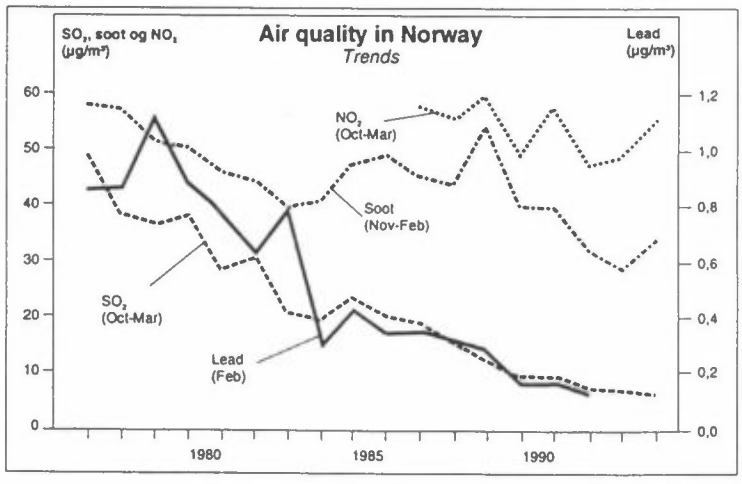
NILU: TR 19/94

NILU : TR 19/94
REFERENCE : Q-301
DATE : DECEMBER 1994
ISBN : 82-425-0638-8

The use of air quality indicators in Norway

Bjarne Sivertsen



Norsk institutt for luftforskning
Norwegian Institute for Air Research
Postboks 100 - N-2007 Kjeller - Norway

Contents

Side

The use of air quality indicators in Norway

1. Introduction

A monitoring and surveillance programme for air quality has been operated by the Norwegian Institute for Air Research (NILU) on behalf of the State Pollution Control Authority (SFT) since 1977. Air quality indicators for the routinely operated surveillance programme in Norway have been selected as presented by Sivertsen (1991).

The Norwegian monitoring and surveillance programme has been divided into sub- programmes covering

- traffic air pollution,
- urban and residential areas,
- background areas, including "acid rain" problems,
- ozone layer depletion, greenhouse gases
- hazardeous micropollutants; local to global scale,
- impact on building materials and monuments,
- radioactivity surveillance and alarm.

Data from 5 of these sub-programmes can be used in the OECD project on Air Quality Indicators.

In addition to the routinely operated surveillance programme, several detailed studies and investigations have been undertaken throughout the last 15 years. So-called basic investigations have been performed in 5 urban/industrial areas to establish information about the relationship between emission sources and air quality. In all these areas dispersion models including emission inventories and meteorological data were established.

Studies on the concentrations of various hazardous air pollutants have also been undertaken as "snap shots" over short periods of time. None of these studies have been designed to estimate trends. However, some of them have been repeated after a few years to evaluate the development and the impact of emission reductions.

2. The use of AQI for urban surveillance

Measurements of selected air pollutants have been undertaken in urban and residential areas since 1977. The pollutants originally selected were SO_2, soot (black smoke) and lead. From the mid eighties also NO_2 measurements were included in the programme. These measurements were mainly related to traffic relevant monitoring stations. PM_{10} and $PM_{2,5}$ have been measured since 1985 in the traffic air pollution programme.

The number of monitoring sites have been changing over the years from 45 in the seventies and eighties to a low number of 19 stations in 1993/94. In addition street

canyon measurements in Oslo and background stations located in what could be specified as "rural stations", can be added to the reporting for the OECD study. The monitoring programme in 1993/94 covered 17 urban areas. In addition 4 stations were operated in the border areas of Norway and Russia (far north). These stations are mainly influenced by industrial emissions from smelters in Russia, and will thus not fit into the definition of the OECD study statistics.

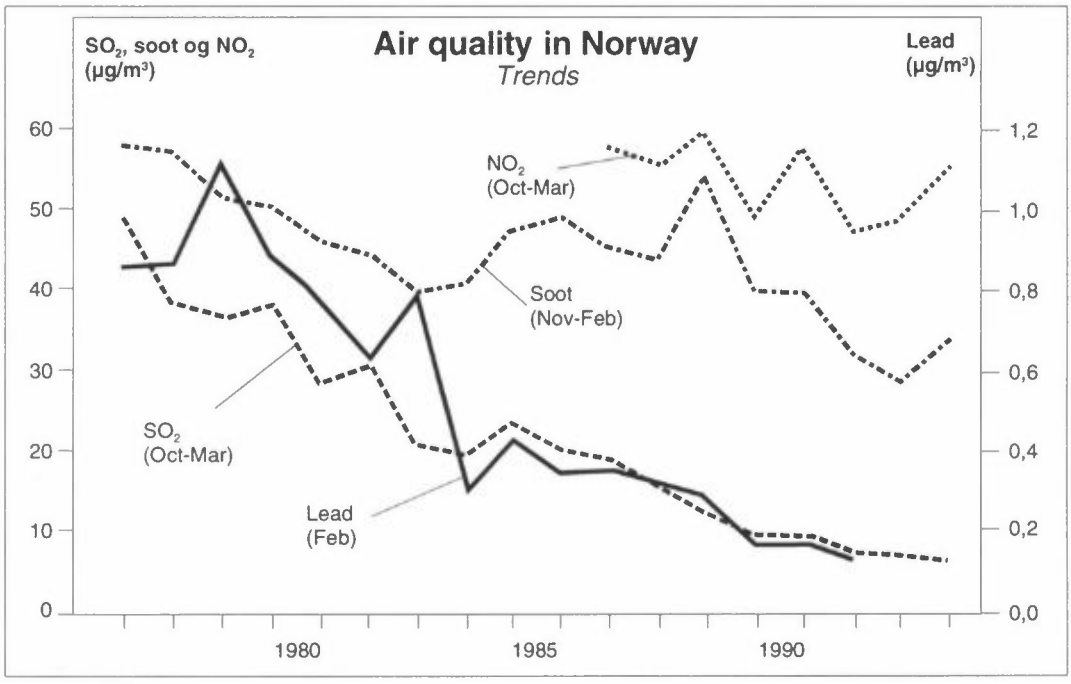


Figure 1: Air quality trends as an average for 8 selected urban areas in Norway (1977-1994).

Data from 8 selected cities in Norway have been used to demonstrate the long term trend in SO_2, soot, lead and NO_2 in Norway as shown in Figure 1. The figure shows the development in time of the winter average concentrations since 1976/77. The Norwegian air quality guideline values are specified for 6 month winter averages. Data presentations thus mainly include winter average concentrations. Studies have also been performed to look at the differences between summer and winter averages, as shown in Figure 2.

The significant reduction in SO_2 levels has been caused by a shift to lighter and sulphur poor fuel oils and a steady change to using hydro electric power for home heating. The reduction in lead concentrations is partly caused by the introduction of unleaded gasoline since 1983 and lowering the lead content in all gasoline since 1980.

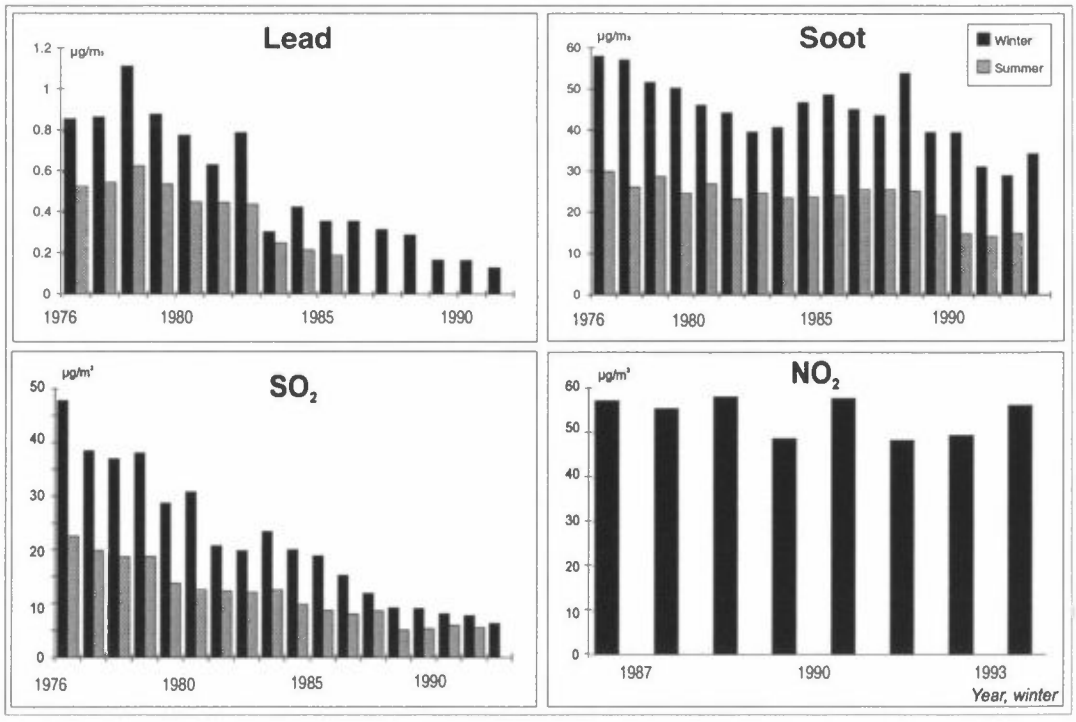


Figure 2: Winter and summer average concentrations of lead, soot, SO_2 and NO_2 (1977-93)

The levels of soot and suspended particles decreased due to the reduced use of heavy fuel oil until 1983. After that time most of the suspended particles in Norwegian cities originate from automobile traffic emissions. The traffic also causes high concentrations of NO_2 especially during cold winter days with strong surface inversions. NO_2 is at present, together with PM_{10}, the main local air pollution problem in Norway.

The presentation of simplified frequency statistics in the form of boxplots as proposed by the OECD expert meeting (February 1994) has been included in the last national surveillance report presented to SFT (Hagen, 1994). An example of the NO_2 concentrations measured in 8 cities in Norway is presented in Figure 3. This figure also includes maximum concentrations which was not supposed to be included in the OECD plots. The shape of the box-plot also looks different from the shape agreed upon in the OECD meeting. This will, however, be changed in the near future.

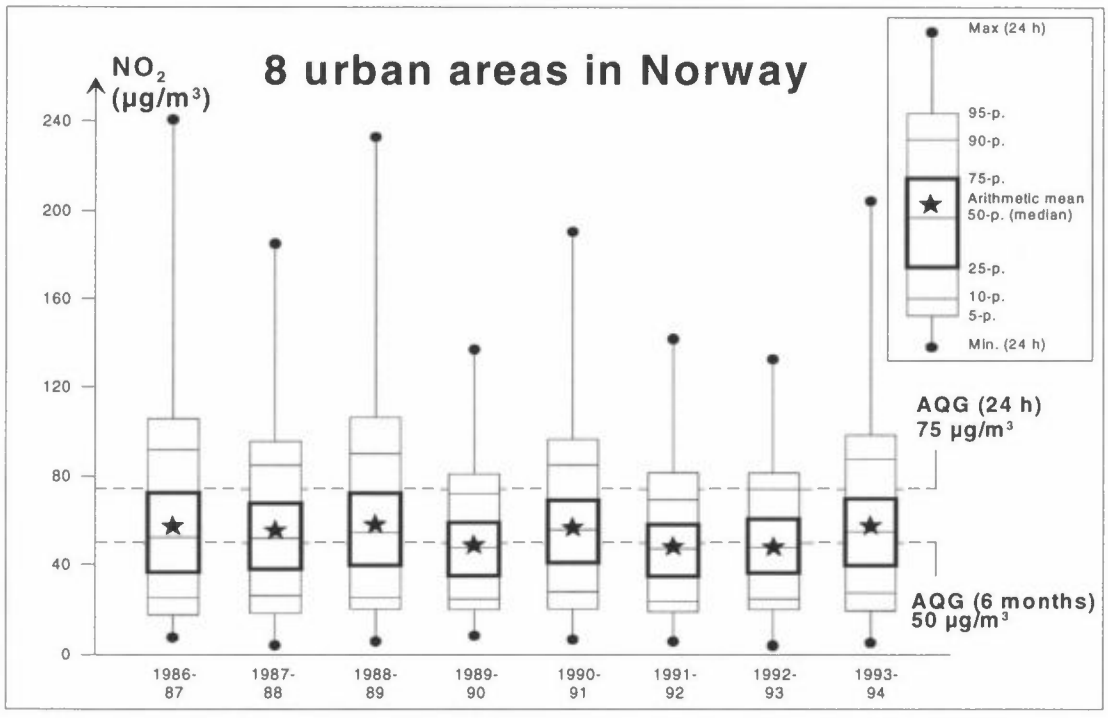


Figure 3: Boxplots of NO_2 concentrations for 8 selected urban areas in Norway (1986-1994).

Measurements of lead in air have been part of the routine programme until 1992. The significant reduction in lead levels from 1979 until today can be seen in Figure 4 to be closely linked to the reduction in lead content in gasoline. Lead is not being analysed in the urban programme any more.

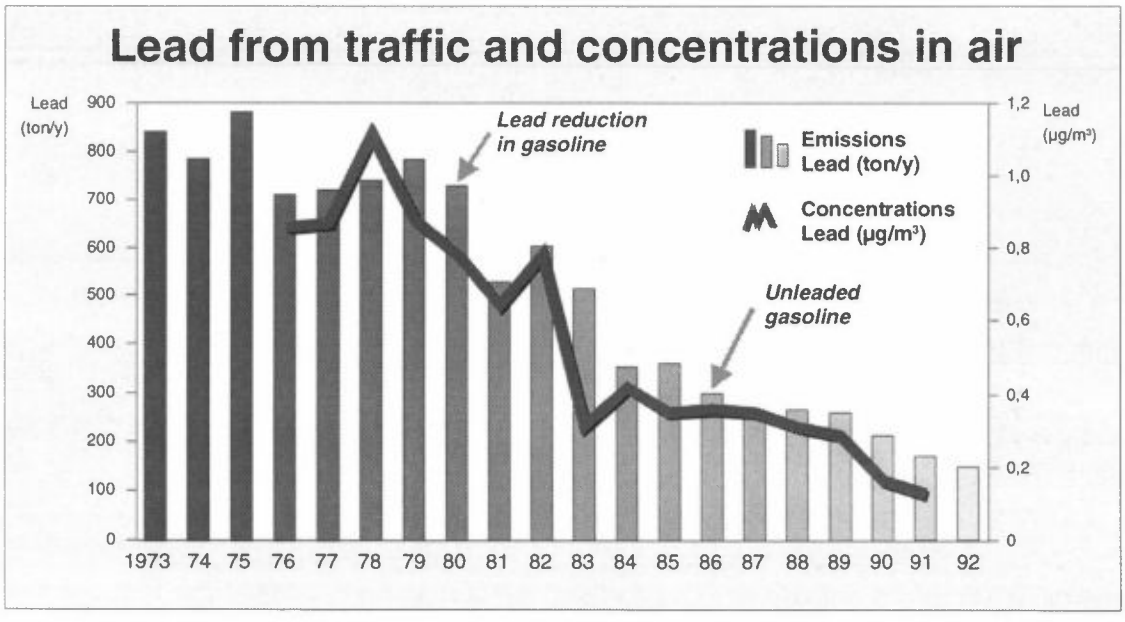


Figure 4: Emissions of lead from traffic together with measured concentrations in air in urban areas of Norway.

3. Exposure estimates

The development of exposure models has been an important issue at NILU during the last 8 years. Different types of models have been developed and are today becoming part of the routine reporting of the air quality in Norway. The surveillance programme is being redesigned to introduce an "exposure number" as a new air quality indicator. The new programme will mainly be based on on-line continuous monitoring. The "exposure number", BE, is defined as the number of people living in areas with air pollution levels exceeding the Norwegian air quality guideline values (AQG) values.

Work is also being undertaken to enable estimating the number of hours (PET) or days (PED) that people are exposed to concentrations above AQG values.

Figure 5 presents the number of people in Norway living in areas exceeding AQG values in 1992. The figure includes a forecast for the year 2005. For SO_2 it can be added that the estimates recently performed based on new measurement data already indicate a decreased exposure from 29 000 in 1992 to 13 000 persons in 1993/94.

Number of people exposed above AQG values in Norway

	Conc. (µg/m^3)	av. time	Urban scale (1000 persons) 1992	2005
NO_2	50 75	6 m. 24 h.	660 210	390 42
PM_{10}	70	24 h.	700	340
SO_2	90	24 h.	29	29

Figure 5: The number of people living in areas where Norwegian air quality guideline values may be exceeded.

Estimates of the number of people living along the road system in Norway exposed to NO_2 concentrations above AQC values is presented in Figure 6. Two scenarios for 2005 are also included in the figure.

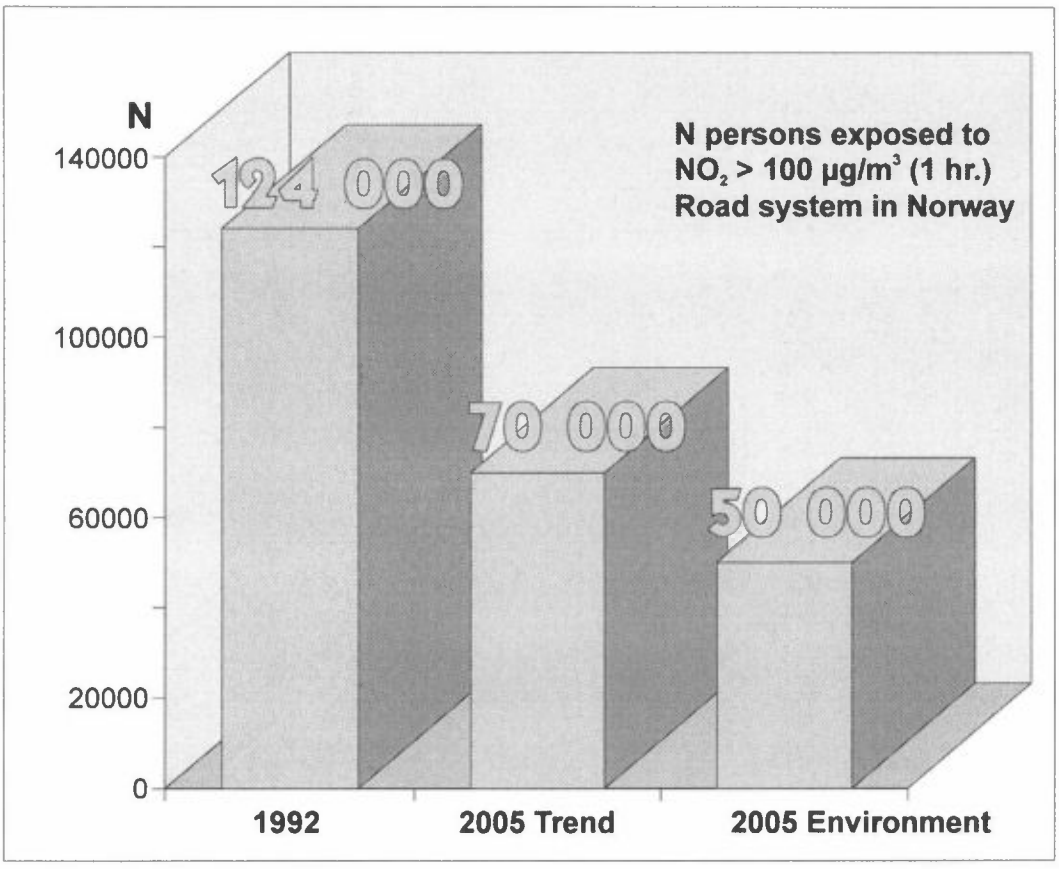


Figure 6: Number of people exposed to NO_2 concentrations exceeding 100 µg/m³ as an 1 h average value along the road system in Norway in 1992 and for two different scenarios for the year 2005.

4. Data from rural and background areas

A total of 42 background stations were operated in Norway in 1993 to map the rural and background concentrations in air and precipitation of various pollutants. A summary of the deposition of sulphur and nitrogen is presented in Figure 7.

Long range transport of acidifying compounds is recognised to be among the most severe environmental problems in Norway. Measurements and model estimates show that the highest concentrations of sulphur and nitrogen components occur in the southern and south-western part of Norway (Tørseth and Joranger 1994).

High concentrations of sulphur in precipitation and air also observed along the Russian border, due to large emissions from nickel smelters in Russia (Tørseth and Pedersen 1994, Sivertsen et al. 1994).

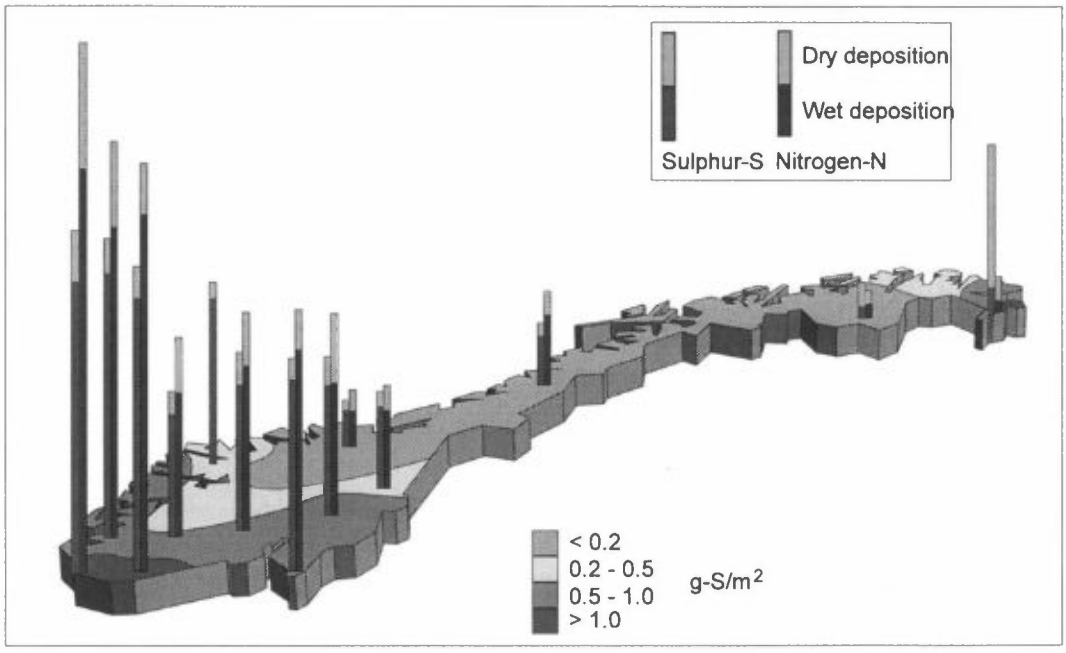


Figure 7: Dry and wet deposition of sulphur and nitrogen in Norway (1992)

Measurements of SO_2 and NO_2 have been undertaken at about 14 of the background monitoring sites. Most of these stations are related to the EMEP network. Typical maximum 24 h average SO_2 concentrations range from 1 to 7 µg/m³. An exception is the border area to Russia where we may have 24 h average concentrations exceeding 100 µg/m³.

Typical NO_2 concentrations range from 1.2 to 15 µg/m³ as 24 h averages.

Ozone concentrations have been reported as 7 h-average daytime concentrations and as number of "episodes". An episode occurs if the 1 h-average concentration exceeds 200 µg/m³ at one site, or if it exceeds 120 µg/m³ at several sites.The number of episodes is important for considering health impact in residential areas and the potential for NO_2 formation and impact on health inside urban areas.

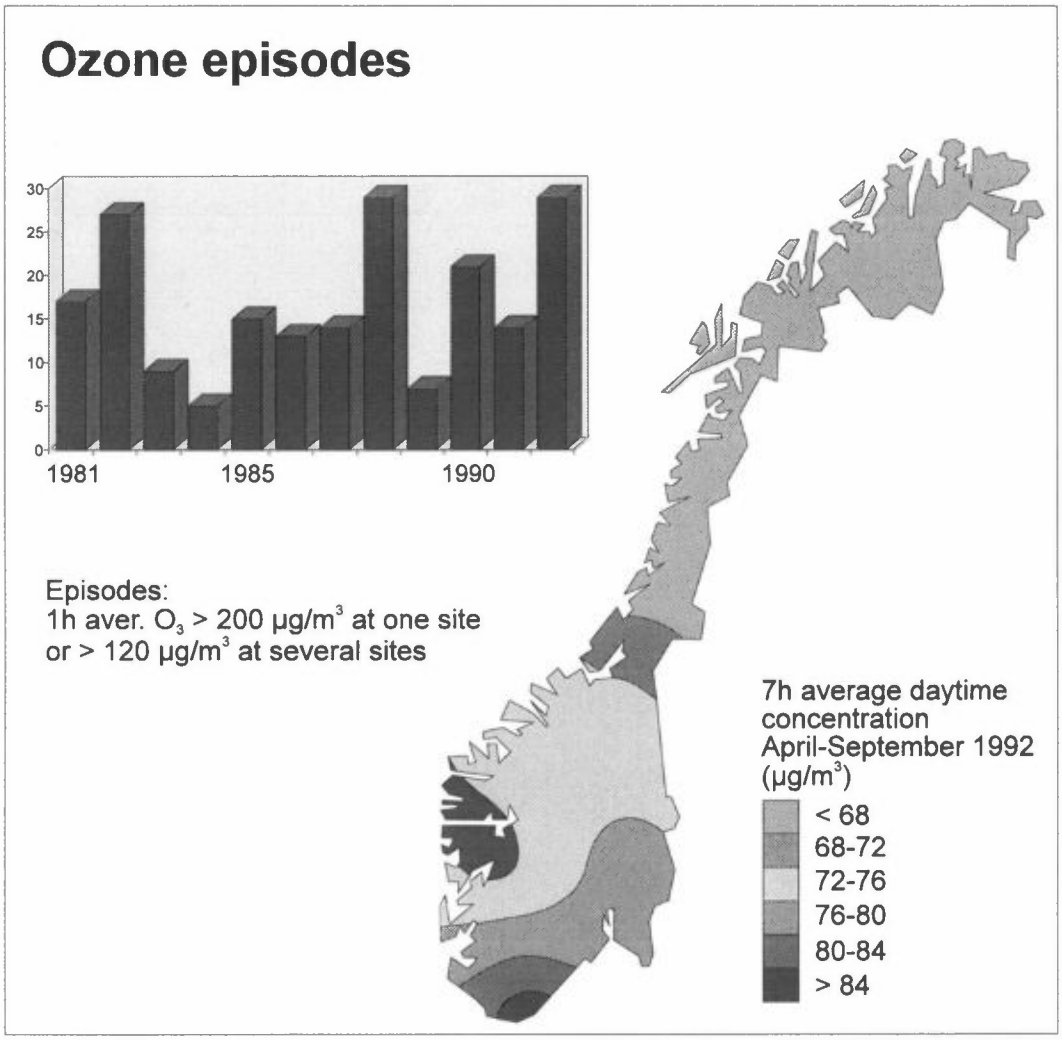


Figure 8: The spatial distribution of 7 h average daytime concentration of ozone in Norway. The number of episodes are also presented from 1981 to 1992.

5. Hazardous air pollutants (HAPs)

A list of priority micro pollutants has been available in Norway since 1987 (SFT 1987). This list was divided into four groups, out of which the highest priority were on:

1. Lead, Fluorides, Cadmium, Copper, Chromium, Mercury, Zinc, Chlorinated alkylbenzenes, Dioxins, Phenols, PAHs ,PCBs.
2. Aluminium, Arsenic, Nickel, Chlorinated benzenes, Ethanes, and Paraffins.

From 1993 the list of priority micro pollutants (toxic, carcinogenic, and environmental harmful pollutants) has been re-evaluated (Dons and Beck, 1994). The list of priority pollutants has been ranged into 4 groups according to the potential environmental hazard to humans and to the environment. The four groups are:

1. Pollutants representing considerable problems in Norway.
2. Pollutants representing medium to large problems.
3. Pollutants assumed to represent minor problems.
4. Pollutants for which knowledge is lacking.

This new list of priority micro pollutants in Norway contains:

Group 1: Lead, Cadmium, Copper, Mercury, Dioxins, Fluorides, PAHs, BCBs, tinogranics
Group 2: Nickel, Zinc, DDT, HCB, Gamma-HCH, Chlorinated Alkyl-benzenes, Tetrachloroethene, Tetrachloromethane, 1,1,1-Trichloroethane, Trichloroethene, Trichloromethane,
Group 3: Arsenic, Chromium, 1,2,-Dichloroethane, Hexachlorobutadiene, Pentachlorophenol, Trichlorobenzene.
Group 4: Brominated flameretardents, (fire extinguishers), chlorinated paraffins, Polychlorinated naphtalenes.

As part of the Norwegian surveillance and monitoring programme undertaken by NILU, the hazardous pollutants have been roughly divided into three groups:

1. Inorganic pollutants in air, precipitation and biolological samples
   - toxic elements
   - fluorides
2. Organic pollutants related to atmospheric problems
   - VOC, light HCs
   - Chlorinated HCs
   - Aldehydes and ketones
   - PAN
3. Organic pollutants found in environmental media
   - PAH
   - PCB
   - Pesticides
   - Dioxins

Typical for the measurements of hazardous air pollutants (HAPs) in Norway is, as in many of the OECD countries, that samples have been taken at selected points in time with different sampling times. Only "snapshots" of information is thus available. Some of these measurements have been repeated at random intervals, but there are no continuous data for HAPs in Norway. An exception is lead in urban and residential areas and measurements of fluorides in vegetation around aluminium smelters. The lead measurements were, however, stopped in 1992 as the levels in ambient air have been reduced to far below AQC levels.

Some examples of HAP data from Norway are presented in the following.

5.1 Toxic elements in residential areas

A screening of the concentrations of selected elements in 18 Norwegian urban and residential areas have been undertaken in 1989-90 (Thrane 1983,a-e) and repeated in 1991 (Hagen 1991)

The elements are selected from the SFT priority list of toxic pollutants. A summary of the results is presented in Figure 9.

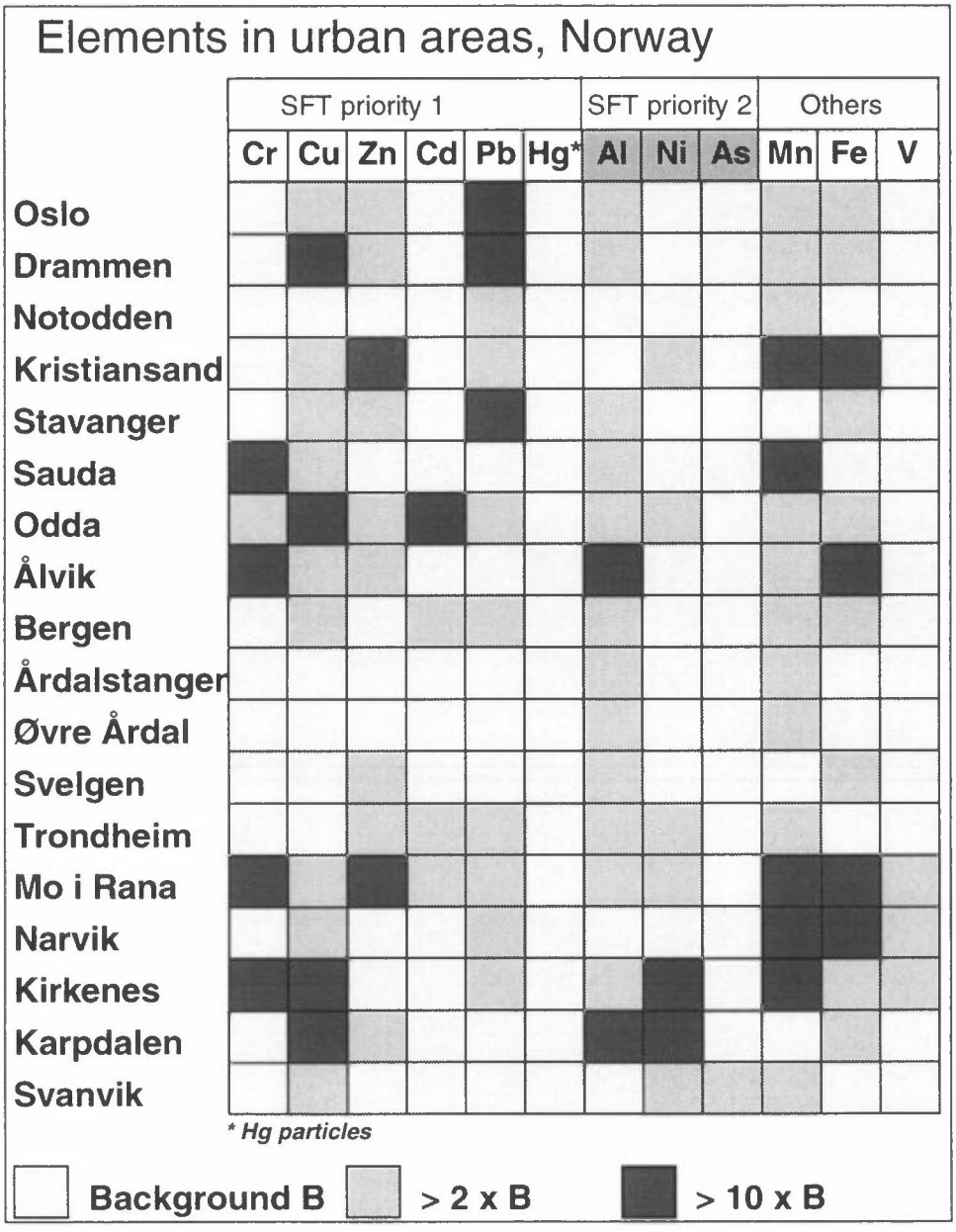


Figure 9: A screening of the levels of 12 elements in 18 areas in Norway relative to the background level as measured at Birkenes in Southern Norway.

This simplified presentation indicate areas where the levels of the 12 selected elements exceed 2 and 10 times a typical background concentration as measured at the EMEP station Birkenes in the southern part of Norway.

This type of screening has been used to identify problem areas where it is necessary to reduce the emission of some of the elements dependent upon the potential health and environmental impact.

Another type of studies have been performed during 1988 to 1994 of 5 selected toxic elements in the border areas between Norway and Russia (Sivertsen et al. 1994). The elements Ni, Cu, Cd, As Zn, Cr, Fe, Mn, V, Pb and Co have been measured in air, precipitation and snow samples. Model estimates of concentration distributions and seasonal and annual dry depositions have been undertaken as presented in Figure 10 (Sivertsen et al. 1992).

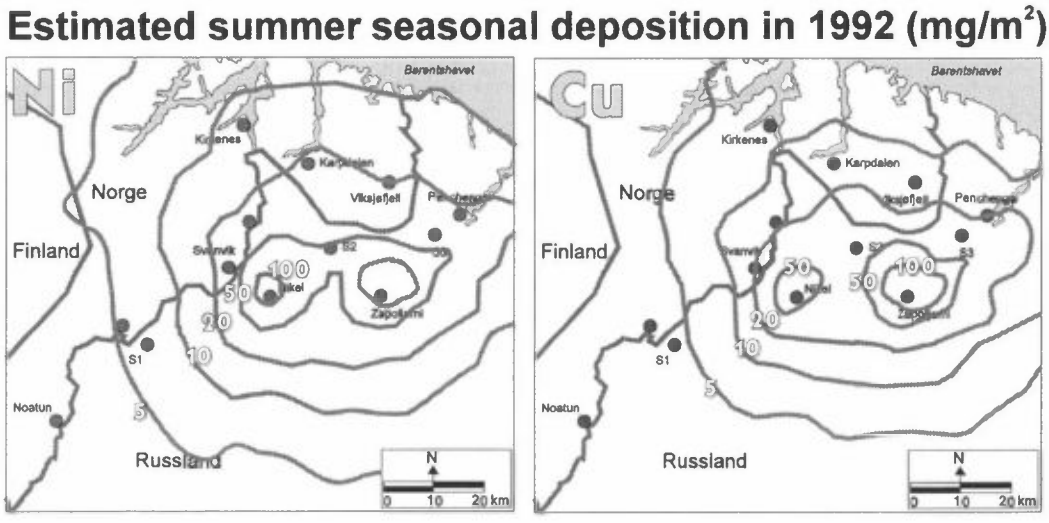


Figure 10: Estimated summer seasonal deposition of nickel and copper in the border areas of Norway and Russia based upon measurements of air quality and meteorology

The extremely high concentrations of nickel and copper which are 10 to 20 times typical background values, are due to high emissions from nickel smelters in Russia. Cobalt, Arsenic and Cadmium concentrations are about ten times higher than in the southern part of the country.

5.2 Toxic elements in background areas

Environmental indicators for long-range transported heavy metals have been developed (Berg et al. 1994). The indicators are based on data for lead and cadmium from national moss surveys which are performed regularly in Norway. The interpolation programme " kriging" has been used to transform data from irregular grids to regular grids. Contour maps have been produced and areas exceeding estimated background levels have been presented. The indicators are used to characterise the atmospheric deposition of long-range atmospheric transported heavy metals and to present the long term changes in time.

5.3 PAHs in residential areas

About 40 compound of PAHs have been analysed during two measurement campaigns. The aim of this study has been to investigate the levels of PAHs in residential areas due to emissions from aluminium smelters. The first study was performed in 1980-82, and repeated in 1990-91.(Hagen 1993)

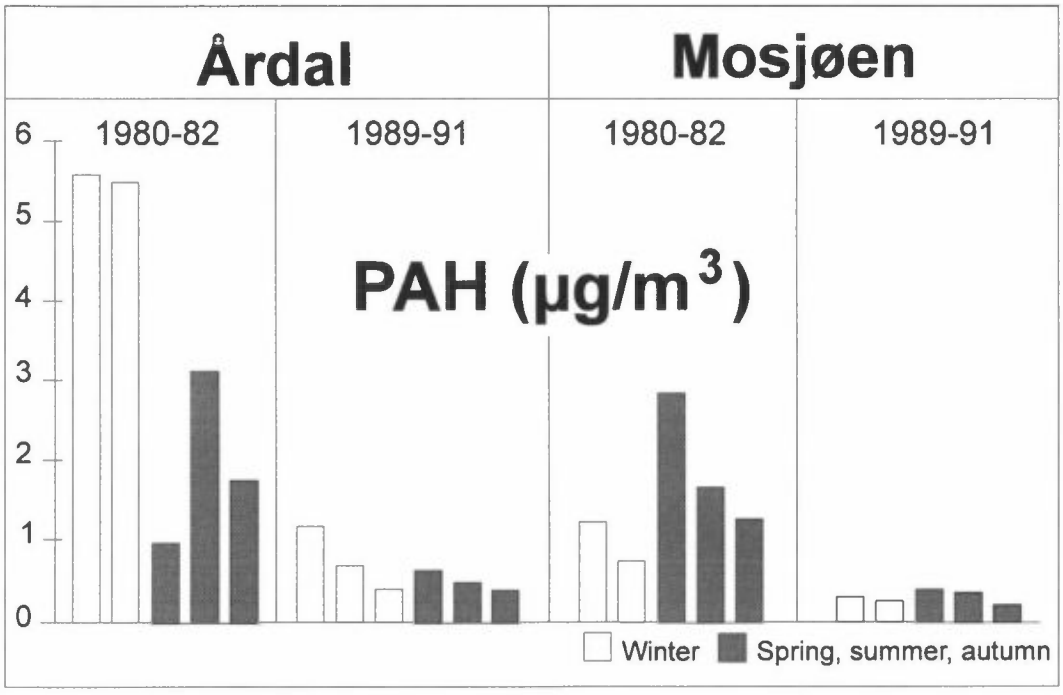


Figure 11: PAH concentrations measured in two out of seven investigated residential areas surrounding aluminium smelters in Norway.

Figure 11 shows the total PAH concentrations in two of the investigated residential areas. The figure clearly demonstrates the significant decrease in total PAH in ambient air from 1980-82 until 1990-91.

The most important single compounds in the air during the winter season 1991 were phenanthrene and fluoranthene. Levels of these compounds are presented in figure 12. Here all 7 sites located in areas with aluminium smelters are presented together with reference data from Oslo and the small town of Lillestrøm. The two compounds selected are higher at all the smelter related residential areas than in Oslo and Lillestrøm. This was not necessarily the case for other PAH compounds (e.g. BaP).

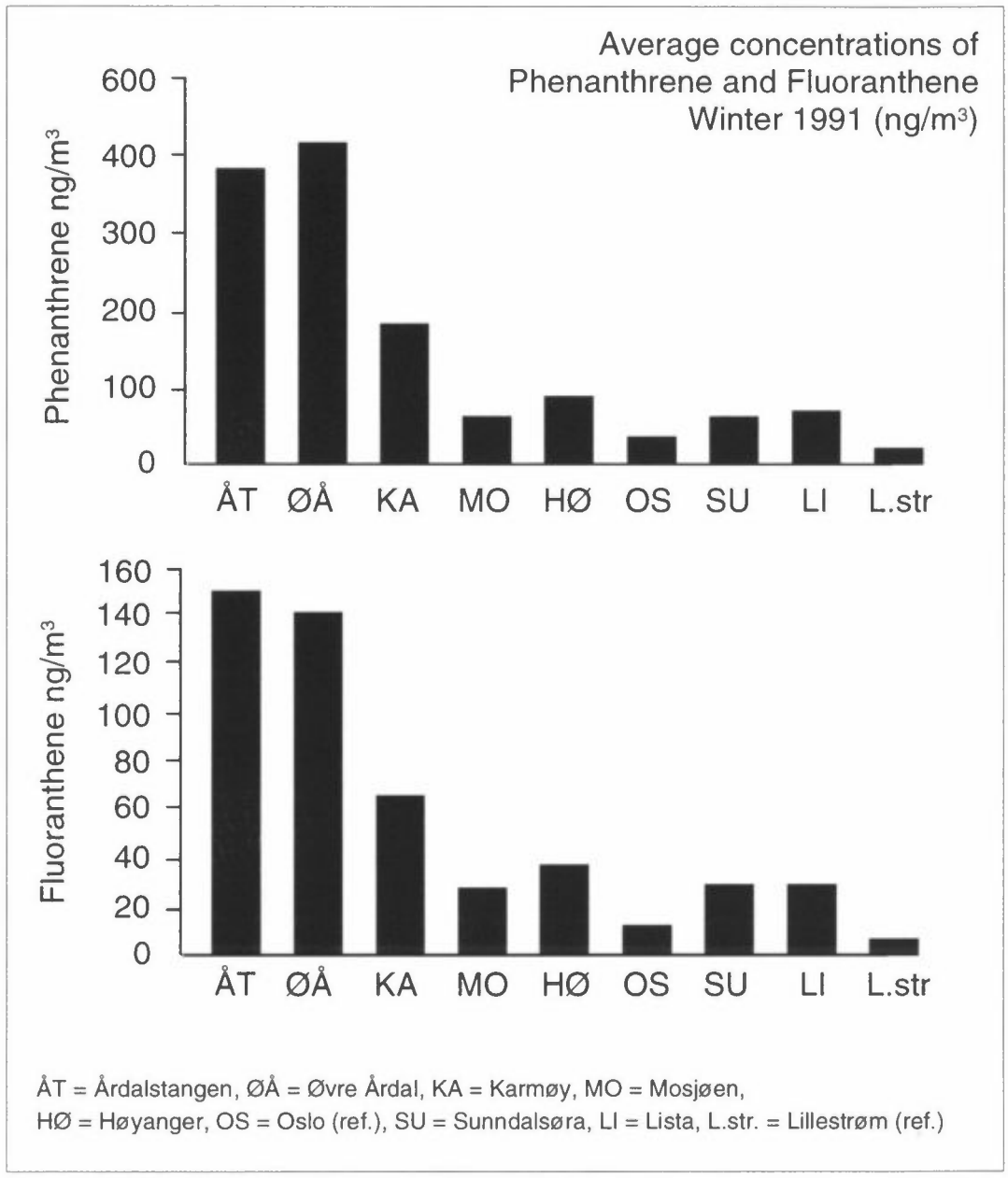
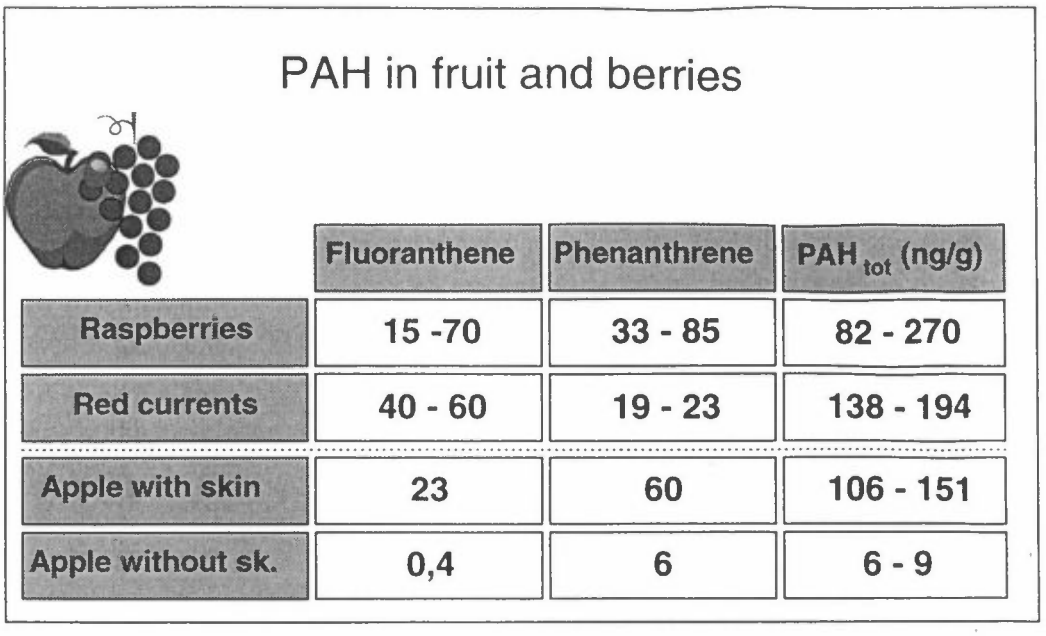


Figure 12: Average concentrations of Phenanthrene and Fluoranthene measured in 7 residential areas at aluminium smelters and in two control areas; Oslo and Lillestrøm during the winter season 1991

In addition to performing analyses in air, samples of berries, fruits and cabbage have also been analysed for about 40 PAHs. Figure 13 presents the levels of fluoranthene, phenanthrene and total PAH in fruit and berries (Mikalsen et al. 1994). It can be seen e.g. that the content of PAHs in apples with skin is much higher than in apples where the shells have been peeled off.

Figure 14 indicate the significant distance dependency of PAHs in lettuce. The sampling sites defined as residential areas have normally been located at distances outside the highest impacted areas i.e. more than about one kilometre away from the smelters.



	Fluoranthene	Phenanthrene	PAH_{tot} (ng/g)
Raspberries	15 -70	33 - 85	82 - 270
Red currents	40 - 60	19 - 23	138 - 194
Apple with skin	23	60	106 - 151
Apple without sk.	0,4	6	6 - 9

Figure 13: Concentrations of PAHs in selected fruits and berries at one of the aluminium smelter sites (Sunndalsøra) in Norway

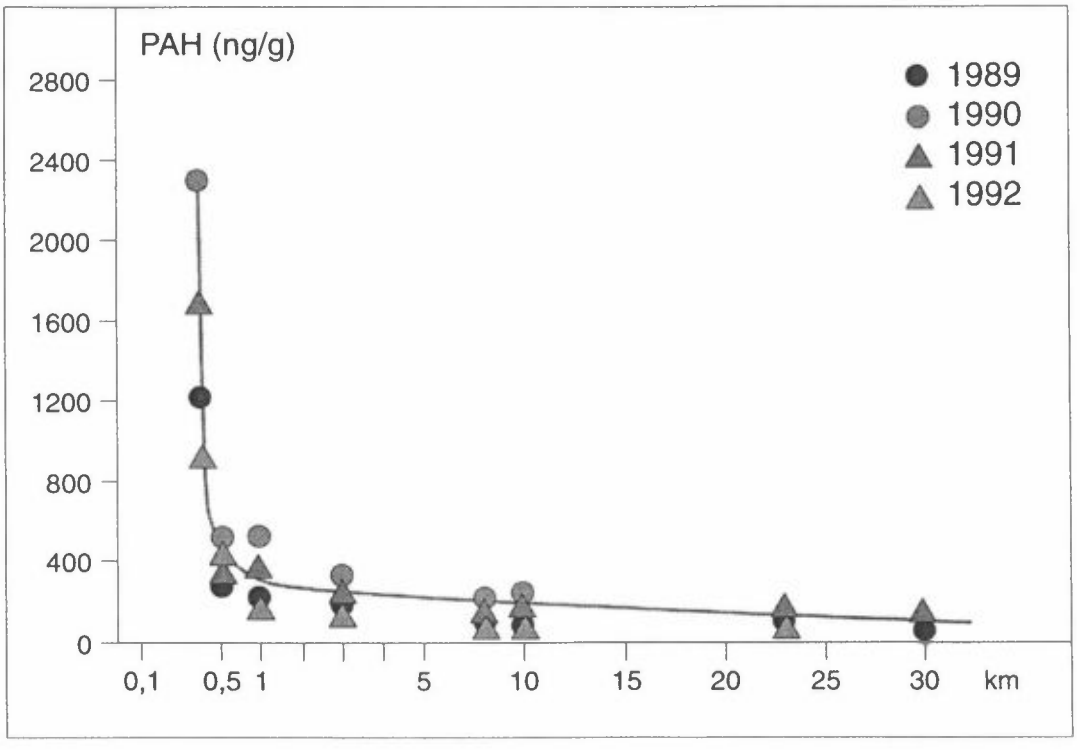


Figure 14: PAH concentrations in lettuce as a function of distance from the aluminium smelter in Sunndalsøra.

PAH concentrations have also been measured in urban areas in Norway. Population exposure to PAHs in Oslo were estimated for 1984/85. (Sivertsen ed. 1986). These exposure estimates were based on inhalation exposure and indicated

that the traffic contributed about 25-30%, space heating by 35-55% while long range transported and background air pollution contributed with about 20 % (see Figure 15).

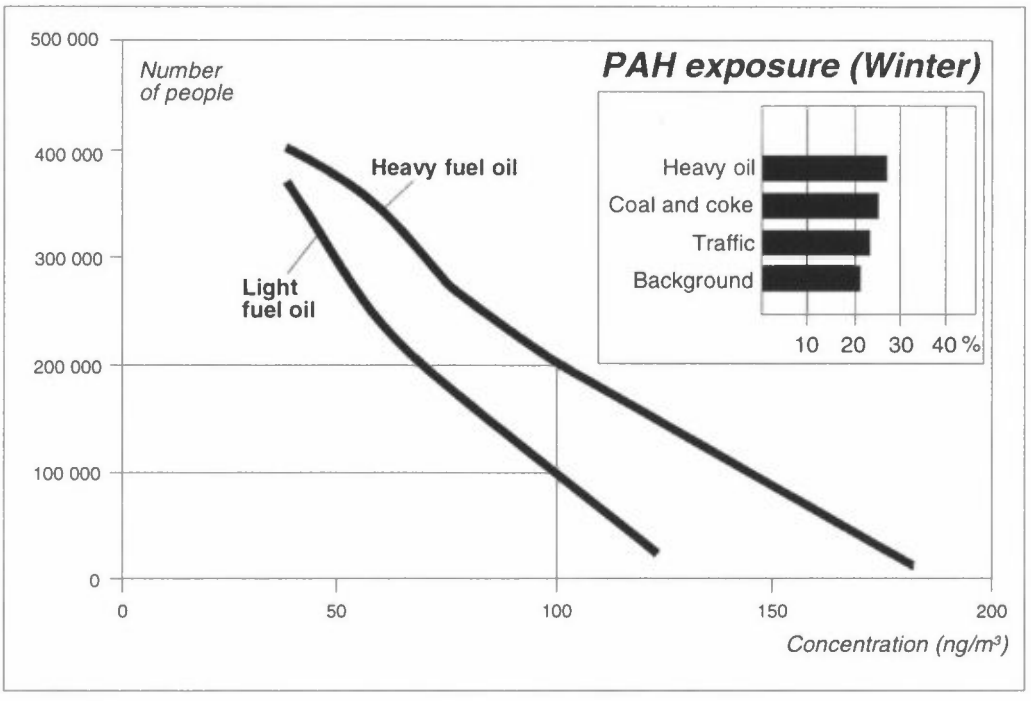


Figure 15: The number of people in Oslo subjected to mean winter half-year PAH concentrations and the relative contributions (in %) from 4 source categories (1984/85).

Assuming that the oil based home heating was based upon the use of heavy fuel oil, about 100 000 people would live in areas with total PAH concentrations in excess of 100 ng/m^3.

5.4 Chlorinated organics in background areas

Persistent chlororganic compounds are transported from industrial areas into the Arctic regions, where some of these compounds are found in high concentrations in air, precipitation and, particularly, in biological samples.

A combination of advanced chemical analyses of samples collected in the Arctic and meteorological trajectory analyses have identified potential source areas as shown in Figure 16.

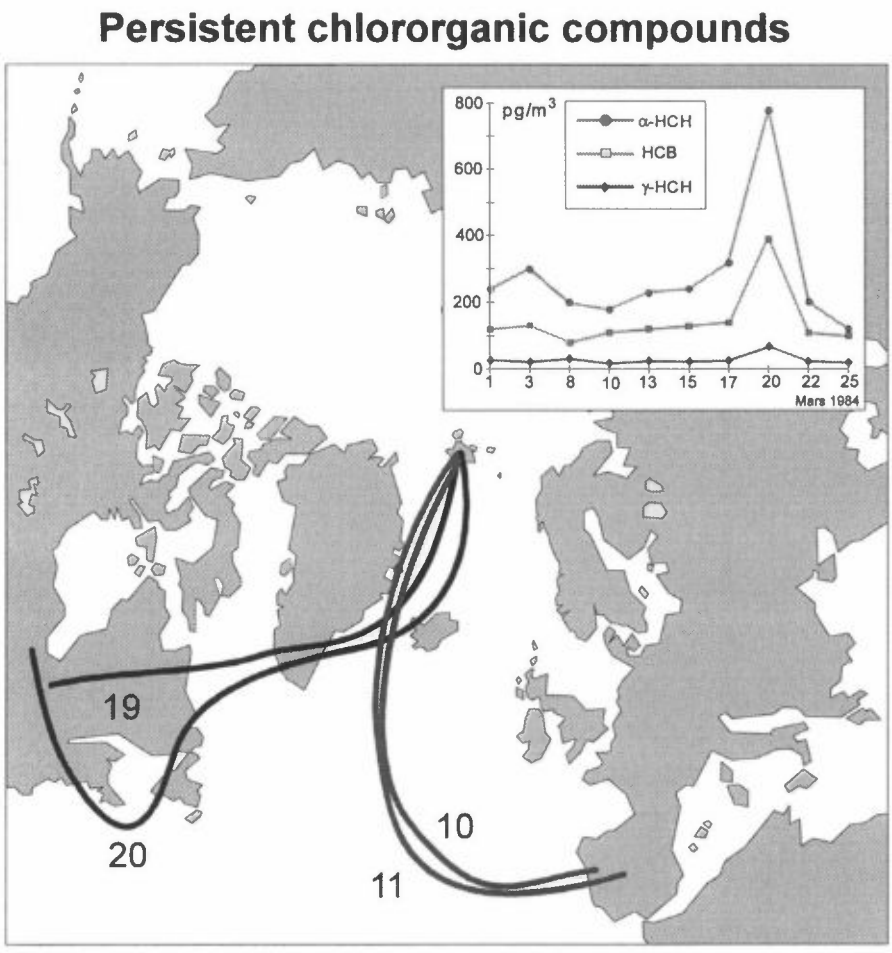


Figure 16: Persistent chlororganic compounds (HCH, HCB) are being transported from industrial source areas into the Arctic.

Measurements of the pesticides Hexachlorocyclohexane (HCH) and Polychlorinated biphinyl (PCB) at four locations in Norway ; Lista (58 deg. 10'N), Kårvatn (62 deg. 30' N), Svanvik (69 deg. 10'N) and NyÅlesund (78 deg. 54' N) show interesting variations as a function of latitude in figure 17 and 18 (Braathen 1994).

The concentrations of alpha-HCH has been reduced since 1984 while the gamma-HCH concentrations have increased. Concentrations of gamma-HCH decrease northwards with distance from the source areas, while alpha-HCH increases northwards. Alpha-HCH might form from chemical reactions in the atmosphere from gamma-HCH.

The PCB concentrations in Southern Norway, close to the main source areas, are about ten times higher than in the northern part of Norway.

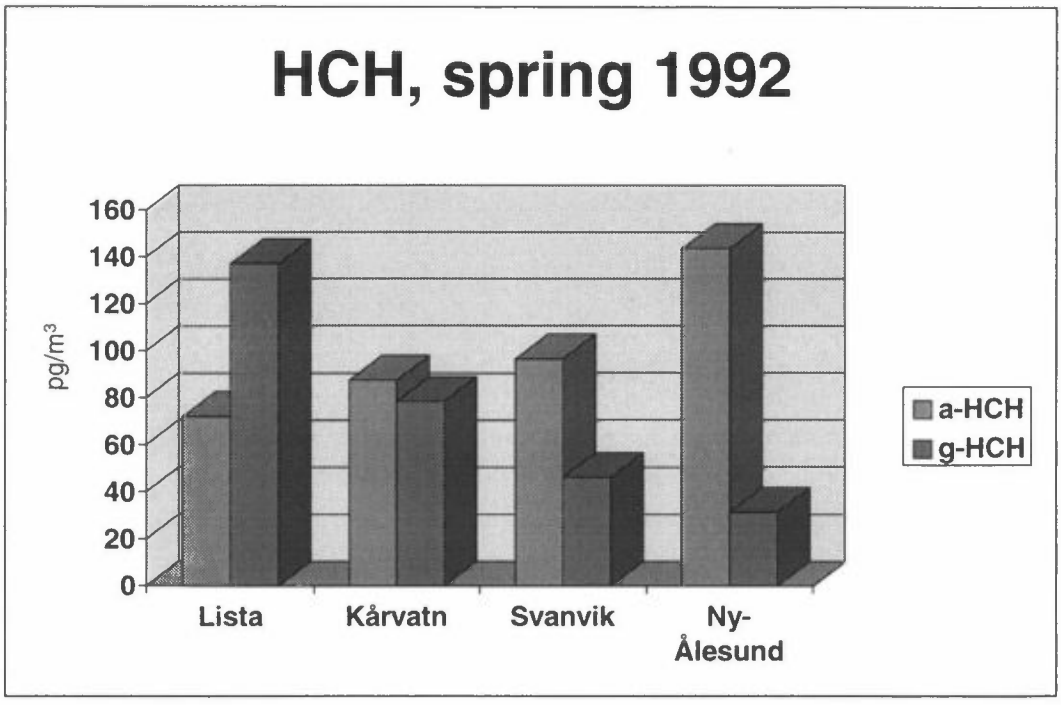


Figure 17: HCHs measured at 4 locations at different latitudes during the spring 1992.

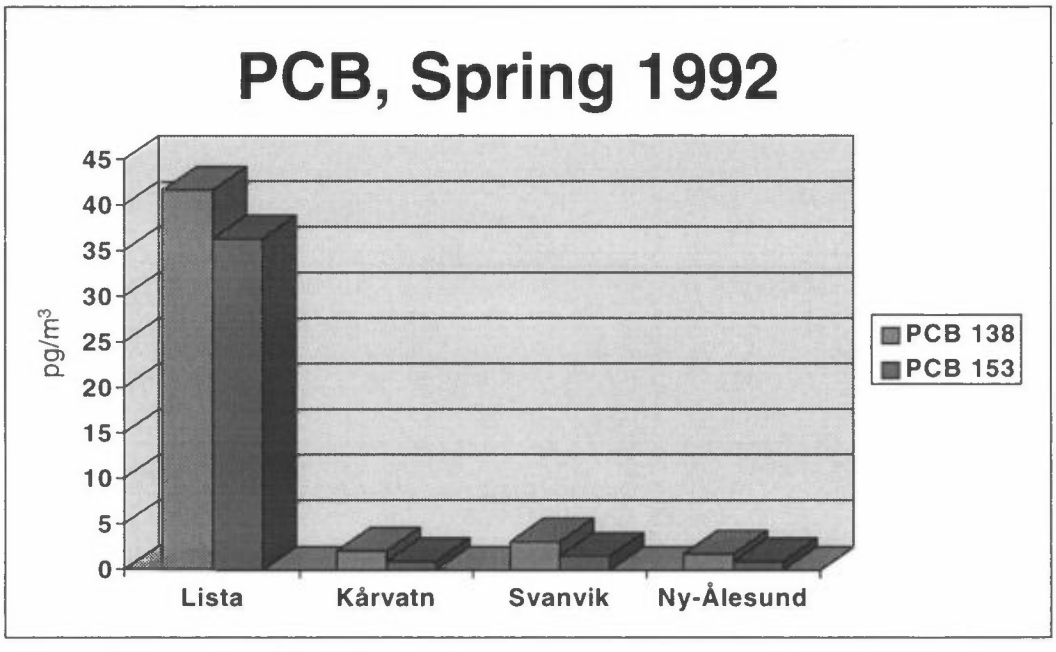


Figure 18: PCB measured at 4 locations at different latitudes during the Spring 1992.

5.5 Dioxin concentrations

All types of persistent organochlorines have been found in biota of the Arctic as shown in ch. 5.4. Studies performed as early as 1991 (Oehme, 1991) showed that

also polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) was present in seal blubber from Spitzbergen.

NILU has developed and established an advanced laboratory for determination of persistent organochlorins, from which the dioxin analyses have been widely known. Concentrations are usually given in toxicity equivalents according to the Nordic model (different from the international only by one factor; PeCDF).

From the investigations undertaken in air one study on emission factors of PCDD and PCDF for road traffic has been presented (Oehme et al. 1991).

During the last years analyses of dioxins have been performed for a number of environmental and biological samples. An example is given in Figure 19.

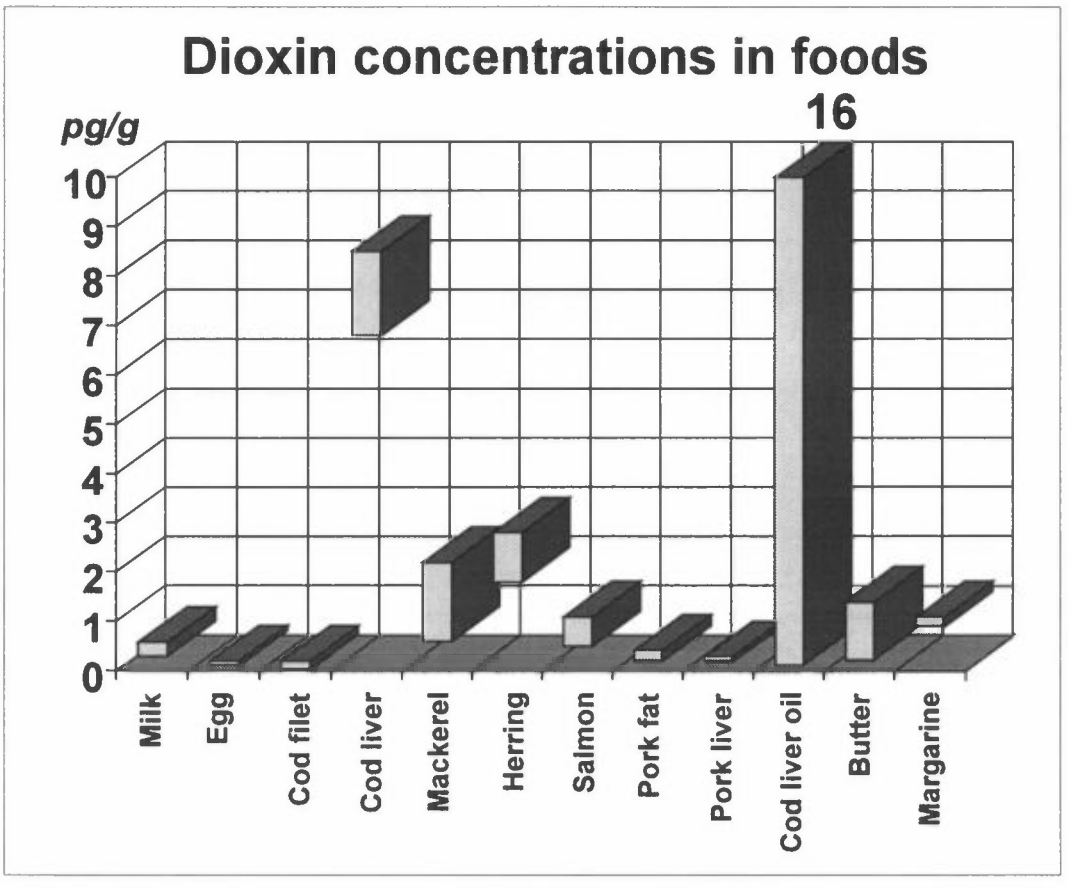


Figure 19: Concentrations of dioxins (pg/g toxicity equivalents) in different food products.

Cod-liver oil show high concentration in the figure. However measures have been taken to reduce this level. More recent analyses show that this has been achieved. Concentrations in crab meat from an industrialized fjord is not included as the concentrations would have exceeded the scale by a factor 2 to 4.

6. Concluding remarks

The hazardous air pollutants comprise a large number of compounds with very different environmental properties, complexity and impact. The present situation and the near future development in Norway has lead to the identification of 32 priority hazardous substances.

The substances are ranked into four groups according to their evaluated environmental consequences in Norway. For each of the compounds all available material on emission sources, environmental fate, occurrence in the environment and measures and aims for reduction of their impact have been discussed (Dons and Beck, 1993).

There are at present no continuous and regular investigations of the environmental levels of these substances. The studies of levels and exposures are mostly of an ad hoc or campaign character. Some investigations are repeated from time to time, but it will not be possible to establish time series or perform any trend analyses.

Most of the evaluation of exposure to man and the environment that have been performed have been based upon model estimates. It will be important also in the future to be able to combine spot samples and random measurements with model estimates.

Aknowledgement

The author wants to thank L.O. Hagen and O-A. Braathen for valuable input to this report.

7. References

Berg, T., Pedersen, U., Steinnes, E. (1994) Environmental indicators for long-range atmospheric transported heavy metals. Lillestrøm (NILU F 8/94).

Braathen, O-A. (1994) Organic air pollutants - challenges for NILU. (presented at NILU September 1994).

Dons, C. and Beck, P.Å.(1993) Miljøgifter i Norge, Oslo, (SFT rapport nr. 93:22).

Hagen, L.O. (1991) Kontrollmålinger av PAH i luft ved aluminiumverk, vinteren 1991. Lillestrøm (NILU OR 42/91).

Hagen, L O (1994) Rutineovervåking av luftforurensning, April 1993- mars 1994 . Kjeller (NILU OR 46/94)

Hagen, L.O., Bartonova, A., Berg, T., Røyset, O. and Vadset, M. (1990) Kartlegging av tungmetaller i luft i tettsteder, 1989-1990. Lillestrøm (NILU OR 18/90)

Mikalsen, A., Hagen, L.O. and Braathen, O.-A. (1994) PAH i nyttevekster. Lillestrøm (NILU TR 4/94).

OECD (1994) Project on Air Quality indicators. Report from the expert meeting 1-3-February 1994 (Techn. note)

Oehme, M. (1991) Dispersion and transport paths of toxic persistent organochlorines to the Arctic- levels and consequences. *The Science of the Total Environment, 106, 43-53.*

Oehme, M., Larssen, S., and Brevik E.M. (1991) Emission factors of PCDD and PCDF for road vehicles obtained by tunnel experiment. *Chemosphere, Vol. 23, p 1699-1708.*

SFT (1987) Miljøgifter i Norge, Oslo, (SFT rapport nr. 79).

Sivertsen, B. (1991) Development of air quality indicators, Background document prepared on behalf of the OECD Environment Directorate for the WHO/OECD workshop on Air Quality Guidelines, Paris 2 5 July 1991 Lillestrøm (NILU OR 37/91).

Sivertsen, B. editor, (1986) Final report MIL-4, The relative contribution of air pollutants fron various sources to man and the environment. Lillestrøm, Nordisk Ministerråd.(Miljørapport 1986:4).

Sivertsen, B., Baklanov, A., Hagen, L.O., and Makarova, T. (1992) Air Pollution in the Border Areas of Norway and Russia. Summary Report 1990-91. Lillestrøm (NILU OR 8/92).

Sivertsen, B., Baklanov, A., Hagen, L.O. and Makarova, T. (1994) Air Pollution in the Border Areas of Norway and Russia. Summary Report April 1991-March 1993. Kjeller (NILU OR 56/94).

Tørseth, K. and Joranger, E (1994) Overvåking av langtransportert forurenset luft og nedbør. Atmosfærisk tilførsel 1992. Lillestrøm (NILU OR 14/94).

Tørseth, K. and Pedersen, U. (1994) Deposition of sulphur and nitrogen components in Norway 1988-1992. Kjeller (NILU OR 16/94).

Thrane, K.E. (1983a) Luftkvalitet i et boligområde på Sunndalsøra. Lillestrøm (NILU OR 1/83)

Thrane, K.E. (1983 b,c,d,e,) Polysykliske aromatiske hydrokarboner i uteluft i boligområder nær aluminiumverk. Lillestrøm (NILU OR 67, 68, 69 og 70/83).

Norsk institutt for luftforskning (NILU)
P.O. Box 100, N-2007 Kjeller - Norway

REPORT SERIES TECHNICAL REPORT	REPORT NO. TR 19/94	ISBN-82-425-0638-8	
DATE 4.1.95	SIGN.	NO. OF PAGES 22	PRICE NOK 45

TITLE The use of air quality indicators in Norway	PROJECT LEADER Bjarne Sivertsen
	NILU PROJECT NO. Q-301
AUTHOR(S) Bjarne Sivertsen	CLASSIFICATION * A
	CONTRACT REF.

REPORT PREPARED FOR:
Norwegian Insitute for Air Research and Norwegian Pollution Control Authority

ABSTRACT
Different air quality indicators have been applied in Norway to report the leves and trends of air pollution to the Norwegian authorities. Measurements of the standard indicators; SO_2, PM_{10} (soot), NO_2, Pb and CO have been measured since 1977. Various selected hazardeous air pollutants have been studied occationally and have been reported as "snap shot" information.

NORWEGIAN TITLE
Lufkvalitetsindikatorer brukt i Norge

Air Quality	Indicators	Hazardeous pollutants

ABSTRACT (in Norwegian)

* *Classification*
- *A Unclassified (can be ordered from NILU)*
- *B Restricted distribution*
- *C Classified (not to be distributed)*