EMEP ASSESSMENT REPORT – SLOVAK REPUBLIC

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Emissions

A substantial decrease of anthropogenic emissions was recorded in Slovakia in the 1990s (Fig. 1 and 2, Tab. 1) as a consequence of political and economical changes.

Fig. 1 Emissions in the Slovak Republic [10^3 tons]

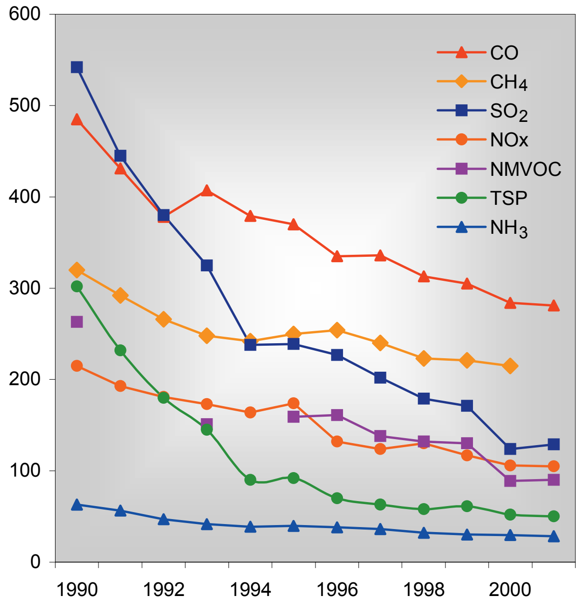
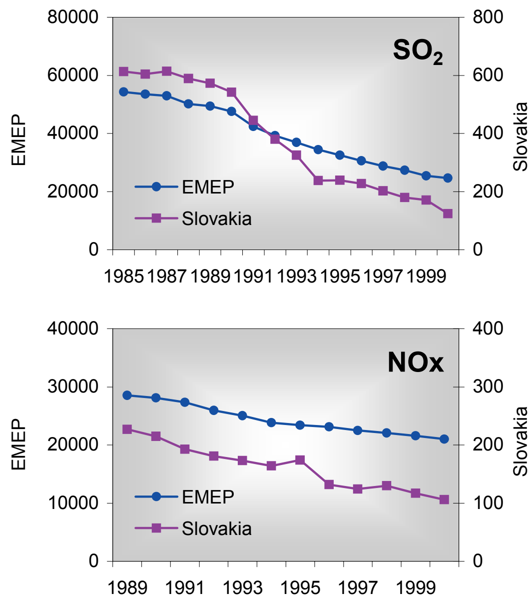


Fig. 2 EMEP and Slovakian emissions[10^3 tons]



Tab. 1 Heavy metals emissions in the Slovak Republic [tons]

	1990	1992	1994	1995	1996	1997	1998	1999	2000	2001
Pb	152	149	84	81	78	79	67	55	74	65
Cd	9	11	7	10	9	10	8	7	7	7
As	154	86	46	39	47	47	40	13	11	15

	1990	1992	1994	1995	1996	1997	1998	1999	2000	2001
Cr	79	71	12	12	10	10	9	10	8	8
Ni	74	63	32	34	34	31	31	26	24	28
Hg	13	6	4	4	3	4	4	4	4	4

1. Measures to reduce emissions in the Slovak Republic:
   - Adoption of the Act 309/1991 on air protection: establishment of MoE and local environmental authorities, implementation of new emission and ambient air standards, emission fees, mandatory fulfilment of commitments resulting from international treaties, etc.
   - Restructuralization and transformation of the Slovak economy, shutting down the ineffective productions.
   - Deregulation of prices for fuels, raw materials and energy.
   - Decentralizalization of power engineering systems.
   - Increasing energy efficiency of power plants and industry sector (modernization).
   - Share increase in use of renewable energy sources.
   - Implementation of energy saving measures (new energy conservation act, etc.).
   - National programme for reduction of heating losses in buildings.
   - Massive substitution of coal for natural gas.
   - Commissioning of new nuclear power plant Mochovce (880 MWe).

- Introduction of unleaded gasoline, obligatory use of catalytic converters in new cars since 1993.
- Emission and ambient air monitoring improvement.
- Adoption of new Act 478/2002 on air protection, which completely transposed relevant EU air quality legislation.

2. Present status in relation to the desired environmental quality:
   All Slovak emission indicators decline much faster as compared to the average European emission trends. The average level of regional background concentrations of pollutants in ambient air and precipitation follow the downward trend in emissions. Critical load exceedances of acidity in forest soils decreased from 50% in 1990 to 17% around 2000. Critical levels for SO_2 and NO_x are not exceeded at the whole territory of Slovakia at present apart from some urban locations. The situation concerning critical loads of heavy metals and POPs is not clear in Slovakia. The main current problems in Slovakia are high level of fine particles (PM10) and ground level ozone. The massive national reduction of ozone precursor emissions resulted in decrease of ozone extremes only, while the average level has not been changed and exceedances of 8h average 120 $\mu g.m^{-3}$ were slightly increased in the 1990s.

3. The need for further action to reduce pollution levels:
   The positive effect of EU air pollution legislation (transposed into the Slovak legislation) is assumed. To meet the Gothenburg Protocol emission ceilings is realistic for Slovakia. Slow downward trend of regional concentrations and critical load exceedances is expected in Slovakia in the next decade. Future trends of current ground level ozone level will depend on the ozone precursor emission trends on European scale.
   More attention should be given to POPs, HMs, accumulation of nitrogen in the natural ecosystems, regional transport and source apportionment of fine particles and ground level ozone.

Monitoring of regional air quality in the Slovak Republic

Regional air pollution and quality of precipitation over the territory of Slovakia has been monitored under the Slovak Hydrometeorological Institute since 1977. Originally, the only station Chopok has been established in 1977, included from the beginning of its operation into two international programs, GAW WMO and EMEP UN ECE. Until 1993 the network of seven regional stations has been gradually put into operation, but in 1999 two stations had been shut down due to the lack of monetary means. At present the regional network consists of five stations, all are the EMEP stations: Chopok, Topoľníky, Liesek, Stará Lesná and Starina. Location and altitude of the individual stations are presented in Fig. 3. The program of measurements on these stations is summarized in Tab. 2.

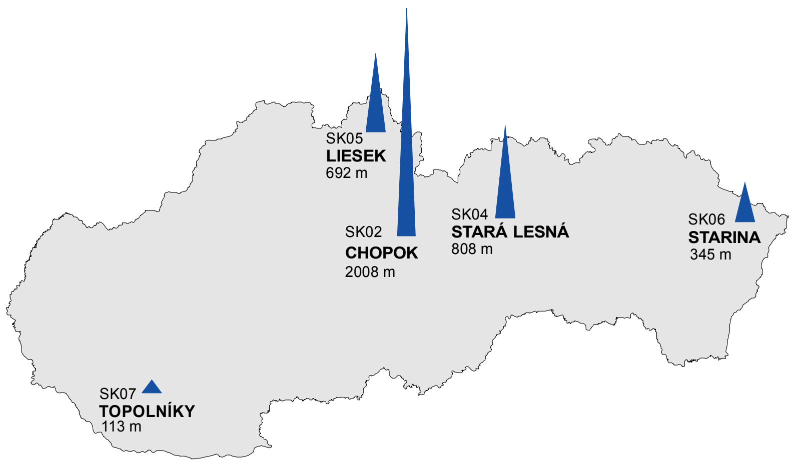


Fig.3 EMEP stations in Slovakia

Tab.2 Programme of measurements

AMBIENT AIR	**Gas**	SO_2, NO_x, HNO_3 - 24-hours sampling – daily O_3 - continuous registration by analyzer VOCs C_2-C_6 ,10-15 min sampling 2x weekly at 12.00 noon
	Particles	TSP and PM10 mass concentrations - 7 day sampling - weekly Pb, Cu, Zn, Mn, Cr, Ni, Cd -7 day sampling - weekly SO_4, NO_3 - 24- hours sampling - daily
PRECIPITATION	**Daily**	pH, conductivity, SO_4, NO_3, Cl, NH_4, Na, K, Ca, Mg, F, PO_4
	Monthly	pH, conductivity, SO_4, NO_3, Cl, NH_4, Na, K, Ca, Mg, Zn, Mn, Fe, Al, F, PO_4 Pb, Cd

Assessment of time series and trends

SO_2, sulphates

Very evident decrease of both, sulphur dioxide and sulphate concentrations in air, was recorded at all Slovak regional stations during the last two decades of the last century. Figures 4 -7 illustrate the monthly average concentrations and trends of SO_2 and SO_4 at two Slovak EMEP stations Chopok and Stara Lesna. Massive decrease of both sulphur compounds by 60 % or more has been observed since the beginning of their measurements. In lowlands the decrease has not been expressed so clearly. In the 1980s the typical annual average concentrations of sulphur dioxide and sulphate (7-8 $\mu g S.m^{-3}$; 3-4 $\mu g S.m^{-3}$, resp.) dropped approximately 40-50 %. The average SO_4-S/SO_2-S ratio ranged between 0.3-0.4 and did not show any significant changes during the whole period. Concentrations of SO_2 and sulphate are decreasing with the altitude. Current concentrations at the summit Chopok station are five-six times lower than in the Slovak lowlands. The regular annual course of SO_2 concentrations (decreasing amplitude with altitude) was registered. Annual course of sulphate concentrations in air was not so regular. At the Chopok station, the summer maximum of sulphate was observed. The decrease of SO_2 and sulphate in air at the Slovak regional stations was faster than the decrease of the total European sulphur emissions and corresponds more with emission decrease in the Slovak Republic and neighbouring countries. Figure 8 illustrates the trajectory sector dependance of SO_2 concentration at summit station Chopok in the period 1985-2000. On the whole, the 4082 valid data were processed. The southern and south-eastern sectors exhibited the highest average concentrations in winter, while in summer the highest concentrations were observed in the northern and north-western sectors. The north-western sector occurrence was the most frequent.

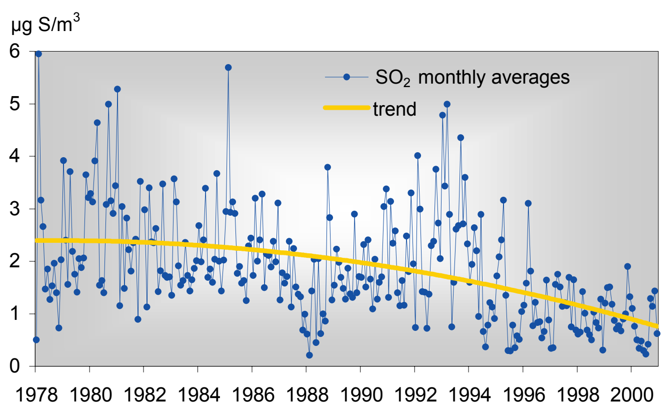


Fig. 4 SO_2 - Chopok

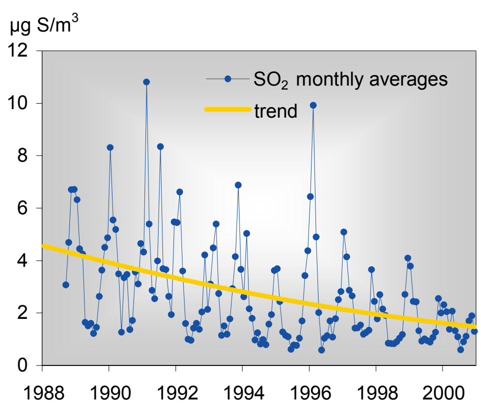


Fig. 5 SO_2 – Stara Lesna

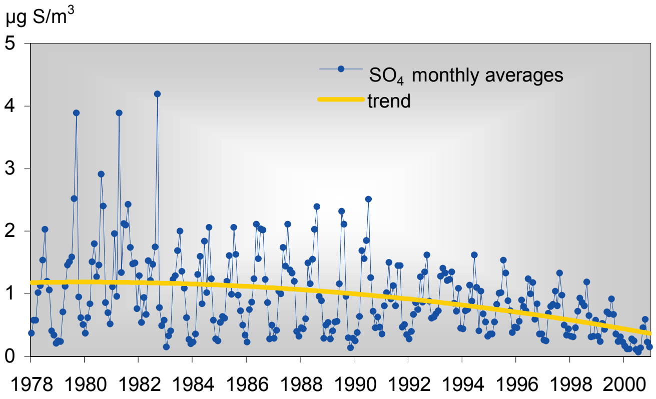


Fig. 6 SO_4 - Chopok

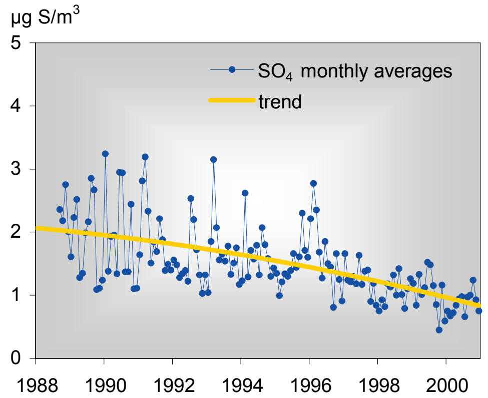


Fig. 7 SO_4 - Stara Lesna

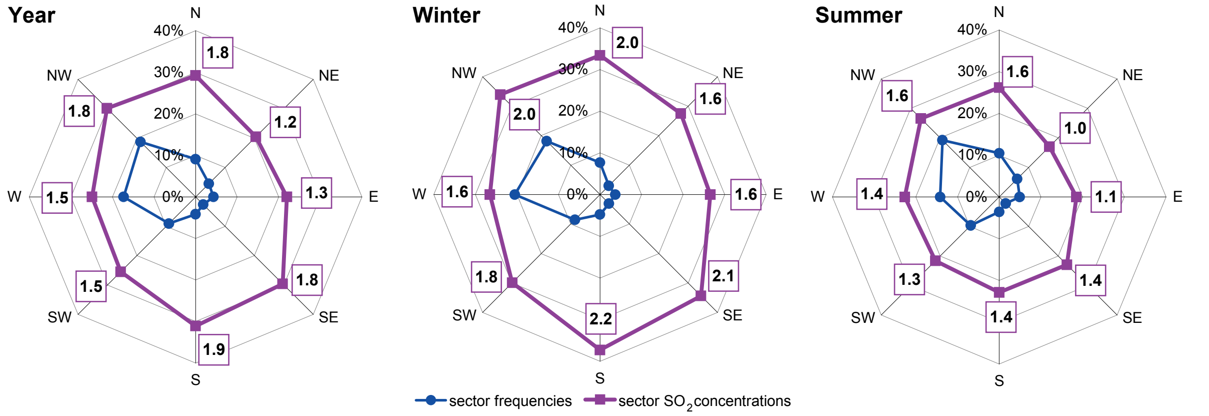


Fig. 8 Trajectory sector dependance of SO_2 concentration in µgS.m^{-3} (in frames) at Chopok (2008 m a.s.l) in the period 1985-2000. 69.8% of all daily means were processed.

NO_x, nitrates

Unlike to sulphur compounds, the decrease of regional concentrations of nitrogen oxides and nitrates in air at the Slovak regional stations was not so distinctive. Time series of NO_x concentrations from the Chopok station (Fig. 9) shows only slight downward trend. On the other hand, the current NO_x concentrations in the Slovak lowlands are 30-40 % lower than the average level in the 1990s. The trends on stations located in higher positions are expected between these two levels (Fig. 9 and 10), because the measurements started later at most of the stations. Nitrate measurements were launched only in 1993. The available data sets are too short for estimation of trends (Fig. 11 and 12). However, the average concentrations from the first half of the 1990s are higher than the current level. The differences in NO_x and nitrate concentrations between lowlands and upper located stations were not as evident as for sulphur compounds. The typical annual course of NO_x and nitrate concentrations was observed only in lowlands, with distinctive maximum in winter months. For the upper located stations, the annual course was not so regular, especially in case of nitrate. At the Chopok station, the summer NO_x maximum has been often observed. The regional measurements

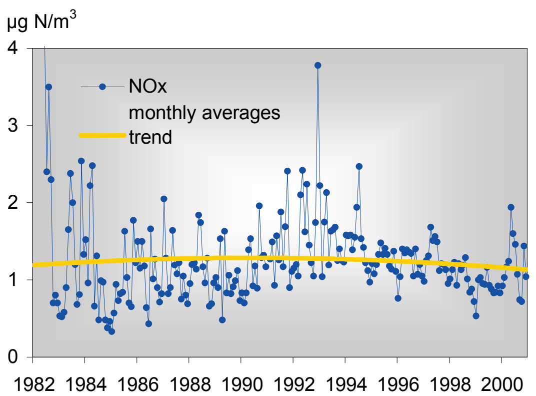


Fig. 9 NO_x - Chopok

at the territory of Slovakia confirm that the regional level of oxidised nitrogen compounds in air is much more controlled by the long-range transboundary transport as it is in case of sulphur compounds. Figure 13 illustrates the trajectory sector dependance of NO_2 concentration at summit station Chopok in the period 1985-2000. On the whole, the 3640 valid data were processed. The sector dependance was not clearly represented. The highest average concentrations in winter was observed in south-western sector, while in summer in northern sector.

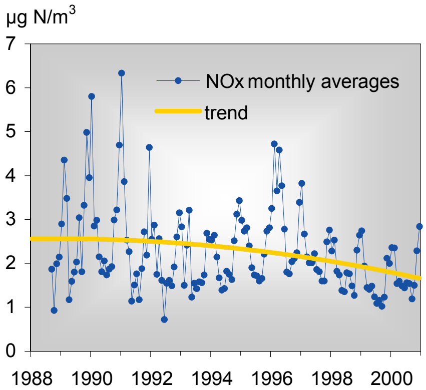


Fig. 10 NO_x - Stara Lesna

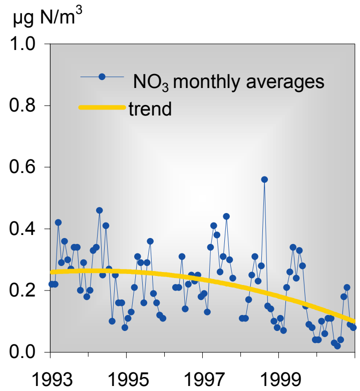


Fig. 11 NO_3 - Chopok

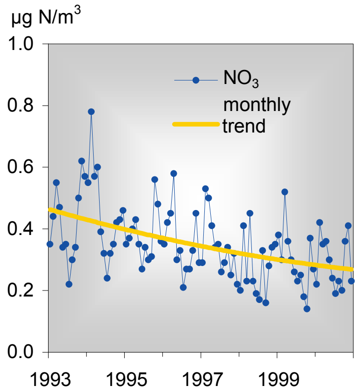


Fig. 12 NO_3 - Stara Lesna

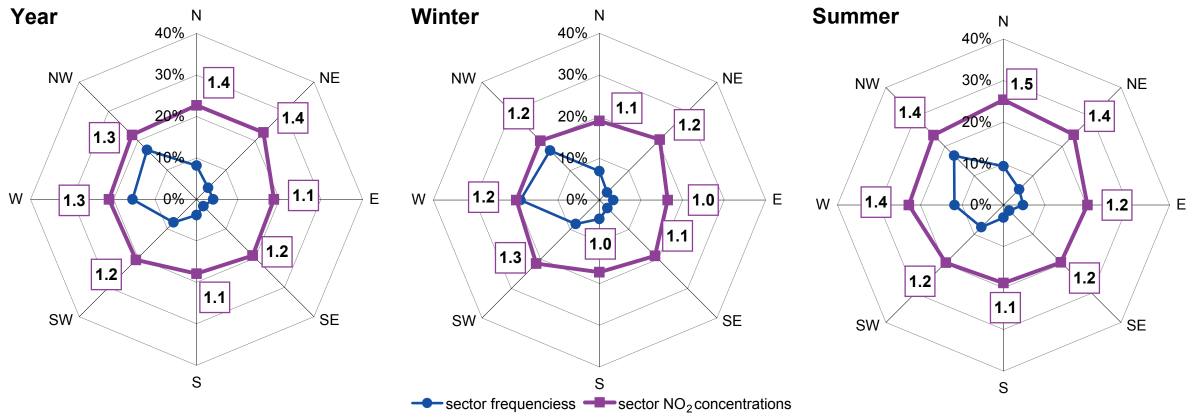


Fig. 13 Trajectory sector dependance of NO_2 concentration in $\mu g N.m^{-3}$ (in frames) at Chopok (2008 m a.s.l) in the period 1985-2000. 62.3% of all daily means were processed.

Particulate matter, heavy metals

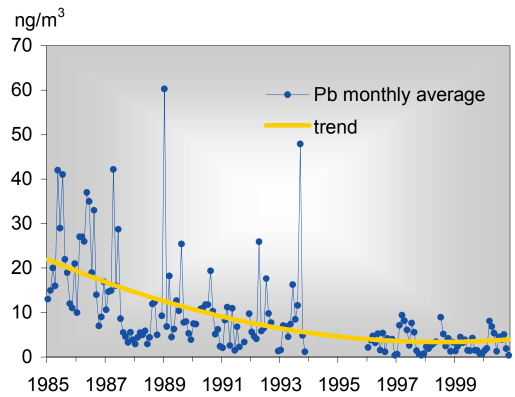


Fig. 14 Pb - Chopok

Regional average concentrations of particulate matter (PM), depending on location and altitude, range between 15 and 45 $\mu g.m^{-3}$ as TSP (total suspended particles). The highest levels of concentrations have been observed in the dry and windy lowlands. The influence of the local agricultural activities is obvious. The lowest concentrations are typical for the alpine locations. The regional TSP concentrations are more controlled by the local processes, including anthropogenic activities. Share of the local influence is declining with the altitude. No trend in regional concentration level was identified from the beginning of observations. The annual course of TSP concentration is not clearly manifested, but higher concentrations are usually observed in the cold half-year.

The content of heavy metals in TSP is decreasing at all Slovak regional stations from the beginning of their observations. The typical Slovak regional average lead concentration 45-50 ng.m^{-3} in the middle of the 1980s decreased at all stations on values below 20 ng.m^{-3} within the last years. At the same time the summit Chopok station observed the drop in the average lead concentrations from 20 to 3 ng.m^{-3} (Fig. 14). The similar, but not so evident trend was observed also for several other heavy metals (Cu, Zn, Mn, Cd, Ni and Cr). Their trend is attributed to the massive decrease of heavy metals emissions in Slovakia and neighbouring countries (replacement of solid fuels, decrease in production and modernisation of ferrous and non-ferrous metallurgy, unleaded gasoline, etc.). Some local effects were identified, e.g. the high level of manganese and chromium at the EMEP Liesek station, attributed to the relatively close located ferro-alloy plants.

Ozone

The first ground level ozone measurements in Slovakia were performed, like in many other European countries, in the second half of the nineteenth century. The semi-quantitative Schoenbein test-paper method was used. Slovak historical ozone data have indicated the average ozone level less than 30 µg.m^{-3}. The present level is at least twice as much higher. In 1967 and 1968 Dr. Warmbt from former GDR conducted ground level ozone monitoring in the High Tatras (Poprad 707 m a.s.l. and Lomnicky stit 2632 m a.s.l.). The automatic ozone analyzers based upon iodometric principle were applied. The automatic urban air quality monitoring network in the Slovak Republic was put into operation in 1992/1993. At the same time the Slovak regional stations (EMEP) started to be equipped with ozone analysers. The Thermoelectron and MLU analyzers, based on UV absorption principle, have been used. Considering all available data, the annual average increase of ground level ozone concentration in Slovakia has been estimated about 1 µg.m^{-3}.yr^{-1}, for the period 1969-1992. In the 1990s, no significant trend was observed at the Slovak stations. Inter-annual variability of ozone concentrations is attributed to the photochemical activity of the years. The daily average values for the period 1992-2000 are presented in Fig.14. The typical urban average ozone concentrations for Slovak towns in the 1990s were 40-45 µg.m^{-3} and for suburban locations about 50 µg.m^{-3}. The highest ozone concentrations have been observed at the regional stations located above 1000 m a.s.l. (EMEP Chopok station, new ozone stations Kojsovska hola 1243 m a.s.l. and Strbske Pleso 1348 m a.s.l.). The alpine daily and

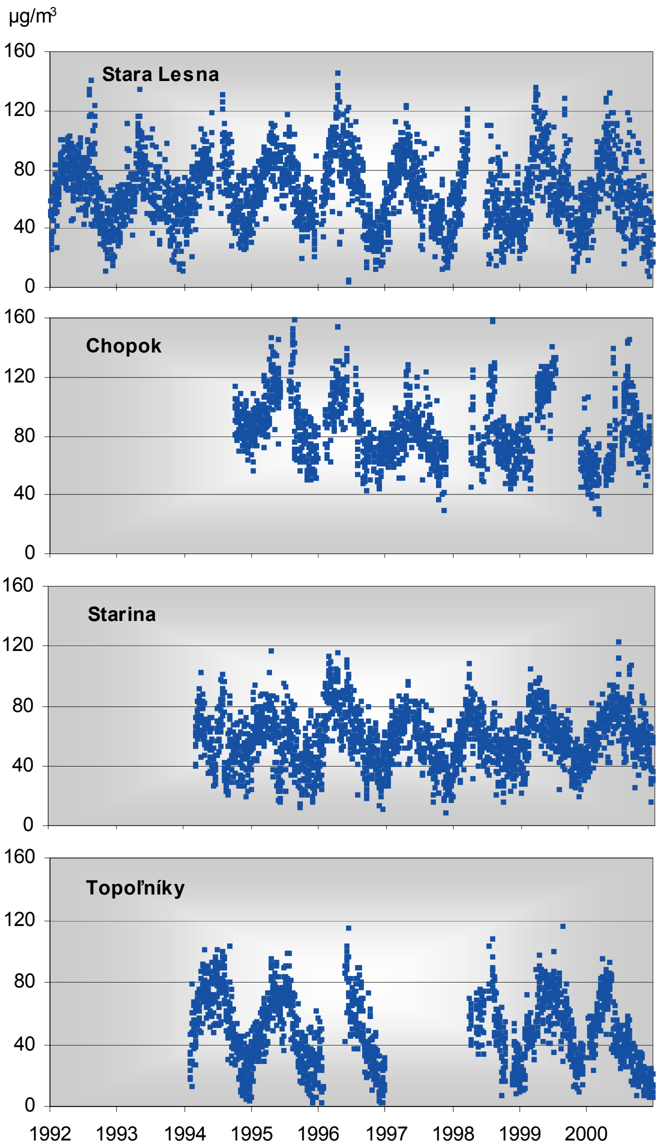


Fig. 14 Ground level ozone (daily averages) at the Slovak EMEP stations

annual concentration courses are typical for these stations. The exceedance of the ambient air quality standard 110 µg.m^{-3} (8 hours average) is rather frequent, particularly in the photochemical active years. The one-hour concentration 180 µg.m^{-3} has been exceeded only occasionally, the warning level 360 µg.m^{-3} has not been reached over the whole period and the information level to the public (180 µg.m^{-3}) has been overstepped more frequently in the first half of the 1990s, while exceedance of ambient air quality standard 110 µg.m^{-3} indicates very small increase during the last decade of the 20th century (average from all stations, including urban).

In Figure15, the trajectory sector analysis of ozone concentrations from Stara Lesna (1992-1996, summer period) is presented, using the EMEP trajectory statistics. Sector dependence on concentration does not seem to be very apparent, however it might be observed for the higher average concentrations in case of air transport from the south and the east. It seems the massive decrease of Slovak anthropogenic ozone precursors emissions during the 1990s (about 50 %) probably influenced the ozone extremes only, but the average level is more controlled by the large-scale processes. Slovakia is situated in the centre of Europe. More than 40 % of its territory is covered by the forest. Therefore biogenic emission of ozone precursors might play more important role in regional level of ozone formation process as is generally assumed.

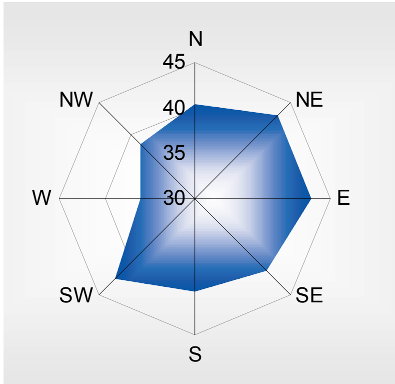


Fig. 15 Trajectory sector dependence of ozone concentrations – Stara Lesna, 1992-1996

Volatile organic compounds

VOCs C_2-C_6, or the so-called light hydrocarbons, started to be sampled in autumn 1994 at the Starina station. The VOCs measurements in Slovakia were implemented under the assistance of the Norwegian Institute for Air Research. The Starina station is one of the small numbers of European stations, included into EMEP network with regular sampling of volatile organic compounds. They are measured and assessed according to the EMEP method elaborated by CCC-NILU. Measurements of identical samples carried out in the Slovak Hydrometeorological Institute and in NILU showed high degree of agreement in the intercomparison period. The Slovak Hydrometeorological Institute had participated in the AMOHA (Accurate Measurements of Hydrocarbons in the Atmosphere) project. This project was carried out under the leadership of the National Physical Laboratory in United Kingdom and the Fraunhofer Institute in Germany. The aim of this project is to elaborate the European Directive for optimum sampling, measurement and evaluation of hydrocarbons in ambient air.

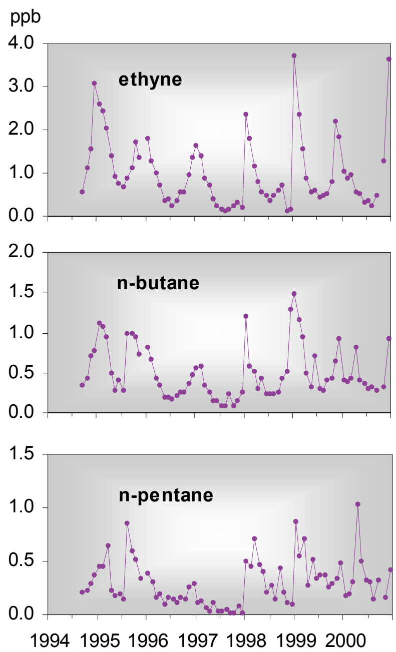


Fig. 16 VOCs - Starina

VOCs concentrations at the Starina station ranged within one order of magnitude from decimals of ppb up to several ppb (Fig. 16). Among the VOCs measured ethane is the most abundant. Annual course of concentrations is not very regular, but significantly higher concentrations for all measured VOCs were observed in cold half year. Only natural isoprene records summer maximum. Short time series of VOCs data from the Starina station do not allow assessing the trend.

Precipitation

The annual amount of precipitation in Slovakia ranges between 500 and 2000 mm on average, depending on location and altitude of the respective station. Because of the effect of wind the precipitation amounts, reported from mountainous stations, are systematically underestimated. No corrections are used, but they should be taken into account when depositions are estimated. Concentrations of all chemical substances dissolved in rainwater are spatially rather conservative. Chemical composition of precipitation over the industrial continents is more controlled by regional in-cloud processes. Bellow-cloud scavenging of gases is ineffective process in the most of cases. It means that concentrations should reflect more the large-scale distribution and trends of emissions and very pronounced horizontal and vertical concentration gradients may not be expected. The time and spatial variations of precipitation amounts and intensity play also an important role. Slovakia is small country. Results of the chemical analysis of precipitation mostly confirmed the above-presented statements. The significant horizontal gradient or the dependence of altitude on concentrations of substances in rain was not identified. But it should be mentioned that the gradual replacement of bulk for wet only sampler makes problems at the trend analysis. The only significant decrease of sulphate concentrations and corresponding increase of pH values were observed at all Slovak regional stations (Fig. 17, 18, 19 and 20). The trend reflects the development of regional sulphur emissions. Downward trend of both, nitrates and ammonium concentrations, more distinctive at ammonium, was recorded (Fig. 21 and 22).

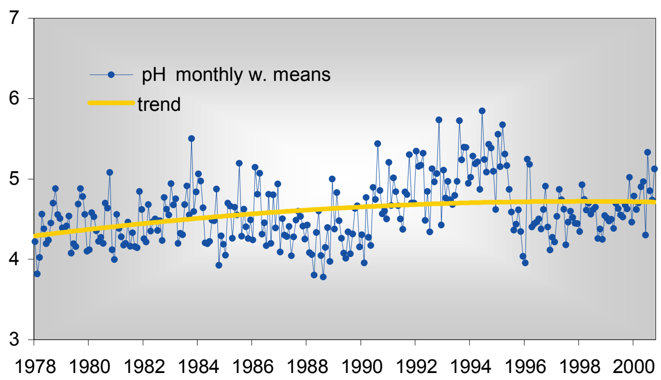


Fig. 17 pH - Chopok

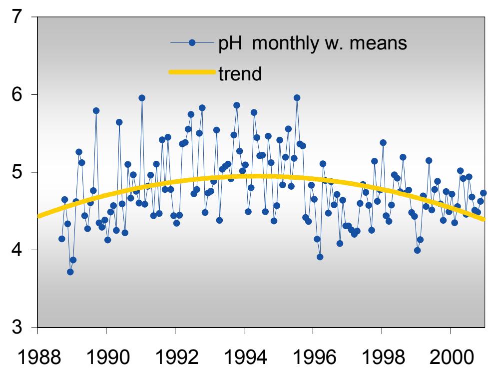


Fig. 18 pH - Stará Lesná

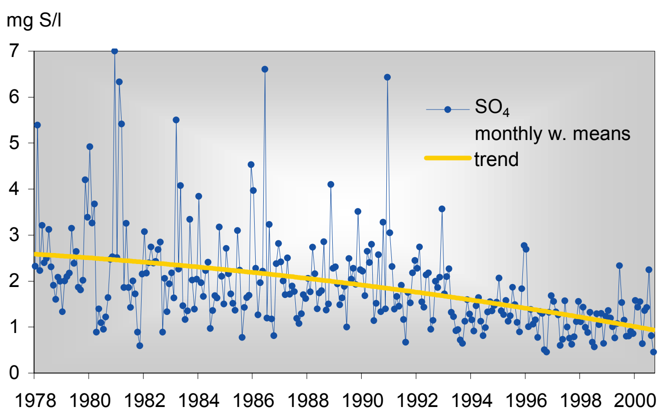


Fig. 19 SO_4 - Chopok

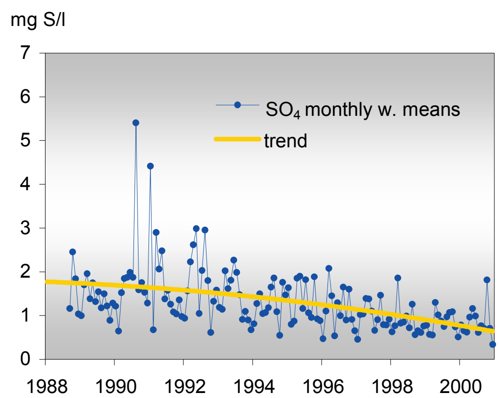


Fig. 20 SO_4 - Stará Lesná

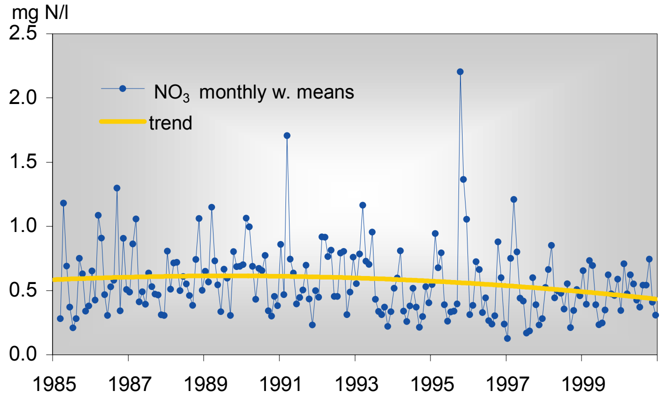


Fig. 21 NO_3 - Chopok

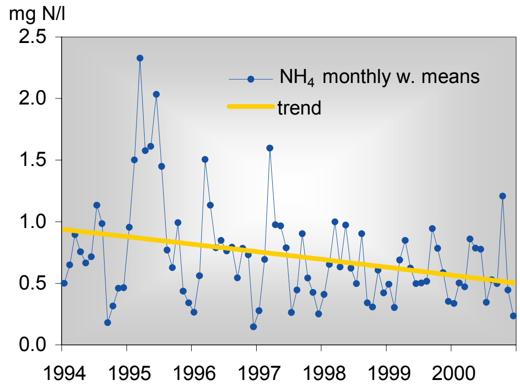


Fig. 22 NH_4 - Chopok

Concentrations of other constituents did not show any trends. Extremely high concentrations of heavy metals in precipitation were reported to CCC NILU from the Chopok station for the year 2000, but the reason has not been clarified yet. The local contamination such as illegal burning of waste has not been confirmed yet (SO_2 level does not seem to be affected). Speculative explanations (high occurrence of fogs/clouds, occult wet depositions, extreme winds, or long range transport from industrial areas in Poland and the Czech Republic located nearby) need further clarification.

Data assessment

Comment on data quality

Sampling at the stations and chemical analysis in the laboratories follow from major part the EMEP manual for sampling and chemical analysis. QA/QC programme has been partly implemented, but further improvement is needed. Accreditation of network and laboratories is ongoing process. Development of standard operation procedures is in progress. Unfortunately present budgetary and capacity limitations do not allow its full implementation. The quality of analysis in the laboratory is very good and tested annually via GAW and EMEP intercomparison measurements. Precipitation and air data were classified as “A” for all compounds apart from NO_2 and K in precipitation (classified as “B”). Some reserves still exist in regard to the sampling procedures at the stations, particularly concerning the ground level ozone monitoring. In some years ozone data are not appropriate. The deficiencies in QA/QC ground level ozone monitoring are caused by the systematic limitations of the SHMI budget as well as working capacities. The maintenance of the stations has not been carried out sufficiently enough in some years (delays of repairs, seldom inspections, lack of input cleaning and regular calibrations, etc.), resulting in data gaps. Concerning VOC data some gaps appeared within last couple of years due to the old GC break down. The purchase of the new one was very time consuming as well its putting into the standard operation.

1980 - 2000 data checking

All air and precipitation data in the SHMI database have been checked against the NILU database. Found discrepancies have been sent to NILU.

Comparison of measured and model data

As compared the measured and model data, the EMEP model data are overestimated for the territory of Slovakia. The very complex topography of Slovakia apparently play significant role. The preliminary estimations indicate quite high dispersion of values. The correlation of calculated and measured concentrations is decreasing with altitude.