Convention on Long-range
Transboundary Air Pollution

Pilot Programme on Integrated Monitoring
of Air Pollution Effects on Ecosystems

2 ANNUAL SYNOPTIC REPORT 1991

Environment Data Centre
National Board of Waters and the Environment
Helsinki 1991
Convention on Long-Range Transboundary Air Pollution

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Edited by Pirjo Ferin-Westerholm, EDC
Päivi Tahvanainen, EDC

Author Guy Söderman, EDC

Data processing Väinö Malin, EDC
Kim Dahlbo, EDC
Sirpa Kleemola, EDC
Iris Niininen, EDC

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GUIDANCE TO THE READER

The 2nd Annual Synoptic Report (1991) emphasizes the between-site and in-site variability of the main variables measured within the Integrated Monitoring Programme. The report does not go into detailed analysis of correlation between different variables — this will be covered by the Programme Evaluation Report in 1992.

For the reader the following guidelines may be of use:

**Firstly,** the variance of s.c. driving variables are presented. These are variables of local climate and runoff.

**Secondly,** main chemical elements are presented — one in each chapter. In the presentations the monitoring areas are depicted on a map showing their position within the element depositional field. The areas are grouped according to ecozones. For each area an element bar graph is depicted (fig.1). The bar layers from top to bottom represent compartments/subcompartments of the monitored ecosystem. The abbreviations of the used compartments are:

- **AC** Ambient air (neq/m³)
- **DC** Precipitation (peq/l)
- **SF** Stem flow (peq/l)
- **TF** Throughfall (peq/l)
- **SW1** Soil water of the topsoil; 0-10 cm depth (peq/l)
- **SW2** Soil water at 10-20 cm depth (peq/l)
- **SW3** Soil water below 20 cm depth (peq/l)
- **GW** Groundwater (peq/l)
- **RW1** Lake surface water (peq/l)
- **RW2** Lake water at 3 m depth
- **RW3** Lake water at 5 m depth
- **RW4** Lake water at mean depth of lake (peq/l)
- **RW5** Lake water at near-bottom depth (peq/l)
- **RWR** Runoff water (peq/l)
- **NC** Needle/leaf contents (meq/kg)
- **LF** Litter contents (meq/kg)
- **SC1** Contents of organic soil layer (meq/kg)
- **SC2** Contents of mineral soil; 0-10 cm depth (meq/kg)
- **SC3** Contents of mineral soil; 10-20 cm depth (meq/kg)
- **SC4** Contents of mineral soil; deeper than 20 cm (meq/kg)

The top-bottom order implicates roughly the gravitational flow from one compartment to another. The exchangeable storages are presented at the bottom of the graphs. The values of the bars are concentration levels (units are given above). Levels are shown for the annual mean and the minimum and maximum monthly average. Numbers at the end of each bar explain the temporal variation (number of time samples) and the spatial variation (number of observation points/permanent plots). The values refer to the hydrological period November 1989 - October 1990 unless otherwise stated.

If bars are missing no measurements exist (no data have been reported) for this medium; if areas are lacking no measurements exist (no data have been reported) at all.

Some time-series showing the between-year variation are presented if such data have been available for repetitive measurements in excess of three years.

Finally the element budgets (expressed in mg/m² based on the formula DD+WD-RUNOFF) are shown on a map diagram for those areas where calculations can be made. In the budget calculations the input has been corrected for dry deposition using the chloride-correction method (Wright, R.F. & Johannessen, M. 1980. Input-output budgets of major ions at gauged catchments in Norway. Drablos & Tollan [eds.] Ecological impact of acid precipitation. Oslo.) since throughfall measurements are not extensively in use yet. In the case of sulphur and base cations correction for marine sea-salts have also been made (Mapping critical loads. Nordic Council of Ministers 1990. Miljörapport [Environmental report] 1990:14, Nord 1990:98). For hydrogen (pH) proton balances have been calculated if possible.

**Thirdly,** biological variables have been presented as indicators of the forest stands and the understorey vegetation.

The variables for the forest stand refer to characteristics of the dominating tree species. The units are percentages for canopy coverage, discoloration, defoliation and vitality, metres for tree height and stem diameter. The PSI-lichen index has been presented in the 1st Annual Synoptic Report.

The variables for the understorey vegetation refer to the community structure of the permanent plots. The variables are coverage in percentage and frequency of occurrence for different life forms and flora groups and fertility index of the species with the largest area coverage.
CHAPTER 1

Driving variables

Monthly temperature curves (°C), precipitation (mm) and streamflow (l/s•km²) bars are shown for the periods associated with measurements/observations in the areas dealt with in the report. For comparison curves and bars for long-term climate at the closest meteorologic stations are shown (dashed). Observe that these stations may be quite far away and at different altitudes from the monitoring areas so they are not always directly comparable with the local climate. The long-term climatic information, however, indicates the typical climatic regime for the ecoregions in question and are therefore of interest for perennial biologic activity.

Nemoral Region (CS01, CS02, DD01, PI01, PI02, SU11, GB01, GB02)

Temperature curves for the hydrologic period November-October are sinusoidal. The coldest months are normally slightly below 0°C becoming colder towards east. During the observation period the minima in the Czech areas were above 0°C. The vegetation period normally exceeds 8 months. Precipitation lies between 25 and 100 mm/month with the largest amounts in summer and winter. Streamflow is very low and mostly below 5 mm/month in Mlynaruv (CS02) and Anenske (CS01) and in summer their streams tend almost to dry out. Flow is predominantly caused by surficial groundwater output to streams. Data on recent climate at Stechlin (DD01), Gardliczno (PL02), Lekuk (PL01) and Preila (SU11) are missing.

In the western parts the temperature curves are smoother and the monthly averages range between +5 and +15 °C becoming somewhat colder along the northern Atlantic. The vegetation period is quite long, between 7-8 months. Afon Hafren (GB02) is in the shadow of the Welsh mountains and Allt-a-Mharcaidh (GB01) somewhat away from the western Atlantic coast and therefore not very humid.
The European mountains usually experience summer rains with higher summer temperatures and lower winter temperatures than at lower altitudes. The vegetation period is some 6 months. Temperature rise in the mountain areas of Liz Sumava (CS04), Forellenbach (DE01) and Erlentobel (CH01) were reduced in April after which very steep (in excess of 5 degrees) in May. In Erzgebirge at Jezeri (CS03) the thermal rise was smoother. Daily resolution thermographs from Forellenbach and Erlentobel indicate high temperature amplitudes from day to day, even in excess of 10°C. Frost and non-frost day alternation is high particularly during the winter period. High winter rainfalls were experienced in the Bavarian Alps and very high rainfalls in the Swiss Alps. The daily resolution pluviographs of Forellenbach and Erlentobel show the frequent number of heavy rainshowers in the high mountain areas. The reflection by streamflow is not high in Liz Sumava but pronounced in the steep linear-shaped lateral valley drainage of Erlentobel (and probably also in Forellenbach).
DEO1 Forellenbach, temperature

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CH01 Erlentobel, temperature

TEMPERATURE (°C)

CH01 Erlentobel, precipitation

PRECIPITATION 1989/1990 (MM)
The thermal regime is normally somewhat more colder than along the Atlantic coast and in Central Europe, but still with monthly means above 0°C. Between-day amplitudes are seldom very high as exemplified by Birkenes (NO01). The vegetative period is ca 6 months. The precipitation diagrams are bimodal with rain periods in winter/spring and autumn. Streamflows follow the rainfall pattern rather well, with predominant high values during snowmelt and smaller peaks during late autumn rainstorms as shown by daily graphs of precipitation and runoff at Birkenes. During high summer in May - August streams almost dry out with flows below 5mm/month. In Birkenes, an area with shallow soil, the runoff is very nicely mirrored against rainfall.
NO01 Birkenes, temperature

Daily mean temperature - Jan.-Dec. 1990
Daily precipitation - Jan.-Dec. 1990

NO01 Birkenes, precipitation

NO01 Birkenes, runoff
Boreal Region
(NO02, FI01, FI03, SE03, FI04, FI05, SU16)

The temperature curves become much more steeper in this region, normally clearly below 0°C for half the hydrological year. Winter minima are felt in January or February often with monthly temperatures below -15°C. The beginning of 1990 was however much milder and wetter as normal. The curves of Valkeakotinen (FI01), Hietajärvi (FI03), Pesosjärvi (FI04) and Vuoskojärvi (FI05) also display cold spells in March whereas summer and autumn temperatures were very close to long-term average ones. The vegetation period is normally 6 months in the southernmost areas but shortens to 4 close to the subarctic forest line.

Kårvatn (NO02) on the Norwegian coast is very humid with rainfalls exceeding 100mm/month with the exception of the summer period. Flow in Kårvatn is accentuated in snowfree periods. Notable is the extremely high flow in the summer months caused by springwells bringing down water from the late melting snow and ice of the Caledonian mountains. This steady pumping flow is also discernable in the daily flowgraph. The autumn in both Finnish and Swedish areas were slightly drier than normal. Flows are concentrated to snowmelt in spring, usually defined to April-May in the Southern Boreal and to May-June in the Middle and Northern Boreal. Flow is restricted to surficial groundwater output during most of the hydrological period. Streams can dry out (or come to stand still) during long periods in the summer and autumn. In Hietajärvi the flow is much steadier due to the proportionally high extent of peatbog areas.
Annual mean temperatures in Alentejo (PT01) exceeds +10°C and the vegetation period lasts throughout the year. The area is characterized by winterrains, which were very high in November-December 1989. Contrary, severe drought lasted for 3 months in June-August 1990. In Komlosi (HU01) both the thermal and rainfall regime resembled that of Central Europe in 1988/89. The daily resolution graphs from Komlosi also show that whereas air temperature fluctuates rather much, soil temperatures (in sand) are quite different. Surface soil temperatures are more constant in winter but show high between-day variation in summer. With depth the thermographs smoothen and frost does not play a role at depths below 50 cm from surface. Temperature regimes significant for different biological activity (leaf development, herbal growth and nutrient uptake by roots) thus vary quite much. Rainfall at Komlosi are scattered between days with distinct shower occasions. Runoff is here subterranean with seepage to groundwater. Despite the occasional showers during the summertime the groundwater level steadily lowered throughout the observation period insinuating that most of the rainfall was consumed by plants or evaporated.
1989/90
- - 1971-80 Clino 08562

1988/89
- - 1931-60 Buda/Kescz.

HU01 Komlosi, temperature 1988 XI-1989 X

Temperature (°C)

Months
HU01 Komlosi, precipitation 1988 XI - 1989 X

HU01 Komlosi, water level in the central well 1989
Montaneous East (SU03, SU05)

The Caucasian BR (SU03) on the southern slopes of Caucasus experiences a much milder and wetter climate than the Juga Massif (SU05) on the north side. Rainfall in the Caucasian BR is associated with the winter, in Juga with summer.

(Great Lakes - St. Lawrence) Nearctic Nemoral (CA01)

The long-term climatic regime of Turkey Lakes (CA01) resembles thermally the Southern Boreal region but rainfalls are frequently between 50-100 mm/month. The number of rainy days is high as displayed by the pluviograph. Streamflow is bimodal with peaks late in the calendar year (November-December) and during high summer (June-July).
CA01 Turkey Lakes, precipitation

TLW Precipitation

CA01 Turkey Lakes, stream discharge

TLW Stream Discharge
CHAPTER 2

Sulphur

2.1 Fields of deposition

The main source of sulphur is in the anthropogene emissions from burning fossil fuel and from sulphic ore smelters. Close to the sea the natural source is sea-spray which might constitute a considerable part of the deposition along the coasts. Sea-spray sulphur is neutralized and does not take part in the acidification process but passes through the ecosystem. Hence corrections for sea-salts are commonly done in processing budgets for the element. The monitoring network covers rather well different depositional regimes of sulphur. Lack in coverage is specially felt in northern Italy and Spain and north of the Black Sea, where regional high deposition occur.

Field of deposition of $S$ ($g/m^2/a$) in 1988 acc to EMEP [CCC 4190].

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2.2 Short-term temporal variation

Nemoral Region (CS01, CS02, DD01, PL01, PL02, SU11, GB01, GB02)

The central nemoral areas are subject to high deposition of sulphur. Levels in precipitation range from 100 to more than 250 µeqv/l/month. Ambient air concentrations are also high as displayed by the Anenske (CS01) area. AC is sum of SO₂S (g) and SO₂S (part.). Atlantic rains bring sea-salts rich in sulphur to the coastal areas. Sulphur levels in the runoff of the Czech areas are much higher than in rainfall, ranging from 500 to more than 1500 µeqv/l/month. Runoff concentrations vary much more than concentrations in wet deposition. The highest levels are normally reached during summer when flow is at smallest and evaporation increases concentrations of streamwater.

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Montane Central (CS03, CS04, DE01, CH01)

Sulphur concentrations in rainfall in the mountains are lower than in areas north of them. The highest levels are found in Erzgebirge, at Jezeri (CS03), where the intra-annual variation is at largest. Levels on the Czech side of the Bavarian mountains are higher than on the German side. Data from Forellenbach (DE01) indicate that levels are higher in throughfall, soilwater and groundwater than in precipitation. Sulphur concentrations increase thus by an enrichment factor of 2 on passage through canopy and by 2.5 after passage through soil to groundwater. Mean annual concentrations in runoff water of Liz Sumava (CS04) and Erlentobel (CH01) are quite the same, but the intra-annual variation in the Swiss Alps are very high; once again probably due to alternations of high and low flow.
Mean annual monthly levels in rainfall are very alike, ca 60 μeq/l/month, except for Valday (SU15) where values are twice as high. The monthly variation is largest in Gårdsjön (SE04) implying much transboundary fluxes from Central Europe. Levels rise in throughfall by an enrichment factor of 2 in Birkenes (NO01) but with as much as 3.5 in Gårdsjön and Valday. In Birkenes levels increase on passage through soil to groundwater and runoff water, in which the enrichment factor is already 5 (> 400 μeq/l/month). In Gårdsjön the levels are high in the topsoil, and in mineral soil they grow with depth but somewhat decrease in groundwater and runoff water. In Berg (SE02) groundwater levels are also lower than mineral soil water levels but increase much in the runoff, occasionally by an enrichment factor of 10 in comparison to rainfall during spring snowmelt. In Valday concentrations of the groundwater is at highest (max > 1200 μeq/l/month).
In the southern parts the precipitation levels are low and in the middle and northern parts they are even lower but with higher maxima. Throughfall concentrates by an enrichment factor of 1.5...2. Measurements of stemflow during summer months indicate high enrichment factors; in the southern parts by 10 (> 400 μeqv/l/month) in the northernmost, eg. in Vuoskojärvi (F105) by 100. The higher levels are caused by evaporation of water and inclusion of dry deposited particles concentrating the remaining canopy throughfall and downflow along stems. For epicortical organisms, in particular lichens, the consequent stemflow of summerrains poses a considerable acidic shock which might disturb their uptake of nutrients from humid air and hence become deformed and lose vitality. Contrary to conditions in formerly mentioned ecoregions, the sulphur levels decrease with the passage through soil and only slightly increase with depth in lakes and runoff water. Even in Kårvatn (NO02) throughfall levels exceed precipitation levels which are similar to topsoil water levels. With increasing depth in soil through the passage to groundwater and runoff water the levels are again rising.
Forest Steppe - Submediterranean Ecotone [PT01, HU01]

In Alentejo (PT01) the sulphur levels of the lake surface water are lower than in Central Europe and of the magnitude to be found in southern Finland. In Komlosi (HU01), with high annual evaporation, the enrichment factors of throughfall and stemflow are very considerable (100 to 700). Stemflow of pines shows concentrations between 2000 and 7000 μaqv/l/month which exceeds any living conditions for epiphytic organisms.
Montane East (SU03, SU05)  
Precipitation values range between 200–2000 µeq/l/month. In Juga Massif (SU05) the throughfall enrichment factor is ca. 2. Runoff water concentrations are slightly higher than those of precipitation and groundwater concentrations are rather low.

Nearctic Nemoral (CA01)  
Sulphur levels of precipitation and runoff resemble highly those in the Southern Boreal region in Europe.

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2.3 Long-term temporal variation

In this section, time series of monthly fluxes of sulphate sulphur expressed as meq/(m^2•month) are shown for the IM areas Hietajärvi (FI03), Kårvatn (NO02) and Berg (SE02). N.B. Not corrected for sea-salts.

![Graphs showing meq/m^2•month for F103 SO4S, NO02 SO4S, and SE02 SO4S](image)
2.4 Mass balances
Mass balance calculations for the periods 1988/89 and 1989/90 show that anthropogenic sulphur accumulates in the eastern part of Europe but is predominantly leached in the Hemiboreal and Nemoral Regions. According to earlier investigations (Hauhs et al., 1989) retention has been correlated with younger glacial soils and leaching with genetically older soil types outside the range of glacial transformation. The presented picture does not fully agree with this statement. Notable is that in those areas where leaching occur, the concentration levels grow with passage to groundwater and runoff, whereas in accumulating areas in the Boreal Region levels drop in soil due to neutralization by humic topsoil. As seen from table 1 the C/S ratio of the topsoil is very high in the northernmost areas, between 200 ... 400, and extreme in Velikiy (SU16), > 2500.

In the figure on the left, the output of sulphate sulphur is plotted versus the bulk/wet input, expressed as mg/(m² • a). There is a substantially higher output than input, which can be attributed to dry deposition, if internal processes involving sulphate and resulting in net leaching are considered negligible. In the figure on the right the dry deposition is estimated by the chloride correction method. Some of the difference is eliminated, but it is still obvious that the dry deposition originating from e.g. SO₂ is not well covered by the chloride correction method. The outflux from the Birkenes area (NOO 1) in 1989-90 was over two times higher than of any other area for the years of which data for sulphate I/O calculations are available in the IM data base.
Canada $SO_\text{g}$ 1988-89, scale unit 100 mg/m$^2\cdot$a

$SO_\text{g}$ 1989-90, scale unit 1000 mg/m$^2\cdot$a
CHAPTER 3
Nitrogen oxides

3.1 Fields of deposition

The main anthropogenic source is the combustion of fossil fuels in traffic and in energy plants. Thunder flashes and NOx by plant respiration are natural sources, but not in the order of emissions from combustion in highly populated areas.

The monitoring network covers quite nicely the different depositional regimes, with perhaps the exception of northern Italy.

Field of deposition of NO$_3$N (mg/m$^2$) in 1988 acc to EMEP (CCC 4190).
3.2 Short-term temporal variation

Nemoral Region [CS01, CS02, DD01, PL01, PL02, SU11, GB01, GB02]

Wet deposition values range between 50 - 75 µeq/l/month in all areas. Runoff concentrations in Anenske (CS01) are very high, above 600 µeq/l/month and temporally even 2500 µeq/l/month. In comparison, at Mlynaruv (CS02) runoff levels are between 10 - 130 µeq/l/month. In areas of United Kingdom the nitrate runoff levels are very low. High concentration values in needles at Lekuk (PL01) probably reflects high uptake since the topsoil also show high levels. The area has a rich alder growth promoting fixation of nitrogen.
Montane Central [CS03, CS04, DE01, CH01]

The area of Jezeri [CS03] in the Czech Ore Mountains is quite out of range compared to other areas. Measurements indicate precipitation peaks > 250 μeqv/l/month and correspondingly high runoff concentrations. Temporal precipitation peaks, although much lower, are also recorded at Erlentobel [CH01], while precipitation values are low at Forellenbach [DE01]. In Forellenbach throughfall data show an enrichment factor of 2 if compared with precipitation. Topsoil water concentrations exceed those of groundwater here, and the mineral topsoil itself has high concentrations (spatial average ca 400 meqv/kg).
Boreonemoral Ecotone (NO01, SE01, SE02, SE04, SU02, SU04, SU15)

Precipitation values range between 10 - 80 $\mu$eqv/l/month with a slight decline towards north. Some temporal peak values up to 200 $\mu$eqv/l/month are recorded at Valday (SU15). Throughfall concentration levels exceed precipitation levels at least at Gårdsjön (SE04) and Valday, whereas they are close to another at Birkenes (NO01). Normally, in areas of glacial till and superficial bedrock, runoff concentrations exceed groundwater concentrations which in turn exceed soil water concentrations as shown in Birkenes. In Valday percolation of nitrate to groundwater is high. Topsoil concentrations are also quite high, ca 400 meqv/kg.
Boreal Region [NO02, FI01, FI03, SE03, FI04, FI05, SU16]

Uptake by biota is high as emphasized by needle concentrations and availability by topsoil concentrations in Valkeakotinen [FI01] and Pesosjärvi [FI04]. Nitrogen becomes a limiting factor more to the north as seen by Vuoskojärvi [FI05]. In the west, at Kårvatn [NO02], nitrogen nitrate levels are almost the same for every measured media. In Finland annual mean levels rise passing from precipitation to throughfall to stemflow. In Valkeakotinen the monthly variation show temporal concentration peaks in throughfall, stemflow and runoff water during the growing season. In Vuoskojärvi peaks in precipitation indicate long-range transports.
Forest Steppe - Submediterranean Ecotone (PT01, HU01)

In Alentejo (PT01) lake surface concentrations are higher than in the Boreal region, but lower than in the Boreonemoral. In Komlosi (HU01) enrichment takes place from precipitation to throughfall to stemflow. The stemflow enrichment factor is 1.5 in comparison to throughfall. Temporal peaks up to 650 μeqv/l/month in stemflow clearly promotes algal growth upon stems (which causes the bright green colour of the local poplar trunks). The permeable soil at Komlosi promotes seepage to (deep) groundwater.

Montane East (SU03, SU05)

Precipitation concentrations are low, at maximum ca 60 μeqv/l/month. Throughfall concentrations does not differ much from these. Nitrate concentrations are low in the groundwater and slightly rise in runoff water.

Nearctic Nemoral (CA01)

Precipitation levels at Turkey Lakes (CA01) resemble those of Boreonemoral/Southern Boreal European regions. They are lower than along the Atlantic east-coast and in the central orobiomes and much lower than the levels recorded in the European Nemoral region.
3.3 Long-term temporal variation

In this section, time series of monthly fluxes of nitrate nitrogen expressed as meq/(m²•month) are shown for the IM areas Hietajärvi (FI03), Kårvatn (NO02) and Berg (SE02).

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In the figure above the output of nitrate nitrogen is plotted versus the sum of inputs of nitrate nitrogen and ammonium nitrogen, expressed as mg/(m²•a). The strong nitrogen retention at low loads is loosened with increasing load. The area NO02, Kårvatn, which received the lowest load (1989-90) is an interesting anomaly in this framework possibly due to nitrogen fixing vegetation. Area GB02, Afon Hafren, with an output of a little over 1000 mg/(m²•a), owes its high leaching to tree-felling operations. Again is the Birkenes area in the extreme regarding leaching (cf. the corresponding sulphur figure in section 2.4).

The C/N ratio of the topsoil is shown in table 1. According to the figures high - moderate biological activity, C/N < 27, would only be found in Komlosi (HU01), Forellenbach (DE01) and Berg (SE02 in 1982) whereas other areas have low biological activity to being biologically inactive, C/N > 27. These values are however not too indicative and must be verified by microbiologic monitoring (which has been started in some areas already).

3.4 Mass balances

Nitrogen nitrate displays retention almost throughout Europe (and Canada). Only in two areas leaching is found, in Afon Hafren (GB02) where it is caused by loss in uptake of the biomass due to tree-felling (Alan Jenkins, oral communication) and in Kårvatn (NO02) where probably some of the nitrate loss may be associated with alder grooves of the area. The relative retention (and N-volatilization) ranges in in the Nemoral Region and in the oceanic part of Boreonemoral Ecotone between 70 - 90 % but in the Boreal Region and more continental Boreonemoral Ecotone it is > 95%.
\( \text{NO}_3^N \ 1989-90, \text{ scale unit } 100 \text{ mg/m}^2\cdot\text{a} \)
CHAPTER 4

Nitrogen ammonia

4.1 Fields of deposition

Most emissions stems from evaporation of excrements of husbandry; also application by N-fertilizers might increase ammonia levels. The area coverage is not especially good since the most effected area in the Netherlands (poorly shown by the map) is not covered by the network.

Field of deposition of NH₄N (mg/m²) in 1988 acc to EMEP (CCC 4190).

Field of deposition of NH₄N (mg/m²) in 1988 acc to EMEP (CCC 4190).
4.2 Short-term temporal variation

Nemoral Region (CS01, CS02, DD01, PL01, PL02, SU11, GB02)

Concentrations in both ambient air and precipitation are high in the eastern parts, e.g., levels exceed 200 ueq l/ month in Mlynaruv (CS02) and Preila (SU11). Proportionally high runoff concentrations are also noted for Anenske (CS01) and lake surface water levels in the alder-rich Lekuk Lake area (PL01). The Polish areas also indicate the enrichment with lake depth and depletion of oxygen.
Montaneous Central [CS03, CS04, DE01, CH01]

Annual mean levels in precipitation in the mountains of Czech and Slovak Federal Republic do not differ much from lowland values, but the temporal peaks are higher, > 300 μeq/l/month for Liz Sumava (CS04) and > 800 μeq/l/month for Jezeri (CS03). Data from Forellenbach (DE01) indicates enrichment with a factor of 1.5 ... 2 from precipitation to throughfall. Contamination of soil water (max > 150 μeq/l/month) and groundwater is evident for this area.
Boreonemoral Ecotone (NO01, SE01, SE02, SE04, SU02, SU04, SU15)

Levels in precipitation might be lower or higher than throughfall levels. The geographic picture indicates a decline towards north and east. Flow concentrations vary depending on soil type: in Berg (SE02) there are relatively high runoff water concentrations, in Tiveden (SE01) there are relatively high groundwater concentrations. In Soviet temporal peaks in precipitation are recorded, up to 250 μeq/l/month in Berezina (SU02) and up to 300 μeq/l/month in Valday (SU15). In Valday the enrichment factor for throughfall is close to 4, and temporal peaks during the growing season are discernable in both groundwater and runoff water.
Boreal Region (NO02, FI01, SE03, FI04, FI05)

The concentrations become much lower in this region, in particular in the west at Kårvatn (NO02). The lakes of the Finnish areas indicate enrichment of ammonia levels with depth as in the Polish lakes of the Central Nemoral. Concentrations in throughfall might be higher or lower than in rainfall. Stemflow concentrations are normally high and show large variations, probably due to contamination from internal sources (insects, bird droppings etc.). Towards north the concentrations of ammonia become quite insignificant-only temporal peaks like in ambient air at Pesosjärvi (FI04) and in rainfall at Vuosjärvi (FI05) stand out.
Forest Steppe - Submediterranean Ecotone (PTO1,HU01)

The concentrations in surface water in Alentejo (PTO1) are low. Quite low concentrations of air and rainfall are recorded in Komlosi (HU01) but the enrichment in throughfall and stemflow is extreme due to high evaporation [factors by >500 and >1000...5000].
Montane East (SU03, SU05)

The concentrations are quite insignificant but for rainfall and throughfall in the areas of Caucasus BR (SU03) and Juga Massif (SU05).

Nearctic Nemoral (CA01)

The levels are most similar to those of the nemoral areas of United Kingdom and Tiveden (SE01) in the Boreonemoral ecotone.
4.3 Long-term temporal variation

In this section, time series of monthly fluxes of nitrogen ammonium expressed as meqV/(m²•month) are shown for the IM areas Hietajärvi (FI03), Kårvatn (NO02) and Berg (SE02).

**FI03 NH4N**

**NO02 NH4N**

**SE02 NH4N**
4.4 Mass balances

Net retention/nitrification of nitrogen ammonia occurs in all monitored areas. The relative retention is normally 99-100% of the deposition. Only in areas with a large lake percentage the relative retention figures are somewhat lower 95-97%.

$NH_4N\ 1988-89$, unit scale $100\ mg/m^2\cdot a$
NH$_4$N 1988-89, scale unit 100 mg/m$^2$•a

NH$_4$N 1989-90, scale unit 100 mg/m$^2$•a
CHAPTER 5
Hydrogen/pH

5.1 Fields of deposition

High deposition areas are associated with southernmost Scandinavia and the mountains of Central Europe. With the exception of northern Italy, the network has a quite sufficient coverage.

Field of deposition of $H^+(\text{meq/m}^2)$ in 1988 acc to EMEP [CCC 4190].
5.2 Short-term temporal variation

Nemoral Region [CS01, CS02, DD01, PL01, PL02, SU11, GB01, GB02]

The acidity of precipitation ranges between pH 4 and pH 5, except for Anenske (CS01) where lower temporal values are recorded, and Afon Hafren (GB02) and Preila (SU11) where higher temporal values are recorded. Values of lakes samples and runoff samples are much higher, > pH 7; even > pH 8 in the Polish areas. Commonly the surface waters are well beyond the critical level of pH 5.8 for hydrobiological activity and diversity, with the exception of occasional drops below this level in Afon Hafren (GB02) and Allt-a-Mharcaidh (GB01). In Stechlin (DD01) and Gardliczno (PL02) the pH is 3.5 ... 4 in organic and mineral topsoil but increases with depth to 4.5 ... 5.5.
Montaneous Central (CS03, CS04, DE01, CH01)

The acidity of precipitation ranges between pH 4 and pH 5, but may temporarily rise as high as pH 7 under the influence of alkaline dust/fog interception at Liz Sumava (CS04). At Jezeri (CS03), one of the most polluted areas in Europe, pH in precipitation is below 4. Recordings in Forellenbach (DE01) indicate a gradual increase of acidity from rainfall to throughfall to soil water. pH values of groundwater and runoff water is > 6, except in Jezeri where it is constantly below the biological critical level. pH (water) values of the mineral topsoil in Forellenbach is 3.5-4 and increase with depth, but not exceeding 5.

**CS03 pH**

- AC: 0 0
- DC: 01 11 8811 8910
- TF: 0 0
- SF: 0 0
- SW: 0 0
- GW: 0 0
- RWR: 01 11 8811 8910
- NC: 0 0
- LF: 0 0
- SC: 0 0

**CS04 pH**

- AC: 0 0
- DC: 01 11 8811 8910
- TF: 0 0
- SF: 0 0
- SW: 0 0
- GW: 0 0
- RWR: 01 11 8811 8910
- NC: 0 0
- LF: 0 0
- SC: 0 0
Even in this region pH values of the precipitation range between 4 and 5. The values grow towards east (Soviet areas). Recordings show a decline of pH after passing the canopies and in soil water, except in Valday (SU15), which is influenced by calcareous soil. The pH level again rises in groundwater and runoff water but does not reach above the critical pH 5.8-level in Birkenes (NO01), Gårdsjön (SE04), Berg (SE02), nor in Tveden (SE01). Only in Valday pH-levels are higher. Here the organic topsoil layer is less acid than the underlying mineral soil layers to a depth of some 20 cm.
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Boreal Region (NO02, FI01, FI03, SE03, FI04, FI05, SU16)

In the western part of this region pH of precipitation is about 5, in eastern and northern parts between 4 ... 4.5. Passing the canopies it (stand precipitation) becomes either more acid as in Kärvatn (NO02) and Vuoskojärvi (FI05), or less acid as in Hietajärvi (FI03) and Pesosjärvi (FI04). In the lastmentioned eastern Finnish areas the influence of alkaline dust (dry deposition) from adjacent regions in Soviet neutralizes water by passage. Increasing acidity is recorded in stemflow in this region where pH-values range between 3.5 ... 4. Acidic shocks to trunk epiphytes must be quite common, even during summer months. In Vuoskojärvi (FI05) pine stemflow values as low as pH < 3 have been recorded. Soil water and surface water pH-values are higher than those of precipitation. Soil water pH (water) is normally between 5 ... 6, running water pH-values from between 6 ... 7 in the western parts, to < 5 in some interior parts (e.g. Valkeakotinen, FI01) and increase to 6 ... 7.5 for some northern areas. In the soil column pH-values increase with depth (except on the Velikiy Island, SU16). At their minimum, in the organic topsoil layer, they are slightly < 4 (Valkeakotinen, Pesosjärvi) or slightly > 4 (Hietajärvi, Vuoskojärvi).
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Forest Steppe - Submediterranean Ecotone (P01, HU01)

The surface waters in Alentejo (PT01) are alkaline (pH 8) due to the calcareous regolith. In Komlosi (HU01) the pH of the precipitation is ca 6 and become more acid upon passing the canopies and along stems, but does not drop below 4. The soils are very alkaline (pH 7.5 ... 8) due to inclusion of calcareous loess.
Montane East (SU03,SU05)

The pH of precipitation in the Caucasian chain of mountains is between 5 and 6. Groundwaters and runoff waters in these areas show pH-values between 6 and 7.

Nearctic Nemoral (CA01)

The pH-characteristics of precipitation, groundwater and runoff water in Turkey Lakes (CA01) resemble those of the European Nemoral.
5.3 Long-term temporal variation

In this section, time series of monthly fluxes of protons expressed as meqv/(m²•month) are shown for the IM areas Hietajärvi (FI03), Kårvatn (NO02) and Berg (SE02).

**FI03 H**

- **megv/m²•month**
- **output**
- **input**

**NO02 H**

- **megv/m²•month**
- **output**
- **input**

**SE02 H**

- **megv/m²•month**
- **output**
- **input**

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5.4 Proton budgets

Proton budgets can be calculated by studying in- and outfluxes of ionic species. There now exists sufficient data from some of the areas contained in the IM database to perform such calculations. Even a coarse estimation of the proton budget requires input/output data of 7-10 species. The procedure used here is based on the annual influx and outflux of protons, NH$_4$N, N03N, SO$_4$5, alkalinity, Ca, Mg, K and Na. The method is conceptually the same as that used by Kallio and Kauppi (1990) (Ion budgets of small forested basins. Kauppi, P. et al (ed.) Acidification in Finland. Springer-Verlag). However, no attempt were made to correct for dry deposition, which in Kallio and Kauppi (1990) is achieved by using a sulphur deposition model, and estimates based on throughfall measurements. Here, the use of the chloride correction for dry deposition estimates is hindered by the fact that for some of the areas in which proton budget calculation otherwise is feasible, the influx of chloride was larger than the outflux, for the hydrological year studied.

A proton budget calculation based on only input/output analysis leaves the contribution of internal processes - weathering, ion exchange and possible retention, biological accumulation (and NH$_4$/NO$_3$-dynamics in the case of nitrogen) - visible only as a net source or sink. Still even such a simplified analysis can give us valuable information on the variability in magnitude of the proton budget and ionic components of importance between different areas. The figures underneath can be seen as exemplifying this. Obvious sources of error are the facts that dry deposition is ignored, no estimation of the effect of organic anions or aluminium has been carried out, and that a period of only one hydrological year was studied.
CHAPTER 6
Calcium

6.1 Fields of deposition

The main source of calcium is in the sea-spray or in dust-blows from arid areas (influence of Sahara in the south). The network covers the areas with the lowest deposition, not those influenced by long-range transport and high deposition.

6.2 Short-term temporal variation

Nemoral Region
[CS01, CS02, DD01, PL01, PL02, GB01, GB02]

The concentrations in rainfall are mostly insignificant, except for the areas of Anenske (CS01) and Stechlin (DD01) where the influence of dust particles from coal-burning is evident. The levels in runoff and surface water of lakes are much higher as displayed by the Czech and Polish areas. Very high values are also found in the topsoil in the Polish areas and in the needles of Lekuk (PL01).

Field of deposition of Ca (mg/m²) in 1988 acc to EMEP (CCC 4190).
Montaneous Central (CS03, CS04, DE01, CH01)

Precipitation values are insignificant, except for the Jезери (CS03) area influenced by Ca-rich coal-burning. Runoff values are high, reaching 200 ... > 800 μequiv/l/month in the Czech areas, and even above 2500 μequiv/l/month in Erlentobel (CH01) where the calcareous flysch affects the output. In Forollenbach (DE01) the levels in the groundwater may in some month exceed 1500 μequiv/l.
Boreonemoral Ecotone (NO01,SE01,SE02,SE04,SU02,SU04,SU15)

Precipitation levels are very low. The enrichment in throughfall implies factors of 6 ... 10. With the exception of Birkenes (NO01) and Valday (SU15) throughfall levels exceed soil water levels. The groundwater concentrations are higher or equal to the soil water concentrations. Runoff water concentrations may be higher (SE02, SU15), similar (NO01, SE04) or lower (SE01) than the groundwater concentrations. In Valday groundwater concentration maxima may reach 2500 µeq/l/month. The organic topsoil also show higher levels than do lower minerogenic soil-horizons, which also affect the pH-values.
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Boreal Region (NO02, F101, F103, SE03, F104, F105, SU16)

As a rule levels in precipitation are lower than in throughfall which again are lower than in stemflow. The concentrations increase in the soilwater and runoff water. The northernmost areas (SE03, F104, F105) show some discrepancies.
Forest Steppe - Submediterranean Ecotone [PT01,HU01]

The lake surface concentrations in Alentejo (PT01) are high and influenced by inflow of solubles from the calcareous regolith. In Komlosi (HU01) enrichment proceeds from precipitation to throughfall to stemflow. In the latter, temporal values up to 2000 μeq/L/month are recorded.

Montaneous East [SU03,SU05]

The precipitation concentrations in the Caucasus are relatively high. In the Juga Massif runoff water temporarily show concentrations in excess of 600 μeq/L/month.
### HU01 Ca

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Nearctic Nemoral (CA01)

The most notable feature in the Turkey Lakes area (CA01) is the high calcium variation in groundwater.

6.3 Long-term temporal variation

In this section, time series of monthly fluxes of calcium expressed as meq/(m²•month) are shown for the IM areas Hietajärvi (FI03), Kårvatn (NO02) and Berg (SE02). N.B. Not corrected for sea-salts.
Following table contains available information on cation exchange capacity and base saturation in soils.

Soil chemistry
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level 0 = PODZ_OH, PODZ_OFH
* includes also PODZ_OH, PODZ_OFH, PODL_O, PODZ_01
6.4 Mass balances

Calcium is leached from all monitored areas. The amounts vary a lot, being highest in limestone rich areas and smallest in petrological regimes of acid rocks. Extreme leaching is displayed by the Erlentobel catchment (CHO1) where the two consecutive periods indicate a leaching rate of 5.5 - 6 kg/ha/yr.

Calcium (together with magnesium) plays an important role in the buffering capacity of the soil. Some base saturation (BASA) and cation exchange capacity (CEC) values are listed in table 1. It may be seen that the base saturation is very low in Forellenbach (DE01) compared with other areas. The saturation is also lowered in the Polish areas and in Velikiy (SU16) close to the Kola peninsula. The highest base saturation and cation exchange capacity is found in the Valday catchment (SU15) on Cretaceous limestone.

Ca 1988-89, scale unit 100 mg/m²•a
Ca 1988-1989, scale unit 100 mg/m²•a

Ca 1989-90, scale unit 500 mg/m²•a
CHAPTER 7
Sodium

7.1 Fields of deposition
The main source of sodium is in sea-spray. The network coverage is rather good, provided that monitoring can be started in the north Atlantic islands too.

7.2 Short-Term temporal variation
Nemoral Region
[CS01,CS02,DD01,PL01,PL02,GB01,GB02]

Precipitation concentrations are low and runoff water concentrations high (some possibly anthropogenically influenced by road-salts) in the central areas; towards west, in United Kingdom, the sodium concentrations in precipitation increase with the influence of sea-salt spray. Gardliczno (PL02) show high concentrations in the topsoil.

Field of deposition of Na [mg/m²] in 1988 acc to EMEP (CCC 4190).

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Montaneous Central [CS03,CS04,DE01,CH01]

Concentrations in precipitation are low compared to those in runoff and groundwater, implying internal ecosystem sources.
Boreonemoral Ecotone (NO01, SE01, SE02, SE04, SU02, SU04, SU15)

The concentrations in precipitation are highest close to the Atlantic coast (NO01) and decrease towards north and east. In Birkenes (NO01) concentrations are high also in throughfall and in the soilwater. The concentrations decrease passing through the ecosystem, except for in Berg (SE02) where they rise in the soil water.
Annual Synoptic Report 1991
Annual Synoptic Report 1991
Boreal Region (NO02, FI01, FI03, SE03, FI04, FI05, SU16)

The concentrations in precipitation and throughfall are highest close to the Atlantic coast (NO01) and decline towards east and north. They grow again closer to the Arctic Sea as shown by Vuoskajärvi (FI05) and Velikiy (SU16). Concentrations in soil water exceed those of runoff water in all areas except for Hietajärvi (FI03) and Reivo (SE03). The soil concentrations are quite insignificant.
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Annual Synoptic Report 1991
Forest Steppe - Submediterranean Ecotone (PT01, HU01)

High concentrations predominate in lake surface water of Alentejo (PT01) and in precipitation, throughfall and stemflow of Komlosi (HU01).

Montane East (SU03, SU05)

Relatively high concentrations are recorded in the precipitation and throughfall of the Caucasian areas. Enrichment takes place towards groundwater and runoff water.
Nearctic Nemoral [CA01]

The Turkey Lakes [CA01] area show the lowermost concentrations of all areas encountered.
7.3 Long-term temporal variation

In this section, time series of monthly fluxes of natrium expressed as meq/m²·month are shown for the IM areas Hietajärvi (F103), Kårvatn (NO02) and Berg (SE02).

![Graphs of monthly fluxes for F103 and NO02 natrium fluxes.](image)
7.4 Mass balances

Sodium shows either retention or loss. Retention is associated with areas close to marine coasts and therefore associated with sea-salts. Leaching takes place in more continental areas as a result of weathering of the regolith. The leached amount is probably correlated with the relative percentage of Na-rich minerals in soil.

$\text{Na 1988-89, scale unit 100 mg/m}^2\text{•a}$
Na 1988-89, scale unit 100 mg/m²•a

Na 1989-90, scale unit 100 mg/m²•a
CHAPTER 8

Potassium

8.1 Fields of deposition

The main source is in the sea-spray and long-range dust from the African continent. The network mostly covers the low deposition class areas.

8.2 Short-term temporal variation

Nemoral Region

(CS01,CS02,DD01,PL01,PL02,GB01,GB02)

Precipitation concentrations are low (but with high variation in Mlynaruv) whereas runoff concentrations are much higher (except for areas in United Kingdom). Concentrations in the argillitic topsoils of the Polish areas are also high, and needles in Stechlin (DD01) and Gareliczno (PL02) also show high values.

Field of deposition of K (mg/m²) in 1988 acc to EMEP (CCC 4190).
Montaneous Central (CS03,CS04,DE01,CH01)

The concentrations in precipitation is usually low, although exceeding 25 μeq/l/month in Czech areas. Runoff concentrations are much higher. Recordings in Forellenbach indicates leaching from canopies (high throughfall values).
Boreonemoral Ecotone (NO01, SE01, SE02, SE04, SU02, SU04, SU15)

In this region precipitation values are also low, but not considerably higher in soil water, groundwater and runoff water. The enrichment factor for throughfall ranges between 7 and 12. Exceptional is Valday (SU15) where potassium concentrations enrich by a factor close to 100 in throughfall.
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Boreal Region (NO02, FI01, FI03, SE03, FI04, FI05, SU16)

Concentrations in precipitation, soil water, runoff water and groundwater are low, most lowest in the west (NO02). The throughfall enrichment factor is ca. 10, the stemflow enrichment factor, on the other hand, might exceed 100...200. Soil water concentrations are highest in Valkeakotinen (FI01), Hietajärvi (FI03) and Velikyi (SU16).
### Forest Steppe - Submediterranean Ecotone (PT01, HU01)

Concentrations grow from precipitation to throughfall and stemflow in Komlosi (HU01). The stemflow concentrations show a very high variation.

### Montaneous East [SU03, SU05]

The concentrations in rainfall do not very much differ from those in groundwater and runoff water. The throughfall enrichment factor is ca 10.
AC  0  0
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SF  01 06 9004 9009
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GW  0  0
RW  0  0
NC  0  0
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SC03 01 01 8801 8801
SC04 01 01 8801 8801

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SW  0  0
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RW  0  0
NC  0  0
LF  0  0
SC  0  0

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TF  01 13 8911 9010
SF  0  0
SW  0  0
GW  01 08 9000 9010
RWR 01 13 8911 9010
NC  0  0
LF  0  0
SC  0  0
Nearctic Nemoral (CA01)

The Turkey Lakes area (CA01) does not stand out very different from the deciduous wood areas in Europe.

8.3 Long-term temporal variation

In this section, time series of monthly fluxes of potassium expressed as meq/m²/month are shown for the IM areas Hietajärvi (FI03), Kårvatn (NO02) and Berg (SE02). N.B. Not corrected for sea-salts.
8.4 Mass balances

Potassium balances show both leaching and retention. To what extent leaching is correlated to the soil chemistry or type of foliage is not yet known.
K 1988-89, scale unit 10 mg/m²•a
K 1989-90, scale unit 10 mg/m²•a
CHAPTER 9

Magnesium

9.1 Fields of deposition

Sea-spray is the most important source. Few high deposition areas are covered by the network.

9.2 Short-term temporal variation

Nemoral Region

Precipitation values are low but runoff water concentrations are high in some of the Czech and Polish areas. In the west at Afon Hafren (GB02) precipitation values show a higher variation and the runoff values are lower.

Field of deposition of Mg [mg/m²] in 1988 acc to EMEP [CCC 4190].
Annual Synoptic Report 1991
Montaneous Central [CS03, CS04, DE01, CH01]

Jezeri (CS03) has outstanding high values although not very different from the nemoral areas. Recordings in Forellenbach (DE01) show enrichment with gravitational flow.
Boreonemoral Ecotone (NOO1, SE01, SE02, SE04, SU02, SU04, SU15)

In the areas of this region enrichment of the element concentrations takes place with gravitational flow. In Birkenes (NO01) and Tiveden (SE01) the enrichment factors are however very small.
Boreal Region [NO02,FI01,FI03,SE03,FI04,FI05,SU16]

The enrichment of concentrations differs slightly from the above mentioned region. Maximum concentrations are found in very different media: in soil water (Kårvatn; Valkeakotinen, at 10-20 cm depth; Velikiy, at 0-10 cm depth), in runoff water (Pesosjärvi, influenced by dolomitic regolith) and in stemflow (Hietajärvi and Vuoskojärvi).
Forest Steppe - Submediterranean Ecotone [PT01, HU01]

High concentration in lake surface water are found in Alentejo [PT01]. In Komlosi [HU01] enrichment occurs with passing of canopy [maximum 1200 μeqv/l/month in stemflow].
Montane East [SU03,SU05]  

In Caucasus BR (SU03) notable is the high variation in the concentrations of precipitation. In the Juga Massif [SU05] enrichment towards groundwater and runoff water is evident.

Nearctic Nemoral [CA01]

The highest concentrations are found in the groundwaters of Turkey Lakes [CA01].
9.3 Long-term temporal variation

In this section, time series of monthly fluxes of magnesium expressed as m eqv/(m²•month) are shown for the IM areas Hietajärvi (FI03), Kärvatn (NO02) and Berg (SE02). N.B. Not corrected for sea-salts.
9.4 Mass balances

Magnesium predominantly show leaching except for some oceanic areas influenced by sea-salt deposition. The largest net losses are associated with limestone/dolomitic areas.

Mg 1988-89, scale unit 100 mg/m²•a
Mg 1988-89, scale unit 100 mg/m²•a

Mg 1989-90, scale unit 100 mg/m²•a
CHAPTER 10
Chloride

10.1 Fields of deposition

The source of this conservative element is in the sea-spray. As poorly reactive salt-bindings it normally passes quite fast through the ecosystem and is often used as a tracer and mass budget balancer (sc. Cl-corrections when output/input ratio is greater than 1).

10.2 Short-term temporal variation

Nemoral Region
[C01, CS02, DDO1, PL01, SU11, GB01, GB02]

Distance from sea causes low concentrations in precipitation, whereas runoff water concentrations are higher in some areas - observe e.g. Anenske (CS01) with maximum > 800 μeq/l/month - due to internal sources. More towards the coast chloride concentrations in precipitation, reflecting sea-spray, increase and exceed those of runoff waters. In Afon Hafren (GB02) precipitation concentrations already exceeds 700 μeq/l/month temporarily.

Field of deposition of Cl (mg/m²) in 1988 acc to EMEP (CCC 4190).
Montaneous Central [CS03,CS04,DE01,CH01]

In the mountains the concentrations in precipitation are lower than in soil water, groundwater and runoff water, in the latter with maxima in Jezeri [CS03], > 150 µequiv/l/month. In Forellenbach the enrichment factor for throughfall is approximately 2.5.
Boreonemoral Ecotone (NOO1, SE01, SE02, SE04, SU02, SU04, SU15)

In continental areas concentrations in precipitation stay below those in soil water, groundwater and runoff water. Closer to the coast precipitation concentrations increase, like in Birkenes (NOO1) and, quite astonishingly also in Valday (SU15). The enrichment factor for throughfall varies: being ca 1.5 at Birkenes and Valday but already 4 at Gårdsjön (SE04). In Tiveden (SE01) soil water concentrations are very high, probably due to leaching of marine Yoldia-sediments.
Concentrations in soil water commonly exceed those of running water and precipitation, except within the sphere of influence of the Arctic Sea (Velikiy, SU16). Throughfall enrichment factors range between 2 and 4 and stemflow enrichments from 5 to 35. Extreme enrichment factors (> 5000) are displayed by data from the Velikiy Island (SU16).
Forest Steppe - Submediterranean Ecotone (PT01, HU01)
Chloride contents of lake surface waters in Alentejo (PT01) is high. In Komlosi (HU01) throughfall enrichment has a factor of 1.5 and stemflow a factor of 3...3.5.

Montaneous East [SU03, SU05]
Low concentrations characterize the Juga Massif area (SU05). The throughfall enrichment factor is ca 4.

Nearctic Nemoral (CA01)
All concentration values are very low indicating high continentality.
10.3 Long-term temporal variation

In this section, time series of monthly fluxes of chloride expressed as meqv/(m²·month) are shown for the IM areas Hietajärvi (Fi03), Kårvatn (No02) and Berg (Se02).

**Fi03 Cl**

![Graph of meqv/m²·month for Fi03 Cl from 1987 Dec to 1990 Dec]

**No02 Cl**

![Graph of meqv/m²·month for No02 Cl from 1987 Dec to 1990 Dec]

**Se02 Cl**

![Graph of meqv/m²·month for Se02 Cl from 1983 Dec to 1990 Dec]
10.4  Mass balances

As a mobile anion chloride should (at least not in a longer perspective) show retentions or losses. For most areas the output > input (measured as bulk deposition) and the difference is accounted for as dry deposition. In some areas the input (measured as bulk deposition) > output which makes balance calculations more complicated. Such areas are influenced by sea-salt transport from adjacent seas of high salinity, eg. Kårvatn (NO02) and Afon Hafren (GB02) close to the Atlantic. The Soviet areas (SU05, SU15) also show higher inputs than outputs, which probably is due to artificial reasons. The list below gives some O/I ratios:

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CI1988-89, scale unit 500 mg/m²a
Cl 1988-89, scale unit 100 mg/m²•a

Cl 1989-90, scale unit 500 mg/m²•a
CHAPTER 11
Aluminium

Most aluminium is found in soil dust. The depositional fields of the element are not known for Europe.

11.1 Short-term temporal variation

Very few aluminium measurements have been made yet and most refer to total aluminium in waters. Aluminium concentrations in precipitation has in several studies shown to be almost insignificant, often below analytical detection.

Nemoral Region [CS02,GB01,GB02]

In Mlynaruve (CS02) and Allt-a-Mharcaidh (GB01) runoff water concentrations are below 10 μeq/l/month, in the latter area the labile fraction is almost 100%. In Afon Hafren runoff concentrations range between 5-30 μeq/l/month of which the labile portion is only 33%.
Montaneous Central (CS03, CS04, DE01, CH01)

Runoff concentrations range between 5-37 μeq/vl/month except for Jezeri (CS03) where the range is 20-65. In Forellenbach (DE01) soilwater concentrations are close to 50 and groundwater concentrations between 0-8 μeq/vl/month.

Current: 00
Dilution: 00
Flow: 00

SW01: 02 01 9010 9010
GW: 03 05 9111 9007
RW: 00
NC: 00
LF: 00
SC: 00

Montaneous Central (CS03, CS04, DE01, CH01)

Runoff concentrations range between 5-37 μeq/vl/month except for Jezeri (CS03) where the range is 20-65. In Forellenbach (DE01) soilwater concentrations are close to 50 and groundwater concentrations between 0-8 μeq/vl/month.

Current: 00
Dilution: 00
Flow: 00

SW: 00
GW: 00
RWR: 01 11 8811 8910
NC: 00
LF: 00
SC: 00

Montaneous Central (CS03, CS04, DE01, CH01)

Runoff concentrations range between 5-37 μeq/vl/month except for Jezeri (CS03) where the range is 20-65. In Forellenbach (DE01) soilwater concentrations are close to 50 and groundwater concentrations between 0-8 μeq/vl/month.

Current: 00
Dilution: 00
Flow: 00

SW01: 02 01 9010 9010
GW: 03 05 9111 9007
RW: 00
NC: 00
LF: 00
SC: 00

Annual Synoptic Report 1991
Boreonemoral Ecotone [NO01, SE01, SE02, SE04]

In Birkenes the range is 17-33 µeqv/l/month nearly all of which is represented by the labile fraction. In the Swedish areas soil water, groundwater and runoff water concentrations are commonly > 50 µeqv/l/month (in Reivo only ca 3 µeqv/l/month). Maximum values range between 150-300 µeqv/l/month in deeper (> 20 cm) soil water. Fractioning at Gårdsjön implies that the labile component of groundwater is some 50% and of runoff water some 40%.
Annual Synoptic Report 1991
Concentrations in runoff water are often low, not exceeding 25 µeq/l/month. Soil water concentrations in Hietajärvi (FI03) are higher, between 15-33, and in Velikiy (SU16) they exceed 100 µeq/l/month. Here also the values of groundwater are about 50 µeq/l/month.

No data exist on aluminium measurements.
Nearctic Nemoral [CA01]

Runoff water concentrations in Turkey Lakes [CA01] range between 5-20 μeq/l/month.

11.2 Long-term temporal variation [Al$_{tot}$]

In this section, time series of monthly fluxes of aluminium expressed as μeq/(m$^2$·month) are shown for the IM area Hietajärvi [FI03].

11.3 Mass balances

Aluminium leaches from every area where measured. The highest losses are calculated for areas with the most acidic deposition in southernmost Scandinavia.
Al 1988-89, scale unit 10 mg/m²·a

Al 1989-90, scale unit 10 mg/m²·a
CHAPTER 12

Tree stands

12.1 State and effect variables

Nemoral Region

So far only records from Poland is available. The dominating tree in Gardliczno (PL02) is Scot's pine and in Lekuk (PL01) oak. The pines of Gardliczno show both high defoliation and discoloration.
Montane Central

Only data from Forellenbach (DE01) is available where the dominating tree species is beech, however with a very varying coverage in different parts of the drainage. The defoliation ranges between 20-40% and the discoloration between 10-20%. On the average 10% of the trees are dead. In Jezeri (CS03) considerable forest-die back occurs, although no data is available.

Boreonemoral Ecotone

Norwegian spruce dominates in the monitoring areas of Birkenes (NO01), Berg (SE02) and Tiveden (SE01). Defoliation is highest at Berg and lowest at Birkenes. In Berg some 30% of the stand is dead. The lichen index, PSI (cf. Bråkenhielm in ASR 1, 1990) is also low at Berg.
Boreal Region

Dominating species are either Norwegian spruce (FI01, SE03) or Scot's pine (NO02, FI03, FI04, except in FI05 - where Betula pubescens tortuosa has a wider areal coverage). Defoliation is highest in Pesosjärvi (50%), but the stand is still vital and the PSI is very high, > 250. The highest discoloration is found in Reivo (SE03) where the portion of dead trees are higher. PSI-values are high in the north, in particular along the Finnish/Carelian border but drop towards the Arctic (FI05, SU16).

Forest Steppe - Submediterranean Ecotone

No data exist.
Annual Synoptic Report 1991
Nemoral and Montaneous East

Few data exist. In Karadag (SU17) on the Crimean peninsula the vitality of Pinus palustris is very low and in the Juga Massif of Caucasus (SU05) Abies nordmanniana has a relatively low vitality and a low PSI-value (35).
12.2 Long-term variation

Two time-series of changes in defoliation are presented. The available data are too scarce for making any conclusions.

![Graph of defoliation % for NO01 Picea abies](image1)

![Graph of defoliation % for SE01 Picea abies](image2)
CHAPTER 13
Understorey vegetation

13.1 State and effect variables

Data is still sparse, mainly from Norden.

Nemoral Region

No data exist.

Montane Central

Data has been collected only for Forellenbach [DE01]

where mosses have the largest coverage but also a high patchiness. The lichen coverage is insignificant. Herbaceous plants dominate over shrubs and dwarf-shrubs. The herbs also have a high fertility. Shrub species are few but frequent.

Boreonemoral Ecotone

Data exist only for Berg (SE02) and Tiveden (SE01). In both areas mosses predominate the coverage. Lichens are few and insignificant in coverage. The

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graminaceous coverage are quite similar for both areas. Shrubs and dwarf-shrubs dominate the plant coverage in Tiveden and the dominating species is also very frequent. In Berg the frequency of the dominating grass exceeds the frequency of the dominating dwarf-shrub.

Boreal Region

Data is available for the Finnish areas and for Reivo (SE03). Except for Valkeakotinen (FI01) mosses have a larger coverage than higher plants. The lichen coverage is insignificant except for Vuoskajärvi (F05). Most plants are shrubs or dwarf-shrubs and the dominating species also have a high frequency (not in Pesosjärvi, FI04). The grass-coverage is usually low, in some areas mainly comprising 1-2 species which however are frequent. The highest fertility values are recorded in Hietajärvi (FI03), otherwise they are very low.

Montane East

Herbaceous species dominates over grass; the grass-species are however frequent.
13.2 Long-term variation

Some time-series are shown for three Swedish areas. Both declining trends as sudden changes can be seen. As to what extent these are objective/subjective must be determined by later detailed evaluation.
Coverage % of vascular plants

Coverage % of shrubs

Coverage % of shrubs

Annual Synoptic Report 1991
Coverage % of graminaceous species

Coverage % of mosses

Coverage % of mosses
Siting of areas

IM - National Focal Centres

**Austria**, Federal Environmental Agency
**Canada**, Canada Centre for Inland Waters, Ontario
**Czech and Slovak Federal Republic**, Geological Survey, Praha
**Denmark**, Environmental Research Institute, Copenhagen
**Finland**, Environment Data Centre, Helsinki
**Germany**; Umweltbundesamt, Pilotstation, Frankfurt
**Hungary**, Water Resource Research Institute, Budapest
**Iceland**; Agricultural Research Institute, Reykjavik
**Netherlands**, Institute for Public Health and Env. Protection, Bilthoven
**Norway**, Air Research Institute, Lillestrøm
**Poland**, Environmental Protection Institute, Warszawa
**Portugal**, Dir. Geral da Qualidade do Ambiente, Lisboa
**Soviet Union**, Institute of Global Climate and Ecology, Moscow
**Sweden**, Environmental Protection Agency, Uppsala
**Switzerland**, Federal Institute for Forest, Snow and Landscape Research
**United Kingdom**, Institute of Hydrology, Oxon
**United States**, Environment Protection Agency, N Carolina
### Monitoring and Data Reporting

#### Initial Phase (Meas.)
- Meteorology
- Deposition
- Runoff
- Water Chemistry
- Air Chemistry
- Throughfall
- Stemflow
- Soil Water
- Groundwater
- Soil Chemistry
- Forest Stands
- Trees
- Understory Vegetation
- Epiphytes
- Litterfall
- Foliage Chemistry
- Moss Chemistry
- Nutrient Uptake

#### Basic Phase (Meas.)
- Vegetation Survey
- Soil Survey
- Plant Survey
- Geochemical Survey

#### Basic Phase (Surveys)
- Hydrobiology
- Lake Chemistry
- Decomposition
- Bird Census
- Bark Chemistry
- Immersion in Aquatic Org.
- Immersion in Terrestrial Org.
- Sediments

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*O* = started  
*•* = reported  
*—* = not possible
## Characteristics of areas in this report

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