Chapter 5

Base cations

Authors: Gun Lövblad, Leonor Tarrason and Kjetil Tørseth
Contributions from: National Assessments

5.1 Base cations and their role to counteract acidification

Base cations are defined as the most prevalent, exchangeable and weak acid cations in the soil. Base cations include ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}) potassium (K^{+}) and sodium (Na^{+}). These ions, except for Na^{+}, are nutrients for forest ecosystems and vegetation and are thus of importance for the sustainability of ecosystem. The base cations occur in air in the particulate phase. In precipitation, base cations are to a large part dissolved and occur as ions. A part of the base cations available to the environment come from rock weathering.

The base cation deposition is essential for determining critical loads for acidity and its exceedance. Input of base cation counteracts the acidification effects as it increases the base cation pool in the soil and, if associated with carbonates or oxides, they also add alkalinity to the soil. Large base cation deposition increases the critical load and low deposition decreases it. Accurate data on base cation deposition is thus of importance in the elaboration of European large-scale abatement strategies, based on the critical load concept.

However, for most areas, the data on base cation deposition are at present relatively uncertain. This gap of knowledge may be less important in parts of Europe, where the soil is insensitive to acid deposition and where large contributions of alkaline deposition are occur by alkaline wind erosion of soil. In parts of the Nordic countries, the base cation input to ecosystems is very important in relation to the acid pollution. For forests on acidified sandy soil in Denmark and south-western Sweden, for example, the sea-salt deposition is a major nutrient source.

5.2 Emissions of base cations

Base cations are emitted to the atmosphere as particles via natural processes such as soil erosion, sea salt etc. as well as from a number of anthropogenic activities. These include combustion of fuels such as coal and wood, different industrial processes, materials handling and storage, agricultural practices etc. Emissions occur as particles of different size distributions and composition. For several types of emissions the magnitude and character is not very well known.

There are generally little emission data available for base cations. Emission inventories have been made for some countries (e.g. Sweden, Lövblad, 1987; Kindbom et al, 1993). An inventory was also made for calcium emissions from industrial sources in Europe (Lee and Pacyna, 1999). For natural emissions even less data are available even though they are considered to contribute with approximately the same amounts as the anthropogenic sources.

During the last few decades, considerable changes in anthropogenic emissions have taken place within Europe (Lövblad, 1987). Monitoring results indicate that in Sweden, and also in other parts of Europe, base cations emissions - and deposition - have decreased markedly between 1970 and 1990. In some areas, mainly those influenced by emissions from Eastern Europe, there has been a decline in base cation deposition from 1990.

5.3 Base cations in air

Few data series are available to evaluate the level of base cations in air. Such information is valueable, in order to learn more about the importance of dry deposition of base cations. EMEP is presently urging the countries to analyse and report base cations sampled with the filter pack method.

5.4 Base cations in precipitation

Base cations are measured in precipitation at most of the EMEP monitroing sites. Such measurements have been carried out for several purposes; to assess the sea-salt contribution and to make quality control measures such as ion balance studies possible.

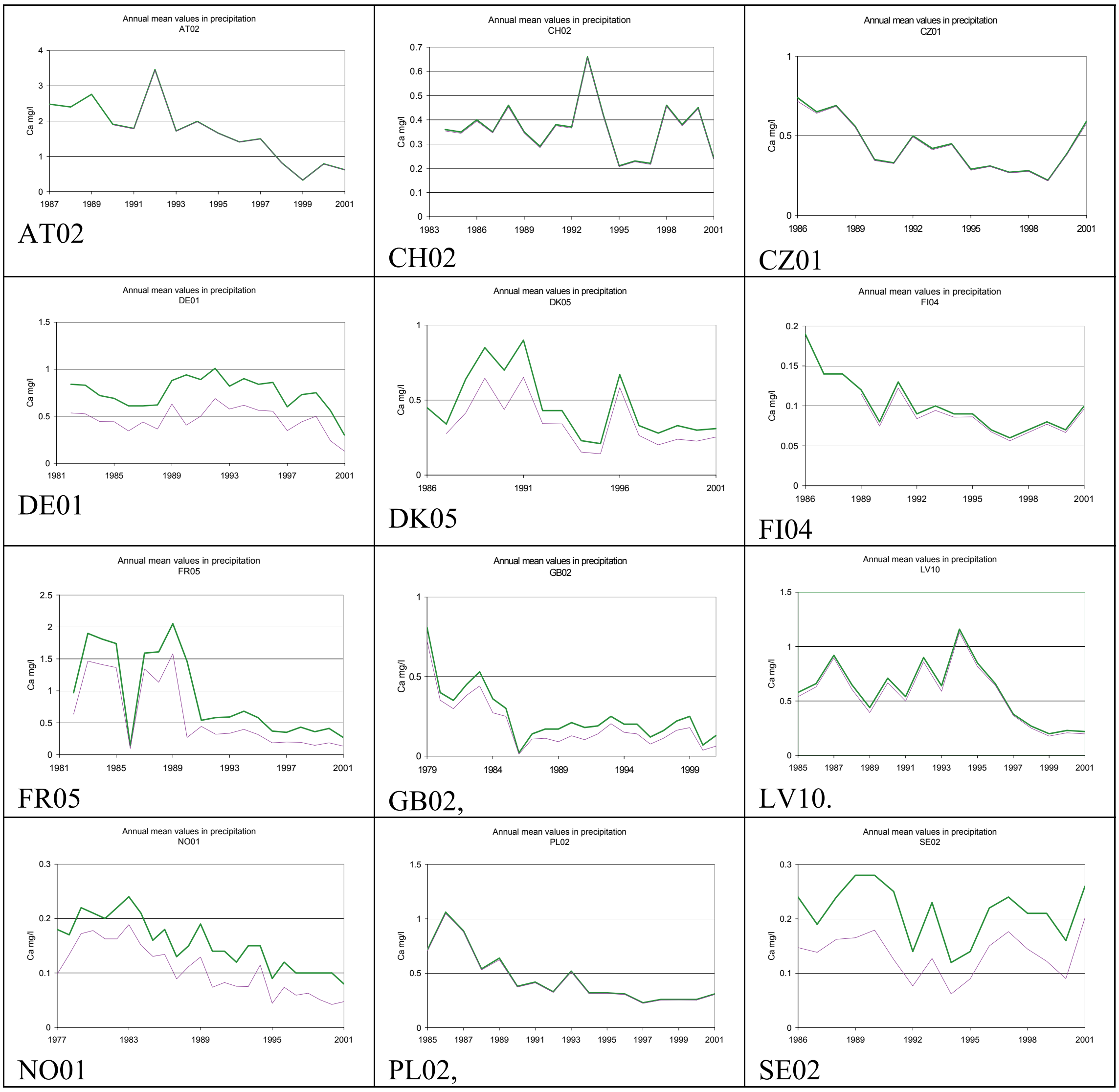
A number of the national assessments have studied the trend for base cations in precipitation (e.g. Hedin et al., 1994; Ukonmaanaho et al., 1998). At many sites there are clear decreasing trends, at other the interannual variation is considerable and trends are not easily detectable. Generally, the levels of calcium in precipitaion (Figure 5.1) are lower towards 2000 compared to the beginning of the 1980s.

Due to the large amount of data on base cations in precipitation, the magnitude of wet deposition is possible to estimate in a relatively accurate way. For dry and consequently also total deposition less data are available. Estimates have been made for Europe (van Leeuwen et al., 1995 and 1996; Draaijers et al., 1997 a and b) some regions, including the Nordic countries (Lövblad et al., 2004). Mapping of base cation deposition over Europe has started in order to give input data for the critical loads mapping and for modelling the recovery from acidification as a basis for the coming revision of the Gothenburg protocol.

5.5 Conclusions on base cations

Base cation deposition is not very well known, except for the wet deposition part. More data are needed as a basis for critical loads mapping and for dynamic modelling of recovery processes. Mapping on a European scale will be carried out by EMEP during 2004 in order to provide information to the dynamic modelling community (see e.g. Westling and Lövblad, 2004).

Figure 5.1 Calcium in precipitation (mg/l) at a number of EMEP sites all over Europe.



5.6 References

Draaijers, G.P.J., van Leeuwen, E.P., De Jong, P.G.H. and Erisman, J.W. (1997a). "Base cation deposition in Europe – Part I. Model description, results and uncertainties". *Atmospheric Environment* **31**, (24), 4139-4158.

Draaijers, G.P.J., van Leeuwen, E.P., De Jong, P.G.H. and Erisman, J.W. (1997b). "Base cation deposition in Europe – Part II. Acid neutralization capacity and contribution to forest nutrition". *Atmospheric Environment* **31** (24), 4159-4168.

Hedin, L.O., Granat, L., Likens, G.E., Buishand, T.A., Galloway, J.N., Butler, T.J. and Rodhe, H. (1994). "Steep declines in atmospheric base cations in regions of Europe and North America". *Nature* **367**, 351-4.

Kindbom, K., Kindbom, K., Sjöberg, K. and Lövblad, G. (1993). "Beräkning av ackumulerad syrabelastning från atmosfären. Delrapport 1: Emissioner av svavel, kväve och alkaliskt stoft i Sverige 1900 - 1990". IVL Rapport B 1109. (In Swedish).

Lee, D.S. & Pacyna, J.M. (1999). An industrial emissions inventory of calcium for Europe. *Atmospheric Environment* **33** () 1687-1697.

Lee, D.S., Kingdon, R.D., Pacyna J.M., Bouwman, A..F. and Tegen, I. (1999) Modelling base cation deposition in Europe - sources, transport and deposition of calcium. *Atmospheric Environment* **33** () 2241-2256.

Lövblad, G. (1987) "Utsläpp till luft av alkali". IVL Rapport B 858. Swedish Environmental Research Institute, P.O. Box 47086, S-402 58 Göteborg, Sweden. (In Swedish).

Ukonmaanaho, L., Starr, M. and Ruoho-Airola, T. (1998). Trends in sulphate, base cations and hydrogen ion concentrations in bulk precipitation and throughfall at Integrated Monitoring sites in Finland 1989-1995. *Water, Air and Soil Pollution* **105**: 353-363.

Van Leeuwen, E.P. Potma, C.J.M., Draaijers, G.P.J., Erisman, J.W. and van Pul, W.A.J. (1995) "European Wet Deposition Maps Based on Measurements". RIVM Report 722108006, National Institute for Public Health and the Environment, Bilthoven, the Netherlands.

Van Leeuwen, E.P., Draaijers, G.P.J. and Erisman, J.W. (1996) "Mapping Wet Deposition of Acidifying Components and Base Cations over Europe Using Measurements". *Atmospheric Environment*, **30** (14), 2495-2511.

Westling, O. and Lövblad, G. (Eds) (2004) Emission, transport, deposition and effects of base cations in relation to acidification. Report from an UNECE LRTAP – ASTA – Nordic Council of Ministers workshop in Gothenburg November 2003. IVL Report B1585, www.ivl.se under download reports.

Data from the EMEP monitoring database www.emep.int.