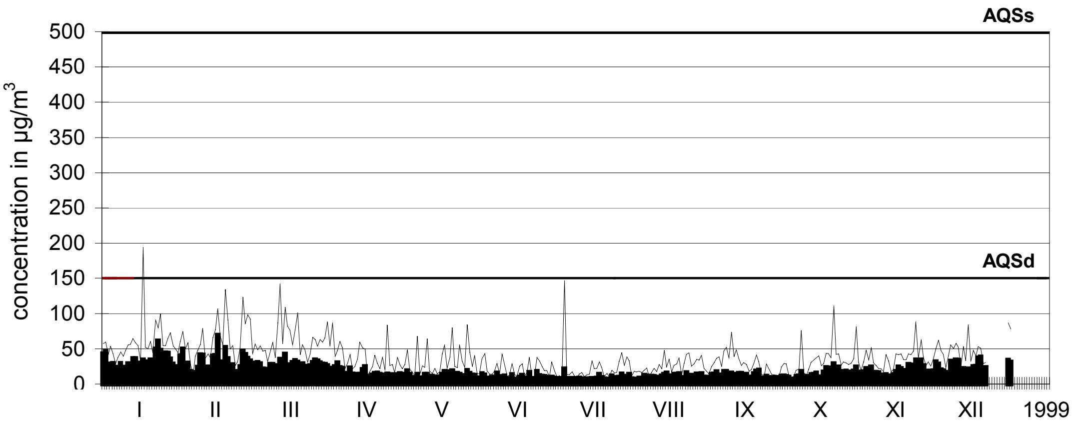
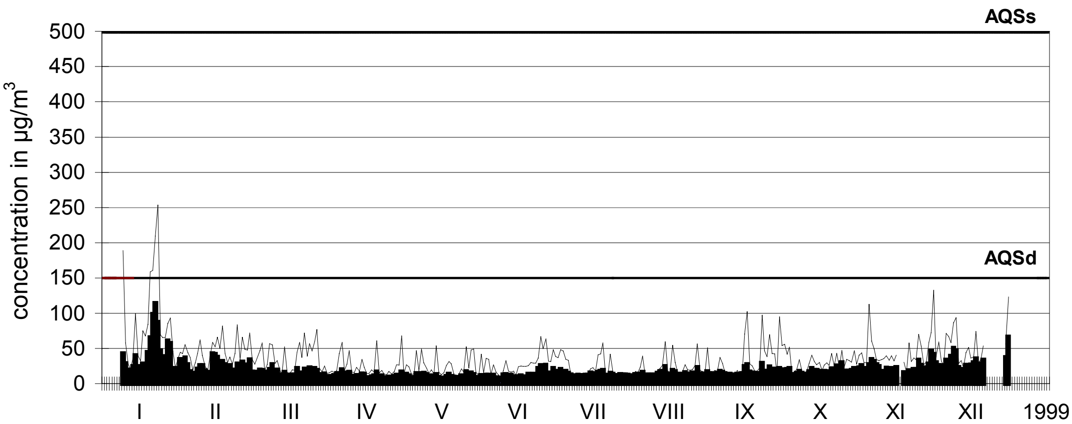


Fig.2.6



■ daily average concentrations —— maximum short-term concentrations

PM

Fig.2.7

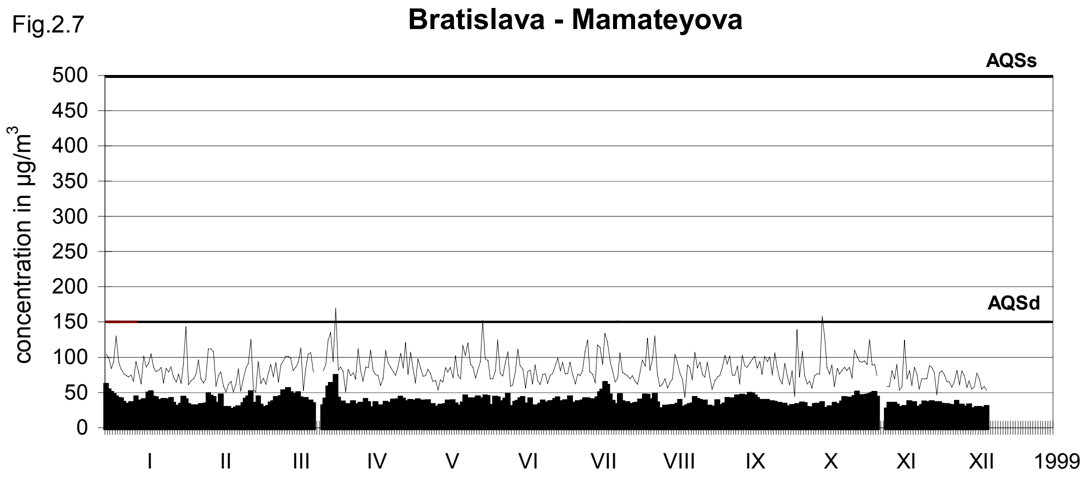


Fig.2.8

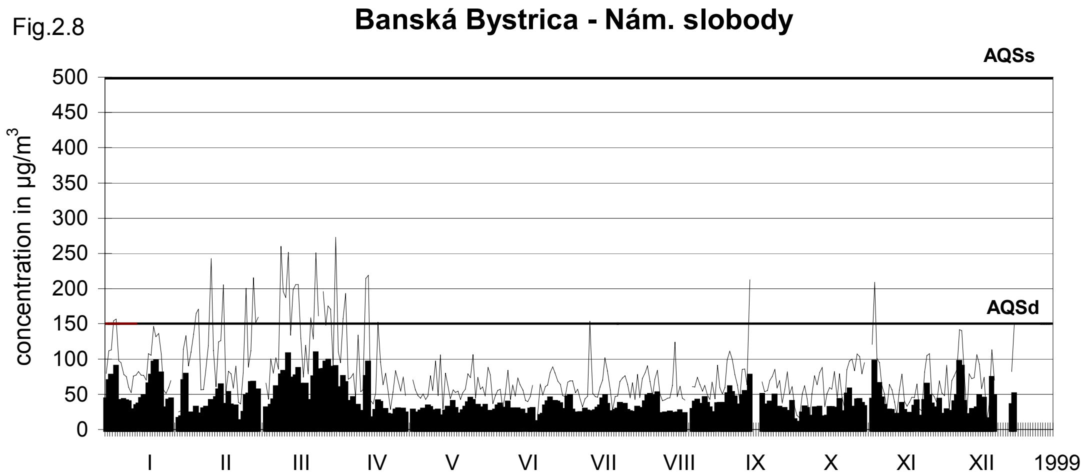
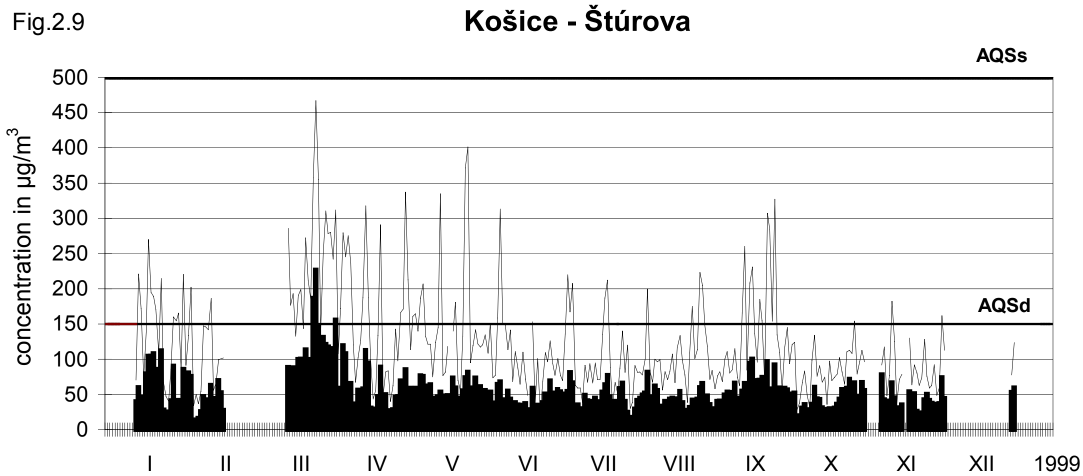


Fig.2.9



■ daily average concentrations —— maximum short-term concentrations

CO

Fig.2.10

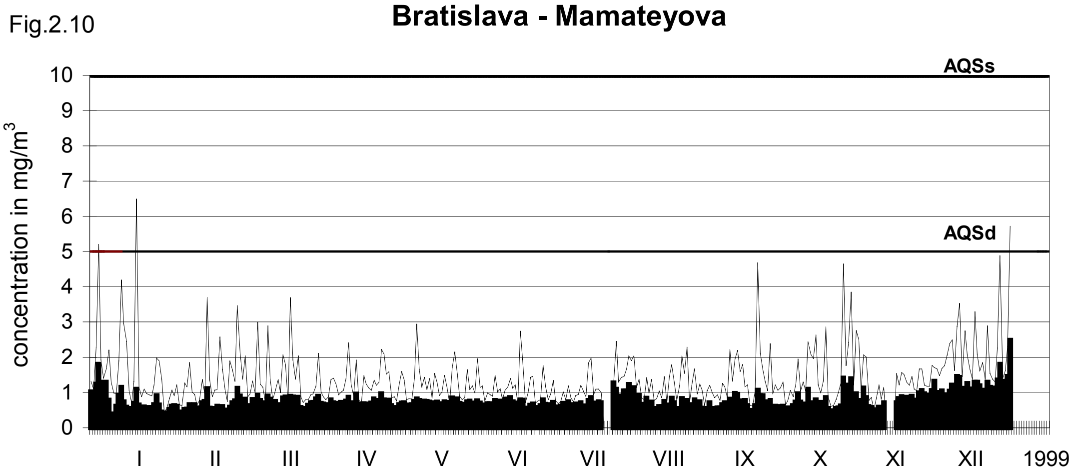


Fig.2.11

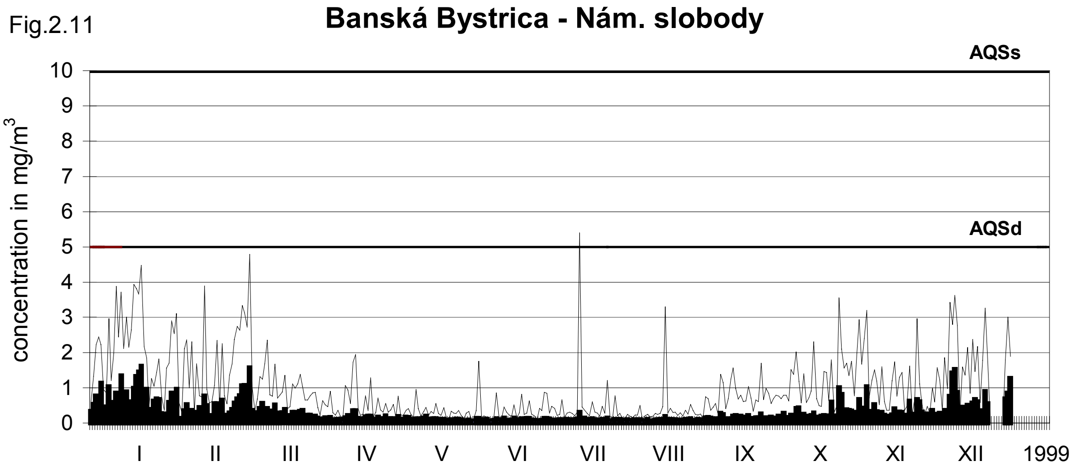
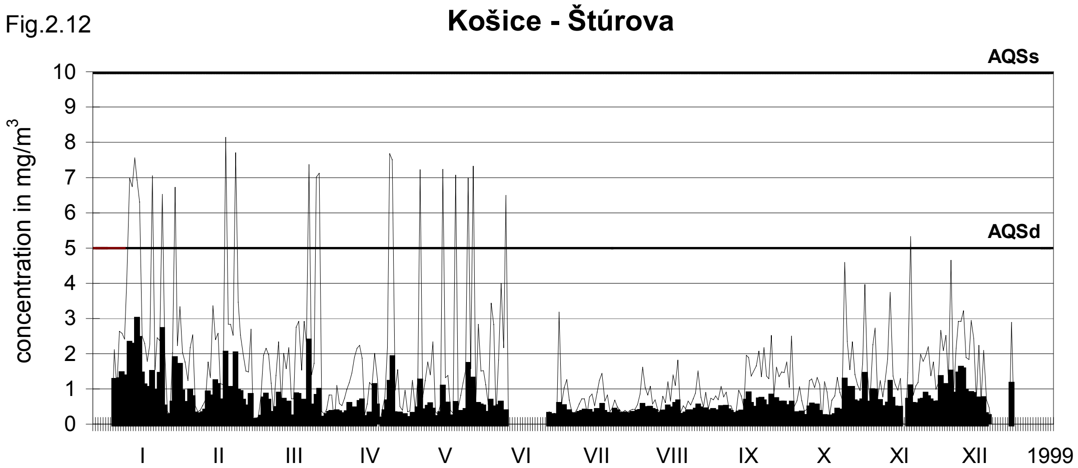


Fig.2.12



■ daily average concentrations —— maximum short-term concentrations

O_3

Fig.2.13

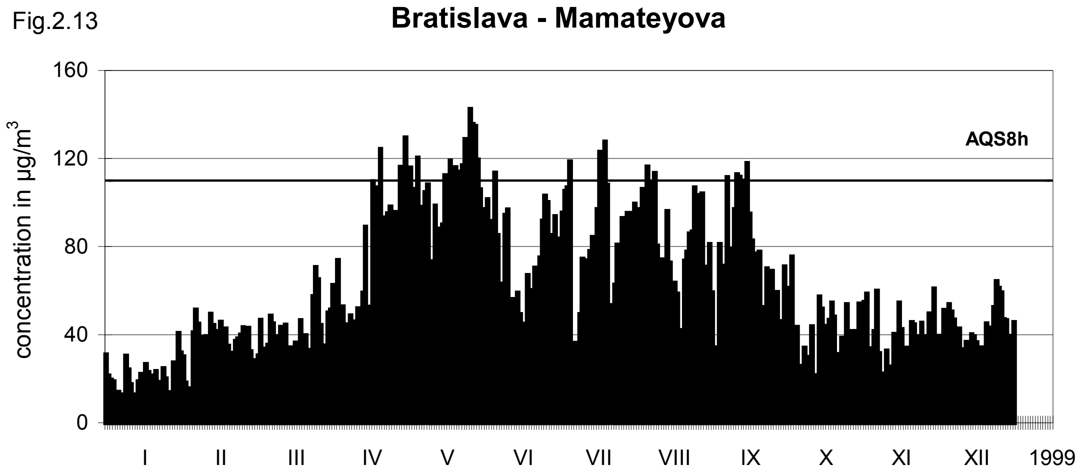


Fig.2.14

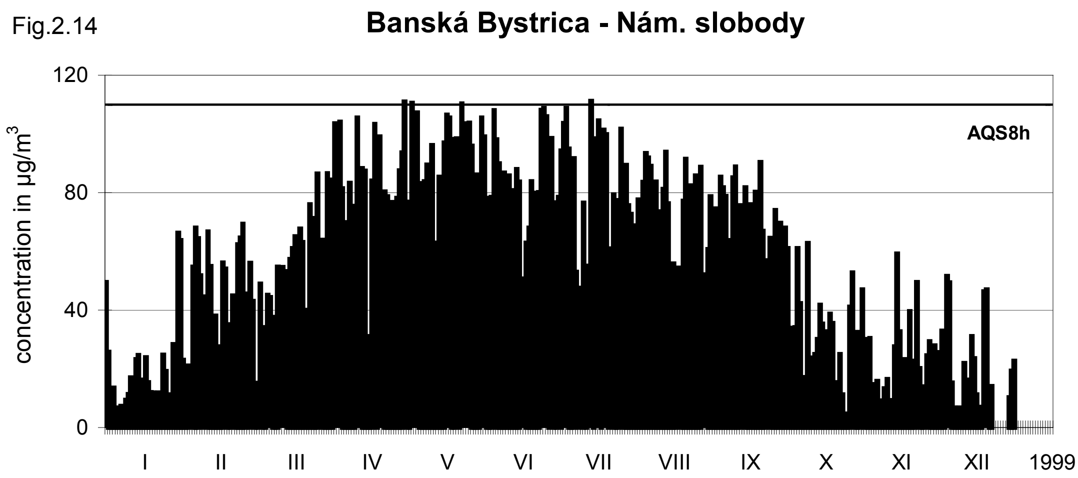
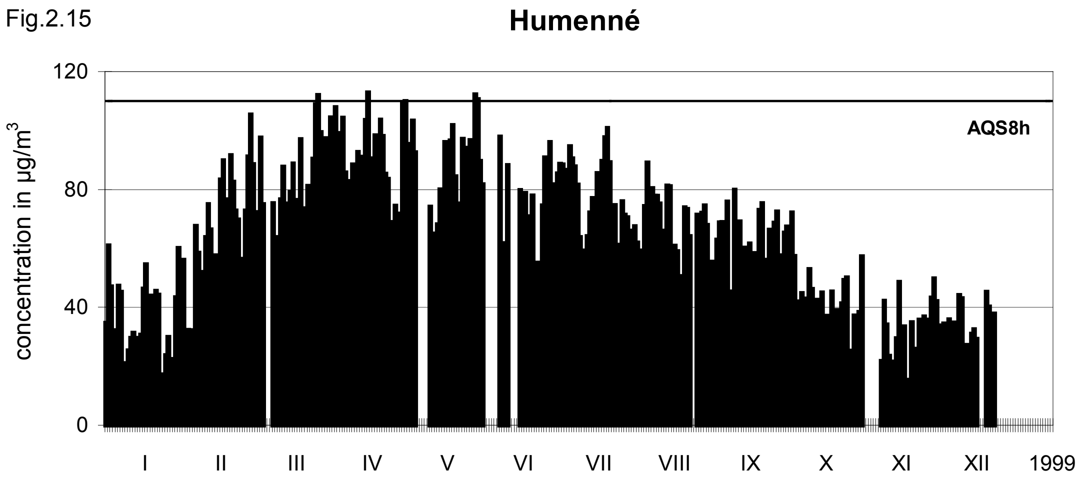


Fig.2.15



8-h concentrations

H_2S

Fig.2.16

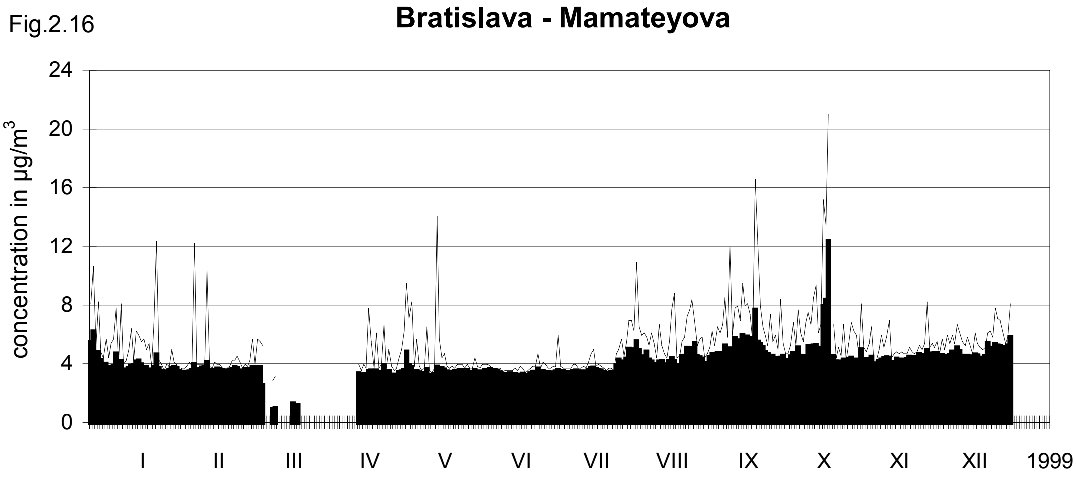
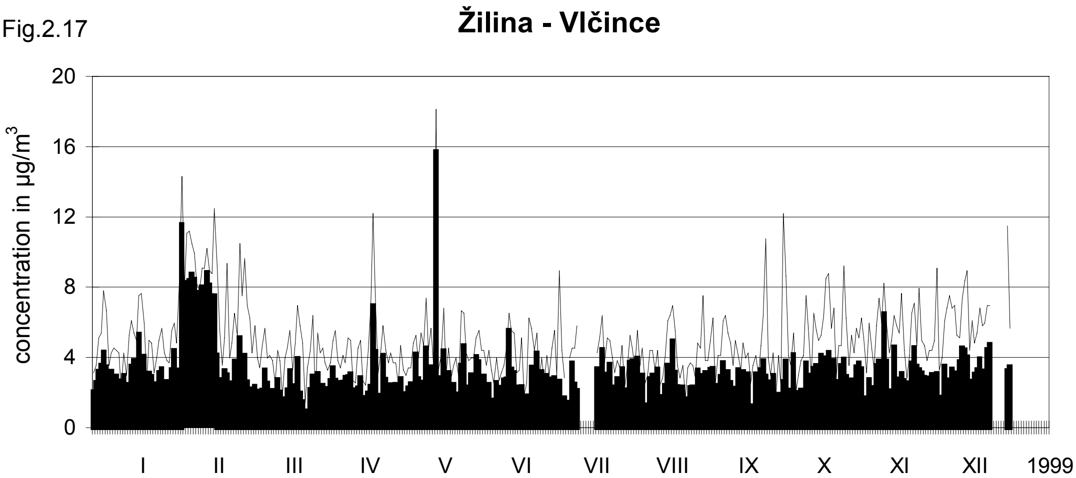


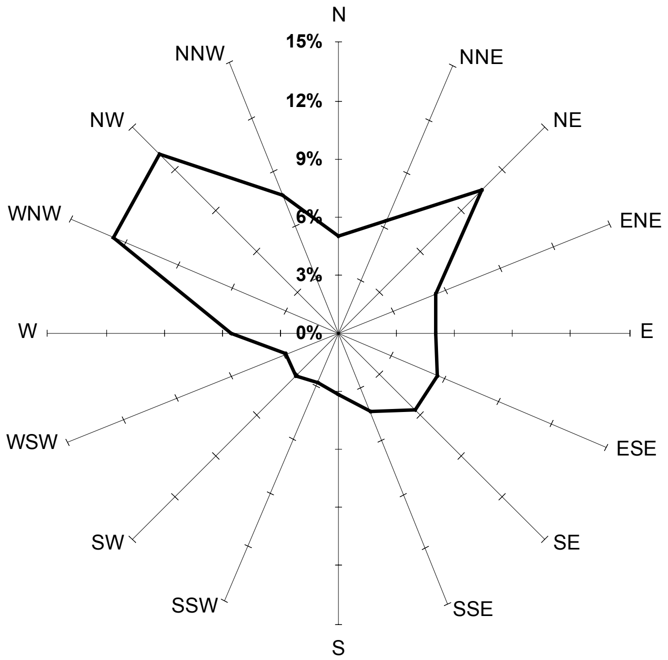
Fig.2.17



■ daily average concentrations — maximum short-term concentrations

Fig. 2.18

Wind rose - Bratislava 1999



Concentration rose (µg/m³) - Kamenné námestie 1999

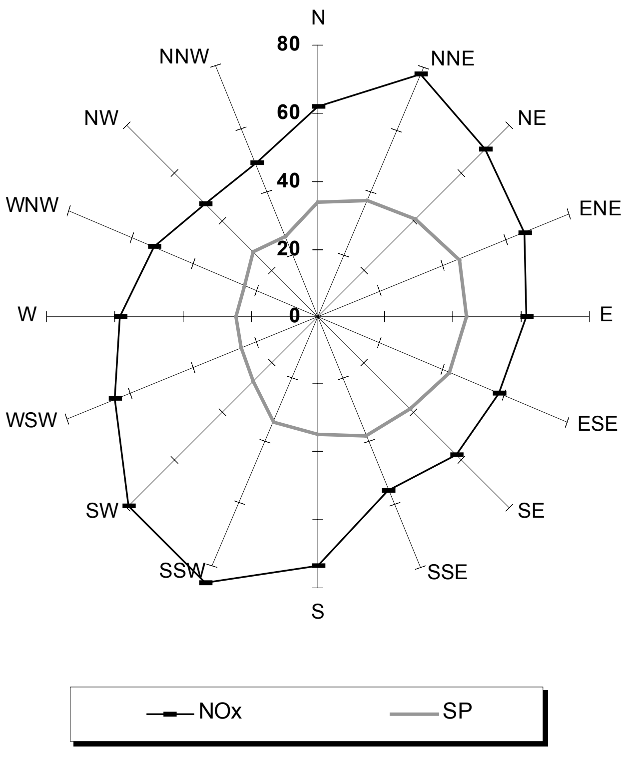
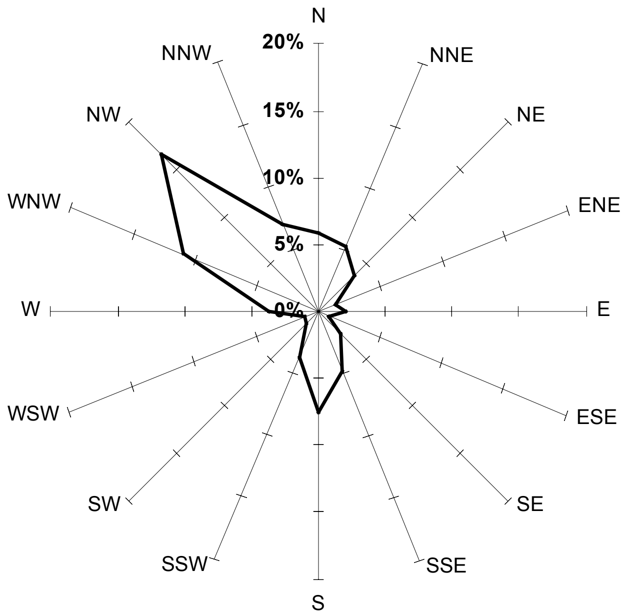


Fig. 2.19

Wind rose - Banská Bystrica 1999



Concentration rose (µg/m^3) B.Bystrica - Nám.slobody 1999

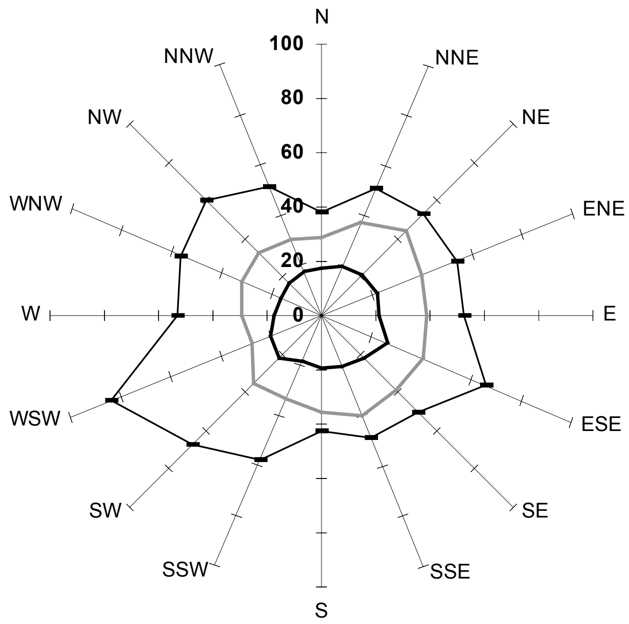
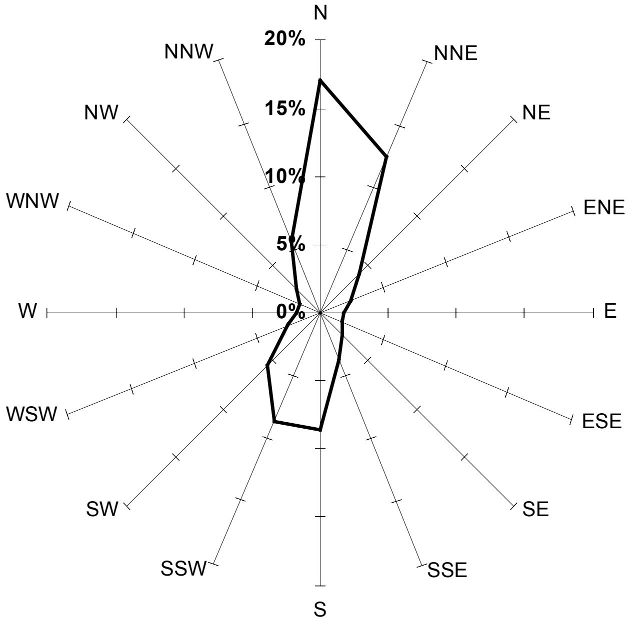
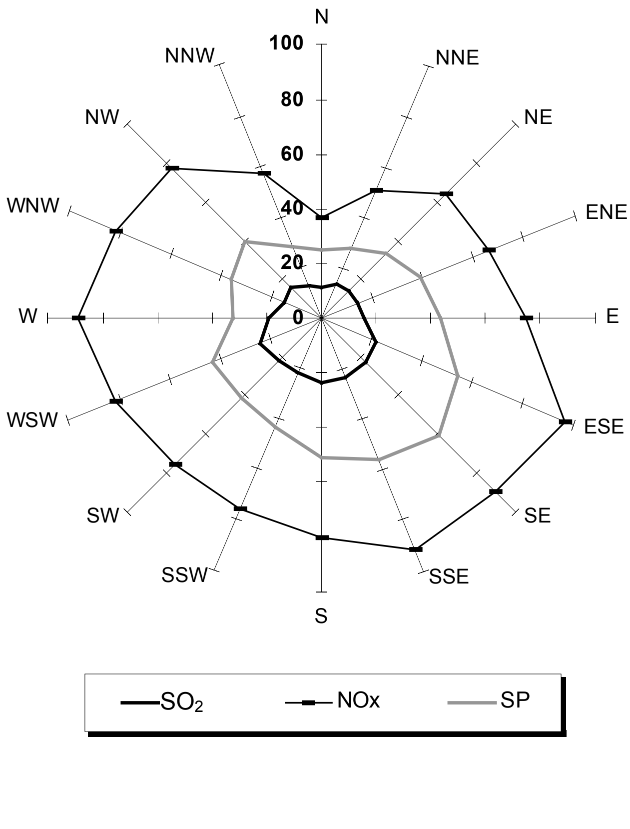


Fig. 2.20

Wind rose - Košice 1999



Concentration rose (µg/m³) Košice - Strojárenská 1999



Tab. 2.4 Statistical characteristics of air pollution [μg/m^3] assessed within period 1.1.- 31.12.1999

West Slovakia		Bratislava		
		Mamateyova	Trnavské mýto	Kamenné nám.
Annual average concentration	NO_x	48.7	144.1	61.0*
	SO_2	14.4	18.3	**
	SP	35.3	39.6	36.4
	H_2S	4.1		
	CO	769.2	1018.6	
95-percentile from daily concentrations	NO_x	91	319	106
	SO_2	41	39	
	SP	48	71	66
	H_2S	5		
	CO	1 262	2 059	
95-percentile from 30-min. concentrations	NO_x	111	418	128
	SO_2	34	43	
	SP	70	87	79
	H_2S	6		
	CO	1 386	2 516	
Daily maximum concentration	NO_x	167	560	203
	SO_2	176	92	
	SP	73	126	126
	H_2S	12		
	CO	2 491	3 204	
30-min. maximum concentration	NO_x	838	1 394	710
	SO_2	490	247	
	SP	170	434	580
	H_2S	21		
	CO	6 489	8 330	

** 50-75% of measurements ** <50% of measurements*

Tab. 2.5 Statistical characteristics of air pollution [µg/m^3] assessed within period 1.1.- 31.12.1999

Central Slovakia		B.Bystrica Nám. slobody	Ružomberok Riadok	Žiar nad Hronom	Martin	Jelšava	Prievidza	Bystričany	Handlová	Žilina		Hnúšťa
										Veľ. Okružná	Vlčince	
Annual average concentration	NO_x	55.4	26.6*	22.5	33.5	22.4	32.3	40.7	27.7	69.2	45.1	25.7*
	SO_2	18.9	15.0*	16.3	22.6	8.3	24.3	22.7	28.5	18.7	20.8	13.2
	SP	36.5	**	41.1	45.9	63.1	58.6	56.8	36.2	44.9	40.0	43.2
	H_2S		3.0*								2.9	
	CO	288.1								414.7		
95-percentile from daily concentrations	NO_x	136	49	42	80	50	75	100	62	148	95	47
	SO_2	40	44	36	61	16	53	51	66	49	61	36
	SP	79		74	86	124	115	106	78	82	76	76
	H_2S		5								6	
	CO	904								1 032		
95-percentile from 30-min. concentrations	NO_x	161	67	53	102	60	95	106	71	178	115	57
	SO_2	45	48	40	63	17	67	55	75	49	58	38
	SP	86		95	106	166	139	124	81	110	97	105
	H_2S		6								7	
	CO	1 049								1 526		
Daily maximum concentration	NO_x	270	90	78	156	138	168	316	135	282	176	75
	SO_2	70	79	190	220	34	506	1 010	578	76	92	88
	SP	108		139	193	175	175	180	143	135	134	130
	H_2S		8								16	
	CO	1 617								2 839		
30-min. maximum concentration	NO_x	663	206	222	957	290	431	370	480	782	533	271
	SO_2	194	148	418	423	93	1226	2 014	1352	469	433	264
	SP	279		498	764	756	496	597	594	449	499	479
	H_2S		40								18	
	CO	5 394								8 842		

** 50-75% of measurements   ** <50% of measurements*

Tab. 2.6 Statistical characteristics of air pollution [µg/m^3] assessed within period 1.1.- 31.12.1999

East Slovakia		Košice				Strážske	Prešov		Krompachy	Humenné	Vranov nad Topľou
		Štúrova	Strojárenská	Podhradová	Veľká Ida		Solivar	Sídlisko III			
Annual average concentration	NO_x	56.8	64.3	45.1	36.9	30.6*	39.7	45.7*	49.0*	20.3	31.2
	SO_2	19.3	17.0	24.8	27.8	20.4	24.5	22.8*	18.0	16.1	15.3
	SP	53.1	**	30.3	68.7	31.2	42.2	41.8*	34.8	32.5	29.1
	H_2S										
	CO	594.3			955.4		309.2				
95-percentile from daily concentrations	NO_x	110	148	99	64	83	92	89	102	36	57
	SO_2	39	41	47	47	35	61	57	53	37	35
	SP	108		68	157	56	80	86	69	59	61
	H_2S										
	CO	1 438			3 199		743				
95-percentile from 30-min. concentrations	NO_x	139	172	106	78	85	119	97	105	43	67
	SO_2	44	46	51	47	38	64	63	53	38	39
	SP	129		73	200	67	98	93	83	72	69
	H_2S										
	CO	1 794			3 891		920				
Daily maximum concentration	NO_x	185	237	162	162	98	216	135	128	47	104
	SO_2	114	141	110	77	91	120	121	114	98	118
	SP	227		160	248	123	122	133	130	138	151
	H_2S										
	CO	2 978			4 799		1 724				
30-min. maximum concentration	NO_x	572	644	568	628	345	832	506	436	357	403
	SO_2	253	244	186	264	258	231	221	234	372	248
	SP	467		398	639	291	548	696	396	446	784
	H_2S										
	CO	8 143			7 969		5 056				

** 50-75% of measurements* *** <50% of measurements*

Tab. 2.7 Annual average concentrations of heavy metals in suspended particles in 1999

Area	Station	Pb [ng/m^3]	Cd [ng/m^3]
Bratislava	Koliba	16	0.6
	Kamenné nám.	29	0.9
	Trnavské mýto	28	1.5
	Lachova	36	1.1
Banská Bystrica	Nám. slobody	26	1.6
Horná Nitra	Prievidza	12	0.4
	Handlová	16	0.8
Žiar nad Hronom	Žiar nad Hronom	19	0.7
	Hliník nad Hronom	8	0.6
Ružomberok	Riadok	17	0.5
Košice	Strojárenská	212	11.7
	Veľká Ida	191	8.6
Krompachy		41	1.6

Tab. 2.8 Air pollution indices in 1999

Area	Station	API_y				API_d				API_s			
		NO_x	SO_2	SP	**Sum**	NO_x	SO_2	SP	**Sum**	NO_x	SO_2	SP	**Sum**
Bratislava	Mamateyova	0.6	0.2	0.6	**1.4**	0.9	0.3	0.3	**1.5**	0.5	0.1	0.1	**0.7**
	Kamenné nám.	0.8		0.6	**1.4**	1.1		0.4	**1.5**	0.6		0.2	**0.8**
	Trnavské mýto	1.8	0.3	0.7	**2.8**	3.2	0.3	0.5	**4.0**	2.1	0.1	0.2	**2.4**
Banská Bystrica	Nám. slobody	0.7	0.3	0.6	**1.6**	1.4	0.3	0.5	**2.2**	0.8	0.1	0.2	**1.1**
Ružomberok	Riadok	0.3	0.3		**0.6**	0.5	0.3		**0.8**	0.3	0.1		**0.4**
Žiar nad Hronom		0.3	0.3	0.7	**1.3**	0.4	0.2	0.5	**1.1**	0.3	0.1	0.2	**0.6**
Horná Nitra	Prievidza	0.4	0.4	1.0	**1.8**	0.7	0.4	0.8	**1.9**	0.4	0.1	0.3	**0.8**
	Handlová	0.3	0.5	0.6	**1.4**	0.6	0.4	0.5	**1.5**	0.4	0.2	0.2	**0.8**
	Bystričany	0.5	0.4	0.9	**1.8**	1.0	0.3	0.7	**2.0**	0.5	0.1	0.2	**0.8**
Žilina	Veľká Okružná	0.9	0.3	0.7	**1.9**	1.5	0.3	0.5	**2.3**	0.9	0.1	0.2	**1.2**
	Vlčince	0.6	0.3	0.7	**1.6**	0.9	0.4	0.5	**1.8**	0.6	0.1	0.2	**0.9**
Hnúšťa		0.3	0.2	0.7	**1.2**	0.5	0.2	0.5	**1.2**	0.3	0.1	0.2	**0.6**
Martin		0.4	0.4	0.8	**1.6**	0.8	0.4	0.6	**1.8**	0.5	0.1	0.2	**0.8**
Jelšava		0.3	0.1	1.1	**1.5**	0.5	0.1	0.8	**1.4**	0.3	0.1	0.3	**0.7**
Košice	Štúrova	0.7	0.3	0.9	**1.9**	1.1	0.3	0.7	**2.1**	0.7	0.1	0.3	**1.1**
	Podhradová	0.6	0.4	0.5	**1.5**	1.0	0.3	0.5	**1.8**	0.5	0.1	0.1	**0.7**
	Strojárenská	0.8	0.3		**1.1**	1.5	0.3		**1.8**	0.9	0.1		**1.0**
	Veľká Ida	0.5	0.5	1.1	**2.1**	0.6	0.3	1.0	**1.9**	0.4	0.1	0.4	**0.9**
Krompachy		0.6	0.3	0.6	**1.5**	1.0	0.4	0.5	**1.9**	0.5	0.1	0.2	**0.8**
Humenné		0.3	0.3	0.5	**1.1**	0.4	0.2	0.4	**1.0**	0.2	0.1	0.1	**0.4**
Prešov	Sídlisko III	0.6	0.4	0.7	**1.7**	0.9	0.4	0.6	**1.9**	0.5	0.1	0.2	**0.8**
	Solivar	0.5	0.4	0.7	**1.6**	0.9	0.4	0.5	**1.8**	0.6	0.1	0.2	**0.9**
Strážske		0.4	0.3	0.5	**1.2**	0.8	0.2	0.4	**1.4**	0.4	0.1	0.1	**0.6**
Vranov n. Topľou		0.4	0.3	0.5	**1.2**	0.6	0.2	0.4	**1.2**	0.3	0.1	0.1	**0.5**

2.4 ASSESSMENT OF AIR POLLUTION IN THE SLOVAK REPUBLIC

Comparison of statistical characteristics of the pollutants measured with the respective ambient air quality standards, which characterise unfavourable impact of air pollution on population, does enable to assess air pollution level by individual pollutants. Assessment of ambient air quality indices, where cumulative effect of selected pollutants is considered, does enable more complex air pollution classification. Statistical characteristics were assessed only for those pollutants, where number of the data measured exceeded 50%. In selected sites the concentration roses were processed for sulphur dioxide, oxides of nitrogen and suspended particles upon the base of wind direction frequencies from professional meteorological stations in Bratislava, Banská Bystrica and Košice. Total look at the level of pollution creeps the assessment of occurrence and duration time of concentrations exceeding the special ambient air quality standards appointed for signals: attention, warning and regulation.

West Slovakia

Three automatic monitoring stations (AMSs) were in operation in west Slovakia, in 1999. All of them are located in Bratislava in such a way as to provide the information about the level of air pollution in different part of the city.

Area

Bratislava

Among the pollutants monitored, mostly oxides of nitrogen, exceeding long-term ambient air quality standards in stations located nearby heavy traffic roads, contribute to high level of pollution. Taking into account all locations, the highest level of pollution due to oxides of nitrogen does represent the area Trnavské mýto. Daily ambient air quality standard (AQS_d) was exceeded in this location for more than 60% days within a year. Pollution by sulphur dioxide is relatively small and annual average concentrations reached the extent from 14.4 $\mu g.m^{-3}$ (Mamateyova) to 18.3 $\mu g.m^{-3}$ (Trnavské mýto). Results of measurements from station Kamenné námestie were not processed due to the considerable frequency of failures. Pollution by sulphur dioxide is of seasonal course, reaching maximum concentrations in winter. In the whole, the 1999 level of pollution by sulphur dioxide did move below ambient air quality standards. The level of suspended particles does contribute considerably to the pollution of the city. Apart from emissions of solid particles from industrial sources, the secondary suspended particles play an important role due to high wind speeds in this area. The highest level was reached in Trnavské mýto, where annual average concentration reached 39.6 $\mu g.m^{-3}$. Carbon monoxide concentrations did not exceed ambient air quality standards in any of the two monitoring stations. (Mamateyova, Trnavské mýto). Regarding the prevailing wind directions, the city is favourable situated to the major emission sources. Considerable failures in measurements did not enable to assess relation of sulphur dioxide concentrations to the individual wind directions. According to index classification the individual locations do belong to considerably or very polluted. In Bratislava and Trnavské mýto the level of pollution did exceed the special ambient air quality standards, for signal Attention in 72 days and for signal Regulation 1 in 19 days.

Central Slovakia

Eleven automatic monitoring stations were in operation in central Slovakia, in 1999. These are localised in the areas of high air pollution level, which do belong to the list of non-attainment areas.

Area

Banská Bystrica

Station Námestie slobody is situated in the city centre, in the area, exposed considerable to emissions from car transport and industrial and municipal sources. Daily concentrations of oxides of nitrogen did exceed daily ambient air quality standards (AQS_d) 10.5% of days within a year. Air pollution by suspended particles was considerable high as well, annual average concentration reached 36.5 $\mu g.m^{-3}$. Air pollution by sulphur dioxide did not exceed hygienic standards in any parameter, annual average concentrations did reach 18.9 $\mu g.m^{-3}$. Correspondingly air pollution by carbon monoxide was below the permissible ambient air quality standards. Value of air pollution index 2.2 does document that the location is of high air pollution degree (very unhealthful), originating mostly from oxides of nitrogen and suspended particles.

Ružomberok

In this location the number of stations was reduced to one AMS, which does monitor hydrogen sulphide as an indicator of sulphur compound emissions from technology of the Slovak pulp and paper processing plants. Oxides of nitrogen play most important share in air pollution of the town apart from the odour substances. Station Riadok has been put into operation since June 1, 1999, therefore the results do not provide sufficient basis for the assessment of pollution in this location. The measured hydrogen sulphide concentrations did not exceed more significantly the level measured in other sites of Slovakia. Annual average concentration of hydrogen sulphide in station Riadok was 3.0 $\mu g.m^{-3}$.

Žiar nad Hronom

Only one automatic monitoring station in town Žiar nad Hronom is in operation in this area. The station monitors major air pollution source in the area, the SNP plant. Suspended particles reached relatively higher level of pollution, annual average concentration figured 41.1 $\mu g.m^{-3}$. In spite of the fact that location Žiar nad Hronom is classified as that one, of moderate air pollution degree, under the unfavourable meteorological conditions such high values of sulphur dioxide were recorded, which exceeded special ambient air quality standard for signal Attention.

Horná Nitra

There were installed three automatic monitoring stations, in the area of Horná Nitra. Station in Bystričany is oriented in the direction of predominant air circulation from the major emission source in the area, the

SEZ (Slovak power plants), Ltd. Nováky. The other stations do monitor ambient air quality in Prievidza and Handlová. Suspended particles and oxides of nitrogen contribute mainly to total air pollution. The highest annual average concentration of suspended particles (58.6 $\mu g.m^{-3}$) occurred in Prievidza. According to the index classification, all three locations (Prievidza, Handlová and Bystričany) do belong to considerably polluted.

Žilina

Two automatic monitoring stations are located in this area. Station Veľká Okružná does monitor the air pollution level in town centre and the other one is located nearby the industrial town zone, in a housing estate Vlčince. The major share in air pollution was due to the oxides of nitrogen. Daily concentrations of oxides of nitrogen did exceed the ambient air quality standard in station Veľká Okružná 15.4% of days within the year and in location Vlčince 4.6%. Annual average concentration of suspended particles was 44.9 $\mu g.m^{-3}$ in station Veľká Okružná. Air pollution by sulphur dioxide is substantially smaller. According to the index classification, station Veľká Okružná does belong to the very polluted site (API=2.3) and station Vlčince is assessed as considerably polluted.

Martin

One AMS is placed in this area, which has been put into operation in 1998. The biggest share in air pollution is due to suspended particles and oxides of nitrogen. Ambient air quality standard was not exceeded at any of the pollutant measured. According to the index classification API_d 1.8, location does belong to the considerably polluted.

Hnúšťa
Jelšava

According to the results monitored, Hnúšťa does belong to the moderately polluted areas. Suspended particles and oxides of nitrogen do ply the major share in air pollution. Relatively smallest level of air pollution is caused by sulphur dioxide, annual average concentration accounts for 13.2 $\mu g.m^{-3}$. Value of air pollution index 1.2 does classify the area as moderately polluted. High concentrations of suspended particles in Jelšava do contribute most distinctively to the total air pollution level. Annual average concentration of suspended particles 63.1 $\mu g.m^{-3}$ exceeded ambient air quality standard AQS_y.. Annual average concentration of sulphur dioxide 8.3 $\mu g.m^{-3}$ is the lowest one in Slovakia. In the whole the area of API_d 1.5, does belong to the considerably polluted.

East Slovakia

Nine automatic monitoring stations were in operation in east Slovakia, in 1999. Three of them did monitor air pollution level at the territory of Košice and one is situated in the adjacent municipality Veľká Ida. In 1998 the air pollution monitoring was enhanced and further station in Prešov has been put into operation.

Area

Košice
Veľká Ida

From the pollutants monitored the main share in air pollution was mainly due to oxides of nitrogen and suspended particles. Among the locations the highest level of air pollution by oxides of nitrogen was in location Strojárenská, AQS_d was exceeded more than 19% of days within the year. Air pollution by sulphur dioxide is relatively small and annual average concentrations ranged between 17.0 $\mu g.m^{-3}$ (Strojárenská) and 27.8 $\mu g.m^{-3}$ (Veľká Ida). The level of pollution by suspended particles also contributes to the city pollution. The highest level was reached at the station Veľká Ida, where annual average concentration reached 68.7 $\mu g.m^{-3}$. According to the index classification the individual locations do belong to the very polluted ones (Štúrová and Veľká Ida) and considerably polluted (Strojárenská and Podhradová).

Prešov
Krompachy
Strážske
Vranov n. Topľou
Humenné

According to the air pollution indices the locations do belong among considerably and moderate polluted. Among the locations listed the ambient air quality standards AQS_d for oxides of nitrogen were exceeded only in Prešov (Solivar) 3.8% of days within the year and in Krompachy 6.6%. In locations Strážske, Humenné and Vranov nad Topľou none of the pollutant monitored showed exeedance of ambient air quality standards. In regard to the ambient air quality standards, the biggest share in air pollution was due to suspended particles and oxides of nitrogen. Annual average concentrations of suspended particles ranged from 29.1 $\mu g.m^{-3}$ (Vranov) to 42.2 $\mu g.m^{-3}$ (Prešov). The level of pollution by sulphur dioxide is smaller and annual average concentrations ranged between 15.3 $\mu g.m^{-3}$ and 24.5$\mu g.m^{-3}$.

Assessment

In 1999, the 24 locations in the Slovak Republic monitored air pollution. According to the air pollution sources in respective locations, the monitoring stations are equipped on purpose-built analysers. Generally it might have been stated, that mainly oxides of nitrogen and suspended particles do contribute to the deterioration of ambient air quality. The detailed assessment of air pollution level in individual locations is introduced under the areas of west, central and east Slovakia. Final part does provide only the total assessment of air pollution level in Slovakia, according to the ambient air quality standards and air pollution indices. Assessment of air pollution, according to the ambient air quality standards AQS_s AQS_d, upon which the concentrations must not be exceeded by more than 5% of cases within a year, is as follows:

Sulphur dioxide

The level of sulphur dioxide pollution is distinguished by considerable seasonal course, which is reflected also by a relatively low annual average not exceeding annual air quality standard in any of the locations. The highest annual average concentrations were measured in Horná Nitra, corresponding well to the other parameters. At all three stations (Prievidza, Bystričany, Handlová) were recorded the cases of exceedances in special ambient air quality standards (Regulation 2). Such a high air pollution level did appear between 20th and 23th of January. It is obvious from Table 2.9, that Regulation 2 lasted in Prievidza only half an hour.

Oxides of nitrogen Short-term ambient air quality standard AQS_s was exceeded (above permitted 5%) only in Bratislava (Trnavské mýto). Daily ambient air quality standard AQS_d was exceeded more markedly in Bratislava (Trnavské mýto), in Banská Bystrica (Námestie slobody), in Žilina (Veľká Okružná) and in Košice (Strojárenská). Annual average concentrations exceeded the annual ambient air quality standard AQS_y only in Bratislava at station Trnavské mýto.

Suspended particles Short-term ambient air quality standard AQS_s was not exceeded in any of the locations in Slovakia and daily ambient air quality standard AQS_d was exceeded over the permitted 5% only in Veľká Ida. Air pollution caused by suspended particles, exceeding the annual ambient air quality standard AQS_y, did occur only in Jelšava and Veľká Ida.

Among the 24 locations in Slovakia, assessed according to the air pollution index classification, six do belong to the very polluted areas.

To compare mutually the level of air pollution in the most numerous number of areas in Slovakia, the air pollution indices were assessed only for three main pollutants (SO_2, NO_x and suspended particles), monitored at the most of the stations. Assessment of the air pollution degree according to the index classification was proceeded in such a way, as the individual location was classified according to the highest air pollution index, which does reach the level of air pollution index API_d in the most cases.

The level of air pollution has been assessed also according to the attachment No 3 of Provision No 112/93 Act Coll. on "Special ambient air quality standards for purposes to announce signals "Attention and Regulation". In Table 2.9 is assessed the number of days with the occurrence and time duration of air pollution at the level "Attention" (At) and "Regulation" (Reg.1 and Reg.2) for individual pollutants and individual stations in non-attainment areas. The most cases for signal Attention occurred in the area of Bratislava, namely 76. Oxides of nitrogen contributed decisively to the high level of air pollution, mainly in locations with heavy traffic (Trnavské Mýto). In the whole, the emissions from traffic contributed decisively to the exceedances of special ambient air quality standards over the whole territory of Slovakia: in 93 cases occurred signal Attention, in 21 cases signal Regulation 1. The number of exceedances of special standards at the rest of pollutants was substantially lower. At sulphur dioxide 21 cases of exceedance occurred for signal Attention, 9 cases of occurrence for signal Regulation 1 and 6 cases of occurrence for signal Regulation 2. In areas Horná Nitra, Ružomberok and Košice occurred cases of exceedances for 24-hour concentrations of „sulphur dioxide plus 2x suspended particles", among these 11 cases reached level corresponding to signal Attention, 4 cases to signal Regulation 1 and 2 cases for signal Regulation 2. High level of air pollution by sulphur dioxide is conditioned mainly by seasonal emission course, with maximum in winter time, when under the unfavourable meteorological condition for emission dispersion, the pollutants cumulated in ground level layer of the atmosphere. Unfavourable meteorological factors, mainly attenuated intensity of dispersion as well as transport of emissions horizontally and vertically in winter half-year contributed substantially to the exceedances of special ambient air quality standards for oxides of nitrogen.

Respective regional administration issues the operational rules for smog regulation system as generally binding regulation. Until now they have been issued only in regions Košice and Prešov.

Tab. 2.9 Occurrence and pollution duration time at level "Attention" (At) and "Regulation" (Reg. 1 and Reg. 2) for respective pollutants in 1999

	Number of occurrences									Total duration time [h]								
	At			Reg. 1			Reg. 2			At			Reg. 1			Reg. 2		
Station/ pollutant	NO_x	SO_2	SO_2 +2P	NO_x	SO_2	SO_2 +2P	NO_x	SO_2	SO_2 +2P	NO_x	SO_2	SO_2 +2P	NO_x	SO_2	SO_2 +2P	NO_x	SO_2	SO_2 +2P
BA Mamateyova	2	2	0	0	0	0	0	0	0	4	1.5	0	0	0	0	0	0	0
BA Trnavské mýto	72	0	0	19	0	0	0	0	0	367.5	0	0	42	0	0	0	0	0
BA Kamenné nám.	2	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Total	**76**	**2**	**0**	**19**	**0**	**0**	**0**	**0**	**0**	**375.5**	**1.5**	**0**	**42**	**0**	**0**	**0**	**0**	**0**
BB Nám. slobody	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RK Riadok	0	0	2	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
Žiar nad Hronom	0	2	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Prievidza	0	7	2	0	2	0	0	1	0	0	43.5	17	0	22.5	0	0	0.5	0
Bystričany	0	5	3	0	4	3	0	4	2	0	24.5	15.5	0	20.5	25	0	22	27.5
Handlová	0	5	2	0	3	0	0	1	0	0	41	16	0	5.5	0	0	2.5	0
Total	**0**	**17**	**7**	**0**	**9**	**3**	**0**	**6**	**2**	**0**	**109**	**48.5**	**0**	**48.5**	**25**	**0**	**25**	**27.5**
ZA Veľká Okružná	6	0	0	0	0	0	0	0	0	12.5	0	0	0	0	0	0	0	0
ZA Vlčince	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12.5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Hnúšťa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Martin	3	0	0	2	0	0	0	0	0	10.5	0	0	6.5	0	0	0	0	0
Jelšava	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KE Štúrova	1	0	1	0	0	0	0	0	0	1.5	0	0	4	0	0	0	0	0
KE Strojárenská	4	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	0	0	0
KE Podhradová	0	0	1	0	0	1	0	0	0	0	0	11.5	0	0	8.5	0	0	0
Veľká Ida	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total	**6**	**0**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**9**	**0**	**11.5**	**5**	**0**	**8.5**	**0**	**0**	**0**
PO Sídlisko III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PO Solivar	2	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0
Total	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4.5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Krompachy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Strážske	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vranov nad Topľou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Humenné	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

2.5 PROCESSING OF MEASUREMENT RESULTS ACCORDING TO EC DIRECTIVES

Council of European Communities (EC) in the framework directive „The Air Quality Framework Directive“ (Council Directive 96/62/EC on ambient air quality assessment and management) defined the principles of air quality assessment.

For the air pollution assessment of EU member countries, the whole territory has to be divided into the individual zones. Regime of assessment in each zone depends upon the actual level of pollution. Three different regimes might be distinguished upon the level of pollution. These regimes are presented in Figure 2.96 and the requirements for the air quality assessment for individual regimes are specified in Table 2.10.

Ambient air quality standards, upper assessment threshold and lower assessment threshold according to the Directive 99/30/EC are listed in Tables 2.11 a 2.12. Alert thresholds were appointed only for:

- SO_2 - if the values of concentrations are above 500 $\mu g.m^{-3}$ during 3 hours
- NO_2 - if the values of concentrations are above 400 $\mu g.m^{-3}$ during 3 hours

Statistical characteristics quoted in tables were processed for all monitoring stations in Slovakia. Stations, in which the limit values for the year 2000 were exceeded, are highlighted in tables by bold (Tables 2.13 a 2.14). Values of pollution, corresponding to the Regime 1, are in tables (Tables 2.15 a 2.16) underlined.

Sulphur dioxide Exceedance of ambient air quality standards occurred only in an area of Horná Nitra. Stations Prievidza, Bystričany and Handlová recorded the exceedance of alert threshold. Upper assessment threshold was exceeded at eight stations.

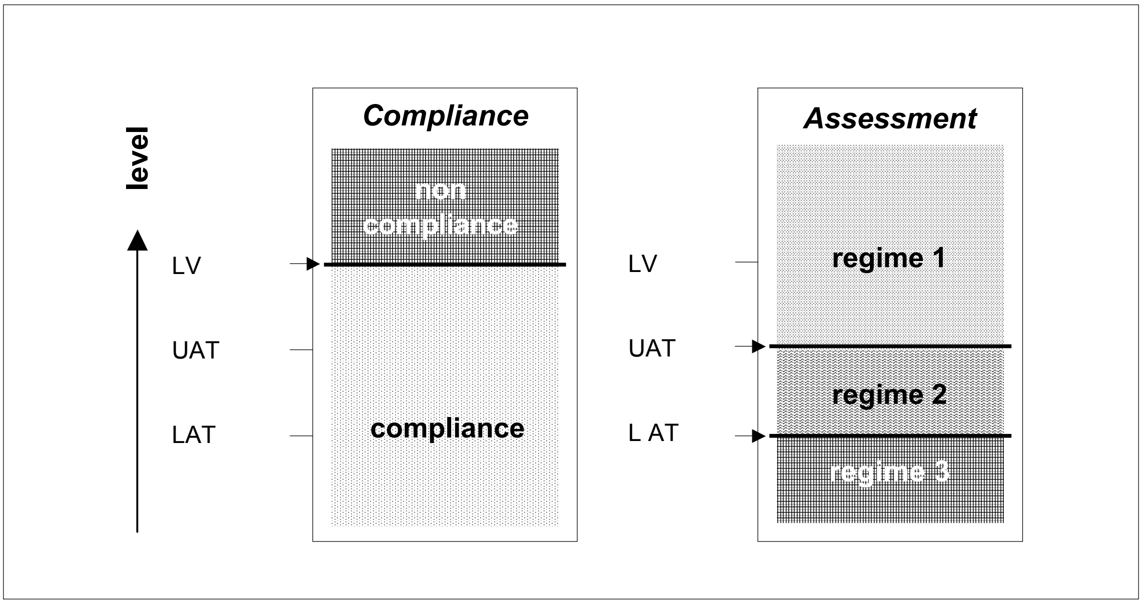
Nitrogen dioxide Limit value (2000) for nitrogen dioxide was not exceeded at any of the stations. Upper assessment threshold was exceeded in Bratislava, Žilina, Prešov, Krompachy and Košice.

PM10 In 1999 PM10 particles were monitored only at three stations: Bratislava (Trnavské mýto and Kamenné námestie) and in Banská Bystrica (Nám. slobody). In frame of the Twining project, the Austrian partner proposed to express TSP as PM10 with the help of correction factor: TSP=1,2∗PM10. Limit value (2000) was exceeded at stations: Jelšava, Prievidza, Bystričany and Veľká Ida. Upper assessment threshold was exceeded at all stations, for which the annual average was assessed**.**

Carbon monoxide The level of pollution by carbon monoxide is considerable low and limit value (2000) was not exceeded at any of the monitoring stations.

Lead At present air pollution by lead does not represent a serious problem. The highest annual average concentration 0.212 $\mu g.m^{-3}$ (Košice) is smaller than the lower assessment threshold (0.250 $\mu g.m^{-3}$).

Fig. 2.21 Regimes of air quality assessment in relation to LAT[1] and UAT[2] and LV[3]



Tab. 2.10 Requirements for assessment in three different regimes

Maximum level of pollution In agglomerations and zones	Requirements for assessment
REGIME 1 **Above upper assessment threshold**	High quality of measurements is obligatory. Measured data can be supplemented by further information, model computations including.
REGIME 2 **Below upper assessment threshold, but above lower assessment threshold**	Measurements are obligatory, however to a lesser extent, or to a lesser intensity, under premise that data are supplemented by other reliable sources of information.
REGIME 3 **Below Lower Assessment Threshold**	
In agglomerations, only for pollutants which an alert threshold has been set	At least one measurement station is required in each agglomeration combined with model computations, expert estimate and indicative measurements. Those are measurements based upon simple methods, or operated in limited time. These are less accurate than continuous measurements, but they may be used to control relatively low level of pollution and as supplementary measurements in other areas.
In non-agglomeration zones for all pollutants and in all types of zone for pollutants for which no alert threshold has been set	Model computations, expert estimates and indicative measurements are sufficient.

[1] *Lower assessment threshold, as defined in Directive 1999/30/EC*
[2] *Upper assessment threshold as defined in Directive 1999/30/EC*
[3] *Limit value*

Tab. 2.11 Upper and lower assessment threshold

	Receptor	Interval of averaging	Limit value [μg/m³]	Assessment threshold [μg/m³]	
				Upper*	Lower*
SO_2	Human health	1h	350	75 (3)	50 (30)
SO_2	Human health	24h	125	-	-
SO_2	Vegetation	1r, 1/2y	20	12 (-)	8 (-)
NO_2	Human health	1h	200	140 (18)	100 (18)
NO_2	Human health	1y	40	32 (-)	26 (-)
NOx	Vegetation	1y	30	24 (-)	19.5 (-)
PM10	Human health	24h	50	30 (7)	20 (7)
PM10	Human health	1y	40	14 (-)	10 (-)
Pb	Human health	1y	0.5	0.35 (-)	0.25 (-)

** allowed exceedances per year in brackets*

Tab. 2.12 Limit values plus limits of tolerance for respective years

	Interval of averaging	Limit value [µg/m³]	To be met by	Margin of tolerance	Limit value + margin of tolerance [µg/m³]										
					Since 31/12/00	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
SO_2	1h	**350**	1/1/05	**150 µg/m³**	500	470	440	410	380	350					
SO_2	24h	**125**	1/1/05	**-**											
SO_2^e	1y, w[1]	**20**	19/07/01	**-**											
NO_2	1h	**200**	1/01/10	**50%**	300	290	280	270	260	250	240	230	220	210	200
NO_2	1y	**40**	1/01/10	**50%**	60	58	56	54	52	50	48	46	44	42	40
NO_x^e	1y	**30**	19/07/01	**-**											
PM10	24h	**50**	1/01/05	**50%**	75	70	65	60	55	50					
PM10	1y	**40**	1/01/05	**20%**	48	46	45	43	42	40					
Pb	1y	**0.5**	1/01/05	**100%**	1.0	0.9	0.8	0.7	0.6	0.5					
Pb[2]	1y	**0.5 (1.0)**	1/1/10 (1/1/05)	**100%**	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5

1) winter period (October 1 - March 31)
2) only for specific point sources
e) for protection of vegetation

Tab. 2.13 Assessment of pollution according to EU directives

	Component	Time of averaging	Limit values for the year 2000 [μg/m^3] (number of exceedances)	Bratislava Mamteyova	Bratislava Trnavské mýto	Bratislava Kamenné nám.	Banská Bystrica Nám. slobody	Ružomberok Riadok	Žiar nad Hronom	Martin	Jelšava	Prievidza	Bystričany	Handlová	Hnúšťa
Health protection	SO_2	1 hour	500 (24)									**29**	**55**	24	
		24 hours	125 (3)	1					2	**5**		**7**	**5**	**5**	
	NO_2	1 hour	300 (18)												
		1 year	60	31.7	57.4	39.0	34.7	15.6*	15.4	24.5	16.8	20.3	20.1	20.3	17.8
	PM_{10}	24 hours	75 (35)		16	6	20	2	7	10	**52**	**41**	**43**	7	7
		1 year	48	29.2	40.0	36.0	36.0		34.2	37.5	**52.5**	**48.3**	47.5	30.0	35.8
	Lead#	1 year	1000#	36	28	29	26	17	19			12		16	
	CO	8 hours (moving average)	15 000												
	Benzene	1 year	10												
AT	SO_2	3 subsequent hours	500									**5**	**5**	**4**	
	NO_2	3 subsequent hours	400												
Vegetation protection	SO_2	1 year	20												
		winter half-year	20												
	NO_x	1 year	30												

*AT - alert threshold (number of days), * 50- 75% of measurements, ** less than 50% of measurements, # lead in ng/m^3*

Tab. 2.14 Assessment of pollution according to EU directives

	Component	Time of averaging	Limit values for the year 2000 [µg/m^3] (number of exceedances)	Žilina Veľká Okružná	Žilina Vlčince	Strážske	Prešov Solivar	Prešov Sídlisko III	Krompachy	Humenné	Vranov nad Topľou	Košice Štúrova	Košice - Strojárenská	Košice - Podhradová	Veľká Ida
Health protection	**SO_2**	1 hour	500 (24)												
		24 hours	125 (3)										1		
	NO_2	1 hour	300 (18)												
		1 year	60	34.8	27.5	22.0	23.3	32.4	38.1	13.2	16.5	31.9	34.8	23.7	29.7
	PM_{10}	24 hours	75 (35)	11	8	1	11	11	9	2	2	27	1		**73**
		1 year	48	39.2	33.3	25.8	35.8	**	22	26.7	24.2	45.8	**		**57.5**
	Lead	1 year	1000#						41				212		191
	CO	8 hours (moving average)	15 000												
	Benzene	1 year	10												
AT	**SO_2**	3 subsequent hours	500												
	NO_2	3 subsequent hours	400												
Vegetation protection	**SO_2**	1 year	20												
		winter half-year	20												
	NO_x	1 year	30												

*AT - alert threshold (number of days), * 50- 75% of measurements, ** less than 50% of measurements, # lead in ng/m^3*

Tab. 2.15 Assessment of pollution according to EU directives

	Component	Time of averaging	Threshold values [µg/m^3] (number of exceedances)		Bratislava Mamteyova	Bratislava Trnavské mýto	Bratislava Kamenné nám.	Banská Bystrica Nám. slobody	Ružomberok Riadok	Žiar nad Hronom	Martin	Jelšava	Prievidza	Bystričany	Handlová	Hnúšťa
Health protection	SO_2	24 hours	UAT	75 (3)	4	1				2	10		10	5	13	2
			LAT	50 (3)	10	4	22	2	2	4	25	0	25	18	35	4
	NO_2	1 hour	UAT	140 (18)		263		2				9			3	
			LAT	100 (18)	7	833	10	46			4	22	3		4	
		1 year	UAT	32	31,7	57,4	39,0	34,7	15,6*	15,4	24,5	16,8	20,3	20,1	20,3	17,8
			LAT	26	31,7	57,4	39,0	34,7	15,6*	15,4	24,5	16,8	20,3	20,1	20,3	17,8
	PM_{10}	24 hours	UAT	30 (7)	133	215	209	160	51	167	199	280	243	270	116	207
			LAT	20 (7)	335	305	296	279	110	254	293	321	305	336	234	315
		1 year	UAT	14	29,2	40,0	36,0	36,0	**	34,2	37,5	52,5	48,3	47,5	30,0	35,8
			LAT	10	29,2	40,0	36,0	36,0	**	34,2	37,5	52,5	48,3	47,5	30,0	35,8
	Lead	1 year	UAT	350#												
			LAT	250#												
Vegetation protection	SO_2	winter half-year	UAT	12												
			LAT	8												
	NO_x	1 year	UAT	24												
			LAT	19,5												
	PM_{10}	1 year	UAT	14												
			LAT	10												

*UAT - upper assessment threshold, LAT - lower assessment threshold, * 50-75% of measurements, ** less than 50% of measurements, # lead is in v ng/m^3*

Tab. 2.16 Assessment of pollution according to EU directives

	Component	Time of averaging	Threshold values [µg/m³] (number of exceedances)		Žilina Veľká Okružná	Žilina Vlčince	Strážske	Prešov Solivar	Prešov Sídlisko III	Krompachy	Humenné	Vranov nad Topľou	Košice Štúrova	Košice - Strojárenská	Košice - Podhradová	Veľká Ida
Health protection	SO_2	24 hours	UAT	75 (3)	1	6	6	10	7	4	1	3	3	3	3	1
			LAT	50 (3)	13	22	9	25	22	19	2	6	6	6	9	11
	NO_2	1 hour	UAT	140 (18)		1	1	4				1		30		1
			LAT	100 (18)	8	10	10	8	10	12		9	7	204	3	3
		1 year	UAT	32	34,8	27,5	22,0	23,3	32,4	38,1	13,2	16,5	31,9	34,8	23,7	29,7
			LAT	26	34,8	27,5	22,0	23,3	32,4	38,1	13,2	16,5	31,9	34,8	23,7	29,7
	PM_{10}	24 hours	UAT	30 (7)	236	171	92	163	131	114	93	73	217	40	49	251
			LAT	20 (7)	312	270	213	258	185	242	212	171	262	63	104	297
		1 year	UAT	14	39,2	33,3	25,8	35,8	**	29	26,7	24,2	45,8	**	**	57,5
			LAT	10	39,2	33,3	25,8	35,8	**	29	26,7	24,2	45,8	**	**	57,5
	Lead	1 year	UAT	350#												
			LAT	250#												
Vegetation protection	SO_2	winter half-year	UAT	12												
			LAT	8												
	NO_x	1 year	UAT	24												
			LAT	19,5												
	PM_{10}	1 year	UAT	14												
			LAT	10												

*UAT - upper assessment threshold, LAT - lower assessment threshold, * 50-75% of measurements, ** less than 50% of measurements, # lead is in v ng/m³*

3.1 ATMOSPHERIC OZONE

The most of atmospheric ozone (approximately 90%) is in the stratosphere (11-50km), the rest of it, in the troposphere. Stratospheric ozone does protect our biosphere against lethal ultra-violet UV-C radiation and to a considerable degree weaken UV-B radiation, which may develop the whole range of unfavourable biological effects such as skin cancer, eye irritation, etc. The depletion of stratospheric ozone and thus the total ozone as well, observed since the end of the 1970s, is associated with the increase in intensity and doses of UV-B radiation in the troposphere and on the Earth surface. The main share in stratospheric ozone depletion is due to the emissions of freons and halons, which are the source of active chlorine and bromine in the stratosphere.

The growth of ozone concentration in the troposphere approximately 1 $\mu g.m^{-3}$ annually has been observed over the industrial continents of the Northern Hemisphere by the end of 1980s. It is associated with the increasing emission of ozone precursors (NO_x, VOCs, CO) from car transport, power generation and industry. In the 1990s the concentration of ground level ozone in Europe is more or less stagnant, which is evident also at the measurements in Slovakia. Increased ozone concentrations in a free troposphere do intensify greenhouse effect of the atmosphere; in a boundary layer of the atmosphere (0-2 km) they impact unfavourable on human health (mainly on respiratory system of human being), vegetation (mainly on agricultural crop and forest growth) and various materials.

3.2 GROUND LEVEL OZONE IN THE SLOVAK REPUBLIC WITHIN 1994-1999

Ambient air quality standards, critical values for ozone

In association with the protection of human health and vegetation, the whole set of standard values, critical levels, respectively ambient air quality standards for the assessment of ground level ozone concentration was proposed by the respective international organisations. Risk areas may be identified upon the comparison of measured ozone concentrations and critical values, respectively ambient air quality standards. In Table 3.1 the recommended ambient air quality standards are listed according to the EU Directive 92/72 EEC.

Tab. 3.1 Ambient air quality standards for ground level ozone concentrations

Ambient air quality standards	O_3 concentration [$\mu g.m^{-3}$]	Average within the time interval
for human health protection	110	8 h *
for protection of vegetation	200/65	1 h / 24 h
for information to the public	180	1 h
for warning to the public	360	1 h

* *8-hour average is calculated as moving average, 4-times per day, upon the base of values within the time intervals 0.00-9.00 h, 8.00-17.00 h, 16.00-1.00 h and 12.00 -21.00 h*

The ambient air quality standard 110 $\mu g.m^{-3}$ (8-h average), the same as within the EU, has been adopted in Slovakia since 1996 to assess the effect of ozone on human health. Until then the less strict standard 160 $\mu g.m^{-3}$ (8-h average) has been adopted. Ambient air quality standard

50 $\mu g.m^{-3}$, recommended by the United Nations Economic Commission for Europe (UN ECE) is often used to assess the long-term effect of ozone on vegetation. It is calculated as an average of ozone concentration from daily hours (9-16 h), during the vegetation period (April-September).

Cumulative effects of exposure on agriculture crop, forest growth and other ecosystems at concentrations of ozone over a certain threshold level are characterised by the so called index of exposure (AOT40), expressed in ppb.h (1ppb = 2 $\mu g.m^{-3}$ at STP). According to the UN ECE experts, threshold level of ozone concentration 40 ppb.h has been proposed at the same time. Critical level AOT40 3 000 ppb.h does correspond to the 5% decrease in agricultural crop yield. The AOT40 value is calculated for the daily hours (characterised by average value of global radiation at least 50 $W.m^{-2}$), during three subsequential months, May, June and July. Preliminary proposed short-term critical value AOT40 for the visible damage of agricultural crop is 500 ppb.h, under the high water vapour pressure deficit (dry weather) and 200 ppb.h under the low water vapour pressure deficit (wet weather), calculated for daily hours during five subsequential days. For protection of forests in Europe, the preliminary critical level 10 000 ppb.h is proposed. In this case as well, the cumulation is calculated for the daily values, but during 6 months (April - September). This critical value is the same for the deciduous and coniferous trees, as well. For natural vegetation is recommended to use the same critical value AOT40 as for agricultural crop.

Long-term and short-term characteristics of ground level ozone in Slovakia within 1994-1999

The measurements of ground level ozone concentration in Slovakia started in 1991, within the operation of monitoring network under the Slovak Hydrometeorological Institute. The number of monitoring stations has been gradually extended. Stations Stará Lesná, Starina (in operation since 1994) and Chopok (in operation since 1994) are a part of the EMEP monitoring network. In 1999 station Bratislava - Koliba was not evaluated due to the small number of measurements. Measurements in Ružomberok were put into operation again and new measurements were introduced in stations Košice-Štúrova, Prešov and Veľká Ida. For monitoring of ground level ozone concentrations, the ozone analysers of the US companies Thermoelectron and MLU have been used in most of the stations. All these analysers operate upon the principle of UV radiation absorption. In 1994, the secondary national ozone standard was installed in the Slovak Hydrometeorological Institute and regular audits by portable calibrator started to be carried out in the stations. Secondary standard of the Slovak Hydrometeorological institute is regularly compared with the primary ozone standard in the Czech Hydrometeorological Institute in Prague. Great inhomogenity in data measured (Table 3.2) is due to the frequent failures of analysers and pumps, as well as the problems with air conditioning, caused by insufficient financing of monitoring system at the Slovak Hydrometeorological institute. In 1999 the failures at the most of the stations were below 10%. Failures over 10% were recorded at two stations and over 30% at three stations among the total number of eighteen stations under evaluation.

In 1999, annual average concentrations of ground level ozone in polluted city and industrial locations of Slovakia ranged within the interval 34-54 $\mu g.m^{-3}$ (Table 3.3). The concentrations in the rest of a territory ranged between 53 and 90 $\mu g.m^{-3}$, mainly in dependence on the altitude. The highest annual average of ground level ozone concentrations was reached in the apical station Chopok (90 $\mu g.m^{-3}$). It is associated with the dominant influence of ozone in a free troposphere on the ozone concentration in higher apical positions. Critical value 50 $\mu g.m^{-3}$ (UN ECE), calculated as the average of daily hours during the vegetation period is regularly exceeded each year over the whole territory of Slovakia (with the exception of urban positions) (Table 3.3). As it follows from the above mentioned, the injuries on vegetation due to the increased ozone concentrations are to be considered even in photochemical less favourable years (1993, 1997 and 1998). Year 1999 does belong to the photochemical active years.

Tab. 3.2 Number of missing daily averages of ground level ozone concentrations [%] within 1994-1999

Station	1994	1995	1996	1997	1998	1999
Banská Bystrica	47.1	10.1	19.1	5.1	2.4	2.5
Bratislava -Koliba			14.8	32.1	27.8	–
Bratislava -Petržalka	16.7	4.1	8.5	9.7	5.8	0.5
Hnúšťa	48.5	1.1	1.5	3.0	7.2	4.9
Humenné	20.5	32.3	–	32.3	1.7	15.1
Chopok		21.9	41.5	17.4	42.7	32.8
Jelšava					0.6	4.9
Košice -Podhradová	35.9	80.8	14.7	11.1	21.0	17.8
Košice -Štúrova						30.7
Martin			0.2	18.5	0.9	6.3
Prievidza	38.4	16.2	30.3	43.2	10.2	9.3
Prešov						10.9
Ružomberok	–	2.2	0.6	32.9	–	47.4
Stará Lesná	13.7	6.8	14.6	11.5	9.2	3.8
Starina	24.4	5.8	5.3	13.4	8.4	0.8
Topoľníky	9.6	1.9	51.9	19.5	58.5	11.2
Veľká Ida						4.7
Žiar nad Hronom	43.0	20.8	2.7	2.6	2.3	5.7
Žilina	2.2	7.9	1.0	5.1	4.6	7.4

– station closed down, respectively long-term failure of station

Tab. 3.3 Long-term characteristics of ground level ozone concentrations [µg.m^{-3}] within 1994-1 999

Station	1994		1995		1996		1997		1998		1999	
	AA	AVP	AA	AVP	AA	AVP	AA	AVP	AA	AVP	AA	AVP
Banská Bystrica	34	68	38	76	28	58	35	80	42	83	42	65
Bratislava - Koliba					51	64	78	97	55	78	–	–
Bratislava - Petržalka	58	96	42	65	30	47	29	52	30	47	52	66
Hnúšťa	41	78	50	88	46	82	40	89	39	82	42	61
Humenné	54	83	49	86	–	–	52	85	57	91	54	69
Chopok			91	102	86	90	78	82	80*	84	90*	88*
Jelšava									50	75	50	69
Košice - Podhradová	32	55	–	–	55	79	43	66	40	62	34	40
Košice - Štúrova											47*	59*
Martin					49	75	47	86	49	91	49	64
Prievidza	58	100	37	57	26	39	40	62	35	67	47	60
Prešov											37	50
Ružomberok	–	–	55	88	34	50	37	64	–	–	34*	49*
Stará Lesná	66	96	69	97	68	94	48	70	49	73	65	82
Starina	57	78	54	73	62	82	53	72	56	76	59	70
Topoľníky	56	91	50	79	76	90	31	49	43*	78	53	65
Veľká Ida											44	60
Žiar nad Hronom	58	95	48	71	54	80	48	85	47	84	49	66
Žilina	44	74	39	70	30	51	39	72	41	84	42	59

AA annual average AVP average from daily hours (9.00-16.00 h) during vegetation period (April-September)
** 50-75% of measurements – station closed down, respectively long-term failure of station*

In Figure 3.1, the seasonal change of daily ozone concentrations in Stará Lesná within 1992-1999 is depicted. Introduced seasonal course is typical for the lowlands and valley (not apical) positions of industrial continents. Original spring maximum of ozone concentration, associated with the transport of ozone from upper atmospheric layers, is extended for the whole summer period, as a consequence of photochemical ozone formation in a boundary layer of the atmosphere. At the same time it follows from this Figure, that the ambient air quality standard for protection of vegetation 65 $\mu g.m^{-3}$ (daily average) is exceeded in Stará Lesná during the whole vegetation period.

Daily average course of ground level ozone concentration in August in Stará Lesná is depicted in Figure 3.2 (higher values in this month are mostly of anthropogenic origin). The figure documents the exceedance of average level in daily maximum values of ozone concentrations about 30-40 $\mu g.m^{-3}$ in photochemically favourable years (1992, 1994, 1995 and 1999) as compared to those ones in less favourable years. Values in 1997 and 1998 are the smallest ones in monitoring period.

Number of exceedances of recommended ozone short-term ambient air quality standards in Slovakia within 1994-1999 is summarised in Tables 3.4-3.6. Standard to warn the public was exceeded only in station Starina (398 $\mu g.m^{-3}$, March 2, 1994). It is very probable this high ozone concentration value may be caused due to the transport of ozone from higher layers of the atmosphere (meteorological conditions were favourable for such transport). The 1-hour maximum concentration (357 $\mu g.m^{-3}$) in Bratislava-Petržalka, in July 1994, reached almost the value of smog warning standard. Relatively frequent, mainly in the record warm year 1994, the exceedance of information standard 180 $\mu g.m^{-3}$ was registered, most frequently in Prievidza, 77 times. In 1999 this standard was exceeded more times (Table 3.4) at two stations (Bratislava-Petržalka and Žilina).

Tab. 3.4 Number of exceedances in ozone short-term ambient air quality standards (AQS) for warning and information of the public within 1994-1999

	AQS_{1h} = 360 $\mu g.m^{-3}$						AQS_{1h} = 180 $\mu g.m^{-3}$					
Station	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Banská Bystrica	0	0	0	0	0	0	0	0	0	0	2	0
Bratislava - Koliba			0	0	0	–			0	0	1	–
Bratislava - Petržalka	0	0	0	0	0	0	58	4	0	0	0	5
Hnúšťa	0	0	0	0	0	0	0	1	2	0	0	0
Humenné	0	0	-	0	0	0	0	0	-	0	0	0
Chopok		0	0	0	0	0		4	0	2	2	0
Jelšava					0	0					0	0
Košice - Podhradová	0	–	0	0	0	0	0	–	0	0	0	0
Košice - Štúrova						0						0
Martin			0	0	0	0			0	0	1	0
Prievidza	0	0	0	0	0	0	77	1	1	0	0	0
Prešov						0						0
Ružomberok	–	0	0	0	–	0	–	1	0	0	–	0
Stará Lesná	0	0	0	0	0	0	0	2	0	0	0	0
Starina	1	0	0	0	0	0	7	1	0	0	0	0
Topoľníky	0	0	0	0	0	0	0	0	0	0	0	0
Veľká Ida						0						0
Žiar nad Hronom	0	0	0	0	0	0	57	0	0	0	1	0
Žilina	0	0	0	0	0	0	0	3	0	0	3	30

– station closed down, respectively long-term failure of station

Fig. 3.1 **Seasonal change of ground level ozone concentration in Stará Lesná within 1992-1999**

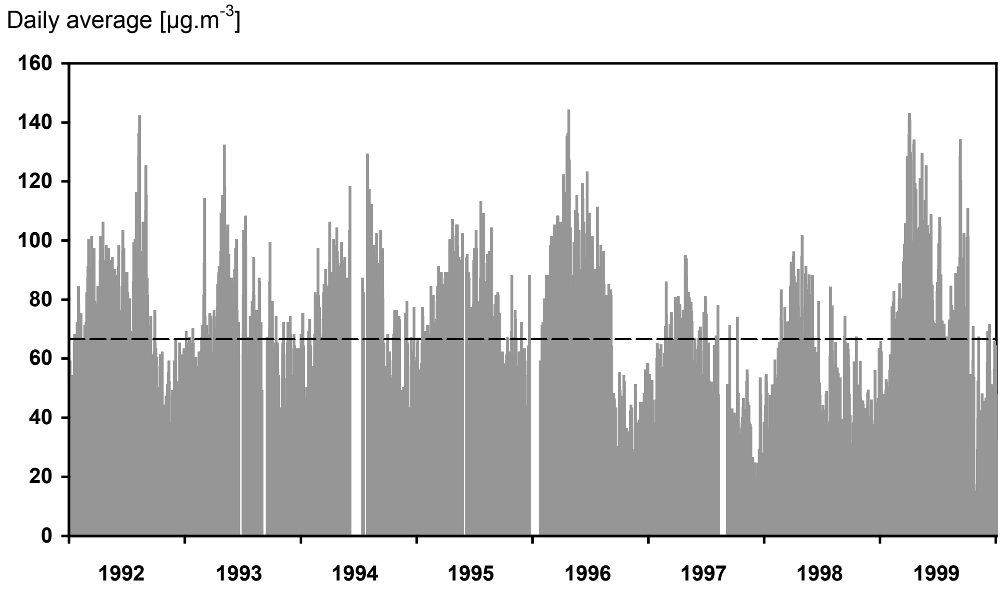
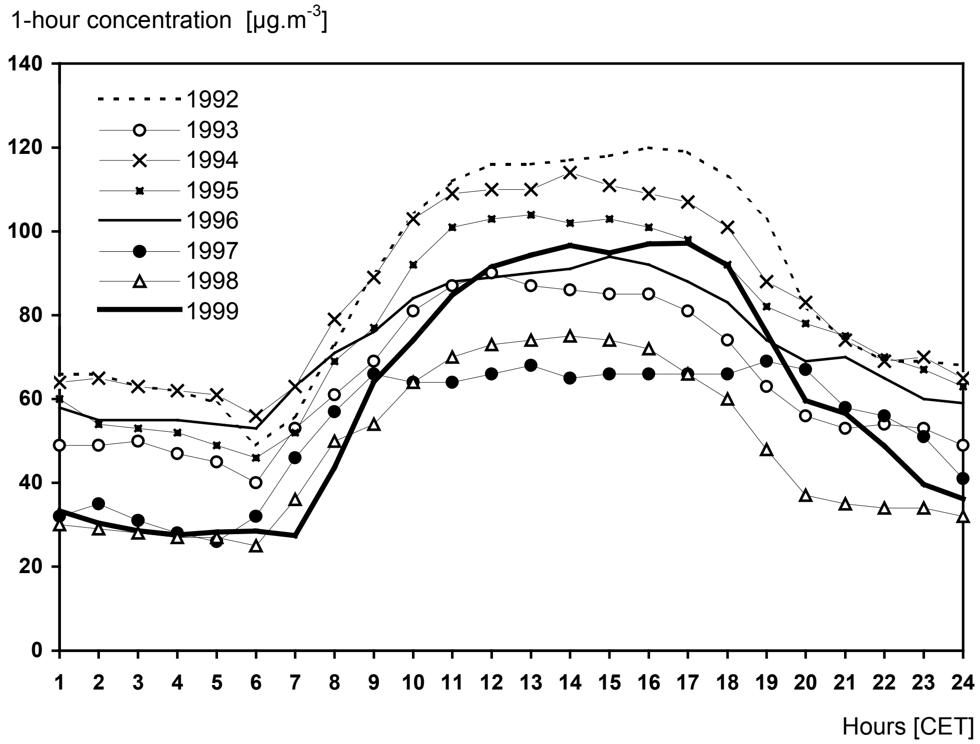


Fig. 3.2 **Average daily change of ground level ozone concentration in Stará Lesná, in August 1992-1999**



Tab. 3.5 Number of exceedances in ozone short-term ambient air quality standards (AQS) for protection of human health, accepted in EU and in Slovakia within 1994-1999

	AQS_{8h} = 110 µg.m^{-3}																							
	1994				1995				1996				1997				1998				1999			
Time interval	0-9	9-17	16-01	12-21	0-9	9-17	16-01	12-21	0-9	9-17	16-01	12-21	0-9	9-17	16-01	12-21	0-9	9-17	16-01	12-21	0-9	9-17	16-01	12-21
Banská Bystrica	0	5	3	15	0	6	0	30	0	0	0	1	0	7	1	5	0	40	1	32	0	23	1	19
Bratislava - Koliba									1	8	9	20	5	42	33	55	0	15	4	15	–			
Bratislava - Petržalka	3	50	22	48	0	8	1	9	0	0	0	0	0	0	0	0	0	1	0	1	0	46	13	40
Hnúšťa	0	12	1	18	0	34	5	49	2	36	7	61	0	26	1	17	0	19	0	15	0	25	5	21
Humenné	1	29	11	31	0	11	1	18	–				0	20	1	17	0	39	6	35	0	12	8	15
Chopok					47	36	40	39	38	24	30	23	10	12	13	11	24	17	21	17	70	56	71	68
Jelšava																	0	49	6	37	2	53	13	43
Košice - Podhradová	0	8	2	10	–				1	14	5	14	0	1	0	1	0	0	0	0	0	1	1	1
Košice - Štúrova																					0	0	0	0
Martin									0	14	6	43	0	17	1	15	0	39	6	41	0	13	0	14
Prievidza	2	41	23	55	0	4	1	9	1	1	1	4	0	1	0	0	0	4	0	2	0	29	6	18
Prešov																					0	0	0	0
Ružomberok	–				2	36	14	49	0	2	1	6	0	0	0	0	–				0	0	0	0
Stará Lesná	4	31	10	29	0	44	10	38	11	58	34	56	0	1	0	2	0	7	0	3	14	68	39	74
Starina	1	14	0	12	0	10	0	3	0	20	6	26	0	10	0	6	0	7	0	3	0	9	2	8
Topoľníky	0	32	5	43	0	13	7	27	1	29	14	36	0	1	0	2	0	9	2	9	0	3	5	27
Veľká Ida																					0	1	0	2
Žiar nad Hronom	0	31	18	49	0	4	4	13	0	10	7	39	0	18	2	23	0	30	7	29	2	20	14	23
Žilina	0	10	9	45	0	7	8	26	0	0	0	3	0	0	0	0	0	29	3	30	2	16	11	18

– station closed down, respectively long-term failure of station

Tab. 3.6 Number of exceedances in ozone short-term ambient air quality standards (AQS) for protection of vegetation within 1994-1999

Station	AQS_{1h} = 200 µg.m^{-3}						AQS_{24h} = 65 µg.m^{-3}					
	1994	1995	1996	1997	1998	1999	1994	1995	1996	1997	1998	1999
Banská Bystrica	0	0	0	0	0	0	20	45	4	18	61	63
Bratislava - Koliba			0	0	0	–			101	198	98	
Bratislava - Petržalka	38	1	0	0	0	0	102	56	6	0	6	105
Hnúšťa	0	0	0	0	0	0	33	108	84	40	42	53
Humenné	0	0	–	–	0	0	72	49	–	71	133	111
Chopok		1	0	1	0	0		166	189	259	*182	*217
Jelšava					0	0					101	115
Košice – Podhradová	0	–	0	0	0	0	46	–	134	36	14	12
Košice – Štúrova						0						*37
Martin			0	0	0	0			97	70	91	89
Prievidza	24	1	0	0	0	0	92	26	8	14	25	134
Prešov						0						8
Ružomberok	–	1	0	0	–	0	–	96	34	4	–	*0
Stará Lesná	0	2	0	0	0	0	122	141	184	68	72	173
Starina	5	1	0	0	0	0	69	66	147	92	106	128
Topoľníky	0	0	0	0	0	0	123	95	123	*2	*31	100
Veľká Ida						0						44
Žiar nad Hronom	30	0	0	0	0	0	85	37	130	80	81	76
Žilina	0	0	0	0	0	4	62	38	11	27	59	48

** big failures of measurements* *– station closed down, respectively long-term failure of station*

Ambient air quality standard 110 µg.m^{-3} (8-hour average), adopted within EU, as well as in Slovakia in 1996, was most frequently exceeded in summer 1994 and mainly in 1996 (Table 3.5), mostly in the region of the High Tatras (Stará Lesná 159 cases, Svit 151 cases). The year 1997 and 1998 were photochemically less active. In 1999 the highest number of exceedances was recorded in Chopok, 256 (however for this station are typical numerous failures in measurements) and in Stará Lesná, 195. Apart from Chopok (mountain concentration course), the most frequent exceedance of this standard was in time intervals between 9.00-17.00 and 12.00-21.00 hour.

Ambient air quality standard for protection of vegetation 200 µg.m^{-3} (1-hour average) was exceeded most frequently in the record warm year 1994, in Bratislava-Petržalka, 38-times. In 1999 this standard was exceeded only at station Žilina. Ambient air quality standard, 65 µg.m^{-3} (24-hour average) is exceeded regularly each year over the whole territory of Slovakia, mostly in higher mountain positions. In 1999 the highest number of exceedances was observed in Chopok, 217 cases. In photochemically active years the number of exceedances over 100 cases was recorded even at some stations in lower positions (Table 3.6).

Table 3.7 comprises the cumulative characteristics of ground level ozone in Slovakia within 1994-1999. It follows from the data in Table 3.7, that the critical values of exposure index AOT40 are regularly exceeded over the most of our territory for 5% (3 000 ppb.h) reduction in agricultural crop yield, over the part of a territory even more times. Similarly the critical value of AOT40 for injury of forest growth (10 000 ppb.h) was exceeded in part of the territory. In 1999 the highest values of exposure indexes were observed since the beginning of measurements. If measurements were complex, the respective values of index of exposure would be expected to be even higher.

Tab. 3.7 Index of exposure AOT40 (over a threshold 40 ppb) for protection of vegetation within 1994-1999 [ppb.h]

Station	AOT40(1)						AOT40(2)					
	1994	1995	1996	1997	1998	1999	1994	1995	1996	1997	1998	1999
Banská Bystrica	3 446	6 842	1 090	4 960	5 594	10 101	5 238	9 907	2 190	7 517	10 854	17 235
Bratislava - Koliba			2 966	8 182	3 080	–			5 436	16 665	8 217	–
Bratislava - Petržalka	16 358	4 694	416	300	201	12 024	19 573	5 460	730	486	872	19 856
Hnúšťa	4 058	11 320	9 010	7 106	5 879	4 333	6 336	16 906	16 068	11 455	10 386	8 922
Humenné	3 768	3 716	–	6 647	8 037	5 316	11 156	6 204	–	9 292	15 067	9 505
Chopok		8 958	4 874	6 150	*3 113	14 760		15 988	11 452	10 359	*11 063	21 713
Jelšava					7 373	15 481					14 406	20 036
Košice - Podhradová	3 274	–	3 664	281	*109		4 895	–	6 646	1 783	*926	1 896
Košice - Štúrova						1 172						2 059
Martin			5 840	5 236	9 720	5 530			10 893	10 179	15 443	9 495
Prievidza	12 299	1 548	412	795	2 292	8 956	19 344	3 025	1 125	1 746	3 133	17 038
Prešov						623						1 062
Ružomberok	–	8 713	1 620	477	–	*178	–	17 080	2 952	999	–	*474
Stará Lesná	4 292	9 788	11 502	1 208	1 775	12 500	13 381	17 164	19 342	1 964	4 350	26 133
Starina	2 327	3 524	5 506	2 211	2 053	4 139	7 345	7 066	9 968	4 399	6 276	7 709
Topoľníky	8 373	6 629	5 626	*559	*1 038	7 156	15 766	10 499	9 810	*788	*3 893	13 140
Veľká Ida						2 747						4 486
Žiar nad Hronom	11 596	1 422	5 758	6 628	7 390	3 310	15 890	4 602	10 946	10 166	12 859	14 336
Žilina	6 221	6 055	1 470	1 665	7 180	2 892	11 566	8 579	2 348	4 354	13 215	10 624

(1) *calculation for daily hours of the months May, June and July*
(2) *calculation for daily hours during vegetation period (April - September)*
* *big failure of measurements*
– *station closed down, respectively long-term failure of station*

It may be stated in conclusion, that the existing measurements confirmed the high level of ground level ozone concentrations in Slovakia. Primary and secondary standards appointed for protection of human heath and vegetation are often exceeded. The level of ground level ozone concentration correlates positively with the air temperature and this is very important in association with the global warming of our planet.

3.3 TOTAL ATMOSPHERIC OZONE OVER THE TERRITORY OF THE SLOVAK REPUBLIC IN 1999

Total atmospheric ozone over the territory of Slovakia has been measured by the Brewer's ozone spectrophotometer in the Department of aerology and ozone measurements of the Slovak Hydrometeorological Institute in Gánovce, near Poprad, since 1993. Apart from the total ozone, the Brewer's ozone spectrophotometer does measure regularly also the intensity of UV radiation within the range of solar spectrum 290-325 nm, by the step 0.5 nm. Station Poprad - Gánovce is a part of the global ozone observing system (GOOS). The results are regularly reported into the World ozone data centre (WOUDC) in Canada and into the WMO Ozone Mapping Centre in Greece. Information about the condition of ozone layer and intensity of harmful solar UV radiation is provided daily to the public via the Press Agency of SR. In 1999, May 22-29, the Slovak Hydrometeorological Institute organised in its workplace Gánovce close to Poprad an international calibration of Brewer’s ozone spectrophotometers. Apart from the domestic instrument and world transfer standard also ozone spectrophotometers from Czech Republic and Poland took part in this calibration.

Annual average value of the total atmospheric ozone reached 331 Dobson units in 1999, the value 2.3% below the long-term average, calculated upon the measurements in Hradec Králové within 1962-1990, which is being used as the standard also in our region. Table 3.8 contains daily average values of total atmospheric ozone and deviations from the long-term average as well as monthly averages and extremes, thus providing the complex overview about the conditions of ozone layer in 1999.

As compared to February 1998, when the most distinctive negative deviation was recorded, February 1999 represents the month with the biggest positive deviation (+8.3%). It proves the big variability of ozone layer by the end of winter and at the beginning of spring. Value above average was measured also in December, in other months the deviations were negative. From the standpoint of effect on the biosphere, the most distinctive biggest negative deviation (-7.4%) was measured in June, because this month the sun is highest in the sky and trajectory of sun rays through ozone layer is the shortest. In last years the shift of bold decreases in total ozone amount was observed since the end of winter to the end of spring up to the beginning of summer. Considerable big negative deviations were recorded in continuous period from April to September. Deviation in September -5.1% is rather exception, because autumn months are distinguished by the biggest stability of ozone layer in our region. Weekly averages of total atmospheric ozone are presented in Figure 3.3. Graph illustrates the described state and at the same time shows annual course, but the distinctive short-term variations in total amount of ozone in our geographical region, as well.

Concentration of chlorine in the stratosphere did reach culmination point by the end of the 1990s. However, model prognoses of gradual reversion of ozone layer into the original state differ about tens of years. Duration of this process depends mainly upon the input parameters, among which the temperature and chlorine are the most important. It is expected that within 20-30 years also monitoring stations will reflect positive trend, first in the south hemisphere and later on in northern.

Figure 3.4 shows the values of thickness in flux of solar UV-B radiation assessed by the spectrum of biological efficiency on erythema (McKinlay and Diffey), measured in time of the local noon. The UV-B radiation modified by this manner is called in scientific literature as the harmful ultraviolet radiation (DUV). At 10.39 of UTC, the sun in Poprad passes through the local meridian, i.e. it has the highest possible height in daily course and under the clear day the UV-B radiation should attain the daily maximum. Distinctive variance in values is due to the influence of weather, mainly of cloudiness on the intensity of UV-B solar radiation,. The intensity of solar UV-B radiation has distinctive daily and annual course in dependence on the height of the Sun. Values in winter are more than 10-times smaller as compared to those ones in summer, however comparable depletion is caused also by the cloudiness and precipitation in summer. The so-called Canadian UV-B index is depicted in Figure 3.4. Its values are associated with the thickness in flux of DUV radiation and the recommended period of residence time in Sun may be derived from them. Values over 7 are attained in summer months around noon and it does mean that the residence time in the sun without appropriate protection should not be more than several minutes at this time. Respective residence time in the sun is dependent upon the photo type of skin and phases of gradual adaptation on the increased doses of solar radiation after the winter period. On the other side, the values smaller than 4, which do appear in October and March mean, that even several hour residence time in the sun is not harmful though the ozone layer may be more distinctly depleted. Considerably high DUV radiation doses are however relevant at the beginning of spring in snowy high mountain positions. More detailed information about this issue is possible to gain on website of SHMÚ (www.shmu.sk), item Ozone news.

The greatest thickness in flux of harmful UV-B radiation (Diffey) 205 mW/m^2 was measured in June 29, at noon. This day 8% of total atmospheric ozone was missing. It was the only value above 200 mW/m^2 within the year. The whole spring and summer period was distinguished by a great variance of noon values, connected with the changeable cloudiness and frequent rain.

In 1999, the UV-B radiation has been monitored every day in regular one-hour or half-hour intervals. The observing programme was temporarily stopped only during the heavy rain. Values of daily total sums in J/m^2 are presented in Figure 3.5. The maximum daily dose 4 658 J/m^2 was measured in June 26.

Total sum of daily DUV radiation in period from April to September was 458 116 J/m^2, representing about 5.5% more than in 1998. It is associated mainly with the total amount of atmospheric ozone in this period, distinctly below the average.

Tab. 3.8 Total atmospheric ozone [DU] in 1999 and the deviations from long-term average

Day	I		II		III		IV		V		VI		VII		VIII		IX		X		XI		XII	
	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev	O_3	Dev
1	280	-14	388	8	343	-9	390	1	343	-10	348	-5	324	-7	324	-2	322	3	268	-8	279	-3	204	-31
2	330	1	339	-6	367	-3	367	-5	350	-8	337	-8	334	-4	344	4	327	5	279	-4	259	-9	223	-25
3	356	9	342	-5	319	-16	359	-7	358	-6	345	-5	324	-7	322	-2	305	-2	276	-5	255	-11	300	1
4	346	5	328	-9	321	-15	413	7	338	-11	332	-9	321	-8	321	-3	309	0	283	-2	271	-5	314	5
5	294	-11	353	-3	338	-11	342	-12	331	-13	345	-5	317	-8	320	-3	305	-1	283	-2	282	-1	333	11
6	250	-25	430	18	432	14	349	-10	352	-7	330	-9	309	-10	306	-7	312	1	293	1	281	-2	324	8
7	292	-12	407	12	429	13	371	-4	355	-6	343	-5	309	-11	297	-9	299	-3	300	4	301	5	270	-10
8	312	-6	447	22	472	24	342	-11	362	-4	337	-7	320	-7	299	-9	300	-2	279	-3	317	11	308	2
9	355	6	435	19	444	17	324	-16	376	0	358	-1	310	-10	284	-13	297	-3	281	-3	275	-4	275	-9
10	404	21	442	21	341	-10	335	-13	362	-4	333	-8	295	-14	279	-14	285	-7	276	-4	265	-8	276	-9
11	307	-9	449	22	369	-3	390	1	375	0	320	-11	340	-1	306	-6	279	-8	260	-10	258	-10	323	6
12	274	-19	445	21	372	-3	365	-6	387	3	308	-14	318	-7	330	1	280	-8	267	-7	253	-12	322	5
13	344	2	449	22	358	-6	387	0	365	-3	307	-15	329	-4	310	-5	284	-6	264	-8	253	-12	382	25
14	310	-9	466	26	360	-6	383	-1	342	-8	307	-14	318	-7	321	-1	293	-3	285	-1	262	-9	360	17
15	353	4	400	8	403	6	376	-3	393	5	311	-13	334	-2	310	-4	290	-4	304	6	309	7	327	6
16	290	-15	303	-19	430	12	368	-5	411	10	308	-14	348	3	298	-8	289	-4	332	16	289	0	307	-1
17	260	-24	430	16	387	1	380	-2	384	3	311	-13	343	1	314	-3	281	-6	333	16	286	-1	312	0
18	269	-22	466	25	408	7	386	0	420	13	320	-10	329	-3	303	-6	277	-7	322	12	368	27	323	4
19	306	-11	401	7	403	5	424	10	356	-4	322	-10	323	-5	296	-8	286	-4	314	10	318	10	284	-9
20	299	-14	319	-15	381	-1	432	12	337	-9	331	-7	320	-5	292	-9	275	-8	291	2	361	25	290	-8
21	303	-13	380	1	421	10	390	1	357	-4	338	-5	312	-7	306	-4	255	-14	286	0	349	20	311	-1
22	286	-18	424	13	379	-1	363	-6	357	-4	366	3	315	-6	318	0	262	-11	280	-2	343	18	294	-7
23	349	0	493	31	383	0	353	-8	359	-3	354	0	370	10	325	2	259	-12	285	0	350	20	310	-2
24	329	-6	505	34	378	-2	333	-13	349	-5	342	-3	337	0	329	3	275	-7	289	1	294	1	323	2
25	351	0	462	23	345	-10	357	-7	348	-6	338	-4	300	-11	328	3	268	-9	269	-6	323	11	284	-11
26	326	-7	345	-9	323	-16	351	-8	359	-2	331	-6	298	-11	311	-2	256	-13	284	-1	284	-3	345	8
27	382	8	275	-27	347	-10	360	-6	348	-5	331	-6	318	-5	302	-4	275	-6	314	10	222	-24	373	16
28	353	0	294	-22	364	-6	354	-7	338	-8	340	-3	303	-9	292	-7	284	-3	240	-16	249	-15	352	9
29	458	29			371	-4	327	-14	345	-6	322	-8	310	-7	291	-7	287	-2	273	-4	248	-16	368	14
30	457	28			365	-5	339	-11	345	-6	326	-7	312	-6	299	-5	256	-12	270	-6	242	-18	373	15
31	443	24			370	-4			332	-9			313	-6	308	-2			271	-5			342	5
∅	331	-3	401	8	378	-1	367	-5	359	-4	331	-7	321	-6	309	-4	286	-5	285	-1	288	0	314	1
Std	53	14	62	17	37	10	27	7	21	6	15	4	16	5	15	4	19	5	20	7	38	13	40	12
Max	458	29	505	34	472	24	432	12	420	13	366	3	370	10	344	4	327	5	333	16	368	27	382	25
Min	250	-25	275	-27	319	-16	324	-16	331	-13	307	-15	295	-14	279	-14	255	-14	240	-16	222	-24	204	-31

O_3 - *total ozone* Dev - *relative deviation from long-term mean (Hradec Králové 1962-1990) [%]* Std. - *standard deviation* [DU]

Fig. 3.3 **Total atmospheric ozone over the territory of Slovakia in 1999**

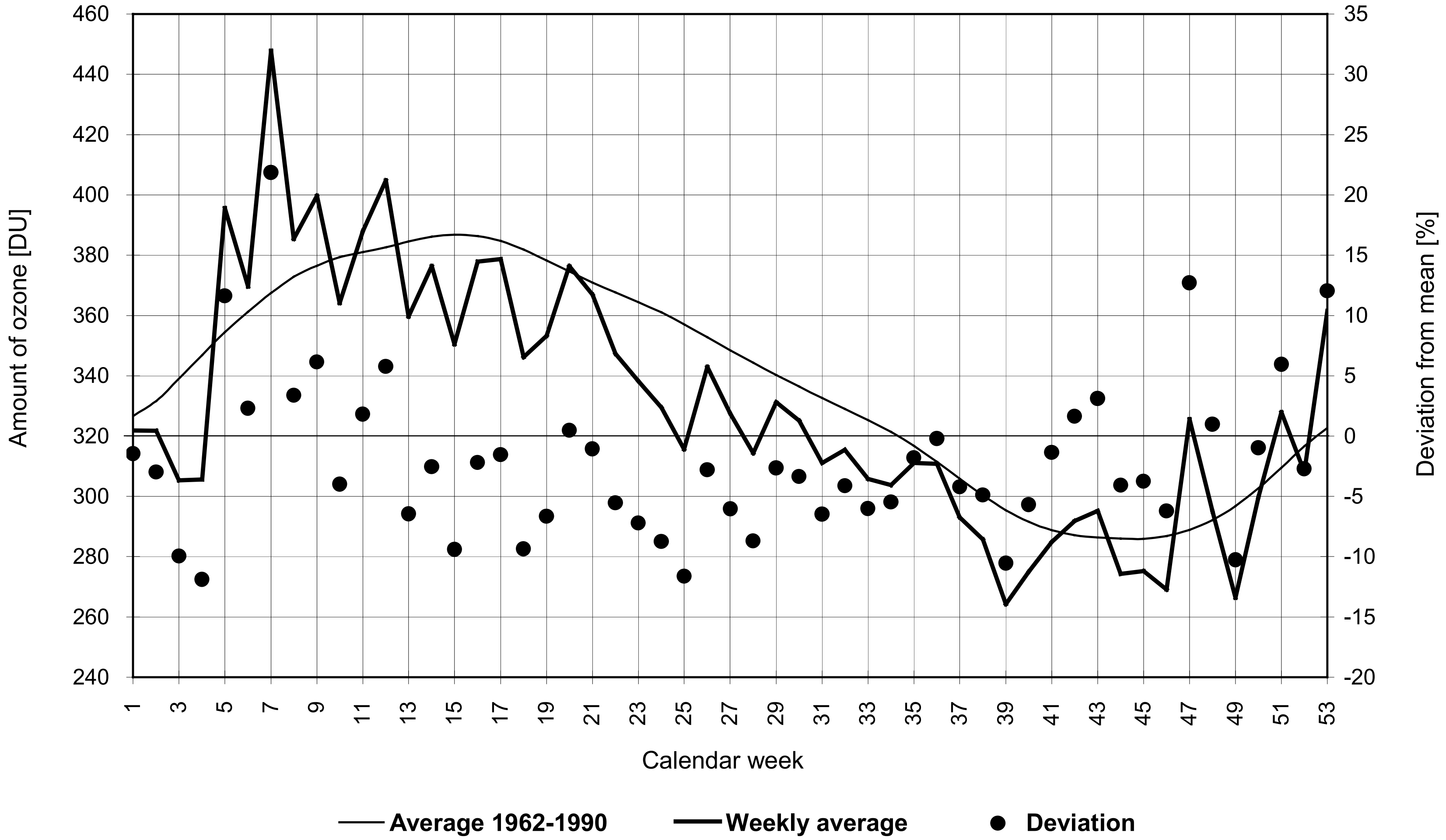


Fig. 3.4

Annual course of DUV (Diffey) radiation noon values
Gánovce 1999

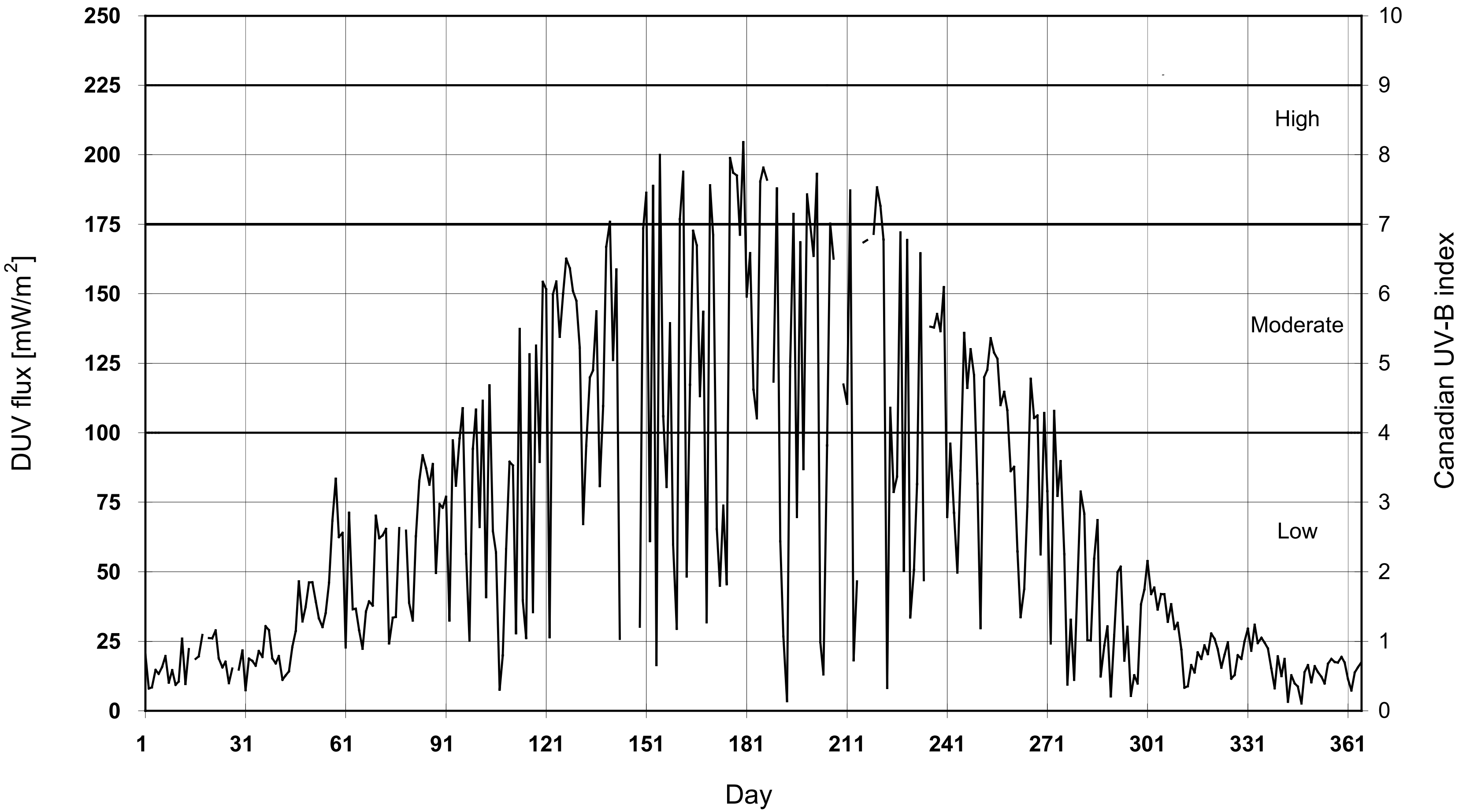
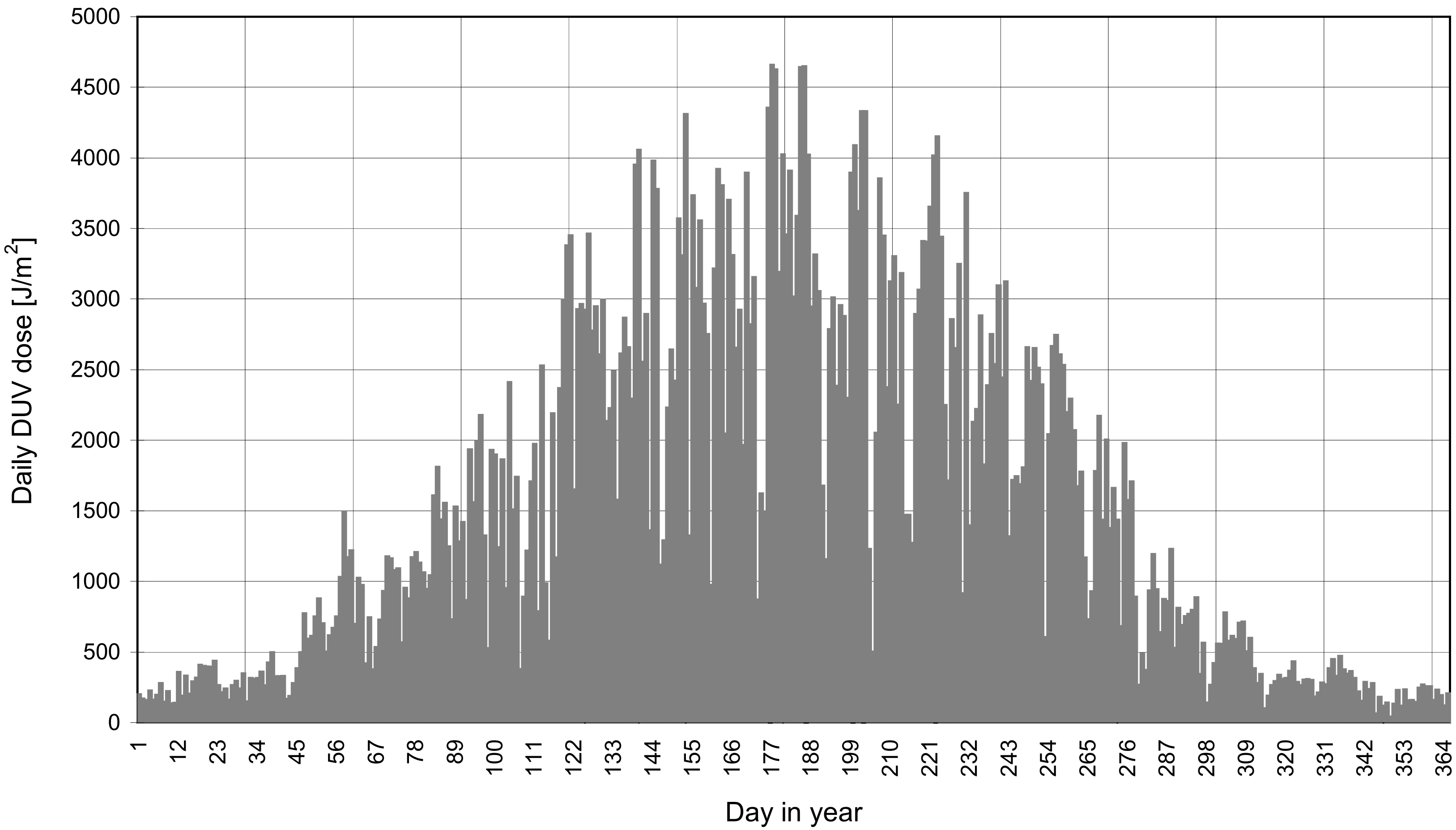


Fig. 3.5

**Annual course of harmful ultraviolet solar radiation daily doses
Gánovce 1999**



4.1 EMISSION AND AIR POLLUTION SOURCE INVENTORY

Anthropogenic emissions of pollutants into the atmosphere cause many present and potential problems, such as acidification, ambient air quality deterioration, global warming/climate changes, destruction of buildings and constructions, disruption of ozonosphere.

Quantitative information on these emissions and their sources are needed requirements for:

- the information of the responsible bodies, expert and lay public
- the definition of environmental priorities and identification of causes of the problems
- the assessment of environmental impact upon the different plans and strategies
- the assessment of environmental costs and benefits upon the different approaches
- the monitoring of effect, respectively effectiveness of the adopted measures
- the support by agreement with the adopted commitments

The data about sources and emissions are needed to provide at national, as well as international level, because of international character of the atmosphere.

The Slovak emission inventory system is at present represented by the Emission and Air Pollution Source Inventory (EAPSI). According to the output, size and type of sources the emission inventory is divided into 4 parts:

EAPSI 1	Stationary sources of the heating output over 5 MW and selected technologies
EAPSI 2	Stationary sources of the heating output 0.2-5 MW and selected technologies
EAPSI 3	Stationary (local) sources of the output below 0.2 MW
EAPSI 4	Mobile sources, regardless of the output

EAPSI 1

EAPSI 1 database is represented by the coherent set of data since 1985. Upon the present inventory, the 967 air pollution sources, i.e. the area-administrative units, defined according to the organisation inventory number, is in operation. For each of these units, the data about quantity, type and quality of fuel consumed, technical and technological parameters of combustion and separation technique, are updated. Upon these data, the emissions of CO, NO_x, SO_2 and particulate matter for the individual sources are calculated by using the emission factors. Since 1996, these values for selected sources have been substituted by the data provided by the operators upon the recalculations from the results of measurements. Emission data from technologies are provided by the individual sources upon their own findings. Emissions from combustion processes and technologies of individual sources are further summarised at the level of area administrative units. Sources registered in EAPSI 1 are provided by the geographical co-ordinates, which does enable to project them in geographical information system.

EAPSI 2

Updating of EAPSI 2 data is carried out in several-year cycle. Inventory and acquisition of data from individual sources were carried out continuously. Summarising was carried out in 1985 and 1989. However, the number of sources registered in EAPSI 2, was growing into such an extent, that the data are not comparable. The third updating was carried out in co-operation with the Offices of environment within the period 1993-1996 and finished in December 1996. New updating will be carried out after the putting the new National emission inventory system (NEIS) into the routine operation.

EAPSI 3

EAPSI 3 database has been updated annually until 1997. Local furnaces were assessed as the area sources at a level of a district. Emission factors and total fuel consumption data by the retail consumers were used to calculate emissions. The decree 268/97 of the Ministry of Environment of the Slovak Republic has accommodated the requirements on data quality, keeping the operational evidence and providing the data to the state administration bodies since 1997. Balance of emissions for 1998 and 1999 has not been processed.

EAPSI 4

EAPSI 4 database is updated according to the requirements of the Ministry of Environment of the Slovak Republic. Emission calculation is being done by the COPERT method, recommended to the signatories of the UN ECE Convention on Long Range Transboundary Transmission of Air Pollutants. It is based upon the number of individual types of cars, the amount of kilometres driven and the consumption of individual fuel types. Apart from the road transport, EAPSI 4 does include the railway, air and shipping transport, as well.

The way of source inventory and data set, registered for the individual sources, does enable to use the national emission inventory system EAPSI also as the supportive database for the international emission inventories, respectively for compilations of the special emission inventories (Table 4.7 and 4.8)

4.2 TRENDS OF DEVELOPMENT IN BASIC POLLUTANTS

Trends of development in basic pollutants are listed in Table 4.1 and in Figures 4.1-4.4.

Particulate matter and sulphur dioxide

Emissions of particulate matter and sulphur dioxide have been decreasing continuously since 1990. Apart from the decrease in energy production and consumption, this was caused by the change of fuel base in favour of the high-grade fuels, as well as the improvement of fuel quality characters used (Figure 4.5). Further spreading of separation technique use, respectively advancing of its effectiveness did share in the particulate matter emission reduction. Downward trend of sulphur dioxide emissions in 1996 has continued also in 1999 as a consequence of the decreased consumption in brown coal, charcoal and heavy calorific oil. Since 1998 the desulphurization process of large power sources has been in partial operation. At the same time the consumption of natural gas is growing.

Oxides of nitrogen Emissions of oxides of nitrogen have showed smooth decrease since 1990. Slight emission increase in 1995 was associated with the increase in consumption of natural gas (Figure 4.5 and 4.6). Decrease of emissions of oxides of nitrogen in 1996 was caused by the change of emission factor, taking into consideration the present condition of technique and technology in combustion processes. Since 1997, the decrease in solid fuel consumption has led to the further decrease in emissions of oxides of nitrogen.

Carbon monoxide Downward trend in carbon monoxide emissions since 1989 has been caused mainly by the decrease in consumption and change of fuel composition (Figure 4.6) in the sphere of retail consumers (EAPSI 3). Carbon monoxide emissions originating from combustion processes of the major sources have been slightly decreasing, as well. Iron and steel industry participate most significantly in the total carbon monoxide emissions from the major sources. Carbon monoxide emission decrease in 1992 was due to the decrease of iron and steel production volume. In 1993, when the iron and steel production was increased again, reaching the 1989 level, the carbon monoxide emissions were proportionally increased, as well. Decrease in carbon monoxide emissions in 1996 is due to the effects of measures being taken into account to limit carbon dioxide emissions in the most important source in this sector, appointed upon the results of measurements. In 1997 and 1999, the carbon monoxide emissions slightly increased again.

4.3 SHARE OF INDIVIDUAL SECTORS IN TOTAL EMISSIONS OF THE SLOVAK REPUBLIC

Figure 4.7 does represent the contribution of stationary and mobile sources to air pollution. It results from the graphs, that the share of traffic in air pollution by oxides of nitrogen and carbon monoxide is significant. On the other hand, combustion processes and industry do contribute to air pollution mainly by oxides of sulphur and particulate matter. Figures 4.8-4.11 represent the share of individual types of production in total emissions from the sources registered in the EAPSI 1. In table 4.3 the emissions of pollutants of EAPSI 1 in non-attainment areas are showed (Decree of the Ministry of Environment of the Slovak Republic no. 112/1993 Act coll.). Table 4.2 lists summary emission data for the selected type of productions according to the OKEČ division.

4.4 SPECIFIC TERRITORIAL EMISSIONS IN 1999

Table 4.4 and Figures 4.12-4.15 provide us by a certain imagination about the territorial distribution of the pollutants emitted. However, it is necessary to distinguish between the amount of pollutants emitted from the respective territory and the ambient air concentrations, because the pollutants emitted may impact on more distant areas, in dependence on the stack height and meteorological characteristics.

4.5 MOST IMPORTANT SOURCES OF AIR POLLUTION IN THE SLOVAK REPUBLIC

Table 4.5 introduces 20 the most important air pollution sources in Slovakia. Share of these sources in total air pollution of Slovakia by the sources of the EAPSI 1 accounts for 88.3-93.1%. Table 4.6 represents the sequence of ten largest polluters in the region according to the quantity of basic pollutants.

4.6 VERIFICATION OF THE RESULTS

Verification of the data gathered during the emission inventory was carried out by the comparison of:

- updated data to the data from previous years and by the verification of reasons for their changes (e.g. change in fuel base, respectively fuel quality characters, technology, separation technique, etc.)
- data listed in the EAPSI 1 questionnaires to the data provided by operators to the district offices for identification of a tax height. Differences appeared mostly in fuel quality characters and this may significantly affect the quantity of the emission calculated in dependence on the quantity of fuel consumed. Further differences arose as a consequence of the fact, that district offices enabled sources to report the emission quantity calculated upon their own measurements. In some cases the differences between the levels found out upon the balance calculation and the recalculation from the results of measurements were significant. In the 1996 and 1999 EAPSI 1 balance, for the selected sources such results of measurements were taken into account, where the level of results measured as well as the procedure of recalculation were satisfactory.

4.7 ASSESSMENT OF DATA QUALITY

Each emission inventory provides only a certain approximation to the real values of the pollutants emitted. The level of representativeness in results may be assessed upon the internationally acknowledged scale, according to the US EPA (Table 4.10). This method was recommended by the Working group on emission inventory, within the UN ECE Convention on Long Range Transboundary Transmission of Air Pollution. The results of emission inventory, assessed in compliance with the above mentioned, are introduced in this annual report.

Not only the data completeness is a criterion of the assessment, but their technical level, as well. Because of this reason, the emission data of particulate matter and sulphur dioxide are assessed as significantly representative (B) and those ones of oxides of nitrogen and carbon monoxide as relatively representative (C). Though, the basic data are of the same level (EAPSI 1), the emission factors for particulate matter and sulphur dioxide are appointed more exactly then the emission factors for oxides of nitrogen and carbon monoxide. Whereas the first data are dependent upon the quality characters of fuel and which may be appointed quite precisely, the latter ones are dependent upon the regime of combustion and thus the data may be of different values, even for the identical technical arrangement.

During the period 1995-1997 the updating of emission factors used in the data base EAPSI to calculate emissions have been carried out under the aegis of the Ministry of environment of the Slovak Republic. The updating have been executed in such a system as to compare the emission factors obtained by the recalculation upon the measurements at the respective sources of the Slovak Republic to the latest published emission factors. The detailed analysis showed the necessity to correct the emission factors. Since 1996 the emission balance have already taken into account the corrected emission factors, published in the Official gazette of the Ministry of environment of the Slovak Republic, part 6, year 1996, into consideration. The new emission factors do better correspond to the present condition of the technique and technology in the sphere of combustion processes.

The EAPSI 2 data are assessed as relatively representative (C). They include relatively big number of sources (approximately 8 900) and the balance is not possible to be carried out within one year. The sources have been changing permanently in their number; the new sources arisen, some of them are divided, the others are closed down. It is expected that at present the evidence of the EAPSI 2 sources have not been completed yet. The emission balance from sources of EAPSI 2 will be possible to carry out only in co-operation with the district offices in system NEIS.

The emission data from local sources, EAPSI 3, are assessed as relatively representative (C). It is necessary to expect, that apart from the fuel purchased in distribution network, also the fuel obtained by different way, is burned, respectively that not all amount of fuel sold in the respective period is also burned out in this period.

The emission data from mobile sources were calculated upon the internationally acknowledged and recommended method, at the professional working place, which was provided by the necessary input data (VÚDI Žilina), and therefore the data are assessed as significantly representative (B).

4.8 TRANSFORMATION OF EMISSION INFORMATION SYSTEM

Since 1989 the new legislation in air protection has been created and at the same time the bodies of state administration in air protection were established. Operators of large and medium size sources have legal duty to announce annually data about the emission and additional associated parameters to the respective district office for the purpose to identify taxes. From technical point of view some district offices used software AIR-2, the other ones processed data manually. Data from individual districts have not been interconnected with the national Slovakian database yet.

As a consequence of historical development the data acquisition from operators of air pollution sources is duplicated and two parallel information systems, not fully consistent, do exist.

Since 1997 the transformation of national information system - project NEIS has been under realisation. Aim of the NEIS project was to substitute the present duplicity in data acquisition on air pollution sources and their emissions by a unified system. This system will enable rational acquisition, processing and further utilising of data on local and national level, in coincidence with the needs following from legal reform of air protection, state environmental policy and international commitments of the Slovak Republic.

Solution of this project was carried out under the gesture of Ministry of Environment of the Slovak Republic, in co-ordination with the Slovak Hydrometeorological Institute, and close co-operation with the Ministry of civil engineering of the Slovak Republic, regional and district offices, as well as with the selected industrial enterprises. NEIS uses the supply of standard database products MS ACCESS and INGRESS.

Software product NEIS is constructed as multi-module system, corresponding fully to the requirements of current legislation. Module NEIS BU does enable to execute complex data acquisition and their processing in respective district offices, as well as carry out the logic control on correctness in emission calculation upon input data and provide the decision about the height of tax. It enables to feed the input data on sources exclusively in a way corresponding to the legislation. Data acquisition is carried out by the set of questionnaires, but possible is to use also software module NEIS PZ, which does enable apart from filling the questionnaires in electronic form also emission calculation and data feeding from respective operators into the district databases NEIS BU. Data from district databases are then fed into the central database NEIS CD, placed at the Slovak Hydrometeorological institute.

Operation of the system has been verified by the so called pilot testing in selected districts within the whole territory of the Slovak Republic and inter departmental steering committee accepted it positively with the recommendation of its fast implementation.

Positive contribution of the emission information system transformation is as follows:

- Elimination of duplicate acquisition and processing of data on sources and their emissions, providing of data standardisation at all levels.
- Providing of modern and effective tool to all, who primary process the data and thus the guarantee for uniform level of acquisition, processing and control of data about the sources and their emissions in all districts.
- Better transparency of procedure to concede the quantity of emissions and thus payment of taxes for pollution of air by operators of the sources due to the built-in control system and necessity to provide the input data into NEIS exclusively in coincidence with the legislative regulations.
- Establishment of national Slovakian database, upon which will be enabled to the top state administration bodies optimally fulfil their tasks.

Implementation of this system had started in 1999 and will be finished by 2001. Since January 1, 2001 the data on emissions will have been necessary to report in a new format, providing at the same time input data for NEIS, in compliance with the updated legislation.

First phase of implementation was carried out within 1999. The training courses were held for all responsible employees of regional and district offices. Operators of air pollution sources and experts on assessment in the field of air pollution had also possibility to participate in these training courses. Expert consultants were at disposal via the so-called hot lines permanently.

At present the district databases NEIS BU are fed by the basic data on large air pollution sources and central database NEIS is under testing.

The aim is to finish NEIS implementation in such a way as to enable all-territory wide introduction of tools of NEIS system for all branches of environment in district offices, as well as for operators of large and medium size sources of air pollution since January 2001. Update of the data for the year 2000 should be carried out only in NEIS.

Tab. 4.1 Trends of development in basic pollutants of the Slovak Republic [thous. ton]

PM emissions

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	DQ
EAPSI 1	259.771	212.065	226.925	208.075	153.590	110.545	79.925	52.335	55.770	38.461	36.646	31.168	34.813	B
EAPSI 2	*36.425	*36.425	*36.425	36.425	*36.425	*36.425	*36.425	*17.097	*17.097	9.478	**9.478	**9.478	**9.478	C
EAPSI 3	55.903	59.536	57.641	54.868	39.593	30.511	26.968	17.869	16.111	19.038	14.166	***14.166	***14.166	C
EAPSI 4	4.341	#4.341	#4.341	4.758	4.076	3.478	3.275	3.646	3.744	2.532	2.696	2.918	+2.918	
Total	**356.440**	**312.367**	**325.332**	**304.126**	**233.684**	**180.959**	**146.593**	**90.947**	**92.722**	**69.509**	**62.986**	**57.730**	**61.375**	

SO_2 emissions

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	DQ
EAPSI 1	491.567	460.991	447.784	421.981	347.084	296.034	246.411	182.746	188.590	197.308	176.564	153.723	147.111	B
EAPSI 2	*37.509	*37.509	*37.509	37.509	*37.509	*37.509	*37.509	*27.091	*27.091	10.577	**10.577	**10.577	**10.577	C
EAPSI 3	81.192	86.551	83.729	79.487	57.298	44.091	39.255	25.926	20.706	16.314	12.087	***12.087	***12.087	C
EAPSI 4	3.527	#3.527	#3.527	3.614	3.061	2.322	2.119	2.932	2.346	2.310	2.393	2.724	+2.724	
Total	**613.795**	**588.578**	**572.549**	**542.591**	**444.952**	**379.956**	**325.294**	**238.695**	**238.733**	**226.509**	**201.621**	**179.111**	**172.499**	

NO_x emissions

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	DQ
EAPSI 1	126.327		146.800	146.474	135.389	127.454	122.169	111.616	118.040	76.853	70.583	74.322	65.436	B
EAPSI 2	*4.961		*4.961	4.961	*4.961	*4.961	*4.961	*5.193	*5.193	3.960	**3.960	**3.960	**3.960	C
EAPSI 3	6.293		6.610	6.783	5.352	4.639	4.218	3.692	5.203	5.852	5.177	***5.177	***5.177	C
EAPSI 4	59.914		*68.521	67.090	58.383	53.321	51.916	52.517	52.886	43.403	44.485	46.238	+46.238	B
Total	**197.495**		**226.892**	**225.308**	**204.085**	**190.375**	**183.264**	**173.018**	**181.322**	**130.068**	**124.205**	**129.697**	**120.811**	

CO emissions

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	DQ
EAPSI 1			162.699	162.047	160.591	132.874	160.112	168.561	165.715	129.388	141.636	118.581	122.149	B
EAPSI 2			*27.307	27.307	*27.307	*27.307	*27.307	*11.409	*11.409	12.037	**12.037	**12.037	**12.037	C
EAPSI 3			150.022	143.633	103.121	78.846	70.107	46.712	42.594	50.794	38.029	***38.029	***38.029	C
EAPSI 4	127.070		151.000	154.397	146.193	142.915	150.880	184.956	181.098	154.273	144.244	144.598	+144.598	B
Total			**491.028**	**487.384**	**437.212**	**381.942**	**408.406**	**411.638**	**400.816**	**346.492**	**335.946**	**313.245**	**316.813**	

 # the 1987 data   ** data obtained by professional estimate*   *** the 1996 data*   **** the 1997 data*   *+ the 1998 data*   *DQ data quality*

Fig. 4.1

PM emissions

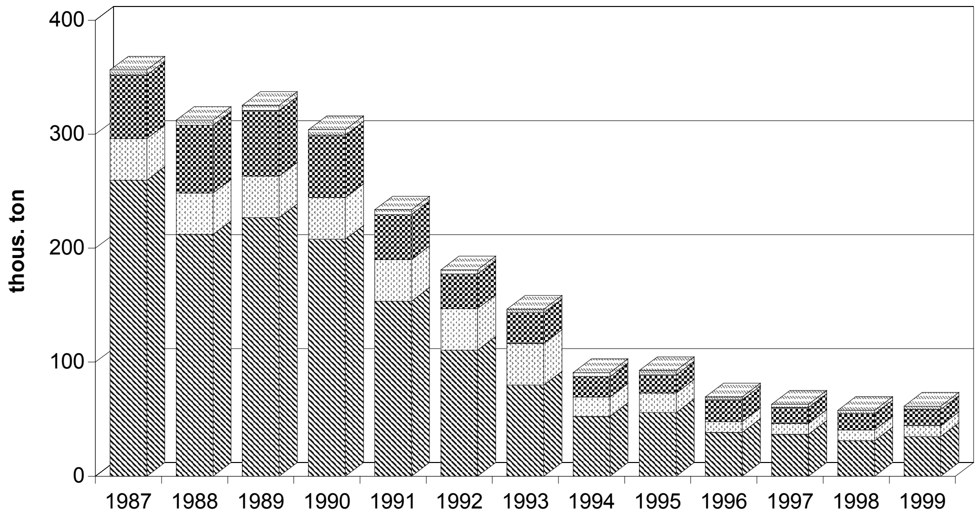


Fig. 4.2

SO_2 emissions

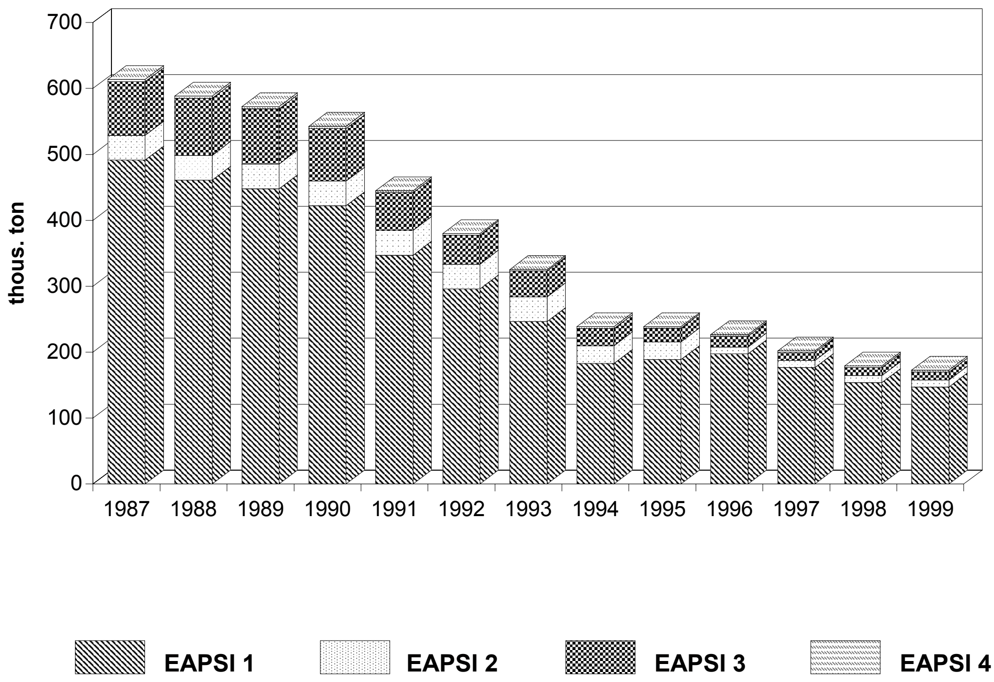


Fig. 4.3

NO_x emissions

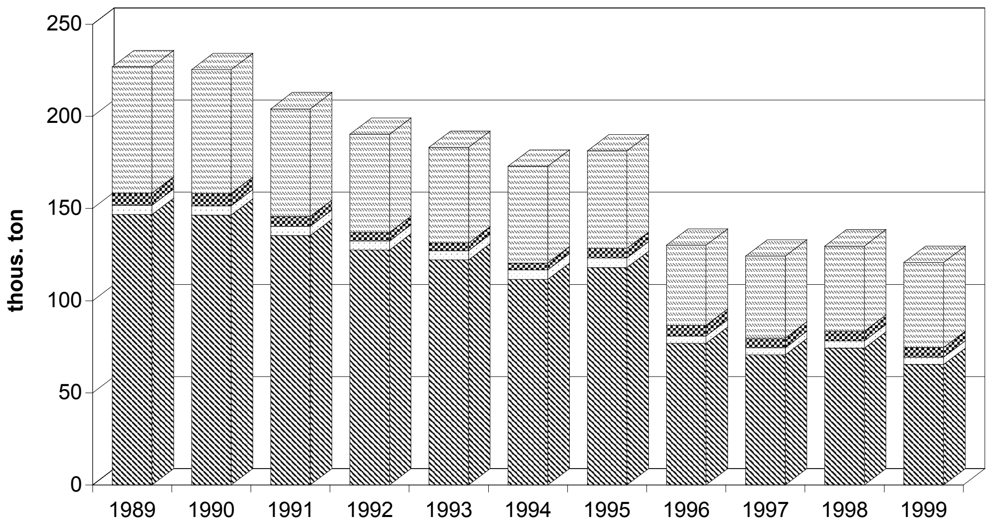


Fig. 4.4

CO emissions

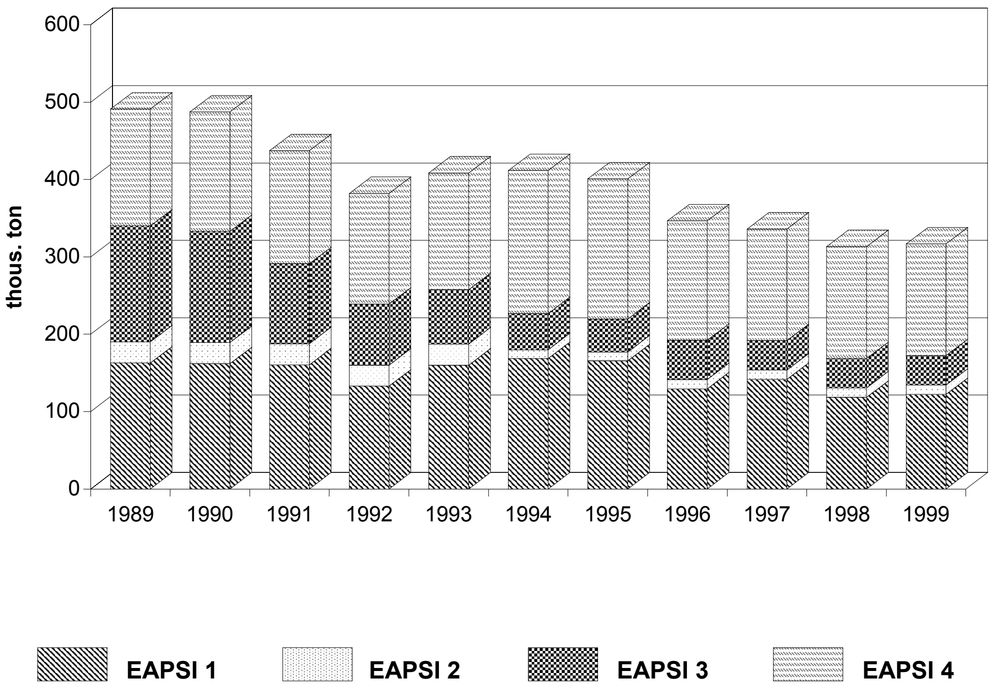


Fig. 4.5 **Development in consumption of the individual fuel types in power industry (EAPSI 1)**

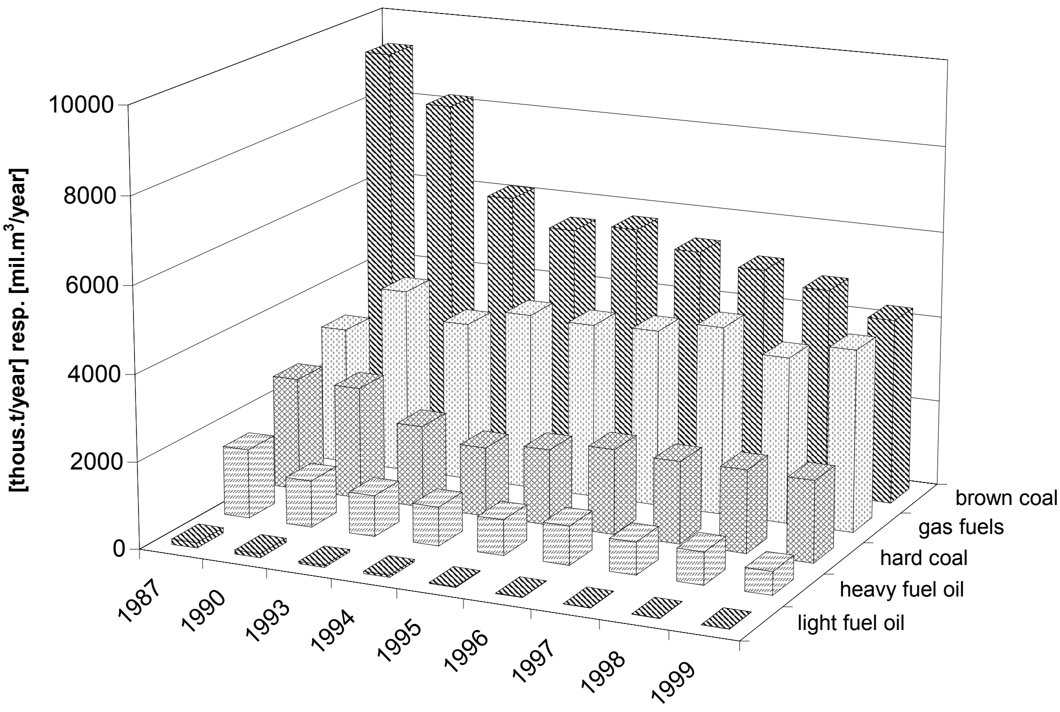


Fig. 4.6 **Development in consumption of the individual fuel types in local combustion chambers (EAPSI 3)**

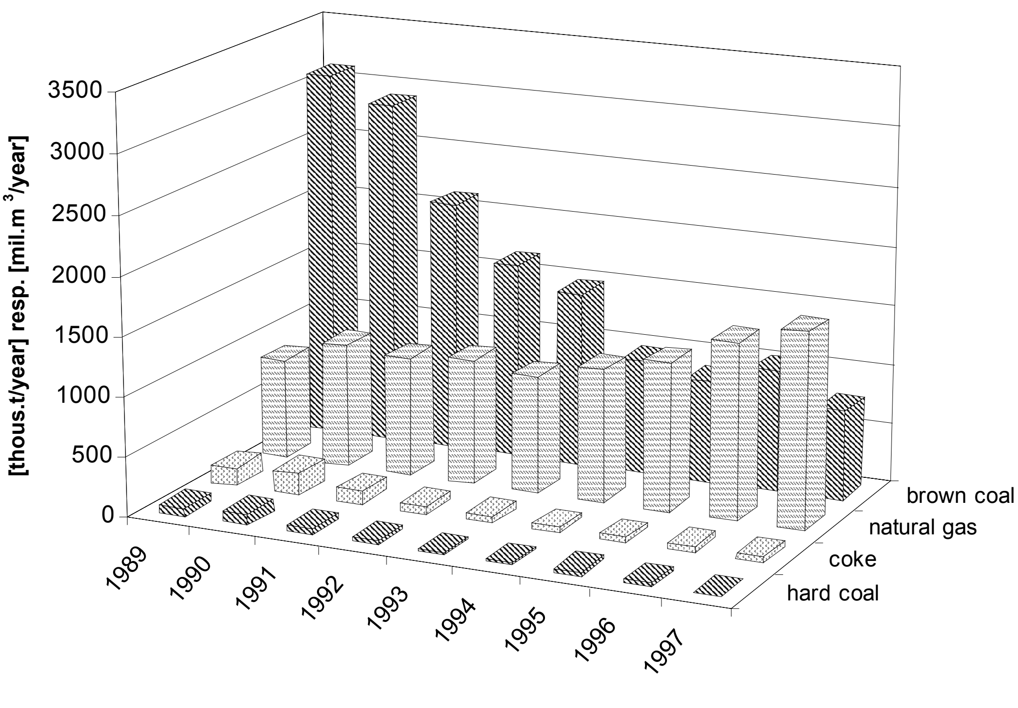
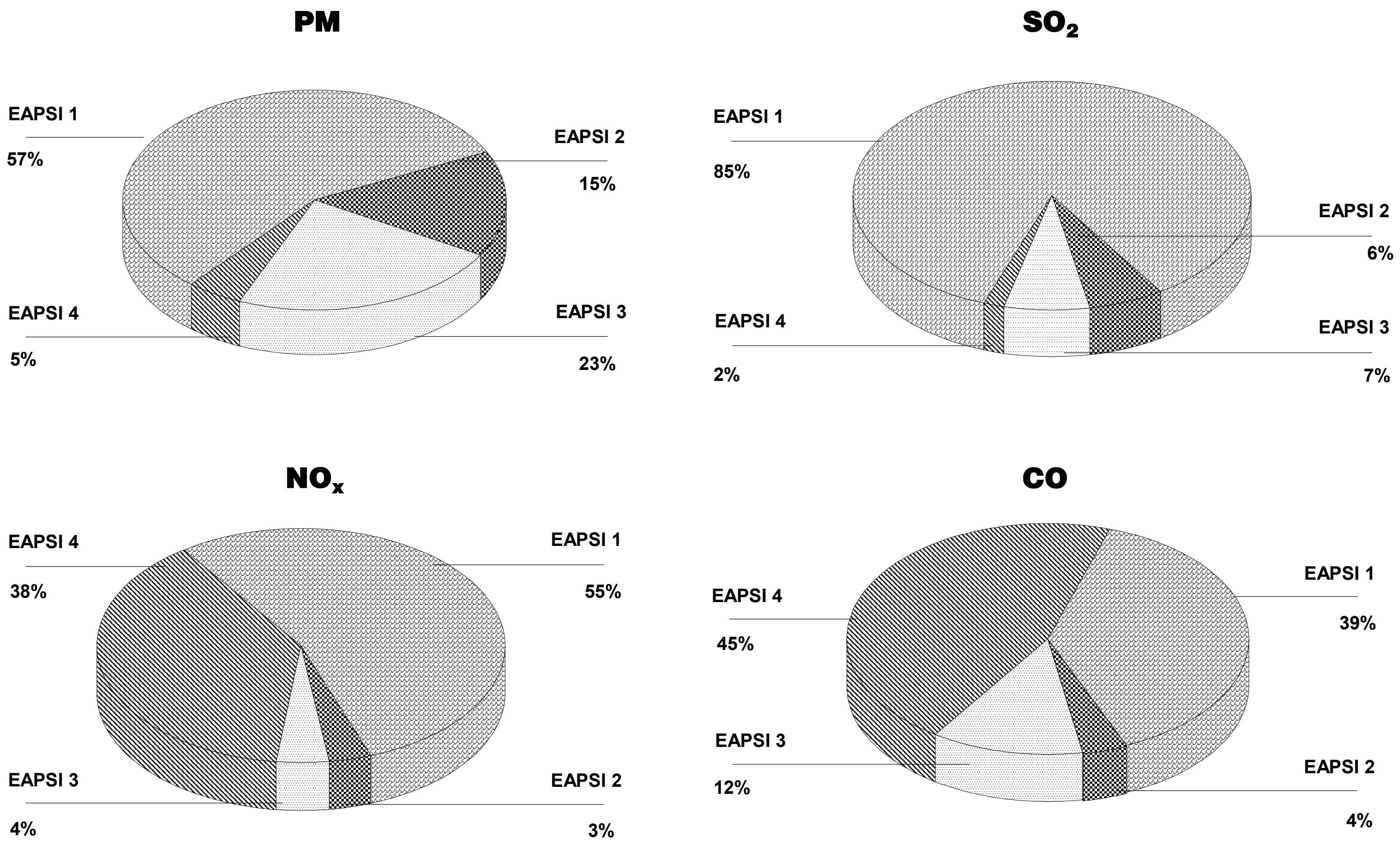


Fig. 4.7

Emissions of PM, SO_2, NO_x and CO in 1999



Tab.4.2 Air pollution in the Slovak Republic (EAPSI 1), emission quantity according to Section classification of economic activities (SCEA) in 1999

Type of production	Code SCEA	PM	SO_2	NO_x	CO
Electricity production and distribution	40.1	10 218	74 425	25 004	1 876
Steam and hot water production and distribution	40.3, 70.1, 70.2, 70.3	356	2 447	2 822	1 031
Industrial technological processes	15-37	23 738	65 029	31 109	115 228
Iron and steel production and processing	27.1-27.3	16 552	14 240	12 787	87 401
Non-ferrous metal production and processing	27.4, 27.53, 27.54	229	3 278	510	8 508
Production of metalloid mineral products	26	1 534	1 036	5 545	10 816
Production of motor vehicles	34	16	65	88	54
Production of chemicals, chemical fibres	24	1 230	11 180	2 601	3 281
Coke production, refined crude oil products and nuclear fuels	23	1 326	20 511	4 440	726
Paper and cellulose production	21	712	7 183	2 196	899
Production of food-stuffs and drinks	15	376	2 622	825	252
Other industrial technological processes	X	500	5 210	6 501	4 013
Stationary sources total		**34 813**	**147 111**	**65 436**	**122 149**

Tab. 4.3 Emissions of pollutants (EAPSI 1in non-attainment areas* within 1997-99

Area	Year	Pollutant			
		PM	SO_2	NO_x	CO
Banská Bystrica	1997	237	562	786	448
	1998	144	437	460	208
	1999	108	188	709	130
Bratislava	1997	1 509	23 408	5 674	1 043
	1998	1 415	21 338	5 396	1 011
	1999	1 354	20 589	5 738	1 142
Hnúšťa-Tisovec	1997	112	76	80	74
	1998	131	50	74	73
	1999	67	17	38	37
Horná Nitra	1997	1 612	45 079	4 244	1 134
	1998	1 581	41 942	5 232	1 020
	1999	1 455	45 173	5 325	1 112
Jelšava-Lubeník	1997	285	47	683	1 252
	1998	309	90	705	1 086
	1999	270	181	603	1 125
Košice	1997	10 558	17 689	15 893	83 959
	1998	9 177	13 390	20 518	72 558
	1999	16 344	15 122	13 365	85 031
Prešov	1997	50	22	173	101
	1998	123	21	180	136
	1999	50	1	162	80
Ružomberok	1997	1 101	2 696	1 276	2 256
	1998	629	1 994	1 100	1 934
	1999	201	2 927	1 111	414
Strážske-Vranov n.Topľou-Humenné	1997	1 540	14 975	3 519	3 439
	1998	977	13 951	3 404	3 395
	1999	910	13 441	2 915	3 557
Stredný Spiš	1997	310	7 283	117	746
	1998	167	2 562	109	736
	1999	29	636	25	202
Žiarska kotlina	1997	352	2 609	426	10 715
	1998	263	2 296	343	10 685
	1999	218	2 678	500	8 601
Žilina	1997	333	3 682	1 298	7 059
	1998	154	2 117	1 161	138
	1999	128	1 748	1 061	128

* *according to the Decree of Ministry of Environment of the Slovak Republic No 112/1993 Act Coll.*

Fig. 4.8 **PM emissions - EAPSI 1**

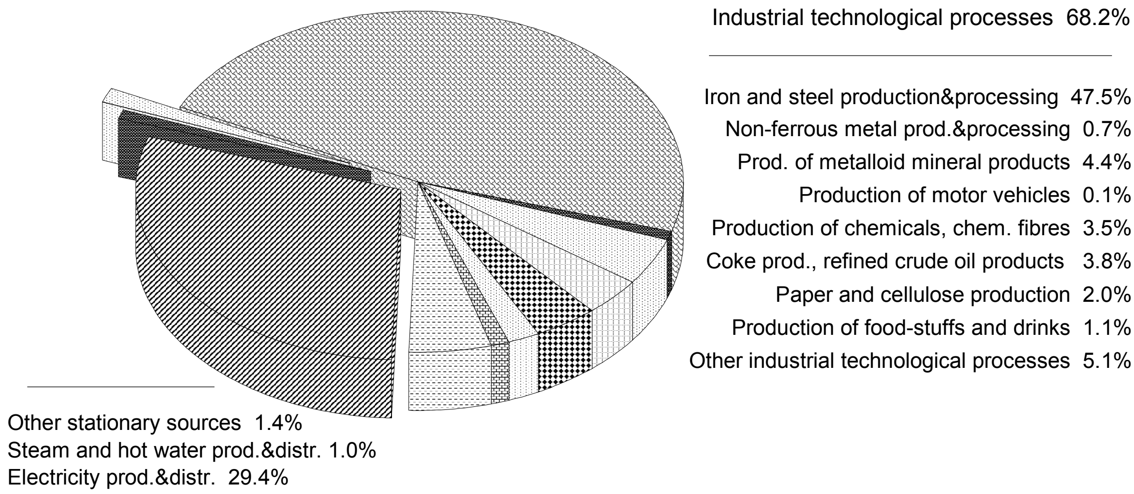


Fig. 4.9 **SO_2 emissions - EAPSI 1**

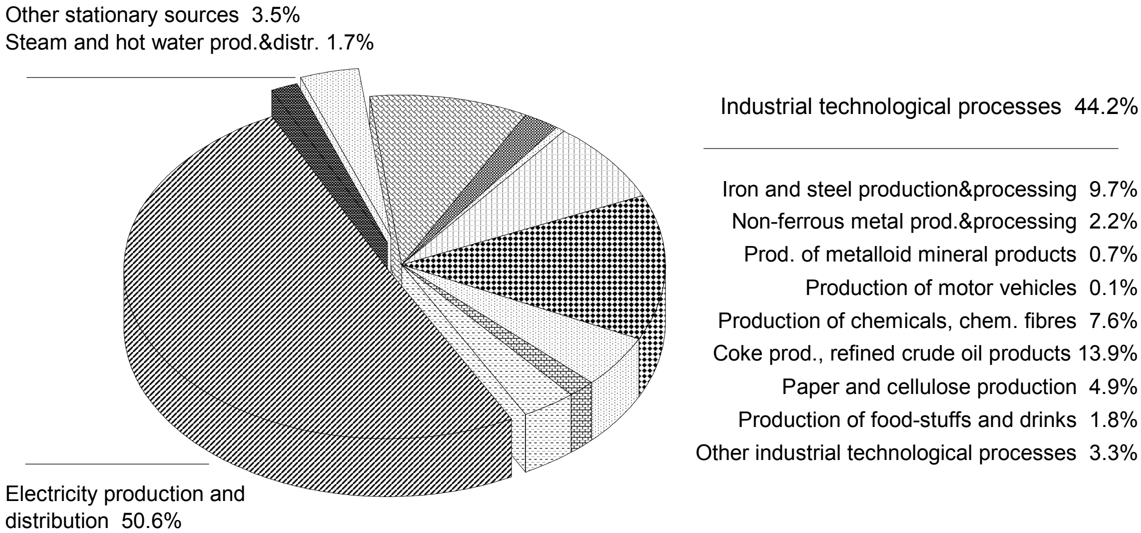


Fig. 4.10

NO_x emissions - EAPSI 1

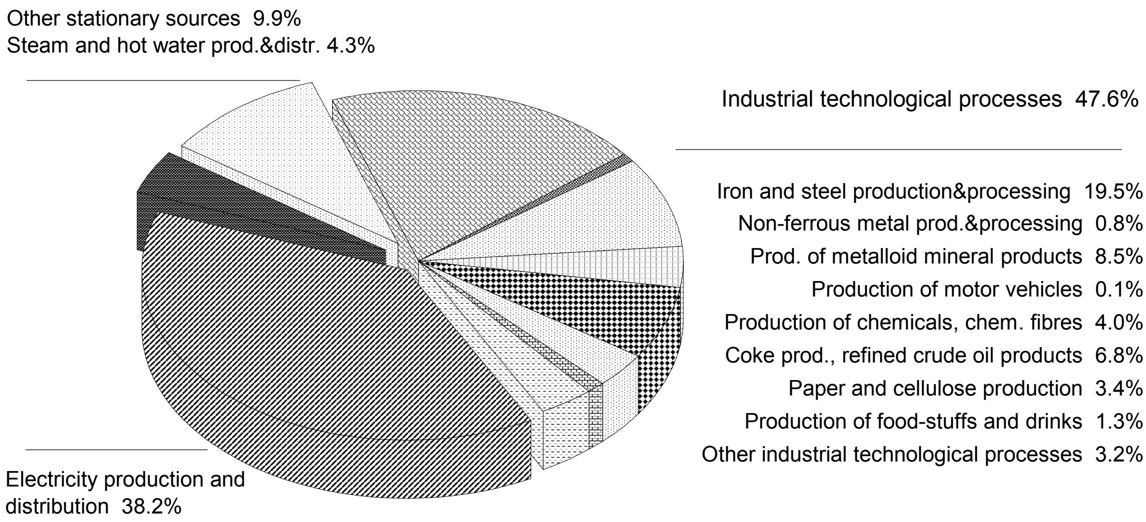
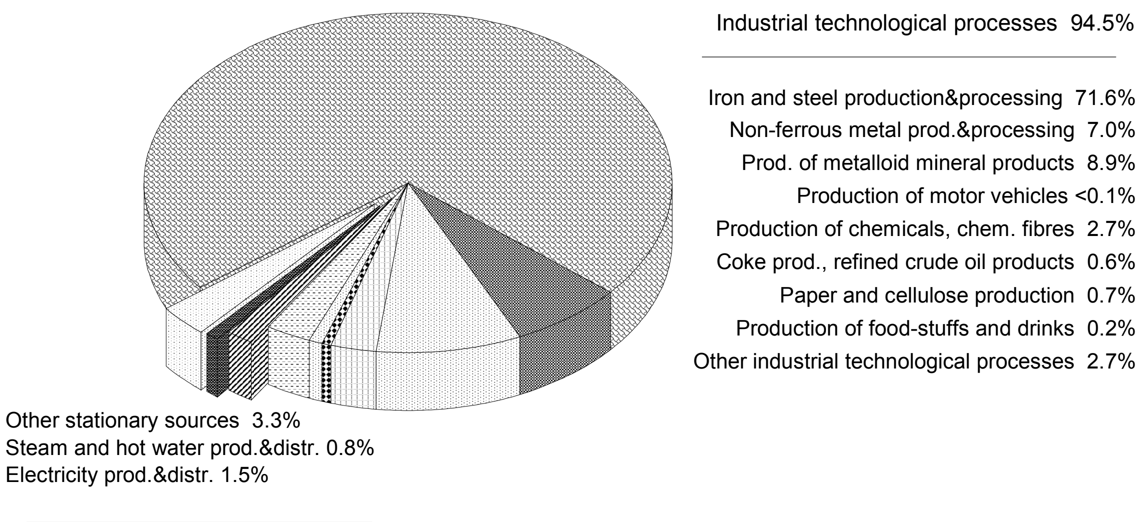


Fig. 4.11

CO emissions - EAPSI 1



Tab. 4.4 Amount of emissions from stationary sources in the Slovak Republic, in 1999, in the territorial division on the districts [t]

District	Emissions [t/year]				Specific territorial emissions [t/y.km^2]			
	PM	SO_2	NO_x	CO	PM	SO_2	NO_x	CO
1. Bratislava	1 889	21 078	6 119	1 860	5.133	57.277	16.628	5.054
2. Malacky	259	185	1 644	1 294	0.297	0.212	1.885	1.484
3. Pezinok	189	372	152	456	0.504	0.992	0.405	1.216
4. Senec	18	22	84	83	0.05	0.061	0.233	0.230
5. Dunajská Streda	600	1 599	413	1 177	0.558	1.487	0.384	1.095
6. Galanta	527	708	312	758	0.822	1.105	0.487	1.183
7. Hlohovec	265	260	163	500	0.993	0.974	0.610	1.873
8. Piešťany	167	161	143	472	0.438	0.423	0.375	1.239
9. Senica	559	964	387	1 421	0.735	1.267	0.509	1.867
10. Skalica	213	185	98	529	0.593	0.515	0.273	1.474
11. Trnava	493	914	916	1 224	1.047	1.941	1.945	2.599
12. Bánovce nad Bebravou	110	58	71	133	0.238	0.126	0.154	0.288
13. Ilava	493	389	828	752	1.373	1.084	2.306	2.095
14. Myjava	73	61	67	155	0.224	0.187	0.206	0.475
15. Nové Mesto nad Váhom	490	441	182	1 536	0.845	0.76	0.314	2.648
16. Partizánske	220	635	181	494	0.731	2.110	0.601	1.641
17. Považská Bystrica	266	770	264	780	0.575	1.663	0.570	1.685
18. Prievidza	2 312	46 041	5 849	2 707	2.408	47.959	6.093	2.820
19. Púchov	378	663	656	898	1.008	1.768	1.749	2.395
20. Trenčín	299	805	967	4 807	0.443	1.193	1.433	7.121
21. Komárno	261	262	250	589	0.237	0.238	0.227	0.535
22. Levice	1 120	1 100	374	2 463	0.722	0.709	0.241	1.588
23. Nitra	539	726	1 799	1 675	0.619	0.834	2.065	1.923
24. Nové Zámky	840	2 265	939	1 473	0.624	1.682	0.697	1.094
25. Šaľa	846	1 937	939	988	2.376	5.441	2.638	2.775
26. Topoľčany	294	275	183	765	0.492	0.461	0.307	1.281
27. Zlaté Moravce	205	201	81	511	0.393	0.386	0.155	0.981
28. Bytča	347	303	90	753	1.230	1.074	0.319	2.670
29. Čadca	633	836	242	1 729	0.833	1.100	0.318	2.275
30. Dolný Kubín	561	604	914	2 423	1.145	1.233	1.865	4.945
31. Kysucké Nové Mesto	220	219	93	585	1.264	1.259	0.534	3.362
32. Liptovský Mikuláš	675	1657	438	1 006	0.511	1.253	0.331	0.761
33. Martin	756	2 229	498	1 200	1.027	3.029	0.677	1.630
34. Námestovo	349	711	123	898	0.506	1.030	0.178	1.301
35. Ružomberok	760	3 427	1 246	1 784	1.175	5.297	1.926	2.757
36. Turčianske Teplice	82	71	25	59	0.209	0.181	0.064	0.150
37. Tvrdošín	671	799	175	1 661	1.401	1.668	0.365	3.468
38. Žilina	1 135	2 634	1 360	5 163	1.393	3.232	1.669	6.335
39. Banská Bystrica	641	1 038	1 009	983	0.792	1.283	1.247	1.215
40. Banská Štiavnica	60	94	30	154	0.216	0.338	0.108	0.554

Tab. 4.4 Amount of emissions from stationary sources in the Slovak Republic, in 1999, in the territorial division on the districts - to be continued [t]

District	Emissions [t/year]				Specific territorial emissions [t/y.km^2]			
	PM	SO_2	NO_x	CO	PM	SO_2	NO_x	CO
41. Brezno	657	841	258	1365	0.519	0.665	0.204	1.079
42. Detva	155	157	66	415	0.326	0.331	0.139	0.874
43. Krupina	208	214	48	515	0.356	0.366	0.082	0.880
44. Lučenec	714	533	300	1365	0.926	0.691	0.389	1.770
45. Poltár	260	202	279	541	0.515	0.400	0.552	1.071
46. Revúca	456	358	686	1538	0.625	0.490	0.940	2.107
47. Rimavská Sobota	648	541	234	1271	0.441	0.368	0.159	0.864
48. Veľký Krtíš	450	478	1443	843	0.530	0.563	1.700	0.993
49. Zvolen	856	3 848	779	2178	1.128	5.070	1.026	2.870
50. Žarnovica	191	212	137	452	0.448	0.498	0.322	1.061
51. Žiar nad Hronom	427	2902	575	9198	0.803	5.455	1.081	17.289
52. Bardejov	492	447	196	1105	0.525	0.477	0.209	1.179
53. Humenné	266	1 507	942	577	0.353	1.999	1.249	0.765
54. Kežmarok	182	176	96	434	0.217	0.210	0.114	0.517
55. Levoča	181	160	64	310	0.507	0.448	0.179	0.868
56. Medzilaborce	40	83	27	80	0.094	0.194	0.063	0.187
57. Poprad	189	146	278	385	0.168	0.130	0.248	0.343
58. Prešov	507	392	440	1 029	0.543	0.420	0.471	1.102
59. Sabinov	385	308	116	858	0.795	0.636	0.240	1.773
60. Snina	128	266	212	258	0.159	0.330	0.263	0.320
61. Stará Ľubovňa	461	408	112	1 048	0.739	0.654	0.179	1.679
62. Stropkov	52	47	22	28	0.134	0.121	0.057	0.072
63. Svidník	73	45	34	24	0.133	0.082	0.062	0.044
64. Vranov nad Topľou	578	3 160	854	519	0.752	4.109	1.111	0.675
65. Gelnica	174	128	59	1516	0.298	0.219	0.101	2.596
66. Košice	16 848	15 723	13 725	85 964	68.767	64.176	56.020	350.873
67. Košice - okolie	827	790	481	1397	0.539	0.515	0.314	0.911
68. Michalovce	9 506	31 402	19 861	4551	9.329	30.816	19.491	4.466
69. Rožňava	582	4897	1491	1964	0.496	4.175	1.271	1.674
70. Sobrance	167	102	43	34	0.310	0.190	0.080	0.063
71. Spišská Nová Ves	414	1 071	194	624	0.705	1.825	0.330	1.063
72. Trebišov	568	532	217	931	0.529	0.495	0.202	0.867
Slovakia	**58 457**	**169 775**	**74 573**	**172 215**	**1.2**	**3.5**	**1.5**	**3.5**

Fig. 4.12 **Specific territorial PM emissions [t/km^2] - 1999**

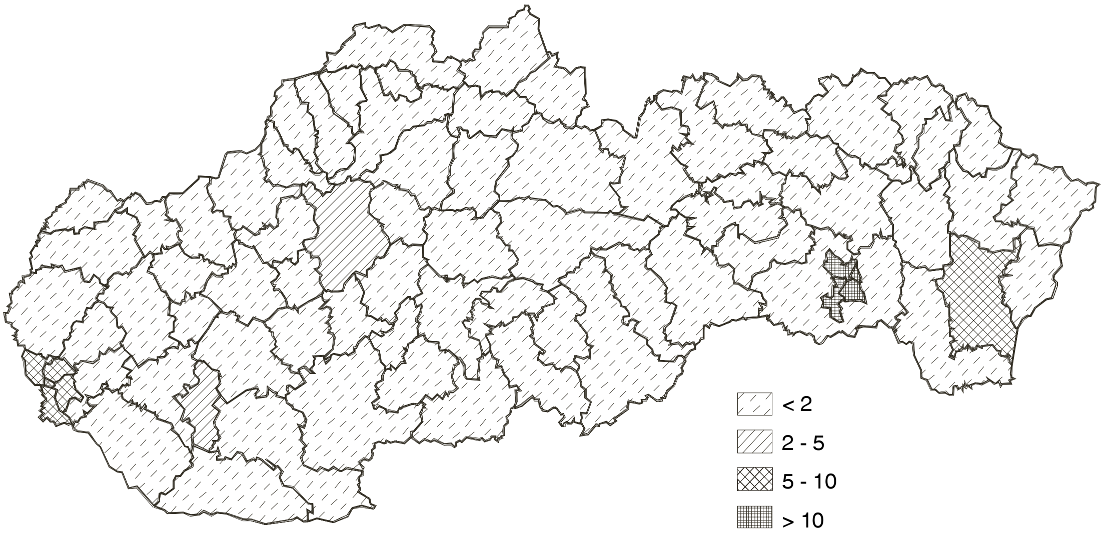


Fig. 4.13 **Specific territorial SO_2 emissions [t/km^2] - 1999**

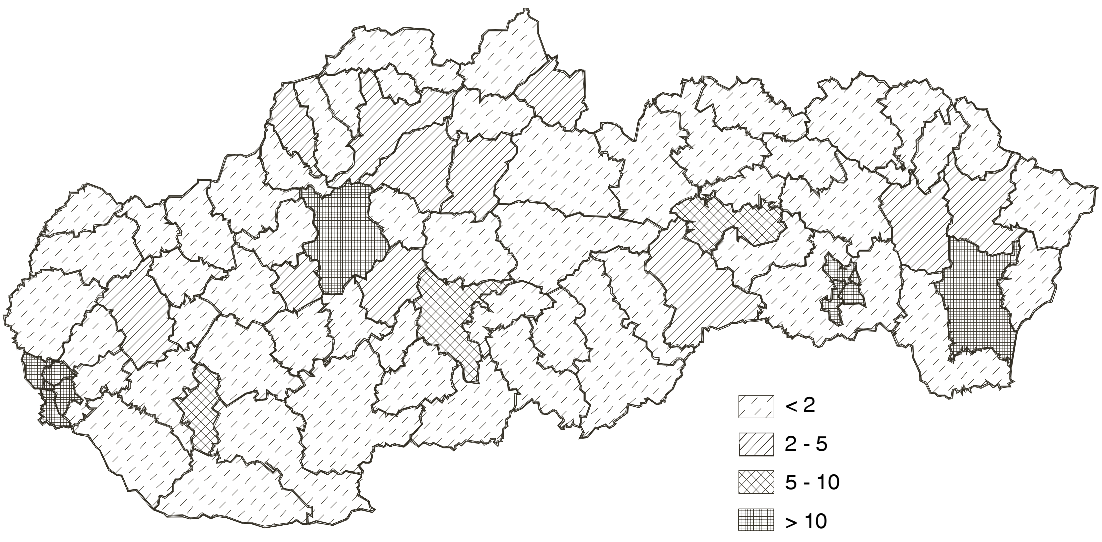


Fig. 4.14 **Specific territorial NO_x emissions [t/km^2] - 1999**

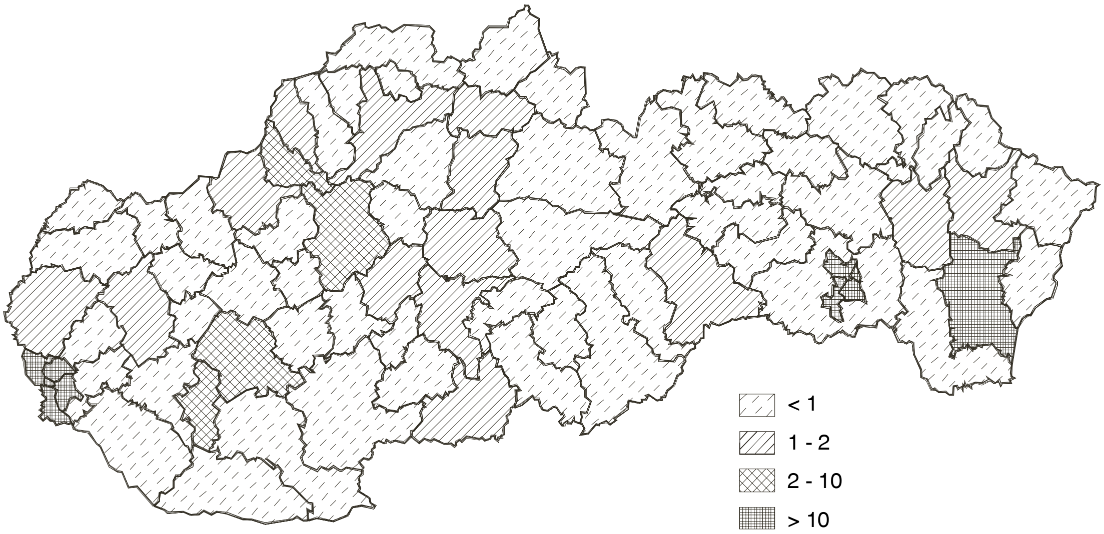
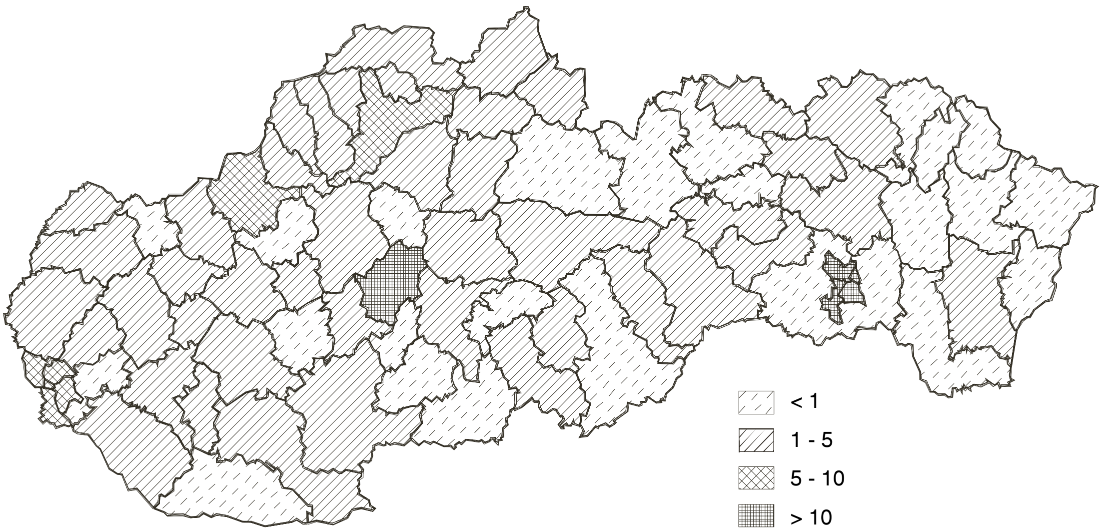


Fig. 4.15 **Specific territorial CO emissions [t/km^2] - 1999**



Tab. 4.5 The most important air pollution sources in the Slovak Republic and their share in the emissions of pollutants (EAPSI 1) in 1999

No.	PM		SO_2		NO_x		CO	
	Source	[%]	Source	[%]	Source	[%]	Source	[%]
1	Východoslovenské železiarne, a.s., Košice	46.49	SE, a.s., Elektrárne Nováky, o.z. Zemianske Kostoľany	30.25	SE, a.s., Elektráreň Vojany I a II	25.40	Východoslovenské železiarne, a.s., Košice	69.43
2	SE, a.s., Elektráreň Vojany I a II	25.47	SE, a.s., Elektráreň Vojany I a II	15.05	Východoslovenské železiarne, a.s., Košice	18.06	ZSNP, a.s., SLOVALCO, Žiar nad Hronom	6.67
3	SLOVNAFT, a.s., Bratislava	3.33	SLOVNAFT, a.s., Bratislava	13.67	SE, a.s., Elektrárne Nováky, o.z. Zemianske Kostoľany	7.75	CEMMAC, a.s., Horné Srnie	3.46
4	SE, a.s., Elektrárne Nováky, o.z. Zemianske Kostoľany	3.07	Východoslovenské železiarne, a.s., Košice	9.38	SLOVNAFT, a.s., Bratislava	6.70	CHEMKO, a.s., Strážske	2.44
5	DUSLO, a.s., Šaľa	1.20	CHEMKO, a.s., Strážske	6.18	SPP, š.p., Veľké Kapušany	2.65	Dolvap, s.r.o., Varín, Kameňolom a váp.	2.41
6	CHEMKO, a.s., Strážske	1.14	Želba, a.s., o.z. Nižná Slaná	2.97	HIROCEM, a.s., Rohožník	2.19	OFZ, a.s., Istebné - prev. Široká	1.32
7	BUKOCEL,a.s., Hencovce	1.05	SSE, š.p., Tepláreň Zvolen	2.12	SE, a.s., Tep. Energetika Košice	2.11	Vápenka, a.s., Margecany	1.01
8	Novácke chem. záv., a.s., Nováky	0.93	BUKOCEL, a.s., Hencovce	1.98	SPP, š.p., Nitra – Ivanka	2.09	SLOVMAG, a.s., Lubeník	0.83
9	Považská cementáreň, a.s., Ladce	0.71	Severoslovenské celulózky a papierne, a.s., Ružomberok	1.42	SPP, š.p., Veľké Zlievce	2.03	HIROCEM, a.s., Rohožník	0.80
10	Slovenské magnezitové závody, a.s., Jelšava	0.53	SEZ, š.p., Tepláreň Žilina	1.15	CHEMKO, a.s., Strážske	1.97	Bučina, a.s., Zvolen	0.63
11	OFZ, a.s., Istebné - prev. Široká	0.50	DUSLO, a.s., Šaľa	0.96	SPP, š.p., Bratislava, záv. Jablonov nad Turňou	1.74	SLOVNAFT, a.s., Bratislava	0.57
12	Cementáreň,a.s., Turňa nad Bodvou	0.50	ZSNP, a.s., SLOVALCO, Žiar nad Hronom	0.96	CHEMES, a.s., Humenné	1.34	SE, a.s., Elektrárne Nováky, o.z. Zemianske Kostoľany	0.57
13	Bučina, a.s., Zvolen	0.49	CHEMES, a.s., Humenné	0.94	SEZ, š.p., Tepláreň Žilina	1.26	SE, a.s., Elektráreň Vojany I a II	0.53
14	Petrochema a.s., Dubová	0.48	SEZ, š.p., Tepláreň Martin	0.94	Severoslovenské celulózky a papierne, a.s., Ružomberok	1.20	ŽELBA, a.s., Nižná Slaná	0.46
15	OFZ, a.s., Istebné - prev. Istebné	0.45	AssiDomän Packaging, Štúrovo, a.s.	0.85	DUSLO, a.s., Šaľa	1.18	SPP, š.p., Jablonov nad Turňou	0.41
16	HIROCEM, a.s., Rohožník	0.42	SE, a.s., Tep. Energetika Košice	0.82	BUKOCEL,a.s., Hencovce	1.12	SPP, š.p., Veľké Kapušany	0.36
17	Pasinvest a.s., Partizánske	0.41	ZSNP, a.s., Energetické hospodárstvo, Žiar nad Hronom	0.77	Považská cementáreň, a.s., Ladce	0.99	Kameňolom a vápenka Glassner a.s., Žirany	0.35
18	CHEMES, a.s., Humenné	0.38	Juhocukor a.s., Dunajská Streda	0.70	OFZ, a.s., Istebné - prev. Široká	0.95	BUKOCEL,a.s., Hencovce	0.28
19	Severoslovenské celulózky a papierne, a.s., Ružomberok	0.36	MAYTEX,a.s., Liptovský Mikuláš	0.62	SKLOOBAL, a.s. Nemšová	0.86	Pasinvest a.s., Partizánske	0.28
20	SEZ, š.p., Tepláreň Žilina	0.35	VITRUM a.s., Krompachy	0.43	AssiDomän Packaging, Štúrovo, a.s.	0.83	Lom cementáreň vápenka Werk 7 s.r.o., Nové Mesto nad Váhom	0.28
Total		**88.26**		**92.16**		**82.42**		**93.09**

Tab. 4.6 Air pollution - sequence of the sources within the region according to the amount of emission in 1999

BRATISLAVA REGION

PM

	Source	District
1.	SLOVNAFT, a.s., Bratislava	Bratislava II
2.	HIROCEM, a.s., Rohožník	Malacky
3.	Odvoz a likvidácia odpadu, a.s., Bratislava	Bratislava II
4.	Malokarpatská drevárska fabrika, a.s., Pezinok	Pezinok
5.	Paroplynový cyklus, a.s., Bratislava	Bratislava III
6.	GUMON SLOVAKIA, a.s., Bratislava	Bratislava II
7.	MATADOR, a.s.,Púchov, divízia Bratislava	Bratislava V
8.	ZEZ, š.p., Bratislava, Tepláreň II	Bratislava III
9.	VOLKSWAGEN SLOVAKIA,a.s.,Bratislava	Bratislava IV
10.	ZEZ, š.p., Bratislava, Tepláreň-západ	Bratislava IV

SO_2

	Source	District
1.	SLOVNAFT, a.s., Bratislava	Bratislava II
2.	ISTROCHEM, a.s., Bratislava	Bratislava III
3.	Malokarpatská drevárska fabrika, a.s., Pezinok	Pezinok
4.	MATADOR, a.s., Púchov, divízia Bratislava	Bratislava V
5.	Odvoz a likvidácia odpadu, a.s., Bratislava	Bratislava II
6.	ZEZ, š.p., Bratislava, Výhrevňa - juh	Bratislava II
7.	Psychiatrická nemocnica, Pezinok	Pezinok
8.	HIROCEM, a.s., Rohožník	Malacky
9.	CEVASERVIS, a.s., Stupava	Malacky
10.	ZEZ, š.p., Bratislava, Tepláreň II	Bratislava III

NO_x

	Source	District
1.	SLOVNAFT, a.s., Bratislava	Bratislava II
2.	HIROCEM, a.s., Rohožník	Malacky
3.	Paroplynový cyklus, a.s., Bratislava	Bratislava III
4.	ZEZ, š.p., Bratislava, Tepláreň II	Bratislava III
5.	Odvoz a likvidácia odpadu, a.s., Bratislava	Bratislava II
6.	ZEZ, š.p., Bratislava, Tepláreň-západ	Bratislava IV
7.	TECHNICKÉ SKLO, a.s., Bratislava	Bratislava IV
8.	ZEZ, š.p., Bratislava, Tepláreň I	Bratislava I
9.	NAFTA GAS, a.s., Plavecký Štvrtok	Malacky
10.	VOLKSWAGEN SLOVAKIA,a.s.,Bratislava	Bratislava IV

CO

	Source	District
1.	HIROCEM, a.s., Rohožník	Malacky
2.	SLOVNAFT, a.s., Bratislava	Bratislava II
3.	Paroplynový cyklus, a.s., Bratislava	Bratislava III
4.	Technické služby, s.r.o., Bratislava, obaľ. bit. zmesí	Bratislava III
5.	ZEZ, š.p., Bratislava, Tepláreň II	Bratislava III
6.	ZEZ, š.p., Bratislava, Tepláreň-západ	Bratislava IV
7.	SKYLIFE, s.r.o., Malacky	Malacky
8.	VOLKSWAGEN SLOVAKIA, a.s., Bratislava	Bratislava IV
9.	Psychiatrická nemocnica, Pezinok	Pezinok
10.	ZEZ, š.p., Bratislava, Tepláreň I	Bratislava I

TRNAVA REGION

	PM		SO2	
	Source	**District**	**Source**	**District**
1.	Trnavský cukrovar, a.s., Sládkovičovo	Trnava	JUHOCUKOR, a.s., Dunajská Streda	Dunajská Streda
2.	JUHOCUKOR, a.s., Dunajská Streda	Dunajská Streda	Trnavský cukrovar, a.s., Trnava	Trnava
3.	AMYLUM SLOVAKIA, s.r.o., Boleráz	Trnava	CUKROVAR NOVA, a.s., Sereď	Galanta
4.	SKLOPLAST, a.s., Trnava	Trnava	Slovenský hodváb, a.s., Senica	Senica
5.	Trnavský cukrovar, a.s., Trnava	Trnava	Trnavský cukrovar, a.s., Sládkovičovo	Galanta
6.	SLOVAKOFARMA, a.s., Hlohovec	Hlohovec	SWEDWOOD SLOVAKIA, s.r.o., o.z Trnava	Trnava
7.	CUKROVAR NOVA, a.s., Sereď	Galanta	Železničné opravovne a strojárne, a.s., Trnava	Trnava
8.	Zlieváreň Trnava, s.r.o.	Trnava	Drôtovňa Drôty, a.s., Hlohovec	Hlohovec
9.	Slovenský hodváb, a.s., Senica	Senica	SKLOPLAST, a.s., Trnava	Trnava
10.	SWEDWOOD SLOVAKIA, s.r.o., o.z. Trnava	Trnava	D-APETIT, s.r.o., Dunajská Streda	Dunajská Streda

	NO_x		CO	
	Source	**District**	**Source**	**District**
1.	SKLOPLAST, a.s., Trnava	Trnava	Zlieváreň Trnava, s.r.o.	Trnava
2.	JUHOCUKOR, a.s., Dunajská Streda	Dunajská Streda	Drôtovňa Drôty, a.s., Hlohovec	Hlohovec
3.	CUKROVAR NOVA, a.s., Sereď	Galanta	Trnavský cukrovar, a.s., Sládkovičovo	Galanta
4.	Slovenský hodváb, a.s., Senica	Senica	SKLOPLAST, a.s., Trnava	Trnava
5.	Trnavský cukrovar, a.s., Trnava	Trnava	JUHOCUKOR, a.s., Dunajská Streda	Dunajská Streda
6.	ZEZ, š.p., Bratislava, Tepláreň Trnava	Trnava	SWEDWOOD SLOVAKIA, s.r.o., o.z Trnava	Trnava
7.	AMYLUM SLOVAKIA, s.r.o., Boleráz	Trnava	AMYLUM SLOVAKIA, s.r.o., Boleráz	Trnava
8.	Trnavský cukrovar, a.s., Sládkovičovo	Galanta	Slovenský hodváb, a.s., Senica	Senica
9.	Drôtovňa Drôty, a.s., Hlohovec	Hlohovec	Cesty Nitra, a.s., Obaľovacia súprava Smolenice	Trnava
10.	SWEDWOOD SLOVAKIA, s.r.o., o.z. Trnava	Trnava	ZEZ, š.p., Bratislava, Tepláreň Trnava	Trnava

NITRA REGION

	PM		SO_2	
	Source	**District**	**Source**	**District**
1.	Duslo, a.s., Šaľa	Šaľa	Duslo, a.s., Šaľa	Šaľa
2.	AssiDomän Štúrovo, a.s., Štúrovo	Nové Zámky	AssiDomän Štúrovo, a.s.,Štúrovo	Nové Zámky
3.	Kameňolom a vápenka GLASSNER, a.s., Žirany	Nitra	Šuriansky cukrovar, a.s., Šurany	Nové Zámky
4.	JCP IZOLÁCIE, a.s., Štúrovo	Nové Zámky	Službyt, a.s., Nitra, kotolňa Chrenová	Nitra
5.	IDEA NOVA, s.r.o., Nitra	Nitra	FERRENIT, a.s., Nitra	Nitra
6.	SES REAL, s.r.o., Tlmače	Levice	Mestský byt. podnik, s.r.o., Šaľa, kotolňa Šaľa-Veča	Šaľa
7.	Šuriansky cukrovar, a.s., Šurany	Nové Zámky	AGROMILK, a.s., Nitra	Nitra
8.	LENCOS, s.r.o., Levice	Levice	MENERT-THERM, s.r.o., Šaľa	Šaľa
9.	Mestský byt. podnik, s.r.o., Šaľa, kotolňa Šaľa-Veča	Šaľa	JCP IZOLÁCIE, a.s., Štúrovo	Nové Zámky
10.	NOVOCHEMA DRUŽSTVO, Levice	Levice	Slov. energetické strojárne, a.s., Tlmače	Levice

	NO_x		CO	
	Source	**District**	**Source**	**District**
1.	SPP, š.p., Bratislava, závod Ivanka pri Nitre	Nitra	Kameňolom a vápenka GLASSNER, a.s., Žirany	Nitra
2.	Duslo, a.s., Šaľa	Šaľa	SPP, š.p., Bratislava, závod Ivanka pri Nitre	Nitra
3.	AssiDomän Štúrovo, a.s., Štúrovo	Nové Zámky	AssiDomän Štúrovo, a.s., Štúrovo	Nové Zámky
4.	Šuriansky cukrovar, a.s., Šurany	Nové Zámky	IDEA NOVA, s.r.o., Nitra	Nitra
5.	Službyt, a.s., Nitra, kotolňa Chrenová	Nitra	FERRENIT, a.s., Nitra	Nitra
6.	LEVITEX, a.s., Levice	Levice	JCP IZOLÁCIE, a.s., Štúrovo	Nové Zámky Nitra
7.	Kameňolom a vápenka GLASSNER, a.s., Žirany	Nitra	Mestský byt. podnik, s.r.o., Šaľa, kotolňa Šaľa-Veča	Šaľa
8.	Bytový podnik, Nové Zámky, CTZ	Nové Zámky	MIER, a.s., Topoľčany	Topoľčany
9.	ZLATÝ BAŽANT, a.s., Hurbanovo	Komárno	Slov. energetické strojárne, a.s., Tlmače	Levice
10.	MIER, a.s., Topoľčany	Topoľčany	ENERGO-BYTOS, s.r.o., Šahy	Levice

TRENČÍN REGION

	PM		SO_2	
	Source	**District**	**Source**	**District**
1.	SE, a.s., Bratislava, o.z. Zemianske Kostoľany	Prievidza	SE, a.s., Bratislava, o.z. Zemianske Kostoľany	Prievidza
2.	Novácke chemické závody, a.s., Nováky	Prievidza	Považské strojárne, Energetika, a.s., Považská Bystrica	Považská Bystrica
3.	Považská cementáreň, a.s., Ladce	Ilava	PASINVEST, a.s., Tepláreň, Partizánske	Partizánske
4.	PASINVEST, a.s., Tepláreň, Partizánske	Partizánske	SE a.s., Bratislava, Tepláreň Handlová	Prievidza
5.	ZTS-ENERGO, a.s., Dubnica nad Váhom	Ilava	MATADOR, a.s., Púchov	Púchov
6.	BEBA INVEST, s.r.o., Dyháreň, Bánovce nad Bebravou	Bánovce nad B	MERINA, a.s., Trenčín	Trenčín
7.	CEMMAC, a.s., Horné Sŕnie	Trenčín	HBP, a.s., Baňa Cígeľ, Prievidza	Prievidza
8.	LR CRYSTAL, a.s., Lednické Rovne	Púchov	Považský cukrovar, a.s., Trenčianska Teplá	Trenčín
9.	HBP, a.s., Baňa Cígeľ, Prievidza	Prievidza	Považská cementáreň, a.s., Ladce	Ilava
10.	Považské strojárne, Energetika, a.s., Považská Bystrica	Považská Bystrica	SYENIT-Z, a.s., Púchov	Púchov

	NO_x		CO	
	Source	**District**	**Source**	**District**
1.	SE, a.s., Bratislava, o.z. Zemianske Kostoľany	Prievidza	CEMMAC, a.s., Horné Sŕnie	Trenčín
2.	Považské strojárne, Energetika,a.s., Považská Bystrica	Považská Bystrica	SE, a.s., Bratislava, o.z. Zemianske Kostoľany	Prievidza
3.	SKLOOBAL, a.s., Nemšová	Trenčín	PASINVEST, a.s., Tepláreň, Partizánske	Partizánske
4.	LR CRYSTAL, a.s., Lednické Rovne	Púchov	Vápenka Werk 7,s.r.o., Nové Mesto nad Váhom	Nové Mesto n/V
5.	Považské strojárne, Energetika, a.s., Považská Bystrica	Považská Bystrica	ZŤS-Metalurgia, a.s., Dubnica nad Váhom	Ilava
6.	MATADOR, a.s., Púchov	Púchov	Novácke chemické závody, a.s., Nováky	Prievidza
7.	Novácke chemické závody, a.s., Nováky	Prievidza	Považské strojárne, Energetika,a.s., Považská Bystrica	Považská Bystrica
8.	PASINVEST, a.s., Tepláreň, Partizánske	Partizánske	V.O.S.R., s.r.o., Pravenec	Prievidza
9.	CEMMAC, a.s., Horné Sŕnie	Trenčín	Považská cementáreň, a.s., Ladce	Ilava
10.	ZŤS-Energo, a.s., Dubnica nad Váhom	Ilava	HBP, a.s., Baňa Cígeľ, Prievidza	Prievidza

BANSKÁ BYSTRICA REGION

	PM		SO_2	
	Source	**District**	**Source**	**District**
1.	Slovenské magnezitové závody, a.s., Jelšava	Revúca	SSE, š.p., Tepláreň Zvolen	Zvolen
2.	Bučina, a.s., Zvolen	Zvolen	ZSNP, a.s., SLOVALCO (výr. Al), Žiar nad Hronom	Žiar nad Hronom
3.	PETROCHEMA, a.s., Dubová	Brezno	ZSNP, a.s., Energetické hospodárstvo, Žiar nad Hronom	Žiar nad Hronom
4.	ZSNP, a.s., SLOVALCO (výr. Al), Žiar nad Hronom	Žiar nad Hronom	PETROCHEMA, a.s., Dubová	Brezno
5.	SLOVMAG, a.s., Lubeník	Revúca	Harmanecké papierne, a.s., Harmanec	Banská Bystrica
6.	PREGLEJKA a.s, Žarnovica	Žarnovica	BIOTIKA, a.s., Slovenská Ľupča	Banská Bystrica
7.	ZSNP, a.s., Energetické hospodárstvo, Žiar nad Hronom	Žiar nad Hronom	SLOVMAG, a.s., Lubeník	Revúca
8.	Zlievárenská spoločnosť, a.s., Hronec	Brezno	IZOMAT, a.s., Nová Baňa	Žarnovica
9.	Stredoslovenská cementáreň, s.r.o., Banská Bystrica	Banská Bystrica	ZSNP, a.s., SLOVALCO (výr. anod), Žiar nad Hronom	Žiar nad Hronom
10.	IZOMAT, a.s., Nová Baňa	Žarnovica	BAŇA DOLINA, a.s, Veľký Krtíš	Veľký Krtíš

	NO_x		CO	
	Source	**District**	**Source**	**District**
1.	SPP, š.p., SLOVTRANSGAZ, závod Veľké Zlievce	Veľký Krtíš	ZSNP, a.s., SLOVALCO (výr. Al), Žiar nad Hronom	Žiar nad Hronom
2.	Stredoslovenská cementáreň, s.r.o., Banská Bystrica	Banská Bystrica	SLOVMAG, a.s., Lubeník	Revúca
3.	SSE š.p. Tepláreň Zvolen	Zvolen	Bučina, a.s., Zvolen	Zvolen
4.	SLOVMAG, a.s., Lubeník	Revúca	ZSNP, a.s., SLOVALCO (výr. anod), Žiar nad Hronom	Žiar nad Hronom
5.	Slovenské magnezitové závody, a.s., Jelšava	Revúca	SPP, š.p., SLOVTRANSGAZ, závod Veľké Zlievce	Veľký Krtíš
6.	ZSNP, a.s., Energetické hospodárstvo, Žiar nad Hronom	Žiar nad Hronom	IZOMAT, a.s., Nová Baňa	Žarnovica
7.	Bučina, a.s., Zvolen	Zvolen	Zlievárenská spoločnosť, a.s., Hronec	Brezno
8.	ZSNP, a.s., SLOVALCO (výr. Al), Žiar nad Hronom	Žiar nad Hronom	Slovenské magnezitové závody, a.s., Jelšava	Revúca
9.	Železiarne Podbrezová, a.s.	Brezno	Železiarne Podbrezová, a.s.	Brezno
10.	BIOTIKA, a.s., Slovenská Ľupča	Banská Bystrica	OTA s.r.o, Cinobaňa	Poltár

ŽILINA REGION

	PM		SO₂	
	Source	**District**	**Source**	**District**
1.	Oravské ferozliatinárske závody, a.s., prev. Široká	Dolný Kubín	Severoslov. celulózky a papierne, a.s., Celpap, Ružomberok	Ružomberok
2.	Oravské ferozliatinárske závody, a.s., prev. Istebné	Dolný Kubín	SEZ, š.p., Tepláreň Žilina	Žilina
3.	Severoslov. celulózky a papierne, a.s., Celpap, Ružomberok	Ružomberok	SEZ, š.p., Tepláreň Martin	Martin
4.	SEZ, š.p., Tepláreň Žilina	Žilina	MAYTEX, a.s., Liptovský Mikuláš	Liptovský Mikuláš
5.	Drevina group, a.s, Turany	Martin	Severoslov.celulózky a pap., ,zav.Solo, a.s., Ružomberok	Ružomberok
6.	Dolvap, s.r.o., Varín, Kameňolom a vápenka	Žilina	Bavlnárske závody – TEXICOM, s.r.o., Ružomberok	Ružomberok
7.	ŽOS Vrútky, a.s, Vrútky	Martin	Oravské ferozliatinárske závody, a.s., Istebné	Dolný Kubín
8.	ST.NICOLAUS, a.s., Liptovský Mikuláš	Liptovský Mikuláš	ZŤS Strojárne, a.s., Námestovo	Námestovo
9.	ZŤS Strojárne, a.s., Námestovo	Námestovo	Drevina group, a.s, Turany	Martin
10.	Ľudová tvorba, v.d., Veľké Rovné	Bytča	OTF- ENERGIA, s.r.o., Nižná	Tvrdošín

	NO_x		CO	
	Source	**District**	**Source**	**District**
1.	SEZ, š.p., Tepláreň Žilina	Žilina	Dolvap, s.r.o., Varín, Kameňolom a vápenka	Žilina
2.	Severoslov.celulózky a papierne, a.s., Celpap, Ružomberok	Ružomberok	Oravské ferozliatinárske závody, a.s., prev. Široká	Dolný Kubín
3.	Oravské ferozliatinárske závody, a.s., prev. Široká	Dolný Kubín	Severoslov.celulózky a papierne, a.s., Celpap, Ružomberok	Ružomberok
4.	SEZ, š.p., Tepláreň Martin	Martin	Oravské ferozliatinárske závody, a.s., Istebné	Dolný Kubín
5.	Považské chemické závody, a.s., Žilina	Žilina	Drevina group, a.s, Turany	Martin
6.	Oravské ferozliatinárske závody, a.s., Istebné	Dolný Kubín	SEZ, š.p., Tepláreň Žilina	Žilina
7.	MAYTEX, a.s., Liptovský Mikuláš	Liptovský Mikuláš	OTF- ENERGIA, s.r.o., Nižná	Tvrdošín
8.	Slovenská. paroplynova spol., a.s., Ružomberok	Ružomberok	ZŤS Strojárne, a.s., Námestovo	Námestovo
9.	Bavlnárske závody – TEXICOM, s.r.o., Ružomberok	Ružomberok	ŽOS Vrútky, a.s, Vrútky	Martin
10.	Severoslov.celulózky a pap., zav. Solo, a.s., Ružomberok	Ružomberok	Severoslov.celulózky a pap., zav. Solo, a.s., Ružomberok	Ružomberok

PREŠOV REGION

	PM		SO_2	
	Source	**District**	**Source**	**District**
1.	BUKOCEL, a.s., Hencovce	Vranov nad Topľou	BUKOCEL, a.s., Hencovce	Vranov nad Topľou
2.	CHEMES, a.s., Humenné	Humenné	CHEMES, a.s., Humenné	Humenné
3.	VIHORLAT, a.s., divízny závod energetika, Snina	Snina	VIHORLAT, a.s., divízny závod energetika, Snina	Snina
4.	KRONOSPAN SLOVAKIA, s.r.o., Prešov	Prešov	UNIOL-VRANOV, s.r.o., Vranov nad Topľou	Vranov nad Topľou
5.	UNIOL-VRANOV, s.r.o., Vranov nad Topľou	Vranov nad Topľou	OBUV BARDEJOV, a.s, Bardejov	Bardejov
6.	OBUV BARDEJOV, a.s, Bardejov	Bardejov	LABSTROJ, s.r.o., Medzilaborce	Medzilaborce
7.	TATRAVAGÓNKA, a.s., Poprad	Poprad	Cestné stavby, a.s., Košice, Obaľ. súprava, Kvetnica	Poprad
8.	Chemosvit-Strojchem, a.s., Svit	Poprad	ORPANN, a.s., Orlov	Stará Lubovňa
9.	TVARONA, a.s., Ulič	Snina	ZEOCEM, a.s., Bystré	Vranov nad Topľou
10.	INTWOOD, a.s, Kružlov	Bardejov	Cestné stavby, a.s., záv.Stropkov	Stropkov

	NO_x		CO	
	Source	**District**	**Source**	**District**
1.	CHEMES, a.s., Humenné	Humenné	BUKOCEL, a.s., Hencovce	Vranov nad Topľou
2.	BUKOCEL, a.s., Hencovce	Vranov nad Topľou	CHEMES, a.s., Humenné	Humenné
3.	VIHORLAT, a.s., divízny závod energetika, Snina	Snina	VIHORLAT, a.s., divízny závod energetika, Snina	Snina
4.	KRONOSPAN SLOVAKIA, s.r.o., Prešov	Prešov	KRONOSPAN SLOVAKIA, s.r.o., Prešov	Prešov
5.	Chemosvit-Energochem, a.s., Svit	Poprad	Cestné stavby, a.s., Košice, Obaľ. Súprava Vydumanec	Prešov
6.	SPRAVBYT, a.s., Prešov, centrálna kotolňa	Prešov	Cestné stavby, a.s., Košice, Obaľ. Súprava Kvetnica	Poprad
7.	Mesto Bardejov v zas. Spravbyt, s.r.o., Bardejov	Bardejov	Chemosvit-Energochem, a.s., Svit	Poprad
8.	PIVOVAR ŠARIŠ, a.s., Veľký Šariš	Prešov	Mesto Bardejov v zas. Spravbyt, s.r.o., Bardejov	Bardejov
9.	UNIOL-Vranov, s.r.o., Vranov nad Topľou	Vranov nad Topľou	OBUV BARDEJOV, a.s, Bardejov	Bardejov
10.	TATRAVAGÓNKA, a.s., Poprad	Poprad	TVARONA, a.s., Ulič	Snina

KOŠICE REGION

PM

	Source	District
1.	Východoslovenské železiarne, a.s., Košice	Košice II
2.	SE, a.s., Bratislava, Elektráreň Vojany I a II	Michalovce
3.	CHEMKO, a.s., Strážske	Michalovce
4.	Cementáreň Turňa, a.s., Turňa nad Bodvou	Košice-okolie
5.	ŽELBA, a.s., o.z. Siderit, Nižná Slaná	Rožňava
6.	FINIS NOVA, s.r.o, Spišská Nová Ves	Spišská Nová Ves
7.	Kalcit, s.r.o., Slaveč	Rožňava
8.	SE, a.s., Tepelná energetika Košice	Košice IV
9.	KERKO, a.s., Košice, záv. Dlaždice, Michalovce	Michalovce
10.	ŽSR SR, Rušňové depo, Košice	Košice IV

SO_2

	Source	District
1.	SE, a.s., Bratislava, Elektráreň Vojany I a II	Michalovce
2.	Východoslovenské železiarne, a.s., Košice	Košice II
3.	CHEMKO, a.s., Strážske	Michalovce
4.	ŽELBA, a.s., o.z. Siderit, Nižná Slaná	Rožňava
5.	SE, a.s., Tepelná energetika Košice	Košice IV
6.	VITRUM, a.s., Krompachy	Spišská Nová Ves
7.	FINIS – NOVA s.r.o., Spišská Nová Ves	Spišská Nová Ves
8.	EKOTHERMAL 99,s.r.o, SPAKO –Krásna, Košice	Košice IV
9.	ŽSR SR, Rušňové depo, Košice	Košice IV
10.	Cementáreň Turňa, a.s., Turňa nad Bodvou	Košice-okolie

NO_x

	Source	District
1.	SE, a.s., Bratislava, Elektráreň Vojany I a II	Michalovce
2.	Východoslovenské železiarne, a.s., Košice	Košice II
3.	SPP, š.p., závod Veľké Kapušany	Michalovce
4.	SE, a.s., Tepelná energetika Košice	Košice IV
5.	CHEMKO, a.s., Strážske	Michalovce
6.	SPP, š.p., závod Jablonov nad Turňou	Rožňava
7.	Cementáreň Turňa, a.s., Turňa nad Bodvou	Košice-okolie
8.	ŽELBA, a.s., o.z. Siderit, Nižná Slaná	Rožňava
9.	EKOTHERMAL 99,s.r.o, SPAKO –Krásna, Košice	Košice IV
10.	KOMAG, a.s., závod Bočiar, Košice	Košice II

CO

	Source	District
1.	Východoslovenské železiarne, a.s., Košice	Košice II
2.	CHEMKO, a.s., Strážske	Michalovce
3.	Vápenka, a.s., Margecany	Gelnica
4.	SE, a.s., Bratislava, Elektráreň Vojany I a II	Michalovce
5.	ŽELBA, a.s., o.z. Siderit, Nižná Slaná	Rožňava
6.	SPP, š.p., závod Jablonov nad Turňou	Rožňava
7.	SPP, š.p., závod Veľké Kapušany	Michalovce
8.	Zlieváreň SEZ Krompachy, a.s., Krompachy	Spišská Nová Ves
9.	SE, a.s., Tepelná energetika Košice	Košice IV
10.	Cementáreň Turňa, a.s., Turňa nad Bodvou	Košice-okolie

Tab. 4.7 Emissions of persistent organic pollutants in the Slovak Republic, in 1997

Sector / Sub-sector	PCDD/PCDF [g.r^{-1}]	PCB [kg.r^{-1}]	PAHs: sum PAH [t.r^{-1}]	PAHs: BaP [kg.r^{-1}]	PAHs: BaA [kg.r^{-1}]	PAHs: DBahA [kg.r^{-1}]
Fuel - power sector	**31.768**	**40.766**	**12.786**	**1 953.212**	**318.969**	**161.507**
System energetics	4.923	17.367	0.017	0.542	70.385	33.199
Municipal energetics	11.816	13.087	7.401	733.792	178.135	84.941
Industrial energetics	14.656	10.312	0.100	3.128	70.499	43.367
Coke production	0.373		5.268	1 512.750		
Crude oil refinery						
Termic industrial processes	**289.196**	**24.885**	**9.326**	**56.280**	**44.985**	**46.774**
Iron production	15.360		9.216	52.224		
Ore sintering	255.000	13.235				
Pig iron production	0.223					
Copper production						
Others	18.613	11.650	0.110	4.056	44.985	46.774
Non-termic industrial processes	**23.574**	**0**	**2.697**	**201.220**	**19.228**	**17.556**
Aluminium production	0.220		2.653	132.246		
Steel production	23.352			66.160		
Carbon material production	0.002		0.040	1.923	19.228	17.556
Wood impregnation			0.004	0.891		
Traffic	**0.678**	**68.46**	**4.561**	**228.089**	**103.165**	**41.895**
Road traffic						
Other traffic						
Waste incineration	**119.311**	**2.638**	**0.006**	**0.224**	**1.345**	**1.121**
Municipal waste	26.955	0.635	0.002	0.084	0.503	0.419
Industrial waste	36.108	1.313	0.003	0.092	0.552	0.460
Dangerous waste	56.248	0.69	0.001	0.048	0.290	0.242
Total	**464.527**	**136.749**	**29.376**	**2 439.025**	**487.692**	**268.853**

Expressed as I-TEQ; I-TEQ is calculated from the values for 2,3,7,8 - substituted co-geners of PCDD and PCDF under using of I-TEF according NATO/CCMS (1988)
** unknown mixture*

Tab. 4.8 Emissions of heavy metals [t] in the Slovak Republic in 1990 and 1992

Sector/ data quality	Year	Pb	As	Cd	Cr	Cu	Hg	Ni	Se	Zn	Sn	Mn
Fossil fuel combustion /B	1990	15.846	67.020	0.644	24.757	22.116	0.942	41.961	2.501	35.683	4.855	218.171
	1992	10.141	39.320	0.404	14.881	13.610	0.518	18.940	1.471	22.645	3.235	133.469
Iron and steel production /B	1990	40.843	1.432	0.242	1.611	15.464	3.826	6.676	1.858	35.186	1.510	11.759
	1992	30.435	0.776	0.199	5.044	11.636	2.072	5.410	1.383	26.660	1.122	10.624
Production of non-ferrous metals/C	1990	5.260	80.114	0.376	50.190	57.652	5.284	22.218		22.009	1.869	20.000
	1992	14.775	53.955	1.045	50.179	51.272	0.833	21.916	4.943	30.036	3.641	0.023
Inorganic chemical industry /B	1990			0.0002			0.297					
	1992			0.0003			0.140					
Cement production /B	1990	6.580	0.081	0.019	0.721		1.351	0.763	0.010	1.679		
	1992	3.075	0.038	0.009	0.337		0.631	0.357	0.005	0.785		
Glass production /B	1990	10.406	1.418	7.026	0.595	0.149	0.012	0.472	4.469	2.731		
	1992	14.668	2.007	9.029	0.681	0.170	0.014	0.539	5.105	3.230		
Magnesite production /B	1990	0.009	0.195	0.014	0.044	0.028	0.007	0.019		0.044		
	1992	0.009	0.214	0.015	0.048	0.031	0.001	0.021		0.048		
Waste incineration /D	1990	12.197	0.015	0.855	0.710	1.373	0.757	0.394	0.012	5.918		
	1992	12.111	0.015	0.850	0.701	1.361	0.754	0.389	0.012	5.887		
Cremation / D	1990						0.003					
	1992						0.003					
Transport / C	1990	75.000		0.497	0.222	6.625		5.515	0.022	7.513		
	1992	96.800		0.527	0.239	6.472		5.281	0.024	7.425		
Total	1990	**166.141**	**150.275**	**9.6732**	**78.850**	**103.407**	**12.479**	**78.018**	**8.872**	**110.763**	**8.234**	**249.930**
	1992	**182.014**	**96.325**	**12.0783**	**72.110**	**84.552**	**4.966**	**52.853**	**12.943**	**96.716**	**7.998**	**144.116**

Tab. 4.8 Emissions of heavy metals [t] in the Slovak Republic in 1994, 1996 and 1997 - to be continued

Sector/ data quality		Pb	As	Cd	Cr	Cu	Hg	Ni	Se	Zn	Sn	Mn
Fossil fuel combustion /B	1994	6.234	20.936	0.251	7.470	6.811	0.294	9.169	0.696	13.139	1.678	68.246
	1996	5.214	12.339	0.237	5.805	4.782	0.391	24.397	0.975	9.169	1.015	40.585
	1997	4.859	10.297	0.220	5.079	4.176	0.353	21.051	0.907	8.384	0.871	33.578
Iron and steel production /B	1994	28.220	0.576	0.214	3.869	11.125	1.571	5.856	1.287	27.070	1.044	10.485
	1996	32.627	0.406	0.191	2.175	12.250	1.121	5.203	1.501	27.180	1.215	5.732
	1997	35.936	0.626	0.203	1.487	13.536	1.697	5.662	1.649	29.527	1.337	6.617
Production of non-ferrous metals/C	1994	9.197	32.124	0.655	0.320	30.862	0.064	2.637	3.000	24.064	2.280	0.041
	1996	19.101	76.933	0.298	0.976	69.703	0.015	6.266	3.263	33.707	4.042	0.113
	1997	14.225	34.280	0.277	0.507	39.173	0.366	3.770	3.249	20.084	2.424	0.059
Inorganic chemical industry /B	1994			0.0002			0.030					
	1996						0.043					
	1997						0.030					
Cement production /B	1994	1.057	0.013	0.003	0.116		0.217	0.123	0.002	0.269		
	1996	0.474	0.006	0.001	0.052		0.097	0.055	0.121	0.001		
	1997	0.513	0.006	0.002	0.056		0.105	0.059	0.001	0.131		
Glass production /B	1994	11.494	1.240	5.100	0.594	0.149	0.012	0.470	4.464	2.723		
	1996	12.830	1.921	7.835	0.586	0.146	0.012	0.464	2.685	4.393		
	1997	13.522	1.895	8.960	0.591	0.148	0.012	0.468	4.430	2.707		
Magnesite production /B	1994	0.004	0.094	0.007	0.021	0.013	0.0003	0.009		0.021		
	1996	0.004	0.081	0.006	0.018	0.012	0.0003	0.008	0.004	0.018	0.028	0.0004
	1997	0.002	0.048	0.003	0.011	0.007	0.0010	0.005		0.011		
Waste incineration /D	1994	13.226	0.016	0.914	0.809	1.512	0.801	0.453	0.012	6.318		
	1996	25.008	0.032	1.807	1.305	2.724	1.634	0.709	0.027	12.527		
	1997	12.402	0.016	0.900	1.163	1.764	0.816	0.343	0.007	5.718		
Cremation / D	1994						0.003					
	1996						0.003					
	1997						0.004					
Transport / C	1994	21.100		0.569	0.267	5.093		3.757	0.027	6.162		
	1996	2.338		0.539	0.249	5.649		4.405	0.025	6.644		
	1997	2.867		0.647	0.305	5.560		3.925	0.022	6.780		
Total	1994	**90.532**	**54.999**	**7.713**	**13.466**	**55.565**	**2.992**	**22.474**	**9.488**	**79.766**	**5.002**	**78.772**
	1996	**97.596**	**91.718**	**10.914**	**11.166**	**95.266**	**3.316**	**41.507**	**8.601**	**93.639**	**6.300**	**46.430**
	1997	**84.326**	**47.168**	**11.212**	**9.199**	**64.364**	**3.384**	**35.283**	**10.265**	**73.342**	**4.632**	**40.254**

Tab. 4.9 NMVOC emissions in the Slovak Republic during 1990, 1993, 1995-97 [t]

	1990	1993	1995	1996	1997
Use of paints and adhesives	32 811	19 349	20 687	19 122	15 653
Chemical cleaning and degreasing	6 650	10 366	11 838	12 108	17 407
Crude oil production, transport and processing	22 386	17 313	11 772	12 655	11 520
Fuel distribution	3 624	3 674	4 237	3 808	5 533
Industrial organic processes	6 437	3 519	1 369	1 386	1 364
Combustion processes	11 465	11 317	3 264	4 005	3 157
Food industry	4 001	3 541	2 633	2 525	2 483
Metal processing industry	1 924	2 136	2 024	2 310	2 183
Wastes	8 298	1 605	574	526	287
Agriculture	651	436	436	436	436
Products	8 278	8 278	8 278	8 278	8 278
Transport	41 308	40 879	40 268	37 232	32 201
Total	**147 833**	**122 413**	**107 379**	**104 391**	**100 502**

Tab. 4.10 Data quality definition according to the US-EPA

Data quality	Data characteristics
A	Data set based upon the results of numerous experiments, using the analytical technique of GC/MS level, which may be considered as representative for the whole population.
B	Data set based upon the results of numerous experiments, using the analytical technique of GC/MS level, which may be considered as representative for significant percentage of the whole population.
C	Data set based upon the small number of experiments, using the analytical technique of GC/MS level, which may be considered as relatively representative for the whole population.
D	Data set based upon the measurements from one source only, using the analytical technique of GC/MS level, or data set, obtained by engineering calculations from the amount of sources.
E	Data set based upon the engineering calculations from one source only, the data sets based upon engineering estimation, data sets, without necessary documentation, which may be considered as representative for the whole population.

5.1 GREENHOUSE GAS EMISSIONS

Framework Convention on Climate Change (UN FCCC)

Global climate change due to the anthropogenic emission of greenhouse gases is the most important environmental problem in the existing history of mankind. Framework Convention on Climate Change (UN FCCC[1]) - the basic international legal instrument to protect global climate was adopted in the UN conference on environment and sustainable development (Rio de Janeiro 1992). The final goal of the Convention is to achieve stabilisation of greenhouse gas concentrations in the atmosphere at the level, which has not yet developed any dangerous interference in the climate system.

In the Slovak Republic, the Convention came into force in November 23, 1994 and in August 1995 was ratified by the parliament. Slovakia accepted all the commitments of the Convention, including reduction of the greenhouse gas emissions by 2000 at a level of 1990. One of the commitments, resulting from the Convention, is to provide greenhouse gas emission inventory regularly.

Kyoto protocol

At the conference of member states (COP Conference of Parties) in Kyoto, the so-called Kyoto protocol was adopted, upon which further reduction of greenhouse gas emissions is demanded. Slovakia and most of the European countries should reduce the total emissions 8% by 2008-2012 as compared to the basic year (1990). Slovak Republic signed the Kyoto protocol in February 26, 1999[2].

Greenhouse effect of the atmosphere

Greenhouse effect of the atmosphere is similar effect as may be observed in the greenhouses, however the function of glass in the atmosphere is taken over by the "greenhouse gases" (international abbreviation GHGs). Short wave solar radiation is transmitted freely through the greenhouse gases, falling down to the earth surface, heating it. Long wave (infrared) radiation, emitted by the earth surface, is caught by these gases in major part and partly re-emitted towards the earth surface. In a consequence of this effect, the average temperature of the surface atmosphere is 33°C warmer as it would be without the greenhouse gases. Finally, this does enable the life in our planet.

Greenhouse gases

The most important greenhouse gas in the atmosphere is water vapour (H_2O), which is responsible for approximately two thirds of the total greenhouse effect. Its content in the atmosphere is not directly affected by the human activity, in principle it is determined by the natural water cycle, expressed in a very simple way, by the difference between evaporation and precipitation. Carbon dioxide (CO_2) does contribute to the greenhouse effect 30%, methane (CH_4), nitrous oxide (N_2O) and ozone (O_3), all three together 3%. The group of man-made (artificial) substances - chlorofluorocarbons (CFCs), their substitutes, hydrofluorocarbons (HCFCs, HFCs) and other "such as"

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[1] http://www.unfccc.de

[2] *Kyoto protocol will come into force 19th day following ratification by at least 55 countries, among which have to be included countries of ANNEX 1 contributing at least 55% to the total 1990 carbon dioxide emissions, as is listed in attachment to the report 25 of the Protocol.*

fluorocarbons (PFCs) and SF_6, do belong to the greenhouse gases, also. There are, the other photochemical active gases as well, such as carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane organic compounds (NMVOCs), which do not belong to the greenhouse gases, but contribute indirectly to the greenhouse effect of the atmosphere. They are registered together as the precursors of ozone in the atmosphere, as they influence the formation and disintegration of ozone in the atmosphere.

Speaking about the emissions of greenhouse gases, in principle it comes to our mind CO_2, CH_4 N_2O and “new gases”, as they are defined in Kyoto protocol. Though they belong to the natural components of the ambient air, their present content in the atmosphere is significantly affected by the human activity. The growth in concentrations of greenhouse gases in the atmosphere (caused by anthropogenic emission) leads to the strengthening of greenhouse gas effect and thus to the additional warming of the atmosphere.

Concentrations of greenhouse gases in the atmosphere are formed by the difference between their emission (releasing into the atmosphere) and sink. Then follows from it, the increase of their content in the atmosphere does operate by two mechanisms: by

- emissions into the atmosphere
- weakening of natural sink mechanisms

Globally[3], the annual anthropogenic emission of carbon dioxide ranges between 4-8 billion tons of carbon (about 4t of CO_2 per capita at the globe). The most important source of a "new" carbon dioxide is presented by the fossil fuel combustion and cement production. The CO_2 is releasing also from the soil (deforestation, forest fires and conversion of grasslands into the agricultural soil), but this contribution is more difficult to quantify. Carbon dioxide is very stable in the atmosphere, its residence time is tens of years (60-200) and is removed from the atmosphere by a complex of natural sink mechanisms. It is expected, the 40% of carbon dioxide presently emitted is absorbed by the oceans. Photosynthesis by vegetation and sea plankton is further important sink mechanism, though only transitional one, because after the dying (eating) of a plant, the carbon dioxide is released again.

The level of methane in ambient air is affected by the human activity in more ways. Land transformation into agricultural one (mainly the rise fields), animal husbandry, coal mining, natural gas mining, its transport and use as well as the biomass burning are anthropogenic activities. The natural methane sources have not been yet fully investigated thus the role of methane in climate change mechanism is not quite clear. As distinct from CO_2, the disintegration of methane in the atmosphere is via chemical reactions (by OH radical). Residence time of methane in the atmosphere is 10-12 years. At present, the annual total anthropogenic methane emission is quoted to be approximately 0.4 billion tons, emission from natural sources is about 0.16 billion tons (IPCCC[4] 1995).

PFCs, HCFCs, HFCs (perfluorocarbons, chloroflourocarbons, halons, bromocarbons, etc.) and SF_6 are entering the atmosphere only owing to the human activity. They are used as carrier ga-

[3] *Climate change 1995, The Science of Climate Change, Contribution of WGI to the 2nd Assessment Report.*

[4] *Intergovernmental panel (IPCC - Intergovernmental panel on Climate Change http://www.ipcc.ch) was established in 1988 commonly by ECE (UNEP) and World Meteorological Organisation (WMO). Its task is to reach the authoritative international consensus in the scientific opinions on climate change. The working groups of IPCC (under the participation of the scientists from the whole world) do prepare the regular updated information for COP (Congress of Parties), where the latest knowledge in association with the global warming is included*

ses of sprays, fillings in cooling and extinguishing systems, as insulating substances, as solvents at the production of semiconductors, etc. Apart from the fact, they attack atmospheric ozone, they are very "high-powered" inert greenhouse gases having a residence time e.g. perfluoromethane (CF_4) even 50 000 years. It means, that also minor emissions are of a great negative effect.

The ground level ozone concentrations are growing as a consequence of CO, NO_x and NMVOC emissions, having very important source in exhaust gases, fossil fuel combustion and as far NMVOCs are considered, the use of solvents, as well.

N_2O enters the atmosphere from several small sources. The most important source does seem to be the emission from soil (nitrogen surpluses as a consequence of intensive fertilising and inconvenient agriculture-technical procedures). Fuel combustion, some industrial technologies, large-scale livestock breeding and sewage are the sources of N_2O emissions. Global anthropogenic emission is estimated to be 3-7 million tons of nitrogen per year. Natural sources are approximately twice as large as anthropogenic ones. The N_2O is disintegrated mainly photochemically in the stratosphere.

5.2 GREENHOUSE GAS EMISSIONS IN THE SLOVAK REPUBLIC

Emissions were appointed in compliance with the method of the IPCC/OECD/IEA[5]. The values listed in Tables are updated annually upon the Statistical yearbooks of the Slovak Republic and in the case of change in the methodology.

Total anthropogenic emissions of greenhouse gases in Slovakia

	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2* [Tg]	62	55	50	48	45	47	47	46	45
CH_4 [Gg]	364	334	304	287	280	289	298	285	270
N_2O [Gg]	19.9	16.9	14.9	12.5	12.6	13.2	11.0	11.0	10.8

Emissions, as determinated to April 15, 2000   ** Carbon dioxide emissions without LUC&F*

At the revision of inventory according to the IPCC practically all numbers have been change. In sector Energy the main cause were changes in statistical data „apparent consumption“, listed in annual books. In sector Industry the emission factors have been changed in co-operation with the Faculty of chemical technology and some data have been completed. In sector agriculture the methodology for determination of nitruos monoxide emissions has been changed (IPCCC Guidelines 1996) and emission factors of methane were reevaluated in cooperation with the University of Agriculture. In sector Wastes the data on quantity of waste have been revised in coincidence with databases of the Agency of environment and the Slovak Hydrometeorological Institute and some emission factors have been reevaluated. In sector Forest ecosystems the methodology has been slightly revised.

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[5] *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 1-3.*

CO_2 - carbon dioxide

Emissions

Most important sources of CO_2 in Slovakia are combustion of fossil fuels due to the power generation and transport (Table 5.1, Figure 5.1). In addition, carbon dioxide does arise during technological processes at production of cement, lime, magnesite and using of limestone. The balance includes also the production of coke, iron and steel, as well as CO_2 emissions arising at aluminium production. Emission factors, appointed upon the carbon content in fuels, were used. Carbon dioxide enters the atmosphere via the conversion of grasslands and forest areas into the agricultural land and forest fires.

Sinks

Slovak Republic spreads out at the territory of 49 036 km^2, of which 41% accounts for the forest areas. Since the beginning of a century the part of agricultural land has been gradually transformed into the forest one. In the period 1950-1991, the amount of carbon fixed in the forests of Slovakia has been increased approximately 50 Tg as a consequence of the forest area enlargement and increase in hectare yield of wood mass. Fixation of carbon in forest ecosystems of Slovakia was appointed upon the carbon balance in the part of forest above the ground (trees, plant canopy, overlying humus) and that one, under the ground (roots, humus in soil) including the assessment of wood exploitation and forest fires. Annual CO_2 sink ranges between 1500 and 4000 Gg. Assumed uncertainty of the assessment is approximately 30-50%.

CH_4 - methane

Agriculture, large-scale beef cattle and pig breeding, are major sources of methane at our territory (Table 5.2, Figure 5.2). The CH_4 does arise as the direct product of metabolism in herbivores and as the product of organic degradation in animal excrements. Calculations of emissions for the Slovak Republic are based upon the data listed in the Statistical yearbooks of the Slovak republic 1996, 1998. Leaks of natural gas in the distribution networks are very important source of methane. Methane is leaking into the atmosphere also at the brown coal mining and biomass burning. In addition, municipal waste dumps and sewage (predominantly septic tanks) do belong to the important methane sources. Methane arises without the direct access of oxygen.

N_2O - nitrous oxide

In comparison to the other greenhouse gases, the mechanism of nitrous oxide emissions and sinks is not explored fully. The values are charged by relatively considerable degree of uncertainty. Surpluses of mineral nitrogen in soil (consequence of intense fertilising) and unfavourable aerial soil condition (heavy mechanisms used at tillage) are the main cause of N_2O emissions. Emissions in power industry and traffic were appointed upon the balance in fossil fuel consumption, by applying the default emission factors according to the IPCC 1996. The N_2O emission, arising by manipulation of sewage and sludge has been appointed also for municipal and industrial waste water treatment plants (Table 5.3, Figure 5.3).

HFCs, PFCs, SF_6

Sources and emissions of the so-called "new gases" have been assessed at the territory of Slovakia. The procedure was carried out in coincidence with the methodology IPCC 1996 and true and potential emissions were appointed within 1995-1998 (Table 5.4). These gases have not been produced in Slovakia. Sources of emissions are in their using as coolants, extinguishing agents, foam substances, solvents, SF_6 as insulating gas in transformers and in metallurgical industry. CF_4 and C_2F_6 arise at aluminium production. Using of HFCs, PFCs, SF_6 has been risen since 1995 and this trend is expected in future, as well.

Aggregated emissions

These are the emissions of greenhouse gases recalculated via GWP100 (global warming potential) on the CO_2 equivalent. According to the currently valid convention, the emission reduction should be reported by recalculation on the CO_2 equivalent in (Figure 5.4 and 5.5).

5.3 ASSESSMENT

Upon the balance related to the year 1998, total anthropogenic emissions of carbon dioxide reached 45 mil. tons (in 1990 they reached 62 mil. t). Emissions of methane dropped from 360 thousand tons in 1990 to 270 thousand tons in 1998. Total emissions of N_2O were estimated on 11 thousand tons (in 1990 they reached approximately 20 thousand tons). Emissions of greenhouse gases reached the highest level by the end of the 1980s. Within the period 1990-1994 they dropped 25% and since 1995 they have been reaching approximately the same level.

Share of Slovakia in the global anthropogenic greenhouse gas emission does account for about 0.2%. Annual emission apportioned per one capita is approximately 8 t/year and thus ranks Slovakia among the countries with the greatest emissions per capita in the world. Following the development in economy according to the present scenario, it is expected not to exceed the level of the 1990 emissions by 2000 at the territory of Slovakia and thus to meet the commitment of the UN ECE Convention. Premises to comply with the requirements of Kyoto protocol may be assessed following the elaboration of the new scenarios upon the economy and energy conception of the government.

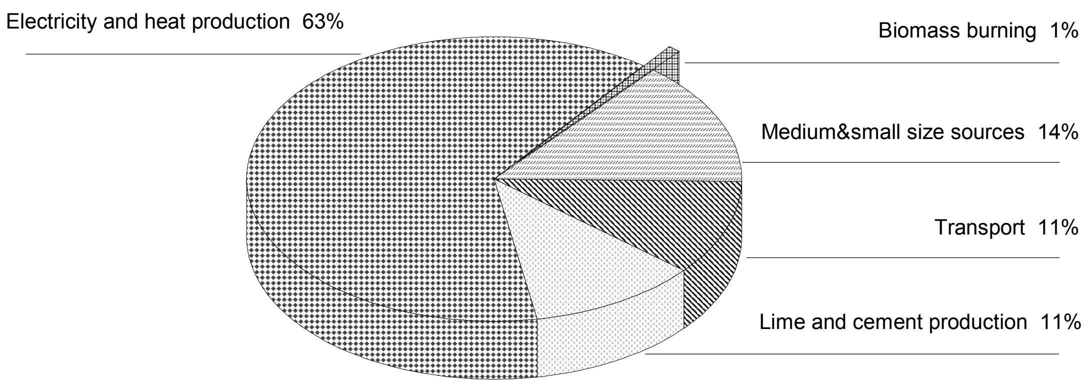
CO_2 - carbon dioxide

Tab. 5.1 Total emissions and sinks of CO_2 [Gg] within 1990-1998

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Antropogenic CO_2 emissions	**62 237**	**54 500**	**50 312**	**47 982**	**45 176**	**46 624**	**46 993**	**46 404**	**44 723**
Net CO_2 emissions*	**59 811**	**52 074**	**47 887**	**45 556**	**41 941**	**43 389**	**42 760**	**42 319**	**43 041**
Fossil fuel combustion	**56 691**	**50 375**	**45 667**	**43 720**	**40 660**	**41 904**	**42 494**	**41 670**	**39 953**
Electricity and heat production	51 621	45 949	41 551	39 691	36 471	37 688	38 330	37 079	35 003
Transport	5 070	4 426	4 116	4 029	4 189	4 216	4 164	4 591	4 950
Processes in industry	**5 546**	**4 125**	**4 645**	**4 262**	**4 516**	**4 720**	**4 499**	**4 734**	**4 770**
Mineral products	5 546	4 125	4 645	4 262	4 516	4 720	4 499	4 734	4 770
Forest ecosystems	**-2 426**	**-2 426**	**-2 426**	**-2 426**	**-3 235**	**-3 235**	**-4 233**	**-4 085**	**-1 683**
Changes in stock of wood mass	-401	-401	-401	-401	-1056	-1056	-2149	-2245	185
Deforestation	141	141	141	141	126	126	111	111	131
Aforestation	-1 351	-1 351	-1 351	-1 352	-1 371	-1 371	-1 391	-1 405	-1 407
CO_2 emissions and sinks in soil	-814	-814	-814	-814	-934	-934	-805	-546	-592
CO_2 emis. from biomass burning**	**1 686**	**1 382**	**1 253**	**720**	**717**	**326**	**316**	**349**	**303**

Emissions, as they were appointed to April 15, 2000
* *Emissions after subtraction of sinks in sector LUC&F*
** *CO_2 emissions from biomass burning are not being accounted into the total emissions*

Fig. 5.1 **CO_2 emissions in 1998**



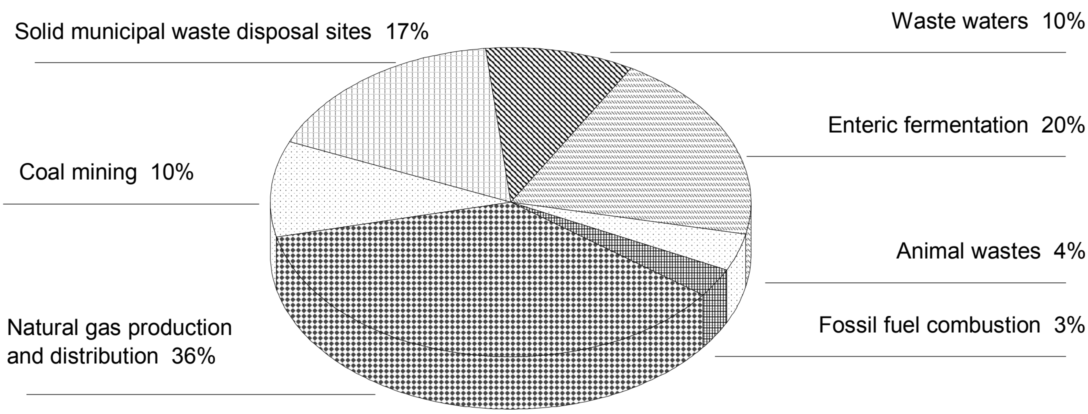
CH_4 - methane

Tab. 5.2 CH_4 emissions [Gg] within 1990-1998

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total CH_4 emissions	**363.7**	**333.8**	**303.7**	**287.4**	**280.5**	**289.4**	**298.0**	**285.3**	**270.2**
Energetics	**148.9**	**128.5**	**116**	**117.6**	**116.5**	**122.9**	**128.0**	**129.3**	**130.8**
Fossil fuel combustion	17.3	14.9	13.4	11.7	10.7	9.5	9.8	9.4	8.8
Electricity and heat production	16.4	14.0	12.5	10.7	9.8	8.7	8.6	8.3	7.7
Transport	0.9	0.9	0.9	1.0	0.9	0.8	1.2	1.1	1.1
Fugitive emissions	121.6	113.6	102.5	105.9	105.8	113.4	118.2	119.9	122.0
Coal mining	33.4	29.0	24.7	24.8	25.4	26.3	26.8	27.4	27.7
Natural gas prod.&distribution	88.2	84.6	77.8	81.1	80.4	87.1	91.4	92.5	94.3
Agriculture	**135.2**	**118.4**	**102.6**	**88.4**	**82.9**	**84.7**	**81.3**	**74.6**	**65.8**
Enteric fermentation	116.3	100.9	86.8	73.9	69.2	70.8	67.9	62.4	54.9
Animal wastes	18.9	17.5	15.8	14.5	13.7	13.9	13.4	12.3	10.9
Forest ecosystems	**3.2**	**3.2**	**3.2**	**3.2**	**2.4**	**2.4**	**0.9**	**1.9**	**0.5**
Biomass burning/ forest fires	3.2	3.2	3.2	3.2	2.4	2.4	0.9	1.9	0.5
Wastes	**86.4**	**83.7**	**81.9**	**78.2**	**78.7**	**79.4**	**87.8**	**79.5**	**73.1**
Waste disposal sites	50.3	50.3	50.3	50.3	50.3	50.9	59.6	51.0	45.8
Waste waters	36.1	33.4	31.6	27.9	28.4	28.5	28.2	28.5	27.3

Emissions, as they were appointed to April 15, 2000

Fig. 5.2 **CH_4 emissions in 1998**



N_2O - nitrous oxide

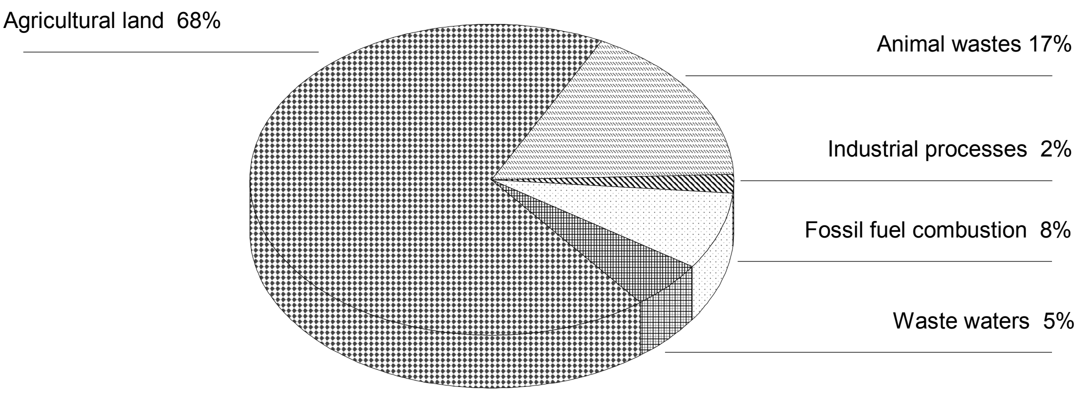
Tab. 5.3 N_2O emissions [Gg] within 1990-1998

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total N_2O emissions	**19.9**	**16.9**	**14.9**	**12.5**	**12.6**	**13.2**	**11.0**	**11.0**	**10.8**
Energy	**0.8**	**0.7**	**0.7**	**0.6**	**0.7**	**0.7**	**0.8**	**0.8**	**0.9**
Energy Industries	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Transport	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5
Processes in industry	**1.9**	**1.8**	**1.6**	**1.3**	**2.1**	**2.3**	**0.2**	**0.3**	**0.2**
Agriculture	**16.6**	**13.8**	**12.1**	**10.0**	**9.3**	**9.6**	**9.5**	**9.4**	**9.1**
Animal wastes	3.6	3.2	2.8	2.4	2.3	2.3	2.2	2.0	1.8
Agricultural land	13.0	10.6	9.3	7.6	7.0	7.3	7.3	7.4	7.3
Forest ecosystems									
Biomass burning/ forest fires	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Wastes	**0.6**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Industrial waste treatment plants	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Municipal waste waters	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5

Emissions, as they were appointed to April 15, 2000

Fig. 5.3

N_2O emissions in 1998



HFCs, PFCs and SF_6

Tab. 5.4 HFCs, PFCs and SF_6 emissions within 1990-1998

	GWP		1990	1991	1992	1993	1994	1995	1996	1997	1998
Total emissions CO_2 equivalent		[Gg]	**272**	**267**	**249**	**156**	**144**	**148**	**91**	**114**	**80**
HFCs emissions CO_2 equivalent		[Gg]					**2.91**	**24.52**	**44.86**	**69.83**	**43.58**
HFC-23	11700	[Mg]						<0.01	0.07	0.07	0.05
HFC-32	650	[Mg]							0.02	0.11	0.07
HFC-41	150										
HFC-43-10mee	1300										
HFC-125	2800	[Mg]						0.01	0.08	0.26	0.43
HFC-134	1000										
HFC-134a	1300	[Mg]					0.01	10.98	25.45	41.80	29.18
HFC-152a	140	[Mg]							<0.01	0.14	0.32
HFC-143	300										
HFC-143a	3800	[Mg]							0.12	0.31	0.46
HFC-227ea	2900	[Mg]					1.00	3.52	3.52	4.39	0.71
HFC-236fa	6300										
HFC-245ca	560										
PFCs emissions CO_2 equivalent		[Gg]	**271.9**	**267.1**	**249.0**	**155.8**	**132.3**	**113.9**	**35.2**	**32.9**	**23.8**
CF_4	6500	[Mg]	36.6	36.0	33.5	21.0	17.8	15.4	4.7	4.5	3.2
C_2F_6	9200	[Mg]	3.7	3.6	3.4	2.1	1.8	1.5	0.5	0.4	0.3
C_3F_8	7000										
C_4F_{10}	7000										
c-C_4F_8	8700										
C_5F_{12}	7500										
C_6F_{14}	7400										
SF_6 emissions CO_2 equivalent		[Gg]	**0.03**	**0.03**	**0.04**	**0.06**	**9.27**	**9.91**	**10.76**	**11.34**	**12.24**
SF_6	23900	[Mg]	0.001	0.001	0.002	0.003	0.388	0.415	0.450	0.474	0.512

Aggregated emissions

Fig. 5.4 **Aggregated emissions of greenhouse gases, 1990-1998**

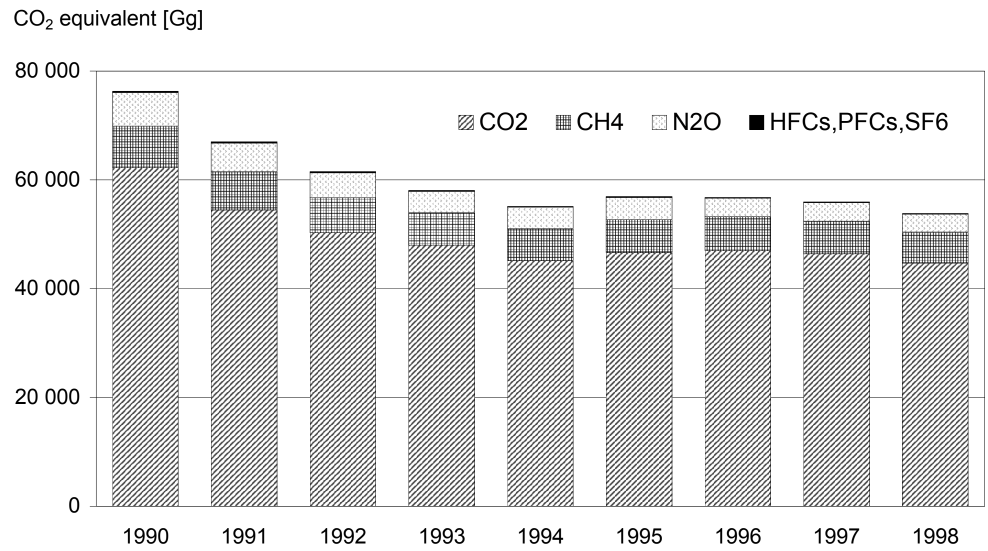
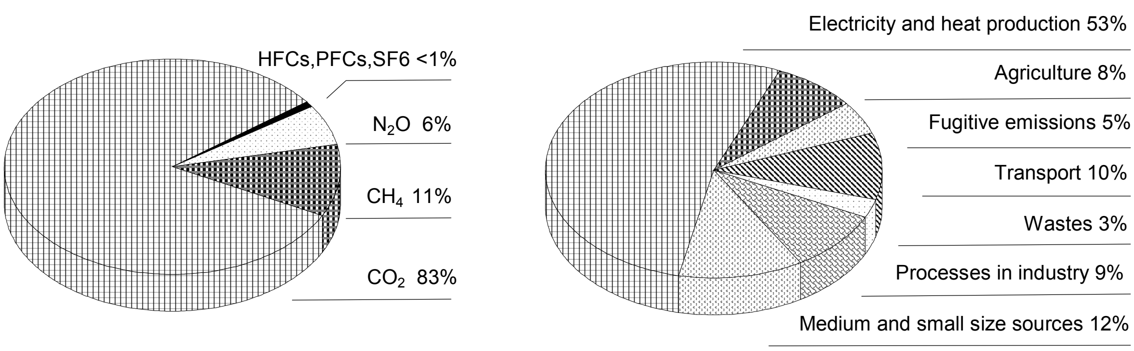


Fig. 5.5 **Aggregated emissions of greenhouse gases in 1998**



APPENDIX 1 Air quality standards according to the Provision of government of the Slovak Republic No. 92/1996 of the Act Coll., by which the Act No. 309/1991 Coll. about the air protection against pollutants, listed in Appendix 6 of this Provision is being carried out

Pollutant	**Expressed as**	**Air quality standards [μg.m⁻³]**			
		AQS_y	**AQS_d**	**AQS_{8h}**	**AQS_s**
Suspended particles		60	150		500
Sulphur dioxide	SO_2	60	150		500
Sulphur dioxide and suspended particles	SO_2 + SP		250*		
Oxides of nitrogen	NO_2	80	100		200
Carbon dioxide	CO		5 000		10 000
Ozone	O_3			110	
Pb in suspended particles	Pb	0.5			
Cd in suspended particles	Cd	0.01			
Odorous substances	Must not be in concentrations to nuisance the public				

Conditions to meet the standard: Concentration of AQS_d and AQS_s for SP, SO_2, NO_x and CO must not be exceeded within the year in more than 5% of cases.

Explanatory notes to the symbols:

***** - Calculated arithmetic sum of daily average concentrations of both components.

AQS_y - Annual average concentration of pollutant. Average concentration is mid value of concentration, found out at a given place within a time period of one year, as an arithmetic mean of average 24-hour concentrations.

AQS_d - Daily average concentration of pollutant. Daily average concentration is mid value of concentration, found out at given place, within the time period of 24 hours. Daily average concentration is also mid value of at least 12 regular measurements of average half-hour concentrations within the time period of 24 hours (arithmetic mean).

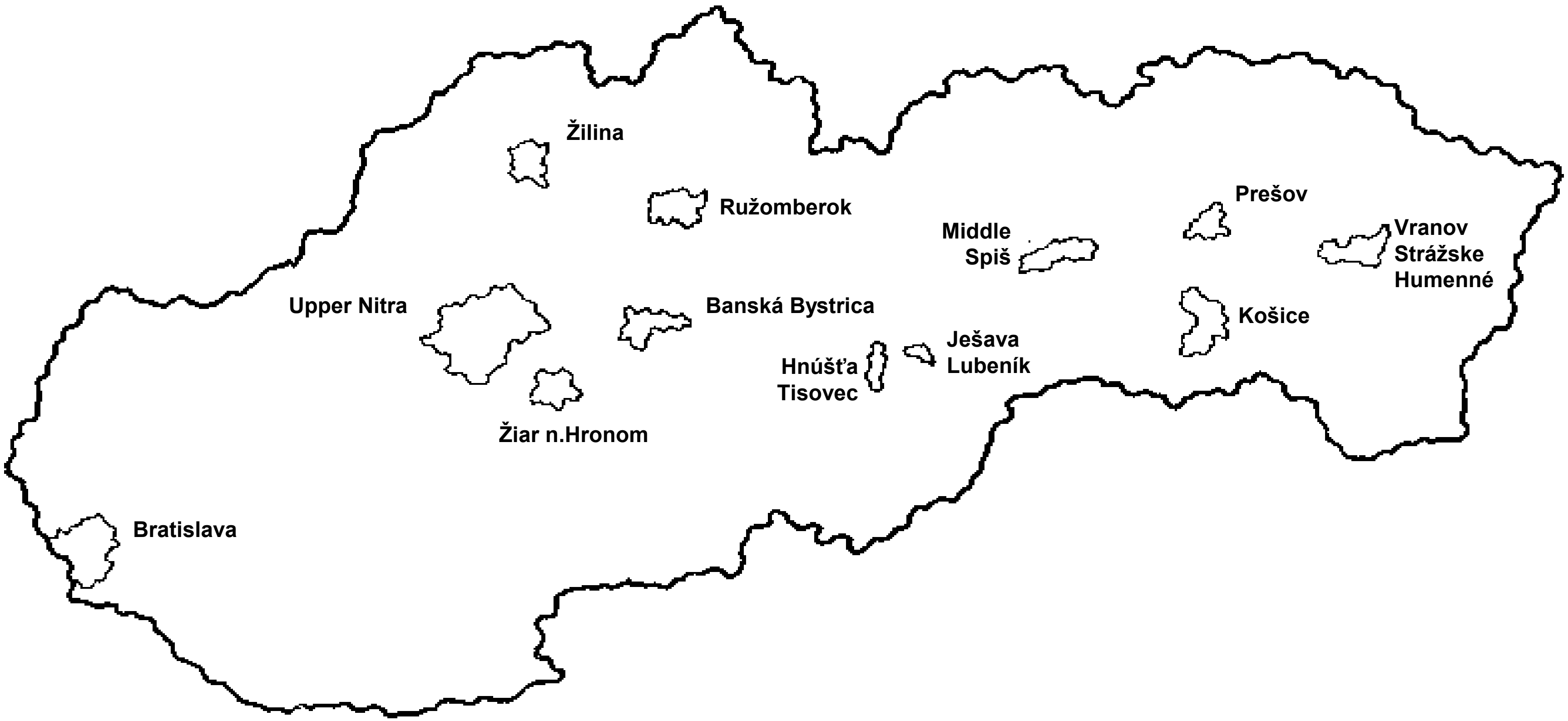
AQS_{8h} - Average 8-hour concentration of pollutant. Average 8-hour concentration is mid value of concentration, found out at a given place, within the time period of 8 hours.

AQS_s - Average half-hour concentration of pollutant is mid value of concentration, found out at a given place, within the time period of 30 minutes.

APPENDIX 2 Polluted areas of the Slovak Republic

Area	Definition of a territory - cadastral territories of cities/towns and districts
Banská Bystrica	Banská Bystrica, Kynceľová, Selce, Slovenská Ľupča
Bratislava	Bratislava, capital of the Slovak Republic, Hamuliakovo, Kalinkovo, Rovinka
Hnúšťa - Tisovec	Brádno, Hačava, Hnúšťa, Likier, Polom, Rimavská Píla, Rimavské Brezovo, Tisovec
Upper Nitra	district of Prievidza
Jelšava - Lubeník	Chyžné, Jelšava, Lubeník, Magnezitovce, Mokrá Lúka, Revúcka Lehota
Košice	Bočiar Haniska, Košice, Sokoľany, Veľká Ida
Prešov	Prešov
Ružomberok	Biely Potok, Likavka, Liptovská Štiavnica, Lisková, Ludrová, Martinček, Ružomberok, Sliače, Štiavnička
Strážske - Vranov - Humenné	Brekov, Dlhé Klčovo, Hudcovce, Humenné, Kladzany, Kučín, Majerovce, Nižný Hrabovec, Nižný Hrušov, Pusté Čemerné, Sedliská, Staré, Strážske, Topoľovka, Továrnianska Polianka, Voľa, Vranov nad Topľou, Závadka
Middle Spiš	Hrišovce, Chrásť nad Hornádom, Kaľava, Kluknava, Kolinovce, Krompachy, Markušovce, Matejovce, Olcnava, Richňava, Rudňavy, Spišské Vlachy, Vítkovce, Vojkovce
Žiarska kotlina	Dolná Trnávka, Dolná Ždaňa, Hliník nad Hronom, Horná Ždaňa, Ladomierska Vieska, Lehôtka pod Brehmi, Lovča, Lovčica - Trubín, Lutila, Prestavlky, Stará Kremnička, Šášovské Podhradie, Žiar nad Hronom
Žilina	Žilina, Lietavská Lúčka

APPENDIX 2 Polluted areas of the Slovak Republic - to be continued



AIR POLLUTION
IN THE SLOVAK REPUBLIC
1999

Issued by

Ministry of Environment of the Slovak Republic
Nám. Ľ. Štúra 1, 811 02 Bratislava

Slovak Hydrometeorological Institute
Jeséniova 17, 833 15 Bratislava

Printing

Reprography of Slovak Hydrometeorological Institute
Special publication: 154 pp., 43 tab., 106 fig.
Number of copies: 100