Comparison of bromide and nitrate transport in the Bainsvlei soil of South Africa under natural rainfall

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Abstract

Bromide is commonly used to simulate the movement of nitrate fertilisers through the soil profile. However, there exists no comparative evaluation of the leaching properties of Br^- and NO_3^--N under local soil and rainfall conditions at Bloemfontein. The purpose of this work was to conduct a field experiment to evaluate the leaching behaviour of Br^- in comparison with NO_3^--N on the Bainsvlei soil of South Africa under natural rainfall conditions. For this purpose, KBr^- and KNO_3 solutions were applied to a 2.45 x 2.45 m^2 plot at rates of 13.5 g $Br{\cdot}m^{-2}$ and 20 g $N{\cdot}m^{-2}$ respectively. The subsequent movement of the solutes through the soil was investigated through studies of the water and mass balances, determined from soil samples taken from a 1600 mm deep soil profile during the period October 2000 to May 2001, the rainy season in Bloemfontein. The results were also analysed with the one-dimensional convective dispersive equation and stream tube models. Two important results were derived from the study: Br^- can be used with confidence as a substitute for NO_3^--N in studies of the movement of the latter through soils, and it is more economical and environmentally friendly to distribute the application of nitrate over the growing season of a crop, instead of applying it as a batch at the time of planting.

Keywords: Field observations, bromide, nitrate, transport

Introduction

In most instances, the leaching of nitrate is the single largest cause of nitrogen loss from the soil-plant system (Cameron and Haynes, 1986). Nitrate leaching from agricultural soils represents an economic loss to the farmer and a pollutant to groundwater resources. Since nitrogen experiences complex biochemical transformations in the soil-plant system, it is often difficult to determine the fate and movement of NO_3^--N through the soil profile. Isotopically labelled fertiliser (using ^{15}N) can be used to distinguish between fertiliser N and N from other sources with a high degree of accuracy. However, the use of these techniques is very costly (Silvertooth et al., 1992). Anions that are biologically and chemically conserved and similarly charged, with low background concentrations in the field, such as Cl^- and Br^-, are therefore often used to simulate the movement of NO_3^--N through natural soil profiles. Since bromide usually has very low background concentrations in the field and bears no known adverse effects to human health, provided it is applied in small quantities (Flury and Papritz, 1993), bromide is usually preferred in such studies (Nachabe et al., 1999; Silvertooth et al., 1992; Jardin et al., 1990; Jaynes et al., 1988; Rice et al., 1986; Smith and Davis, 1974).

The nitrate leaching behaviour of Bainsvlei soil of South Africa, which represents most of the South African land mass (Soil Classification Working Group, 1991), has not been studied before. The purpose of this investigation was to evaluate the leaching behaviour of Br^- in comparison with NO_3^--N in this soil under natural conditions through a field experiment at the experimental station of the Department of Soil, Crop, and Climate Sciences of the University of the Free State, South Africa, from October 2000 to May 2001, the rainy season of the region. The computer package CXTFIT of Toride et al. (1995) was used to determine solute transport parameters with cumulative drainage (instead of time) as independent variable and to compare the movement of Br^- and NO_3^--N in the soil.

Materials and methods

Field experiment and laboratory analysis

The experimental site, located at 26.1°S and 29.0°E with an altitude of 1 372 m, is underlain by a cultivated Bainsvlei Amalia sandy loam soil. It is characterised by orthic topsoil and red apedal/soft plinthic subsoil. The area is semi-arid with a mean annual rainfall of 510 mm.

A square plot (2.45 x 2.45 m^2) of bare soil was prepared for the experiment. The plot was kept bare and weed-free throughout the experiment. The plot was levelled to prevent runoff and erosion from one part of the plot to another and isolated from the surrounding area by a sheet of galvanised iron to prevent surface and shallow subsurface flows into and out of the plot. The sheet of iron was driven into the soil to a depth of 200 mm, with a 200 mm section protruding above ground level.

An access tube for a neutron probe was installed at the centre of the plot to a depth of 2 000 mm to determine the soil water content at various depths. Rainfall was measured with two rain gauges near the experimental plot.

A water sample was taken from a borehole used at the experimental farm to determine the NO_3^--N concentration of the groundwater. The soil was analysed for its textural properties. The results of the soil particle analysis, the textural group and bulk densities of each soil layer are presented in Table 1.

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