

EMEP ASSESSMENT REPORT - CZECH REPUBLIC

Milan Váňa¹⁾, Karel Dejmál¹⁾, Pavel Machálek²⁾, Ivan Holoubek³⁾

1) *Czech Hydrometeorological Institute - Košetice Observatory*

2) *Czech Hydrometeorological Institute-Department of Emission and Sources,*

3) *RECETOX-TOCOEN and Associates*

1. INTRODUCTION

Czech Hydrometeorological Institute operates both of the Czech EMEP stations Košetice and Svratouch (Fig.1.1).

1.1 General Information:

Košetice Observatory (OBK)

Location: South-western part of the Czech-Moravian Highland

Latitudinal and longitudinal co-ordinates:
N 49°35', E 15°05'

Elevation above mean sea level: 534 m

More detailed information concerning physico-geographic conditions was presented in (Váňa, Holoubek, et al., 2001).

Svratouch (SVR)

Location: North-eastern part of the Czech-Moravian Highland

Latitudinal and longitudinal co-ordinates: N 49°73', E 16°03'

Elevation above mean sea level: 737 m

Fig. 1.1: Location of the Czech EMEP stations



1.2 Implementation of EMEP measurements

1.2.1 Gases (component, frequency, method)

- SO₂ (daily, collection on filters) – OBK, SVR
- NO₂ (daily, collection on filters 1990-1996, absorbed in solution 1997) – OBK, SVR
- HNO₃, NH₃ (daily, collection on filters) - OBK, SVR
- SO₂, NO, NO₂ (continuously, automatic analyser) - OBK, SVR
- Surface ozone (continuously, automatic analyser) - OBK, SVR
- Volatile organic compounds (Twice a week, gas chromatography) - OBK
- Aldehydes and ketones (Twice a week, cartridge) – OBK
- Persistent organic pollutants (weekly, gas chromatography) - OBK

1.2.2 Particles

- SPM (Twice a week, collection on filters) - OBK, SVR
- PM₁₀ (Twice a week, collection on filters) – OBK
- PM_{2,5} (Twice a week, collection on filters) - OBK
- SO₄ (Daily, collection on filters) - OBK, SVR
- NO₃, NH₄ (Daily, collection on filters) - OBK, SVR
- Trace metals (twice a week, collection on filters) - OBK, SVR

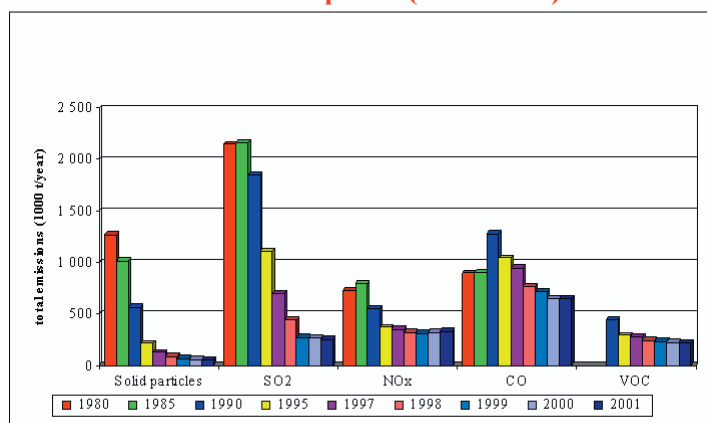
1.2.3 Precipitation

- Bulk (daily, collector) - OBK, SVR (stopped in 1996)
- Wet Only (weekly, open-close collector) - OBK, SVR

2. EMISSION

Based on the data on the total annual emissions of the principal pollutants between 1980 and 2001, sulphur dioxide (SO₂) was obviously the pollutant that caused the most serious emissions in that period. Mainly power generation contributed to its emissions, by burning lignite with a low calorific value, rich in sulphur. Later in that period, a gradual decline in these emissions were due to the reduction in electricity generation in conventional thermal power stations and increasing electricity generation in nuclear power plants, and still later due to the drop in the burning of sulphur-rich heavy fuel oils and increasing use of natural gas as a fuel. In 1991 to 1993, a decline in SO₂ emissions was

Fig. 2.1: Total emissions of principal pollutants in the Czech Republic (1980 - 2001)



also attributable to a drop in industrial production. The most important factor thanks to which SO₂ emissions have declined is the Environmental Programme of ČEZ (the dominant Czech power utility), under which older power station boilers have been decommissioned and, most importantly, an extensive FGD programme was carried out in the period 1994-1998 and fluid-bed boilers were installed. These technical measures significantly contributed to the reduction in total SO₂ emissions from stationary sources in the Czech Republic by 86.4% between 1990 and 2001 (Fig.2.1). In addition, the

separation of sulphur dioxide using wet methods and the refurbishment of dust separators and control systems have been felt in the reduction of particulate emissions by 90.4% in the period under review.

The ČEZ Environmental Programme has also helped to considerably reduce NO_x emissions from stationary sources. The modernisation of cement production was another supporting factor in NO_x emission reduction. The installation of selective catalytic reduction and selective non-catalytic reduction processes in the chemical industry has also contributed to the further reduction in NO_x

Tab. 2.1: Heavy metals and POPs emissions (1990-2001)

Year	Heavy metals			POPs		
	Cd	Hg	Pb	PAH	PCB	PCDD/F
	t.year ⁻¹	t.year ⁻¹	t.year ⁻¹	t.year ⁻¹	kg.year ⁻¹	g.year ⁻¹
1990	4.3	7.5	241.4	752	773	1252
1991	3.9	7.4	215.0	747	772	1220
1992	3.6	7.3	249.0	1131	741	1220
1993	3.5	7.5	228.0	1115	644	1140
1994	3.5	7.2	222.5	951	630	1135
1995	3.6	7.4	203.7	1357	623	1135
1996	2.9	5.9	181.4	971	555	922
1997	3.0	5.5	170.7	657	448	830
1998	2.7	5.2	151.2	657	458	767
1999	2.7	3.7	146.0	557	485	643
2000	2.9	3.8	105.7	488	474	744
2001	2.6	3.3	46.7	470	450	730

emissions from process equipment. However, the total NO_x emissions are negatively affected by a considerable increase in NO_x emissions from mobile sources, specially passenger cars; this is due to the slow growth of the share of motor vehicles equipped with tree-way catalytic converters and the low degree of the replacement and modernisation of the country's vehicle fleet. For the above reasons, the share of NO_x emissions from mobile sources, which in 1990 accounted for 27.0% of total emissions, had climbed to 51% by 2001, thereby exceeding the share of emissions from stationary sources.

Between 1990 and 2001, POP emissions have been marked by a considerable decline in PCDD/F and PCB emissions, which for both groups decreased by almost 42% in that period. PAH emissions decreased by 37.5% in the same period (Tab.2.1).

In respect of the further development in air pollutant emissions in the Czech Republic it is to be expected that they will continue to decrease in the years to come. The principal orientation will be towards the priorities ensuing from the country's international commitments, the implementation of which is provided for in Czech legislation through Act No. 86/2002 on Air Quality Control, which came into effect on 1 June 2002 together with the respective implementing regulations. This mainly involves the meeting of the obligations under the Protocols to CLRTAP and EU Directives (especially Council Directive 96/61/EC on integrated pollution prevention and control - IPPC) and the application of the best available techniques and technologies (BAT).

3. TIME SERIES AND TRENDS

3.1 Sulphur compounds

Both of the Czech EMEP stations have recorded a statistically significant downward trend in average annual concentrations of sulphur dioxide between 1988 and 2002 (Fig. 3.1), which is in line with the marked decline in emission levels in the Czech Republic. Average annual concentrations have dropped from 10-15 $\mu\text{g}\cdot\text{m}^{-3}$ $\text{SO}_2\text{-S}$ at the beginning of the 1990s to 1-2 $\mu\text{g}\cdot\text{m}^{-3}$ $\text{SO}_2\text{-S}$ at present. Variations of sulphur dioxide concentrations over the year are apparent, with the maximums occurring in winter and the minimums in summer.

The highest concentrations were registered in situations when the trajectory originated in the northeast to northwest (Fig. 3.2). The differences between the sectors were markedly smaller towards the end of the period under review.

Average concentrations of sulphates in suspended particulates at the Czech EMEP stations were declining continuously in the 1990s, but not so distinctly as those of sulphur dioxide (Fig. 3.3). The trend is more pronounced in warmer periods. By the end of the 1990s average annual concentrations (1-1.5 $\mu\text{g}\cdot\text{m}^{-3}$ $\text{SO}_4\text{-S}$) had dropped to about one-third of the annual averages observed at the beginning of the period under review. Variations of sulphate concentrations over the year are indistinct, and there is an indistinct maximum in spring.

Air masses arriving from the southeast contain the highest concentrations of sulphates, while the lowest concentrations are registered when the air masses originate somewhere between the southwest and northwest sectors (Fig. 3.4)

Fig. 3.1: Trend of $\text{SO}_2\text{-S}$ in the atmosphere (Košetice 1989-2002)

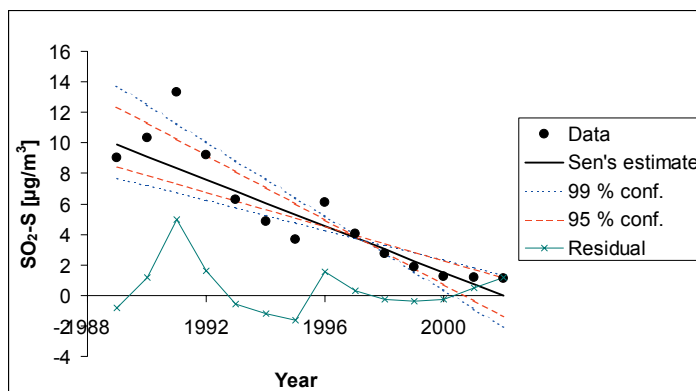
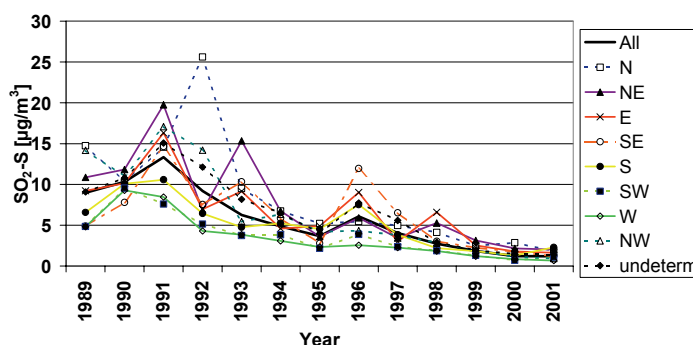


Fig. 3.2: Sector distribution of $\text{SO}_2\text{-S}$ concentrations (Košetice 1989-2001)



3.2 Nitrogen compounds

Nitrogen dioxide concentrations were steadily decreasing in the 1980s but since the 1990s average annual concentrations have stabilised at a level of around $2 \mu\text{g}\cdot\text{m}^{-3}$ $\text{NO}_2\text{-N}$ (Fig. 3.5). Higher concentrations are recorded in winter. No marked differences in nitrogen dioxide concentrations between the individual sectors were identified in the period from 1989 to 2001.

We have not registered any significant trend in the concentrations of nitrate or ammonium nitrogen and no sizeable differences have been found between sectors.

3.3 Surface ozone

In the 1990s, average annual concentrations of surface ozone at the Czech EMEP stations stabilised at a relatively high level of about $70 \mu\text{g}\cdot\text{m}^{-3}$, but they have not been rising since (Fig. 3.6). Since 1996 a slight decline in average annual concentrations and a more distinct drop of average daily maximums have been observed. In the warm season (April to September) average concentrations at Svratouch ($89 \mu\text{g}\cdot\text{m}^{-3}$) are slightly higher than at Košetice ($80 \mu\text{g}\cdot\text{m}^{-3}$). No marked differences have been found between the individual directions (Fig. 3.7). On days when the maximum daily concentrations exceeded $120 \mu\text{g}\cdot\text{m}^{-3}$ air masses originating in the southwest to southeast predominated heavily.

The number of episodes of high surface ozone concentrations dropped markedly in the second half of the 1990s. The ambient pollution limit value applicable in the Czech Republic in the period under review (the sliding eight-hour average higher than $160 \mu\text{g}\cdot\text{m}^{-3}$) was exceeded at the Košetice Observatory on 35 days and at the Svratouch station on 38 days (Fig. 3.8). Most of these episodes were registered between 1992 and 1995 (87% of all cases identically at both Czech regional stations). The second half of the 1990s saw only rare exceedances of the ambient pollution limit value and in 1997, 1999 and 2001 this limit value was not exceeded at all. In 2002 a target ambient pollution limit value for troposphere ozone as part of new legislation (sliding eight-hour average higher than $120 \mu\text{g}\cdot\text{m}^{-3}$). This limit value may not be exceeded on more than 25 days per calendar year over three years on average. At the Košetice observatory the limit value of $120 \mu\text{g}\cdot\text{m}^{-3}$ was exceeded on 439 days in the period under review and at the Svratouch station on 448 days (Fig. 3.9). Also in

Fig. 3.3: Trend of $\text{SO}_4\text{-S}$ concentrations (Košetice 1989-2002)

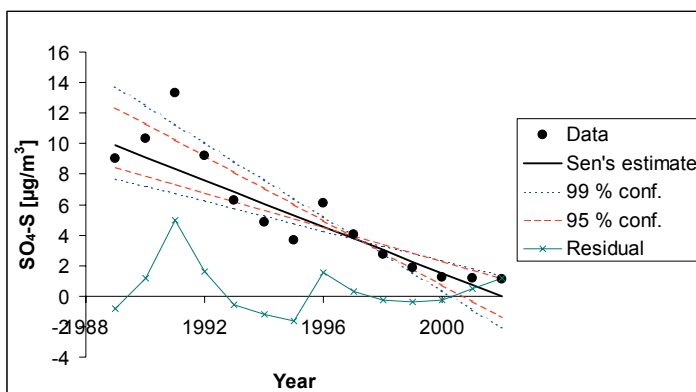


Fig. 3.4: Sector distribution of $\text{SO}_4\text{-S}$ concentrations (Košetice 1989-2001)

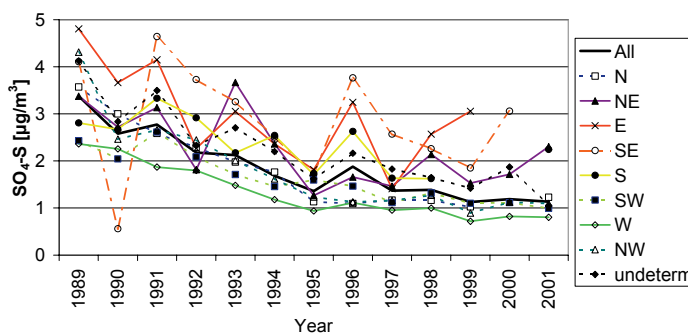
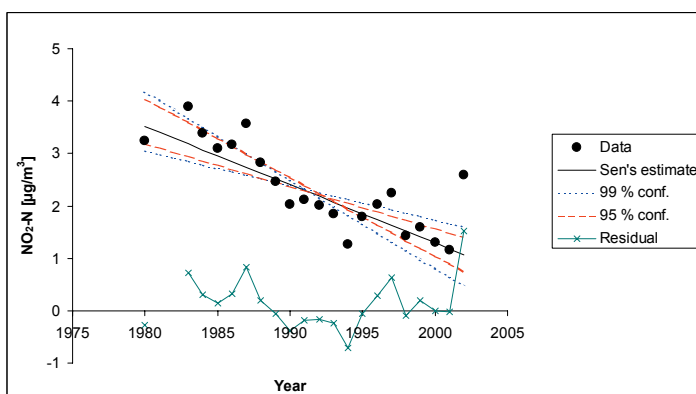


Fig. 3.5: Trend of $\text{NO}_2\text{-N}$ in the atmosphere (Svratouch 1980-2002)



respect of the new target ambient pollution limit value the downward trend of the number of exceedances is apparent although the decrease is not as dramatic as with the $160 \mu\text{g}\cdot\text{m}^{-3}$ limit.

Situations of dramatic increases in surface ozone concentrations, which have an adverse influence on human health, usually occur in longer periods with typically summertime weather (extreme temperatures, cloudless days, high intensity of solar radiation). Extensive regions are progressively affected during these episodes, which extend beyond the Czech national borders.

Assessment of the impact of surface ozone on vegetation, using the internationally recognised AOT40 index, suggests that critical level is exceeded for long periods not only in rural areas but virtually over the whole Czech Republic; this causes damage to forest ecosystems and farm crops. Slightly decreasing tendency of AOT40 indexes at the Czech EMEP stations was observed in 1994-1996. We have not registered any trend in AOT40 indexes in the period 1996-2002 (Fig.3.10.).

Surface ozone concentrations at Czech regional stations display pronounced variations over the year,

Fig. 3.6: Trend of surface ozone in the atmosphere (Košetice 1992-2002)

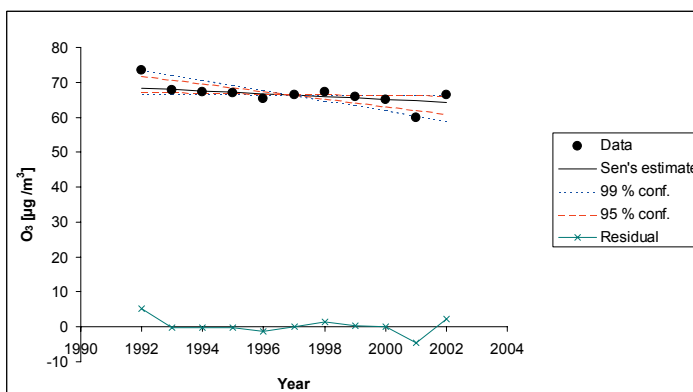


Fig. 3.7: Sector distribution of surface ozone concentration (Košetice 1993-2001)

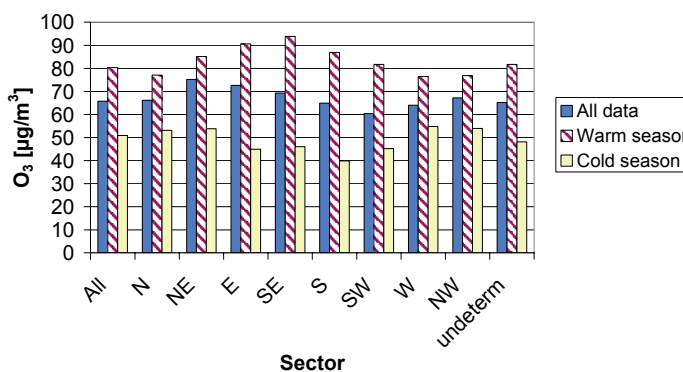


Fig. 3.8: Number of days, when the 8-hour running mean of surface O₃ exceeded 160 µg/m³ (Košetice, Svratouch 1993-2002)

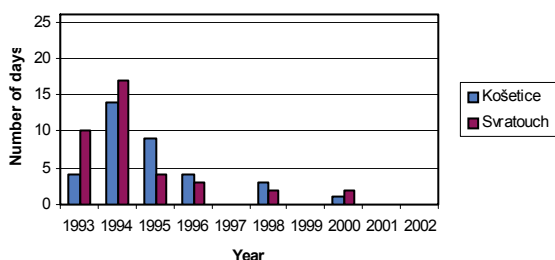
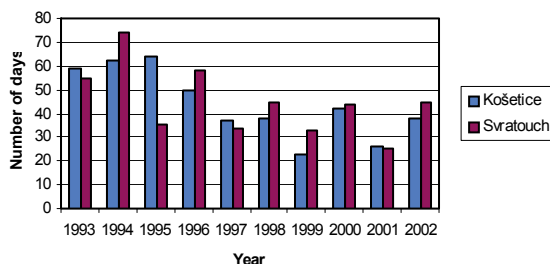


Fig. 3.9: Number of days, when the 8-hour running mean of surface O₃ exceeded 120 µg/m³ (Košetice, Svratouch 1993-2002)



with the maximums at the end of spring. In June and sometimes in July, a drop usually occurs due to the onset of what is referred to as the continental monsoon, which brings along increased cloudiness and lower levels of solar radiation. Then we usually register (especially when the summer is really hot) a second maximum in July and August. In the very cold year 1996 the maximum concentrations were recorded as early as April.

3.4 Volatile Organic Compounds (VOCs)

From 1993 to 2002 no distinct annual variability of average annual VOC concentrations was registered. A statistically significant drop was only observed for cyclohexane (measurements were started in 1995), with annual concentrations dropping from 110 ppt in 1995 to 28 in 2002. The highest concentrations of major VOCs (ethane, propane, benzene, toluene, and isoprene) are recorded in situations when air masses reach our territory from the southwest to southeast (Fig. 3.11).

Most of non-methane hydrocarbons follow an annual course that reflects their emission levels, i.e. with maximums in winter and minimums in summer. Isoprene is an exception. Despite its ranking among the most reactive VOCs, it is of natural origin (deciduous trees release it) and displays an inverse annual course. It also plays an important role in regions outside the most polluted areas. The highest isoprene concentrations were recorded in the hot summers of 1994, 1995 and 2001. The summers in the second part of the nineties were not so warm and isoprene concentrations in summers 1996-1999 were lower.

Fig. 3.10: Trend of AOT40 index (Košetice, Svratouch 1993-2002)

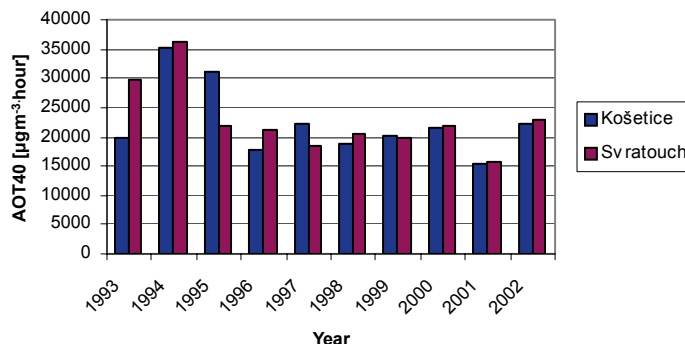
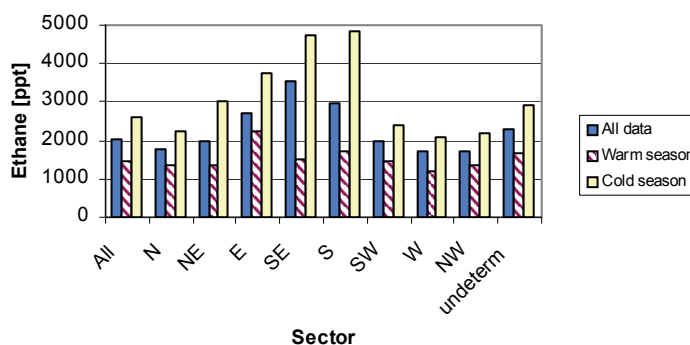


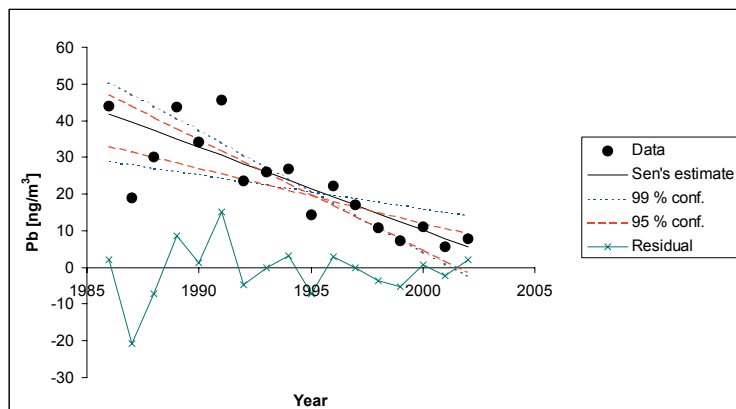
Fig. 3.11: Sector averages for ethane (Košetice 1993-2001)



3.5 Heavy metals

We devote attention to particularly cadmium and lead measurements as part of the EMEP programme.

Fig. 3.12: Trend of lead in the atmosphere (Košetice 1986-2002)



1990s the average annual concentrations stabilised at levels between 0.3 and 0.4 ng·m⁻³. Characteristic of the variations over the year are distinct ups and downs and mainly in the period 1988-1994 average

The distinct drop in the emissions of both of these heavy metals (Tab.2.1.) was reflected in the 1990s in a statistically significant decrease in average annual concentrations at the Czech EMEP stations. Average annual concentrations of lead (Fig. 3.12) followed a steadily downward trend (in 2002 average concentrations amounted to less than 15% of annual averages at the end of the 1980s and the beginning of the 1990s). In respect of cadmium, the drop was mainly registered at the end of the 1980s and the beginning of the 1990s. In the second half of the

monthly concentrations in winter rose to 3 to 5 ng.m⁻³. In the second half of the 1990s the highest monthly averages in winter were around 1 ng.m⁻³.

3.6 Persistent Organic Pollutants

Data for POPs in ambient air is reported only from the countries around North and Baltic Seas, in the Arctic and from the Czech Republic.

In the case of the Czech Republic, the selected POPs (PAHs, PCBs, DDTs, HCHs, HCB) are measured in the area of Košetice observatory since 1988 in ambient air, wet deposition, surface waters, sediments, soils, mosses and needles.

Figure 3.13: Seasonal variation of PAHs in ambient air

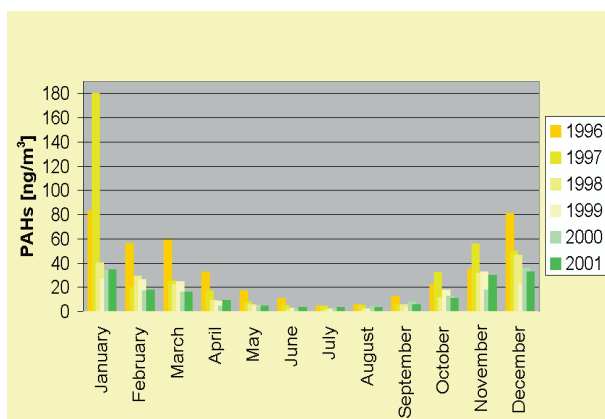
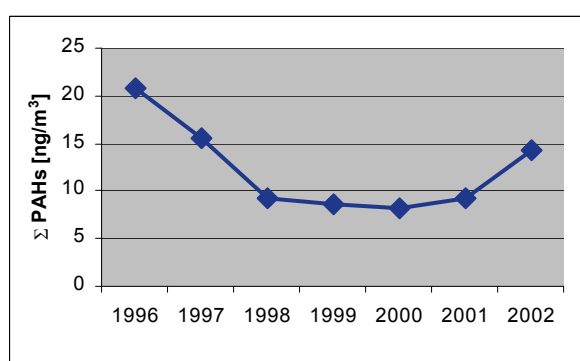


Figure 3.14: The time trends of PAHs in ambient air (gas phase + aerosol)



Concentrations of polycyclic aromatic hydrocarbons (PAHs) identified follow characteristic course prompted by the higher occurrence of these compounds in winter when they are produced by various combustion processes. The seasonal trends of PAHs in ambient air are in good correlation to average temperature and represent typical middle European situation (Fig. 3.13). These trends reflect higher production of PAHs in winter period and higher efficiency of destruction in summer processes. In the case of PAHs we can also recognized decreasing trend during this period (Fig. 3.14), which reflects the results of decreasing of PAHs emissions in the Czech Republic. Slight increasing of PAHs concentrations reflects unfortunately the turn back to the combustion of coal in local heating system mainly from economical point of view.

Figure 3.15: Seasonal variation of PCBs in ambient air

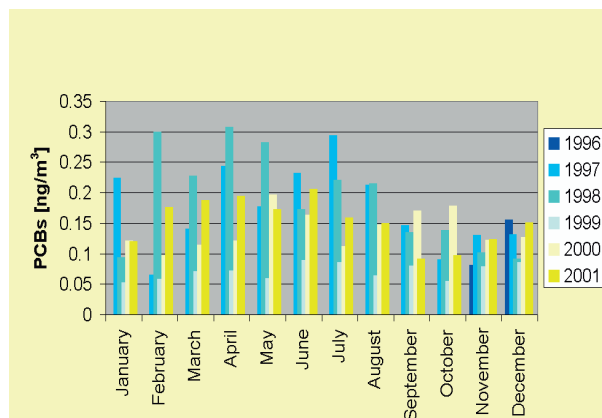
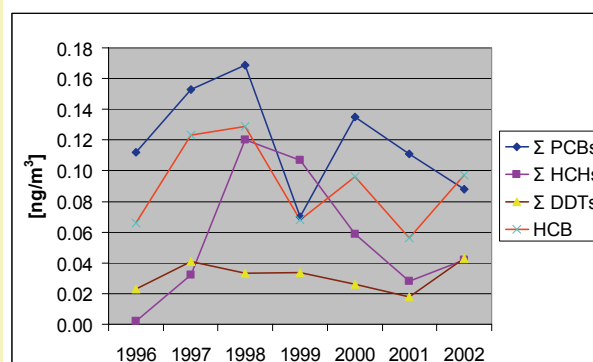


Figure 3.16: The time trends of PCBs, HCHs, DDTs and HCB in ambient air



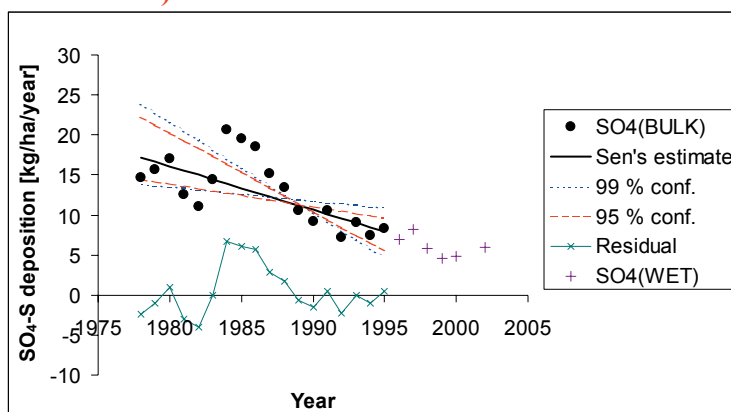
Concentrations of polychlorinated biphenyls (PCBs) and organochlorinated pesticides (OCPs) such as DDTs, HCHs, HCB, display a totally different profile in which no such “seasonality” has been

Identified (Fig. 3.15 – the case of PCBs). These compounds are present in the atmosphere today due to their volatilisation from soil and sediments, i.e. as secondary inputs from old deposits, and also due to a long-range atmospheric transport from regions in which they are still used. These results reflect the global trends. PCBs occurrence remains at the level of the European background. From the PCBs pictures we can see the decreasing tendency during this period. Predominance of degradation metabolites of DDT (DDE and DDD) was observed (the same trend exists in all environmental samples from this observatory). This predominance reflected old loads – input from old usage and environmental accumulation of DDT rather than long-range transport from regions where the compound is still in use. The levels of OCPs and PCBs during the period 1996-2002 (Fig. 3.16).

3.7 Deposition

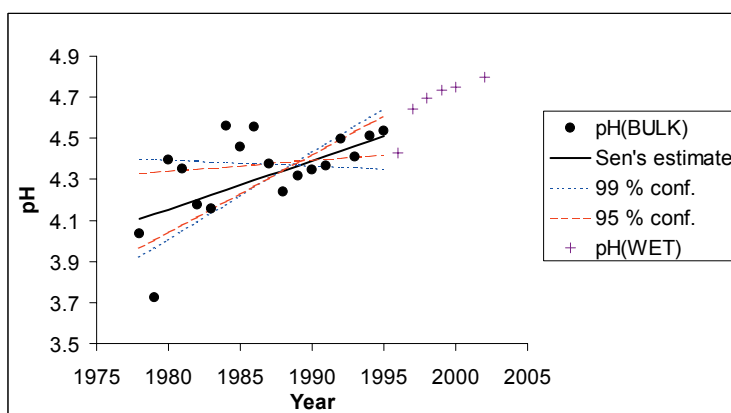
Lower sulphur emissions in the Czech Republic have resulted in a significant decrease of sulphur deposition at the regional level (Fig. 3.17), from about $15 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ at the beginning of the 1980s to $4 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ at present. Nitrogen deposition was declining slightly but no statistically significant trend has been detected. The level of pH in precipitation water increased continuously from 3.7 at the end of the 1970s to 4.8 at the beginning of the new millennium (Fig. 3.18). The highest pH is read in cases when air masses have their origin in the southwest (4.5), and the lowest values are measured when they come from the northeast (4.1). A somewhat downward trend at both Czech stations has been identified for some other pollutants (Ca, Na, Mg).

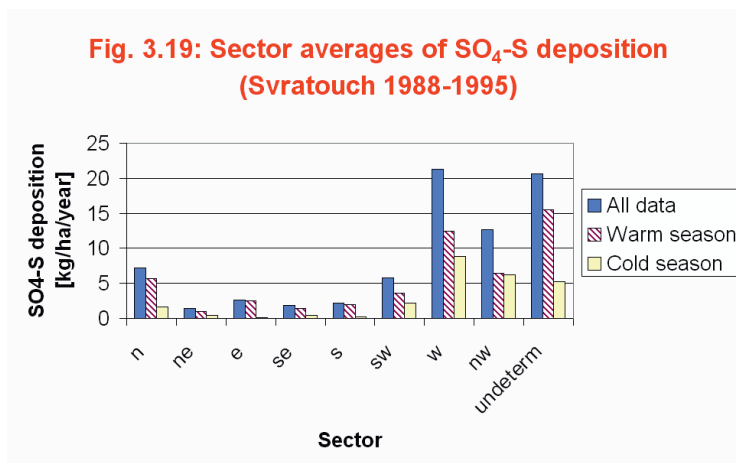
Fig. 3.17: Trend of $\text{SO}_4\text{-S}$ deposition (Svratouch 1978-2002)



Overall, the highest deposition of all the pollutants monitored was found in situations when the trajectories originate in the northwest (Fig. 3.19) and the highest concentrations are registered when air masses from the northeast predominate.

Fig. 3.18: Trend of pH in precipitation (Svratouch 1978-2002)





4. COMPARISON WITH MODELLING RESULTS

The drop in average annual concentrations of sulphur dioxide was much deeper than expected based on modelling results (Fig. 4.1). At the end of the 1980s and the beginning of the 1990s the annual averages generated by the model were up to 3 µg.m⁻³ SO₂-S lower than the values measured at the Košetice station but after 1993 the measured concentrations were lower than those modelled. The

Fig. 4.1: Mean model and observed concentration of SO₂-S (Košetice 1989-1996)

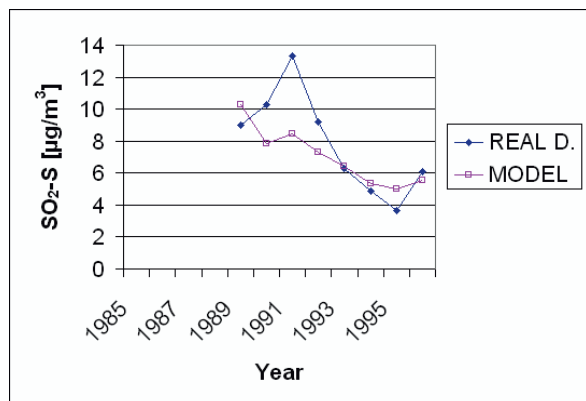


Fig. 4.2: Mean model and observed concentration of SO₄-S (Košetice 1989-1996)

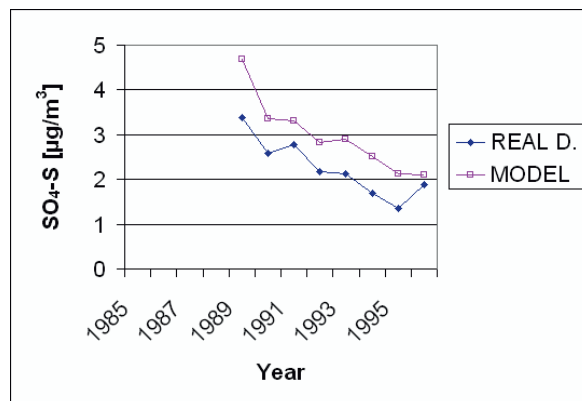
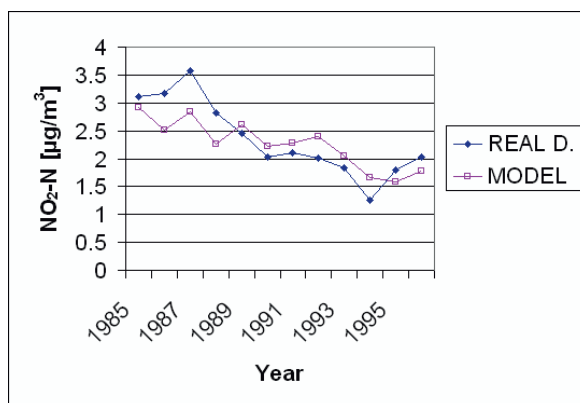


Fig. 4.3: Mean model and observed concentration of NO₂-N (Svratouch 1985-1996)



values measured at the Svratouch station were higher from 1988 to 1996 than the model predicted but towards the end of that period the differences between measured concentrations and modelling results decreased.

Trend in sulphate concentrations was very similar for both measured and modelled results, and the measured concentrations were about $1 \mu\text{g}\cdot\text{m}^{-3}$ $\text{SO}_2\text{-S}$ lower than those generated by the model over the entire period under review (Fig. 4.2)

A very good agreement can also be seen when comparing nitrogen oxide concentrations, primarily in the 1990s (Fig. 4.3).

5. CONCLUSIONS

- In the period under review sulphur compound concentrations dropped thanks to lower emissions not only in the Czech Republic but also in the whole central European region.
- Nitrogen oxide concentrations were continuously decreasing in the 1980s, while in the 1990s they stabilised and no trend was detected.
- Surface ozone concentrations at the regional level of the Czech Republic rise to values that have impacts on human health.
- Average annual concentrations of surface ozone at the Czech EMEP stations stabilised in the 1990s at a relatively high level of about $70 \mu\text{g}\cdot\text{m}^{-3}$. Since 1996 a slight decline has been observed in average annual concentrations, together with a more distinct drop in the number of episodes during which critical levels were exceeded.
- No significant trends have been observed in respect of VOC annual concentrations in the period 1993-2002. Most VOCs show variations over a year, which reflects the distribution of their emissions during the year, i.e. a maximum in winter and a minimum in summer. Isoprene is an exception: it is of natural origin and shows an inverted profile of variations over a year.
- Decreasing tendency of PAHs concentrations was detected during the period 1996-2002
- Lower sulphur emissions in the Czech Republic have helped to reduce significantly its deposition at the regional level. The largest difference can be observed in respect of throughfall, which implies a marked decrease in dry deposition.
- The value of pH increased continuously, from 3.7 at the end of the 1970s to 4.8 at present.
- It applies in general that the highest deposition for most of the pollutants monitored was found in situations when the trajectories originate from the northwest.

6. REFERENCES

1. Air Pollution in the Czech Republic in 1993,1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001. Praha, ČHMÚ 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002
2. Váňa, M. et al.: Results of Air Quality and Deposition Monitoring at the Czech Regional station Košetice. In.: Meteorological Journal, 3, 2000, č.4, s. 9-20
3. Váňa, M., Holoubek, I. et al.: Quality of the Natural Environment in the Czech Republic at the Regional Level (Results of the Košetice Observatory). Praha, ČHMÚ 2001