Wet Deposition of Ammonium in Europe

ED BUIJSMAN* and JAN-WILLEM ERISMAN*
Institute for Meteorology and Oceanography, State University Utrecht, 5 Princetonplein, 3584 CC Utrecht, The Netherlands

(Received: 2 February 1987; revised: 9 October 1987)

Abstract. Ammonium concentration data in precipitation have been compiled to derive a concentration and deposition field for ammonium in Europe. Measurements referring to a total number of 218 measuring sites have been considered. Because of changes in the ammonium concentrations due to the use of improper sampling procedures, a correction procedure is proposed. This makes allowance for the type of sampler used, the length of the sampling period, and whether or not light-protected sample bottles are used. Dependent on the specific sampling procedure used correction factors range from 0.75 to 1.20. According to our calculations, the total wet deposition flux of ammonium in Europe in the early 1980s amounts to 2.4 Mt NH$_4^+$ y$^{-1}$. However, for some parts of Europe the flux cannot be estimated very reliably because of the low number or even the absence of measuring sites. Compared to earlier estimates for around 1960, the ammonium wet deposition flux has increased by approximately 25% during the period 1960—1980.

Key words. Ammonium, precipitation chemistry, wet deposition flux, sampling procedures, Europe.

1. Introduction

Ammonia and ammonium are important atmospheric components for which, at least in a quantitative sense, the atmospheric cycle is poorly understood. Besides, ammonia is the major neutralizing substance in the atmosphere and therefore related to the atmospheric cycles of S and N species.

Apart from the atmospheric chemical point of view, ammonia has given rise to serious environmental concern. This is mainly because once ammonia (or ammonium) comes into contact with the soil, a nitrification process can take place according to the reaction:

\[
\text{NH}_4^+ + 2\text{O}_2 \rightarrow 2\text{H}^+ + \text{NO}_3^- + \text{H}_2\text{O}.
\]

This reaction will lead to an acidification of soils. Moreover, high fluxes of ammonium onto the soil can cause leaching of important plant nutrients, e.g., potassium, magnesium, and calcium, thereby making these nutrients unavailable for plant uptake. In The Netherlands, adverse effects have been observed on soils (Van Breemen et al., 1982), on woodlands (Roelofs et al., 1985), and on poorly buffered aquatic systems (Schuurkes, 1986). All these effects are attributed to high deposition fluxes, both wet and dry, of ammonium and/or ammonia.

* Present address: National Institute of Public Health and Environmental Hygiene, Laboratory for Air Research, P.O. Box 1, 3720 BA Bilthoven, The Netherlands.
The atmospheric chemistry group of the Institute for Meteorology and Oceanography at Utrecht has been involved during recent years in several research projects aiming to quantitatively describe the atmospheric cycle of ammonia and ammonium. Thus, ammonia emission inventories for The Netherlands and for Europe have been published (Buijsman et al., 1984, 1987). Results of the modeling of the long-range transport of ammonia and ammonium have been reported (Asman and Janssen, 1987). Vertical distributions of ammonia and ammonium, amongst other species, have been measured in the lower part of the atmosphere (Erisman et al., 1986).

The wet deposition flux of ammonium in Europe has only been estimated up to now by Bonis et al. (1980). However, these authors based their estimates mainly on measurements carried out in the 1950s and 1960s. Moreover, it has become clear that ammonium in precipitation, which is kept under field conditions, is very sensitive to alterations. Consequently, one has to be very careful in interpreting ammonium wet deposition data. The presence of reliable data is not only important with regard to a correct quantification of biogeochemical cycles, but it also has implications for policy making. Since it has been recognized that ammonium and ammonia can contribute to the acidification of ecosystems, some governments tend to take measures to drive back ammonium/ammonia depositions (see, e.g., Ministry of Housing, Physical Planning and Environment, 1985, 1986).

Finally, during recent years much effort has been spent modelling the long-range transport of ammonia and ammonium on a European scale. To be able to compare modelled wet deposition fields for ammonium and observed deposition fields, there is an urgent need for reliable ammonium concentration data in precipitation (see, e.g., Asman and Janssen, 1987; Derwent, 1987; Fisher, 1987). Problems in interpreting earlier model results (Fisher, 1984) could, at least, be partly attributed to the lack of reliable measurements.

This paper will mainly address the information available to correct ammonium wet deposition data and by doing so, to obtain a better estimate of ammonium depositions occurring in reality.

2. Data Base

Nowadays many precipitation networks exist in Europe with the primary goal of monitoring concentrations of components in precipitation. Our main interest concerns data from these networks referring to the period 1975—1985, because our objective was to make an estimate of the average wet ammonium flux in Europe in the early 1980s. Therefore, older measurements such as those carried out in the IMI/EACN network (Söderlund and Granat, 1982) and those stated by Bonis et al. (1980), were not taken into account.

Data from chemical precipitation networks were accepted for further consideration, if the following conditions were fulfilled: