Study of agricultural pollution at in-situ rock lysimeter at karstic Trnovo plateau in Slovenia

B. CENCUR CURK, M. PINTAR und M. VESELIC

Abstract

Over 40 % of the Slovenian territory are composed of carbonate rock, therefore aquifers in these rocks are very important. The development of agriculture and extensive production lead to potential pollution of precious water sources with fertilizers and pesticides. The main goal of the research was to study the nitrate percolation through karstic soil and underlying unsaturated zone of karstified rock. Simulation of fertilization with synthetic fertilizer KAN (calcium ammonium nitrate) on meadow at an experimental field site was performed. The water in the unsaturated zone was sampled in a research tunnel 10 meters below the surface by a special construction for collecting water seeping from the ceiling of the tunnel. Plants consumed a major part of the nitrate; only a small portion retained in a soil cover and was available for rinsing. The results have shown that impermeable soil cover on karstic rock is not enough to retain the nitrate and to prevent pollution in karst.

Keywords

agricultural pollution, nitrates, carbonate rock, karst, karstic soil, karstified rock, unsaturated zone

Auszug

Über 40 % vom slowenischen Gebiet bestehen aus Karbonat-Gestein, deswegen sind diese Wasserleiter sehr bedeutend. Die landwirtschaftliche Entwicklung und Produktion führen zu einer potentiellen Verschmutzung von wertvollen Wasserquellen durch Dünge- und Schädlingsbekämpfungsmittel. Das Hauptziel der Untersuchung war die Erforschung des Nitrat-Transports durch den Karstboden und die untergelegene ungesättigte Zone des Karstgesteins. Düngungsversuche mit dem Kunstdünger KAN (Calcium Ammonium Nitrat) auf der Wiese des Versuchsfelds Sinji Vrh wurden durchgeführt. Das durch den Karstboden und Gestein durchsickernde Wasser wurde in einem Versuchstollen mittels einer speziellen Probenahmeeinrichtung aufgefangen. Der größte Teil der Nitrate wurde von den Pflanzen verbraucht, während eine kleine Menge im Boden, der am Versuchsfeld eher dünn ist, geblieben ist. Die Versuche haben gezeigt, dass der undurchlässige Boden am Karstgestein zur Zurückhaltung von Nitraten und Verhinderung der Karstwasserverschmutzung nicht ausreicht.

Introduction

Processes of flow and solute transport in fractured and karstified rock are very complex due to heterogeneities and anisotropy of the rock. Therefore experimental field sites are a very important tool for detailed (macro scale) studies of flow and solute transport in karstified rocks. Such experimental field site was planned and equipped for purposes of studying flow and solute transport through karstic soil and rock (CENCUR CURK 1997).

Simulation of fertilization on meadow at this experimental field site was performed in order to study the behaviour of nitrates and their percolation through karstic soil and underlying unsaturated zone of karstified rock. Synthetic fertilizer KAN (calcium ammonium nitrate) was used in standard apportioning. The water percolating through the karstic soil and rock was collected by a special construction for collecting water seeping from the ceiling of the tunnel below the fertilized meadow. The construction enables the sampling in segments along the tunnel. Electrical conductivity, T and pH were measured in-situ in water samples during the experiment. Water samples were examined in the laboratory on nitrate ion and nitrite ion concentration (IRGO) and nitrogen isotope δ15N (IJS - Institute Josef Stefan).

Experimental design

The experimental field site (EFS) Sinji Vrh is located in the western part of Slovenia at the edge of the Trnovski Gozd plateau, which is an overthrust of carbonate rock over Eocene ($E_{1,2}$) flysch. This area is composed of Jurassic ($J_{1,2}$) oolitic limestone and massive (compact) limestone, which passes laterally into crystalline dolomite. This territory is crossed by the Avèe fault with a dinaric

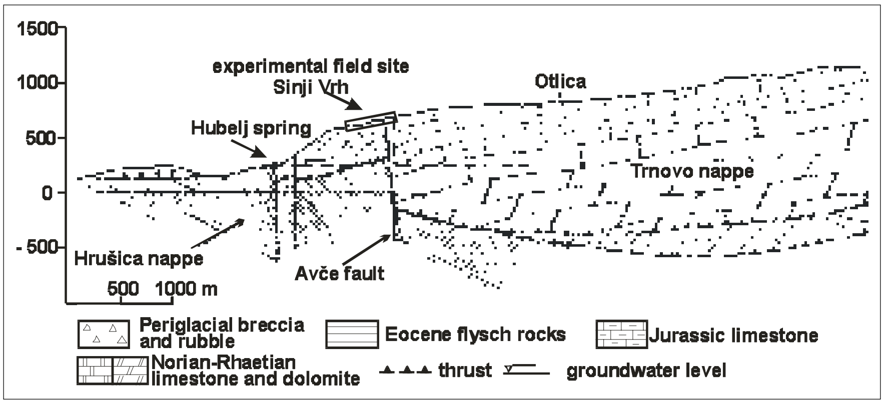

Figure 1: **Geological cross section of Trnovo plateau (JANEZ 1997). - Geologischer Schnitt über das Trnovo Plateau**

Autoren: MSc. Barbara CENCUR CURK, IRGO-Institute for Mining, Geotechnology and Environment, Slovenceva 93, SLO-1000 LJUBLJANA, Ph. D. Marina PINTAR, VGI-Water management Institute, Hajdrihova 28, SLO-1000 LJUBLJANA, Univ. Prof. Dr. Miran VESELIC, University of Ljubljana, Faculty of Natural Sciences and Engineering, Department for Geology, Aškerèeva 20, SLO-1000 LJUBLJANA

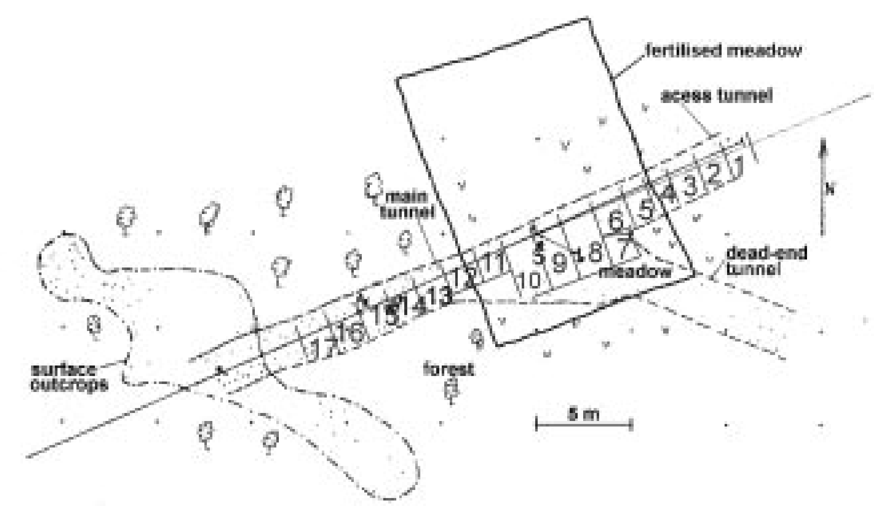

Figure 2: **The experimental field site:- the position of surface outcrops area, research tunnel with segments numeration and fertilized meadow. - Das Versuchsfeld Sinji Vrh: Lage von den Aufschlüssen, dem Versuchstollen mit den Messstellen und dem gedüngten Gebiet (Rechteck)**

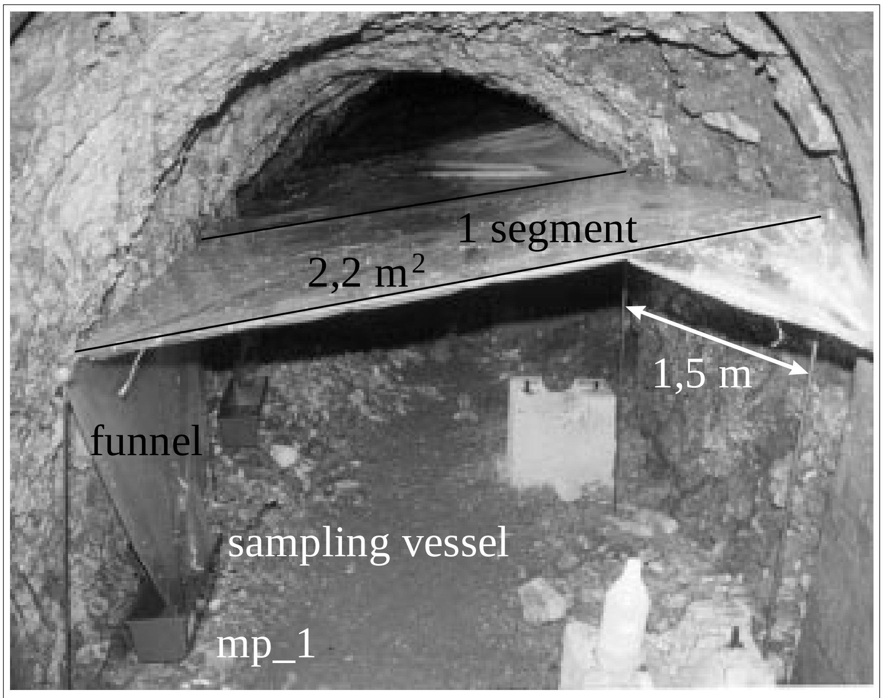

Figure 3: **Construction for collecting water samples in the research tunnel. - Probenahmeeinrichtung im Versuchsstollen**

direction (NW-SE) where the rock is crushed and fractured. The experimental field site at Sinji Vrh is located above the Hubelj spring in the region of the Avèe fault (*Figure 1*).

The experimental field site in the unsaturated zone of fractured and karstified rock presents a 340 m long artificial research tunnel, 5 to 25 meters below the surface. The tunnel direction is nearly constant running southwest - northeast (N66^{o}E). The surface is covered with grassland and small beech forests, which usually cover outcrops. The unsaturated fractured and karstified limestone has a negligible matrix porosity and very high fracture density with some greater conduits (CENCUR CURK and VESELIC 1999). A simulation of fertilization was performed at the northwestern part of the research tunnel, where the distance to the surface is 10-15 m. On the meadow an area of 150 m^2 was used for fertilization experiment (*Figure 2*). For that purpose suction cups in two levels (depth of 15 and 45 cm) were installed in the soil above the research tunnel. The soil is a typical karstic soil (calcaric brown soil) with characteristic deeper pockets extended along weak zones like fractures in the underlying rock. In a 0.7 m deep soil profile the Ah-horizon has a thickness of 15 cm and B-horizon a thickness of 55 cm. In the latter an upper horizon with more roots and higher organic content can be distinguished.

A special construction for collecting water percolating through the rock was developed (*Figure 3*). The construction enables the sampling of the water seeping from the ceiling of the research tunnel in segments along the tunnel (CENCUR CURK and VESELIC 1999). Each segment is 1.5 m long and has a gathering surface of 2.2 m^2. The total length of the collecting area is 49 metres with interruption of 7 metres due to dry rock (after MP17) and the total number of segments is 28 (*Figure 2*).

Two fertilization experiments were performed: the first in June 1998 and the second in September 1999. For both experiments the synthetic fertilizer KAN (calcium ammonium nitrate) was used in standard measures. Electrical conductivity, temperature and pH were measured in situ in water samples during the experiment. The water samples were also examined in the laboratory for nitrate ion and nitrite ion concentrations (IRGO) and nitrogen isotope ^{15}N (IJS).

Results

In the first fertilization experiment (G1) the nitrate ion appeared in water samples of almost all sampling points after approximately 30-35 days (*Figure 4*), which was five days after the heavy rain (4/7/1998; 51.7 mm), followed by more or less constant rain (CENCUR CURK and VESELIC 1998). The first precipitation event (*Figure 4*) after fertilization dissolved the mineral manure and rinsed it into the soil. The highest nitrate concentration (15.1 mg/l) appeared at the measuring point MP5 (*Figure 4*), where one fast channel with strong fluxes exists and was confirmed also in former tracer experiments and by mapping of discontinuities. Concentrations of NO_3^- ion were smaller than a natural background in springtime (before fertilization on 8/

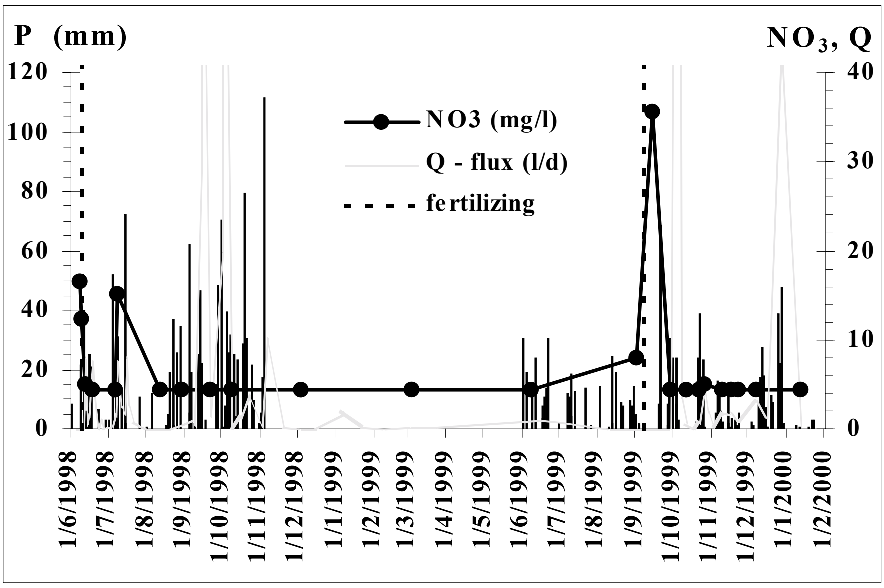

Figure 4: **Precipitation events and NO_3^- concentrations (detection limit. 4.4 mg/l) in sampling points MP5 for fertilisation experiments G1 and G2 (KARAHODZIC, 2000). - Niederschlag und NO_3^--Konzentrationen (NWG 4,4 mg/l) in der Messstelle MP5 bei den Düngeversuchen G1 und G2**

6/1998), when a mineralization in soil proceeds and is rinsed by precipitation water in spring.

The second fertilization experiment (G2) was performed in order to obtain more relevant data on nitrate percolation through the soil cover. For this reason vacuum lysimeters were installed into the soil cover and more isotope analysis were performed. The nitrate appeared one week after one huge precipitation event (68.8 mm; 21/9/1999), about 22 days after the fertilization (*Figure 4*). The isotope data $\delta^{15}N$ confirmed, that the nitrate source was the mineral manure applied on the meadow (CENCUR CURK et al. 2000). The nitrate transport along the fast channel at measuring point MP5 was quicker and appeared after 8 days. In some measuring points another rinse of the manure was detected. After a huge precipitation in next spring (1/3/2000; 85.1 mm) the nitrate was rinsed again - it was retained in the microfractures of the unsaturated zone.

Conclusions

In spite of the fact, that meadow has not been fertilized for 15 years, nitrate ion appeared after 30-35 days in the first fertilizing experiment. Plants consumed a major part of the nitrate and only a small portion was retained in the soil cover, which is not very thick (50-100 cm) and contains a great amount of rubble. The results have shown that thin autochtonous soil cover on karstic rock is not enough to retain the nitrate and prevent pollution of karstic groundwater. However, the maximum nitrate concentrations (up to 16 mg/l in G1 and up to 36 mg/l in G2) were smaller than some values of natural background and limits for drinking water. Therefore the usage of allowed fertilizers in standards measures have to be forced and realized in agricultural practice. Further detailed studies with this respect are needed within the frame of the research on karstic aquifer vulnerability.

An experiment with emphasis on nitrogen balancing (vapor N_2 and N_2O, soil nitrogen compounds, water nitrogen compounds including isotopes analysis) and microbiological activities is planned in order to specify more precisely the nitrogen processes and behaviour in the soil and the rock unsaturated zone.

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