National Assessment Report for Norway

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National emissions

The Norwegian sulphur dioxide emissions decreased from the seventies, and added to about 26 kt SO_2 by the turn of the century. This is 19 per cent of the national emissions in 1980 (Fig. 1). Since 1980 the emissions from industrial production processes and industrial and non-industrial combustion have been strongly reduced through various measures; cleaning of flew gases, closing of some strongly polluting industrial processes, replacement of oil by hydroelectric power, and changing from heavy sulphur-rich oil to light oil. The emissions from mobile sources, both ships and boats, and from road traffic have likewise been much reduced. 65 per cent of the SO_2 emissions in 2000 originated from industrial processes while19 per cent were due to emissions from stationary industrial and non-industrial combustion. Another 16 per cent of the emissions were caused by mobile sources, and emissions from ships and boats accounted for about 13 per cent of these.

The NO_x emissions increased between 1981and 1987 due to growth in road traffic and in emissions from ships and boats. The emissions from road traffic has been decreasing since then due to the increasing fraction of vehicles with catalysts on the roads, although the number of cars has been increasing. After 1987 the emissions from other mobile sources were reduced and reached a minimum in 1992, but increased since then until 1999. The total national emissions also reached a new peak in 1999. Emissions from mobile sources other than road traffic, mainly ships and boats, were the largest single source category from 1987 and contributed with about 47 per cent of the total emissions in 2000. Road traffic contributed with 22 per cent, and stationary emissions related to oil and gas production at sea were responsible for about 17 per cent of the total NO_x emissions in 2000, 223 kt NO_2. The emissions have to be reduced to 156 kt NO_2/year by 2010 in order to comply with the Gothenburg protocol (Statistics Norway).

The oil and gas extraction activities in the North Sea increased strongly from 1980. One consequence of this is that the total national non-methaneVOC emissions have been more than doubled since then. Emissions from other sectors such as road transport and solvent use have decreased from 1980 to 2000. The NMVOC emissions reached 372 kt in 1996 and 363 kt in 2000. The emissions have to be reduced in accordance with the Gothenburg protocol and should not be larger than195 kt in 2010 (Statistics Norway). The extraction and distribution of fossil fuels accounted for about 64 per cent of the total NMVOC emissions in 2000.

The far largest source of ammonia emissions in Norway is agricultural activities. These emissions accounted for about 91 per cent of the total emissions in the year 2000. Another 6 per cent were due to emissions from vehicles. The NH_3 emissions were rather constant between 1980 and 1990 but increased weakly until 1996. After 1996 a small reduction in the ammonia emissions has taken place in Norway. Ammonia is chemically an alkaline substance, but may have an acidifying effect in soil and water due to a bacterial conversion of ammonia to nitric acid. The aim is to have emissions in 2010 at the 1990 level.

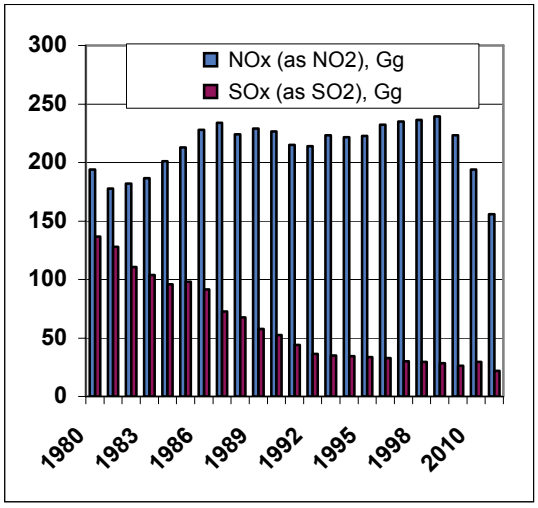


Figure 1. Annual emissions of SO_2 and NO_x from 1980 to 2000 and projections for 2010 and 2020.

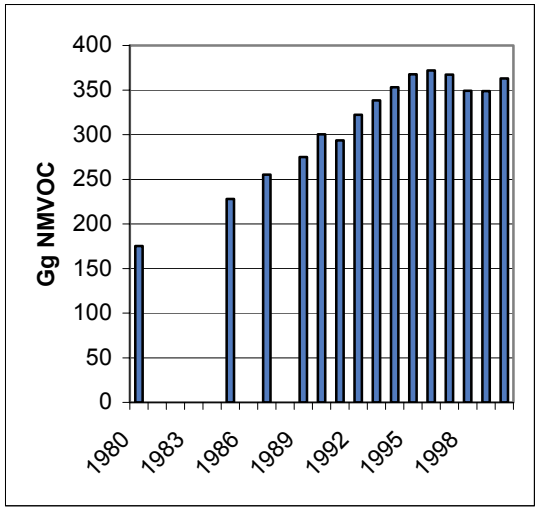


Figure 2. Annual emissions of non-methane VOC from 1980 to 2000.

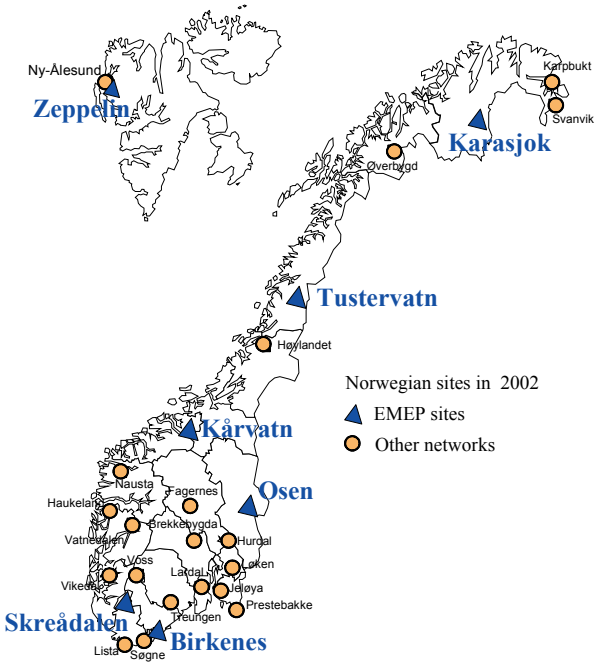
Sodium, magnesium, and chloride originate from sea salt, while calcium and potassium have a mixed origin. The national contributions to airborne concentrations of non-sea salt Ca and K in Norway are small compared to the contributions from emissions in Continental Europe.

The Norwegian emissions of lead, cadmium, and mercury were reduced by 97, 58 and 44 % respectively from 1990 to 2001 (Statistics Norway). This is mainly caused by removal of lead in gasoline and reduced emission from metallurgical industry.

Measurement network and site characteristics

The large precipitation amounts at the western and southern parts of this country are due to cooling of moist air masses from the sea that are lifted by the mountains behind the coastline. Wet deposition of pollutants can be further enhanced by a seeder-feeder effect when raindrops on their way down dissolve pollutants from clouds that are closer to the ground. It is known that concentrations in near-ground clouds can be high, and higher than in precipitation (e.g. Fowler et al., 1988). This occurs e.g. with air transported from southerly to westerly winds to the southern part of Norway. The wet deposition of acidifying substances has been more important than dry deposition processes in Norway.

The first measurement sites in Norway were established in the precipitation-rich belt between the coastline and the mountains in southern Norway. A fairly large network in southern Norway that was in operation in the early seventies has over time been reduced to a small regionally representative network consisting of seven EMEP sites.



Southern part of Norway

Birkenes	*NO01*
Skreådalen	*NO08*
Kårvatn	*NO39*
Osen	*NO41*
Prestebakke	*NO43 (ozone)*
Jeløya	*NO45 (ozone)*
Voss	*NO48(ozone)*

Middle and northern part of Norway

Tustervatn	*NO15*
Jergul	*NO30*
(not shown, but near Karasjok)	
Karasjok	*NO55*

Spitsbergen

Zeppelin	*NO42*

Figure 3. Location of EMEP measurement sites in Norway.

Additionally a fairly large secondary network has been operated for effect studies. The operational network (2002) in mainland Norway is presented in Fig. 3. The site at Karasjok replaced the nearby site at Jergul from 1997.

The southwestern and western transport directions for air masses are the most frequent precipitation-carrying directions at all sites. Directions from southwest via west to north are the most important wind directions, all days taken into account. The southern direction was also important in the middle and northern part of Norway.

Trends in sulphur components in southern Norway

The very strong reductions in the annual average concentrations of sulphur dioxide and sulphate in particles between 1978 and 2000 in the southernmost part of Norway (Birkenes and Skreådalen) are given in Table 1. The results in the Table are based on the Sen slope estimator on annual averages. The annual averages of SO_2 and SO_4air in 2000 were e.g. reduced by 65 and 58 per cent respectively from the 1978/79 averages at Birkenes. Fig. 4 presents the trend in the sulphur dioxide concentrations at Birkenes, Jergul, and at Spitsbergen. Annual means of excess sulphate concentrations in precipitation at Birkenes and Jergul are given in Fig. 5.

The sulphate concentrations in precipitation in southern Norway have significant downward trends at all sites in the annual total concentrations and in all seasons with Osen as an exception. The annual wet depositions and the summer seasonal wet depositions of excess sulphate likewise were significantly reduced at all sites. There were no distinct trends in the precipitation amounts.

Table 1. Changes in concentrations of sulphur dioxide and sulphate in airborne particles in southern Norway between 1978 and 2000. Total changes are relative to the 1978/79 means. Trends are significant at a 0.05 or higher level of significance.

Site	Period	Annual change 1978-2000; µg S/(m^3 · year)		Total change 1978- 2000; in per cent	
		SO_2	SO_4	SO_2	SO_4
Birkenes	Winter	-0.080	-0.046	-59	-75
	Spring	-0.050	-0.055	-65	-63
	Summer	-0.010	-0.021	-37	-43
	Autumn	-0.022	-0.021	-77	-50
	All year	-0.042	-0.032	-65	-58
Skreådalen	Winter	-0.078	-0.033	-59	-83
	Spring	-0.054	-0.050	-74	-82
	Summer	-0.011	-0.020	-67	-50
	Autumn	-0.022	-0.021	-91	-67
	All year	-0.045	-0.030	-77	-70

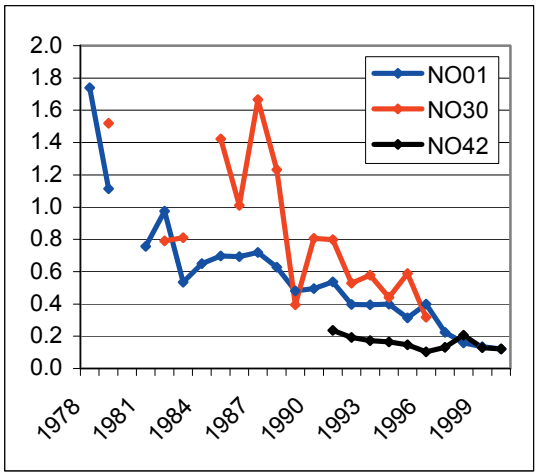


Figure 4. Trends in sulphur dioxide at Birkenes, Jergul, and Spitsbergen. Units: µg S/m^3.

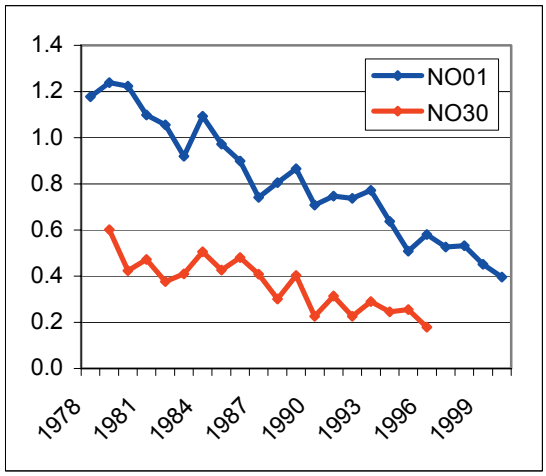


Figure 5. Trends in excess sulphate in precipitation at Birkenes and Jergul. Units: mg S/L.

When the trends in the sulphur dioxide concentrations in different sectors are weighted with the corresponding wind frequencies, the results reveal that emission reductions in the eastern, southeastern, and western sector contributed most to the reduced SO_2 concentrations. The decrease in the southeastern sector is important since the concentrations here have been among the highest, all sector taken into account. The air

transport from this sector is not very frequent. Fig. 6 gives the annual means of sulphur dioxide from different transport directions for four years.

Corresponding combinations of particulate sulphate concentrations and wind frequencies reveal that the emission reductions in east, southeast, south, and west had the strongest effect on the reduced sulphate concentrations in southern Norway. The effect of the reductions in the undetermined sector had, however, the largest effect of all at all sites. The trends in the southwestern direction were not significant, this is surprising since the UK sulphur dioxide emissions in this sector in 1996 were reduced to one half compared to1986-1987.

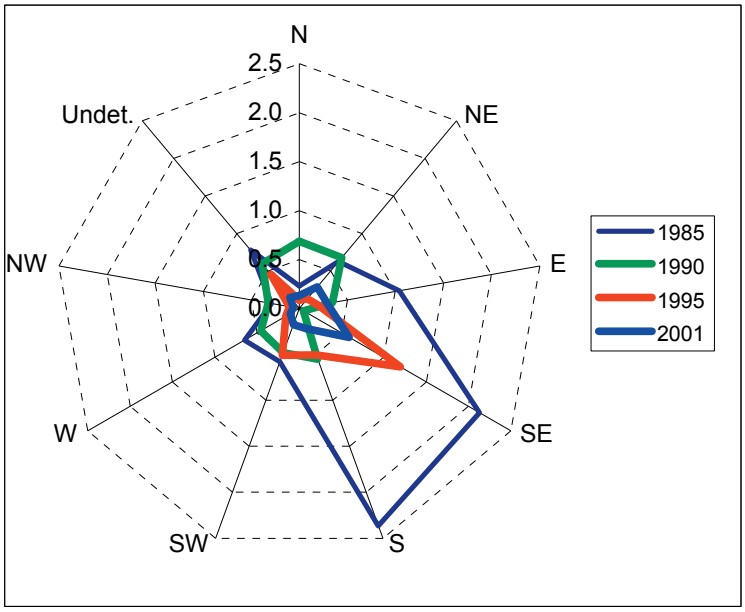


Figure 6. Annual means of sulphur dioxide concentrations for different transport directions for air masses, and for the undetermined transport directions. Birkenes.

Trends in sulphur components in the middle and northern of Norway

The site in the geographical middle of Norway, Tustervatn, experienced significant reduced concentrations in all seasons for sulphur dioxide and for sulphate both in air and precipitation from 1980. This site is located in one of the cleanest regions with respect to air pollution in Norway.

The wet deposition of sulphate has been generally low in all seasons and had a decreasing tendency following the concentrations.

The emission reductions in south had the largest influence on the SO_4 concentrations at Tustervatn, and the reductions in the emissions from east to southwest were all important for the reduction of the SO_2 concentrations in the middle part of Norway. The contributions from undetermined transport directions had large influences on the concentrations.

Table 2. Annual changes in concentrations of sulphur dioxide and sulphate in airborne particles between 1980 and 2000 at Tustervatn, and between 1978 and 2000 at Jergul/Karasjok. Total changes are relative to the 1980/1981 means at Tustervatn and 1978/1979 at Jergul. Trends are significant at 0.05 or a higher level of significance.

Site	Averaging period	Annual change μg S/(m^3 · year)		Total changes; in per cent	
		SO_2	SO_4	SO_2	SO_4
Tustervatn	Winter	-0.053	-0.021	< -90	-78
	Spring	-0.041	-0.041	-80	-83
	Summer	-0.007	-0.011	-54	-42
	Autumn	-0.015	-0.009	-70	-47
	All year	-0.029	-0.019	-88	-61
Jergul/Karasjok	Winter	-0.064	-0.020	-52	-67
	Spring	-0.065	-0.037	-73	-83
	Summer	-	-0.013	-	-56
	Autumn	-	-0.012	-	-57
	All year	-0.044	-0.023	-64	-68

In northern Norway the sulphur dioxide seasonal averages at Jergul were reduced in winter and spring. The concentrations in all seasons were fairly constant until the end of the eighties, but have decreased strongly since then. Summer and spring concentrations have been low since the end of the seventies and have no distinct trend. The sulphate concentrations in air are lower than the sulphur dioxide concentrations, and have, like these, been decreasing since the late eighties.

The excess sulphate concentrations in precipitation have visual decreasing tendencies in all seasons except in winter, and in the annual averages from 1978, none of these are, however, significant. All corresponding wet depositions decreased significantly.

The highest concentrations of sulphate in particles at Jergul were transported from east, southeast, south and southwest. These air masses contained well-aged pollutants from distant Continental sources. The emission reductions with the largest effect on the reduced SO_4air concentrations at Jergul took place in southwestern and southern directions.

Improvements in emissions in southern and eastern directions prove to have the largest effect on the Jergul SO_2 concentrations. The nickel smelters on the Kola Peninsula are among the sources in eastern direction contributing to the SO_2 measured at Jergul.

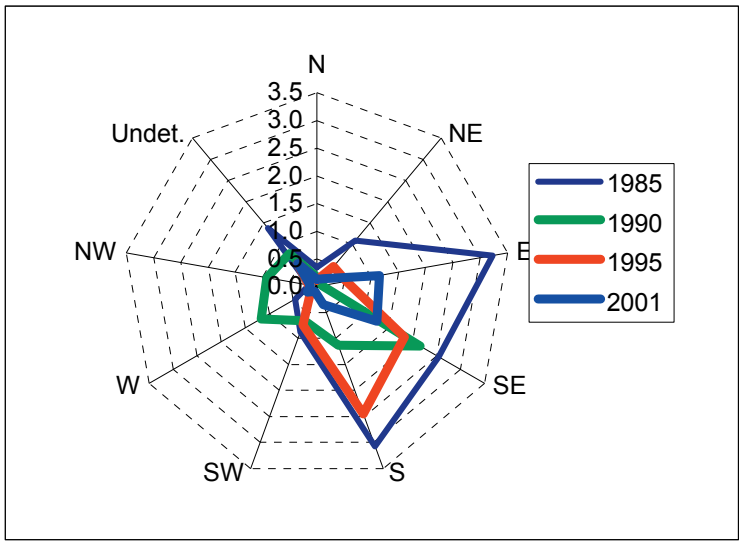


Figure 7. Annual means of sulphur dioxide concentrations for different air mass transport directions, and for the undetermined directions. Jergul 1985, 1990, 1995, and Karasjok 2001.

Trends in nitrogen components in southern Norway

Several neighbouring countries decreased their emissions of nitrogen oxides from the late 1980ies following the Protocol concerning the control of emissions of nitrogen oxides. This Protocol focused on a freezing and reduction of the NO_x emissions with 1987 as the basis year.

The decrease in the emissions of NO_x is clearly detectable in the nitrogen dioxide measurements that were started in 1982 at Birkenes. At Birkenes and Skreådalen the annual and seasonal averages reached their maxima in 1988, which were followed by decreasing averages until 1992 – 1993. The winter concentrations were the highest while the lowest concentrations occurred during summer. This is due both to shorter lifetimes for the oxides during the warm season, and lower emissions.

The nitrogen dioxide concentrations at Kårvatn at the west coast and at Osen in the inland had temporal trends quite similar to those at the two sites above as seen from Fig. 8.

The decrease in the concentrations at Birkenes and Skreådalen can be seen with transport from all directions except from southeast to southwest, which had the highest concentrations. Persistently high concentrations from southerly directions may partly be due to emissions from the highway that connects the southeastern and southwestern parts of the country.

A stratification of the Kårvatn NO_2 data between 1988 and 1996 after air mass transport directions shows a decrease in the concentrations from all directions until 1993. At Osen most of the reduction took place with air transport from south and southwest.

The annual averages of the sum of the nitrates in air, nitric acid and particulate nitrate concentrations are given in Fig. 9. The nitric acid concentrations in Norway are expected to

be low compared to the particulate nitrate concentrations (Semb et al., 1998). The concentrations were very low, and a weak decreasing tendency in the averages can be seen during spring and winter, and in the annual averages at Birkenes and Skreådalen. The sum of the concentrations of nitric acid and nitrate in particles at Kårvatn was always extremely low, and no trends can be seen. There are very weak decreasing tendencies from 1989 in spring and summer concentrations at Osen.

Fig. 10 gives the precipitation weighted annual averages of nitrate in precipitation at the sites in the southern part of the country. There were no distinct tendencies at Birkenes before the end of the eighties when weak but significant downwards trends started during spring and summer as well as in the annual averages. This may reflect some of the decreases seen in the air data. The wet deposition has no trends at Birkenes.

The spring seasonal average of nitrate in precipitation at Kårvatn peaked around 1986 to 1988 similar to Skreådalen. The concentrations of nitrate in precipitation at Osen decreased weakly, but significantly, from 1988 to 2000. This is due to a weak decrease in the autumn concentrations. There are no trends in the wet-deposition of nitrate.

Measurements of the sum of gaseous ammonia and ammonium in particulate matter were started in 1987.

The results are quite different at Birkenes and Skreådalen due to considerable local emissions at Skreådalen. Significant decreasing trends occurred from 1987 for the spring and the much lower winter concentrations, as well as for the annual averages, at Birkenes. The concentration level at Kårvatn is similar to that at Birkenes while the Osen concentrations are lower than those at the other three sites in southern Norway.

Both Kårvatn and Osen had similar low decreases in the spring averages.

The trends in the precipitation measurements of ammonium are slightly different at the sites. The ammonium concentrations in precipitation at Birkenes have been reduced; winter, summer and annual averages have significant downward trends. The spring- and annual total wet depositions decreases are significant. The wet deposition at Kårvatn had a weak winter increase. At Osen there were no trends neither in concentrations nor in wet-depositions.

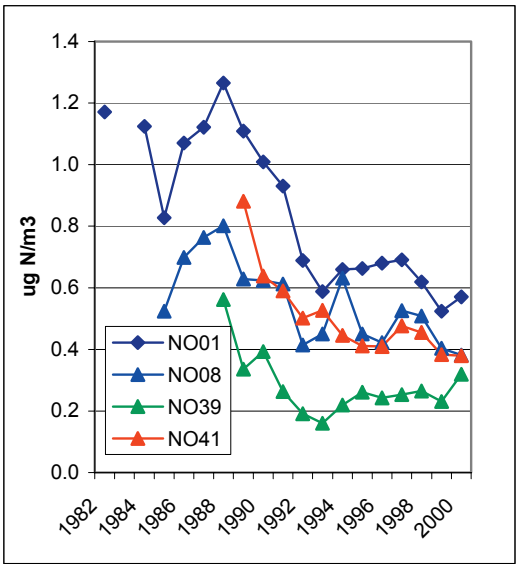


Figure 8. Trends in the NO_2 annual averages in the southern part of Norway. Unit µg N/m^3.

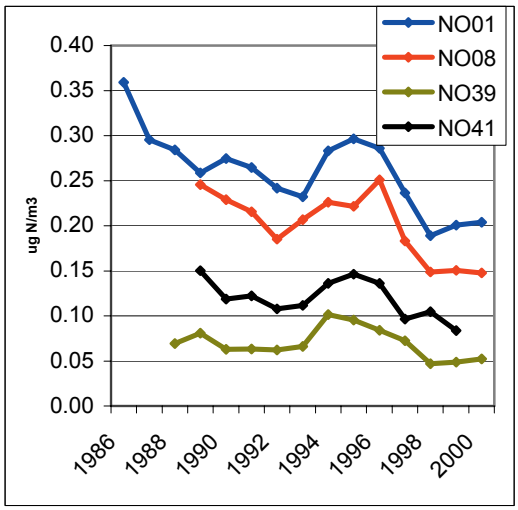


Figure 9. Trends in the annual averages of the sum of nitrate in airborne particles and nitric acid in the southern part of Norway. Unit µg N/m^3.

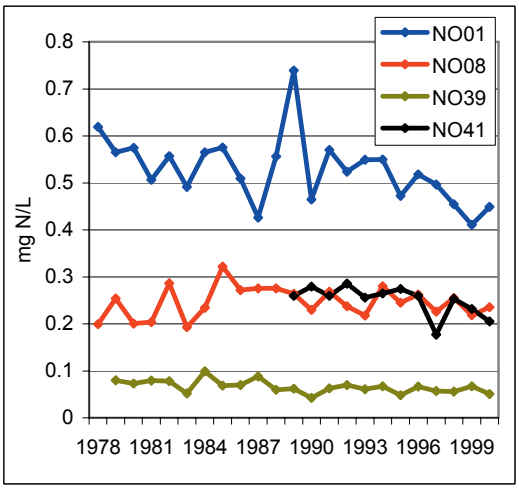


Figure 10. Trends in the annual averages of nitrate in precipitation in southern Norway. Unit mg N/L.

Trends in nitrogen components in the middle and northern parts of Norway

The trend in the nitrogen dioxide data series at Tustervatn in Fig. 11 strongly resembles that in southern Norway. The measurements were started in 1988 and the concentrations decreased until about 1995. There was no detectable trend in the second half of the nineties.

The nitrogen dioxide measurements at Jergul were initiated in 1985, increased and reached a maximum around 1987. Like the data series at the more southern sites the concentrations have been rather constant since 1993/1994.

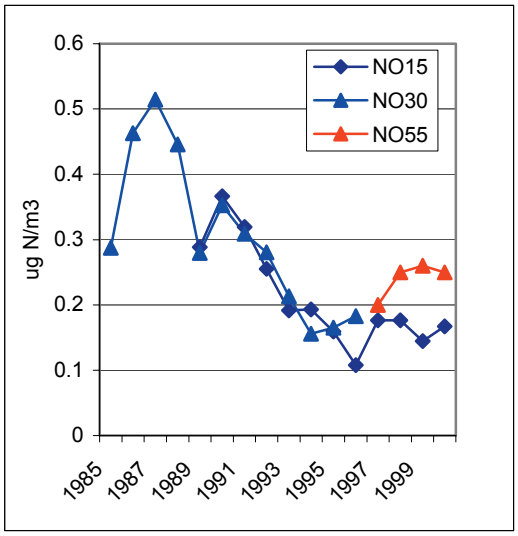


Figure 11. Trends in the NO_2 annual averages in the middle and northern part of Norway. Unit $\mu g\ N/m^3$.

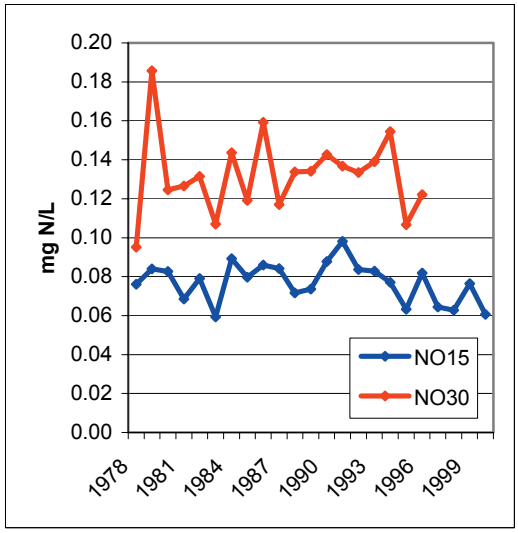


Figure 12. Trends in the precipitation weighted annual averages of nitrate in precipitation in the middle and northern part of Norway. Unit mg N/L.

Stratified data between 1988 and 1996 further reveal that the highest concentrations at Tustervatn occurred with air mass transport from southeast.

The highest concentrations at Jergul between 1985 and 1996 occurred with transport of air masses from directions between east and southwest. The concentration level was relatively constant from 1993/1994.

The concentrations of the sum of nitric acid and nitrate in airborne particles are extremely low at Jergul and at Tustervatn. The spring concentrations had a very weak decrease from 1988 to 2000 at Jergul, but no trends could be seen at Tustervatn.

The precipitation measurements of nitrates in Fig. 12 had, as seen, no trends at Tustervatn and at Jergul.

The measurements of ammonium and ammonia at Tustervatn are influenced by agricultural activities and cannot be used for regional assessment of these components. The annual averages of ammonia and ammonium in particles at Jergul were low and decreased from 1986 until the site was taken out of operation from 1997. The annual reduction was due to decreased spring and summer concentrations from 1988 to 1996.

There were also decreasing trends in the precipitation spring- and summer concentrations of ammonia at Jergul from 1987. These seasonal averages reached their maximum values 1984 – 1986. Neither precipitation nor air concentration of ammonium had any trends during autumn and winter. The concentration maximum in the middle of the eighties was reflected in a corresponding maximum in the annual wet deposition of ammonium. The annual wet deposition decreased weakly from the end of the eighties.

Trends in sulphur and nitrogen compounds in air have also been described by Tørseth et al. (2001).

Total deposition of non-sea salt sulphate and of total nitrogen

The total annual sum of dry deposition of sulphur dioxide and airborne sulphate and the wet deposition of excess sulphate is given in Fig. 13 that also gives the total annual sum of the dry deposition of ammonia and nitrogen oxides and the wet deposition of nitrate and ammonium. The depositions have been presented for two 5-year periods; 1978–1982 and 1997–2001. More comprehensive calculations are given in Hole and Tørseth (2002).

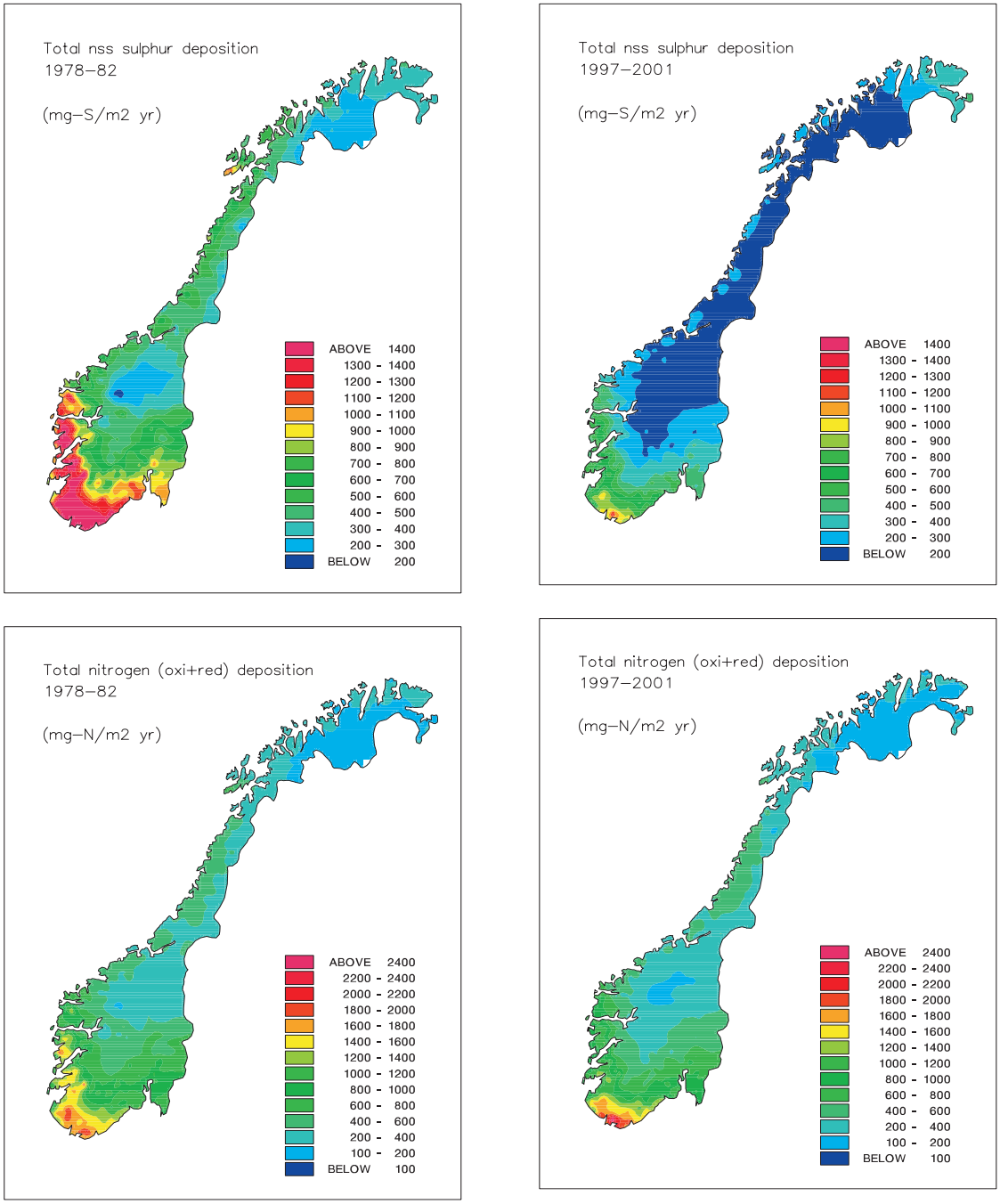


Figure 13. Total deposition of sulphur components and oxidized+reduced nitrogen.

Trends in basecations

Generally, concentration levels of non-sea salt basecations in air were 20–30% lower during the 1990s compared to 1986–1989. The even longer time series on precipitation concentrations from the early 1980s indicate even larger reductions in the order of 50%. The observed reductions are similar to the reductions in SO_2 and SO_4 in air (Tørseth et al., 1999).

Both calcium and potassium may be derived from both anthropogenic activities and from natural processes. The observed reductions are expected to be due to a reduction in emissions from industrial processes.

The highest median concentrations of nss Ca as well as for nss K occurred with transport from eastern to southeastern directions. This sector is mainly influenced by emissions in Eastern Europe. Somewhat lower values occurred with transport from the southern sector that represents Central Europe.

Generally, the ambient concentration levels of nss Ca and nss K are 30–50% higher in southern and south-western Norway compared to central and northern Norway. This gradient is generally somewhat lower than for SO_2, but clearly indicates that advection on the synoptic scale is very important. Furthermore, co-variations are often seen in the time series for all individual sites on a daily basis, and in particular for nss Ca. This indicates that compounds originate in the same areas or are emitted from the same sources. Additionally, examination of the data series from individual sites with corresponding air mass trajectories, consistently points out Eastern Europe as the most important source region. With very few exceptions, these episodes occurred during unusual meteorological events with prolonged transport of air across southern Sweden and the Baltic Sea, from areas with known, large emissions of particulate matter, caused by the burning of oil-shale and production of cement in the Narva area.

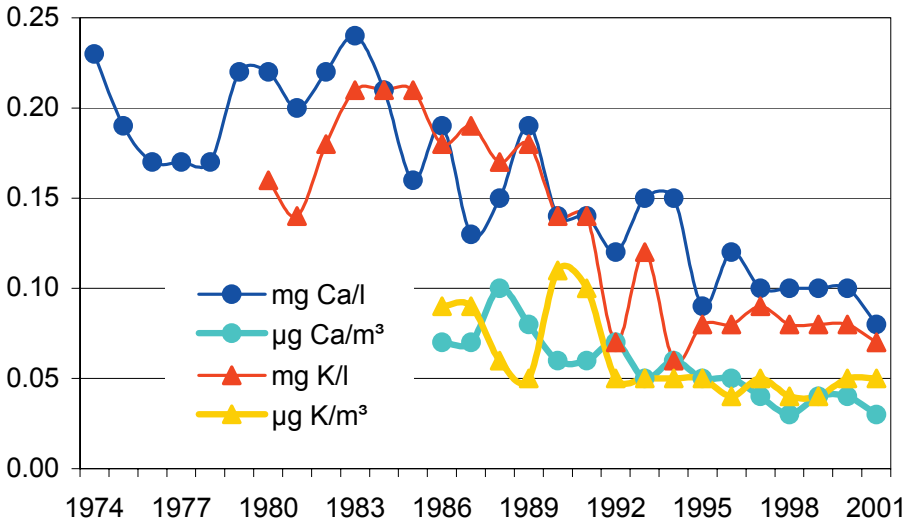


Figure 14: Annual average values of non-sea salt calcium and potassium concentrations in precipitation and in air at the site Birkenes.

Trends in pH in precipitation

Annual precipitation weighted pH averages increased significantly at all sites during 1978 - 2000. The strongest pH increase took place during summer and spring in the southern and middle parts of the country. In the north, at Jergul, the strongest increase occurred during summer/autumn. The winter pH seasonal averages were not significantly changed at Jergul and at Osen.

Trends in surface ozone concentrations

A summary of the trends in the Norwegian ozone monitoring data are given below. Due to varying procedures for the ozone monitoring back in time a detailed investigation of the monitoring history of each of the stations was required. A particular problem was the infrequent calibrations of the various instruments until approximately 1997 when a more rigorous procedure for quality assurance, field inspections and field calibrations were started.

Thus, based on the revealed monitoring history periods of the ozone data were rejected for the purpose of long-term trend studies, while regarded valid for other applications with less strict requirements for accuracy. This reduced the amount of data and the length of the time series considerably, decreasing the relevance of the trend study, but increasing the accuracy and reliability of the underlying data. All further analyses were based on this filtered data set.

These data indicated a reduction in the 99-percentile of the daily (daytime) ozone data in the southern part in the summer half year, although not seen at all sites, of the order of 1 ppbv/year during the 1990-ies. It should be stressed that the uncertainty in the trend rates is high due to the variability from year to year and due to the fragmentary data set. The station Prestebakke was in contradiction to this showing significantly increasing ozone concentrations, particularly marked since 1999. The reason for this is unclear, but must probably be explained by changes in local conditions (land use, nearby emissions etc).

For all sites from Voss and northwards a statistically significant growth in the mean ozone concentration was found for the winter half year with rates of the order of 0.3-0.5 ppbv/year. An increasing trend in the mean ozone concentration was found also in the summer season for a number of the same sites, but not for all, and generally with less significant trends.

An analysis of the ozone data with respect to atmospheric air mass transport was carried out to separate cleaner background conditions from air masses more influenced by European anthropogenic air masses. This indicated a significant increase in the ozone concentration in the background air masses at the northern sites (north of mid-Norway) both in summer and winter. Due to the large variations from year to year it is not clear if this could be explained by a steady growing ozone concentration in the background or due to shifts from one 3-4 years period with low background ozone in the mid 1990-ies to another period of high background ozone values at the end of the 1990-ies. At the stations in the south no clear trend in the background air masses was possible to identify. Whether

this is due to problems of separating the types of air masses or reflects that an increase in background ozone is confined to the northern region is not clear.

Based on the trajectory data used (4-days trajectories for the planetary boundary layer) no clear trends could be seen in the transport pattern itself. Trajectories for Jergul/Karasjok in the far north of the Norwegian mainland indicated higher frequency of transport from E-SE during the last part of the 1990-ies and less periods with background air masses. For the other sites there were no corresponding trends in the frequency of transport sectors.

Trends in heavy metal concentrations

Lead, cadmium and zinc have been measured in precipitation from 1976 at several sites, and in particles from 1991 at Lista (CAMP), and from1994 at Zeppelin mountain (AMAP). The reductions in the Cd and Pb concentrations in precipitation from 1976 to 2002 at Birkenes in Fig. 15 were above 90%, and about 80% for Zn (Berg et al., 2003).

The time series for air measurements are relatively short and no significant trend is observed for this period neither at Lista nor at Zeppelin, except for nickel. For mercury there is no observable trend in the air concentrations, but there has been a reduction at 40% in the precipitation concentrations at Lista since 1990.

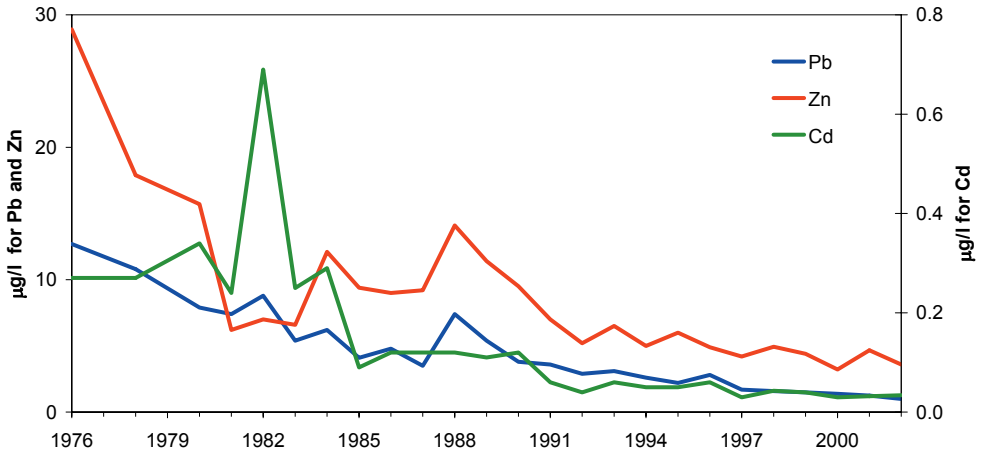


Figure 15. Trends in heavy metal concentration in precipitation at Birkenes, µg/l.

Trends in concentrations of persistent organic pollutants

POPs have been measured in air and precipitation at Lista from 1991 and in air at Zeppelin since 1993, Fig. 16. At Lista there is a significant and large reduction in the HCH concentrations in both air and precipitation, α-HCH: 94 and 85% and γ-HCH: 86% and 77% for air and precipitation concentrations respectively. HCB had a significant reduction in the air concentrations only, at 61% (Berg et al., 2003). At Zeppelin Mountain the same reduction are seen for these components in air. The reductions are in compliance with the reduced use of the substances. For PAH measured at Zeppelin there is a clear downward trend, but for other POPs (including chlordanes, PCBs and DDT) the data coverage is too limited to allow for a complete trend analysis.

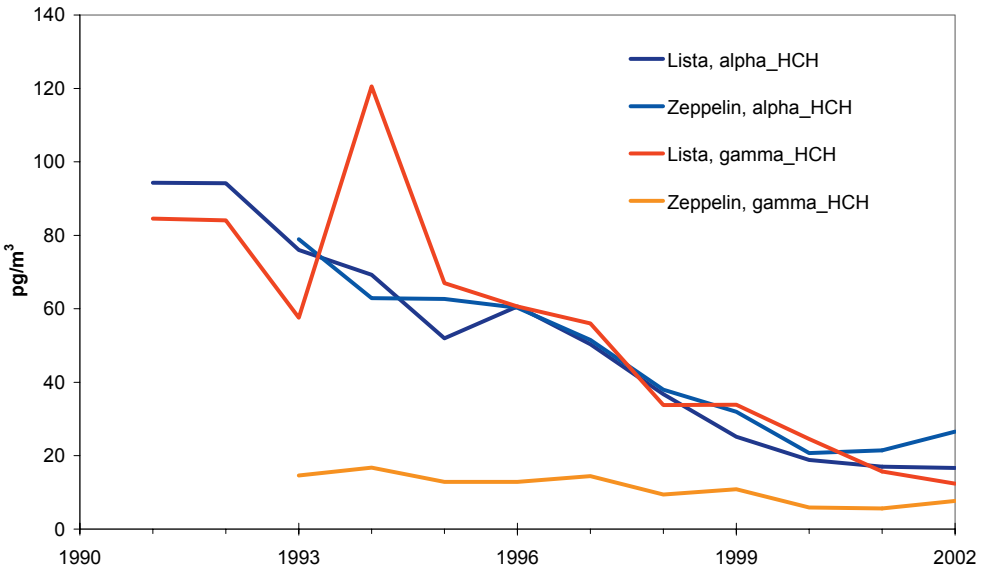


Figure 16. Trends in α- and γ-HCH concentrations in air at Lista and Zeppelin, pg/m^3.

Conclusions

- The national SO_2 emissions have been strongly reduced and were about 19 per cent of the 1980 emissions by the turn of the century.
- The NO_x emissions peaked in 1999, but will have to be reduced further to 156 thousand tones by 2010 in order to comply with the Gothenburg Protocol.
- A small reduction in the NH_3 emissions has taken place from 1996.
- The non-methane VOC emissions peaked in 1996 and should be reduced further to 195 thousand tones in 2010 in order to comply with the Gothenburg Protocol.
- The concentrations of sulphur dioxide and sulphate in air have been strongly reduced in all parts of Norway. The annual averages of SO_2 and SO_4air in 2000 were e.g. reduced by 65 and 58 per cent respectively from the 1978/79 averages at Birkenes. Emission reductions in east, southeast, south, and west gave the strongest contributions to the reduced sulphate concentrations in air. The sulphate concentrations in precipitation and the wet deposition in southern and middle parts of Norway have significant down trends at all sites. In the north there are visual decreasing trends from 1987, these are however not significant. Calculations of the total deposition show a strong reduction in the deposition of sulphur compounds over the last twenty years.
- The NO_2 concentrations in Norway decreased from the late eighties until 1993-1995.
- Concentrations of nitrate in particles and nitric acid have low concentrations in all parts of the country and visual downward trends in the southernmost parts. In northern and middle parts of Norway the concentrations are extremely low. There are significant decreasing concentrations in nitrate in precipitation in the south from the end of the eighties, but no significant trends in other parts of the country. There are no trends in the wet deposition of nitrate.

- Only one site in southern Norway (Birkenes) had significant downward trends for ammonium; from the eighties in air and precipitation concentrations and in the wet deposition. The corresponding data series in the north (Jergul) indicated decreasing trends in the annual averages of the air concentrations, and in the wet deposition from the end of the eighties.
- Calculations of the total deposition of oxidized and reduced nitrogen components show small changes only over the last twenty years.
- There are indications of decreased concentrations of non-sea salt basecations calcium and potassium in southern Norway from the early eighties until today.
- Annual precipitation weighted pH averages increased significantly in all parts of the country during 1978 -2000.
- The surface ozone data indicate a reduction in the 99-percentiles of the daytime summer measurements in southern Norway, however, not seen at all sites. Significant growths in the ozone winter half-year means are found for all sites from Voss (middle part of southern Norway) and northwards. A similar, but weaker trend is found during summer. An analysis with respect to transport directions revealed significant ozone increases in the cleaner background air masses at the northern sites both in summer and winter. This cannot be seen in the south.
- Concentrations of lead, cadmium, and sink in precipitation in southern Norway have been reduced by about 90 per cent since 1976. Measurements of the particle concentrations the last decade reveal, however, no trends.
- Reductions at 75 to 85 per cent can be seen in the α- and γ-HCH concentrations in air and precipitation, both in the southern part of Norway and in the Arctic the last decade. HCB had a significant but lower reduction in the air concentrations during this period.

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