# Hydrochemical characteristics of groundwater from the Kamniškobistriško polje aquifer

# Hidrokemijske značilnosti podzemne vode vodonosnika Kamniškobistriškega polja

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**Abstract:** The article describes basic chemical properties of the Kamniškobistriško polje aquifer groundwater. The aquifer is composed of the upper aquifer in sand and gravel deposits of the Kamniška Bistrica river and of the lower, dolomite aquifer. The water of both aquifers differs significantly as to its chemical composition. Compared to the lower aquifer, the water of the upper aquifer is more mineralized, which is reflected in a higher electrical conductivity and concentrations of $HCO_3$, calcium and magnesium. The water from the upper aquifer is also more loaded with pollutants originating from agricultural activities. On the basis of chemical properties of groundwater from both aquifers it can be concluded that the recharge area of both aquifers is different; the upper aquifer is recharged mainly by precipitation and infiltration of the Kamniška Bistrica river, while the larger quantity of water from the lower aquifer is estimated to originate from carbonate rocks on the western fringes of the Kamniškobistriško polje.

**Izvleček**: V članku so prikazane osnovne značilnosti kemijske sestave podzemnih vod vodonosnika Kamniškobistriškega polja. Ta vodonosnik sestavljata zgornji vodonosnik v peščeno-prodnih sedimentih reke Kamniške Bistrice ter spodnji dolomitni vodonosnik. Po kemijski sestavi se vode obeh vodonosnikov občutno razlikujejo. V primer-

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javi s spodnjim vodonosnikom je voda zgornjega bolj mineralizirana, kar se izraža v večji elektroprevodnosti ter koncentraciji $HCO_3$, kalcija in magnezija. Prav tako je voda zgornjega vodonosnika bolj obremenjena z onesnaževali, ki večinoma izhajajo iz kmetijske dejavnosti. Na osnovi kemijskih značilnosti podzemnih vod iz obeh vodonosnikov ocenjujemo, da je napajalno območje obeh vodonosnikov različno; zgornji vodonosnik se napaja pretežno iz padavin ter infiltracije reke Kamniške Bistrice, medtem ko ocenjujemo, da je v spodnjem vodonosniku večji delež vode iz karbonatnih kamnin zahodnega obrobja Kamniškobistriškega polja.

**Key words:** Kamniškobistriško polje, aquifer, groundwater, chemical composition

**Ključne besede:** Kamniškobistriško polje, vodonosnik, podzemna voda, kemijska sestava

## Introduction

Our research was aimed at determining the basic chemical properties of groundwater of the Kamniškobistriško polje aquifer. The aquifer is composed of two parts: the upper, intergranular aquifer, and the lower, fissured aquifer in dolomite rocks. It is recharged by precipitation, by the Kamniška Bistrica river, flowing into the aquifer from the east, and by inflows from the hills along the aquifer's western border. Chemical analyses of groundwater from different parts of the aquifer were used for a more detailed determination of the influence of recharge, lithological factors and anthropogenic pollution on the chemical composition of groundwater.

## Description of the Kamniškobistriško polje aquifer

The Kamniškobistriško polje alluvial plain extends on the gravel fan of the Kamniška Bistrica river between cities Kamnik, Mengeš and Domžale. Its surface is inclined in the north-south direction, with an altitude of 340 m at Šmarca in the north, and 285 m at Dragomelj in the south. The Kamniška Bistrica river flows along the eastern edge of the Kamniškobistriško polje approximately in direction north-south. At Jarše, the Pšata stream, originating outside the research area at the foot of the Kamnik Alps, flows into the Kamniška Bistrica from the west. The Radomlja stream flows into the Kamniška Bistrica from the east.

The surface of the gravel fan of the Kamniška Bistrica is formed by an 8–12 m thick layer of pure gravel. South of the road Trzin–Domžale the gravel is partly covered by a several meter-thick layer of sand and silt, deposited by the Pšata stream.

The upper gravel layer is underlain with older Pleistocene gravel deposits with inlays of conglomerate and clay. These deposits reach a depth from 35 m to over 70 m in the central part of the plain between the factory Lek and the Depala vas. Along the southern edge of the plain, Pleistocene gravel deposits are 35 m to 45 m deep, while they are less massive on the eastern outskirts, reaching 15 m to 40 m depth.

The base of the sand-gravel deposits contains dolomite which represents a carbonate aquifer with fissure porosity. Deep wells located between Mengeš and Domžale reach the carbonate aquifer at a depth of 50 m to 80 m, and the impermeable base composed of Carboniferous and Permean clayey shales and sandstones lies 160 m below surface in this area (Rogelj & Petauer, 1993, Rogelj, 1998, 1993, Harahodžič, 2011).

The groundwater table in the northern part of the plain is relatively deep under the surface –22 m to 31 m at low-water conditions. In the central part of the plain between Jarše and Mengeš the table at low-water conditions is about 22 m deep. In the area between Trzin and Domžale the groundwater table at low water is at 7 m to 12 m, while it is at 2.5 m to 6.5 m in the southern part of the plain near Pšata. The fluctuation range of groundwater in the area of Kamniškobistriško polje gradually decreases from north to south, amounting to about 7 m in the north and only to about 1 m in the southern part of the area.

The water-bearing gravel layer in the Kamniškobistriško polje is quite thick, amounting to between 32 m and 42 m in the northern part, and to approximately 80 m in the central part between Mengeš and Jarše. The thickness of the water-bearing layer in the Trzin–Domžale profile is about 40 m, decreasing to about 8–40 m in the south between Dragomelj, Pšata and Ihan.

Groundwater balance calculation in the upper aquifer shows an inflow of about 140 l/s of groundwater from Kranjsko polje into the Kamniškobistriško polje at medium-water conditions (Mencej, 1991). The groundwater flow in the central part at the intersection with the Trzin–Domžale aquifer is estimated at 170 l/s, and at about 400 l/s in the southern part of the plain, in the Dragomelj–Ihan profile.

## Materials and Methods

Chemical and isotopic properties of groundwater from the Kamniškobistriško polje were observed at the following monitoring points:

| Monitoring point | Type of object | Aquifer |
|---|---|---|
| DG-1 | pumping well | lower |
| VDG-2 | observation well | lower |
| VDG-3 | observation well | lower |
| VDG-4 | observation well | lower |
| C-2 | pumping well | upper |
| C-3 | pumping well | upper |
| C-4 | pumping well | upper |
| Lek pumping station | pumping well | upper |
| DG-3 | observation well | upper |
| K-1 | observation well | upper |
| L-6 | observation well | upper |
| L-9 | observation well | upper |
| M-1 | pumping well | dolomite |

Locations of monitoring points are evident from the map in Figure 1.

The groundwater samples were obtained by sampling pump Grundfos MP1. Two groundwater sampling campaigns were carried out in April and May 2011 in the Kamniškobistriško polje aquifer. A graphical presentation of average values from both samplings is given below in this article. Chemical analyses of groundwater samples were carried out in the laboratory of JP Vodovod-Kanalizacija, d. o. o., Ljubljana.

## Results and discussion

### Electrical conductivity

Electrical conductivity of groundwater in unpolluted groundwater is usually in correlation with the concentration of dissolved carbonates in water, i.e. with carbonate hardness of water. Measurement results of electrical conductivity of groundwater of the Kamniškobistriško polje are presented in Figure 2.

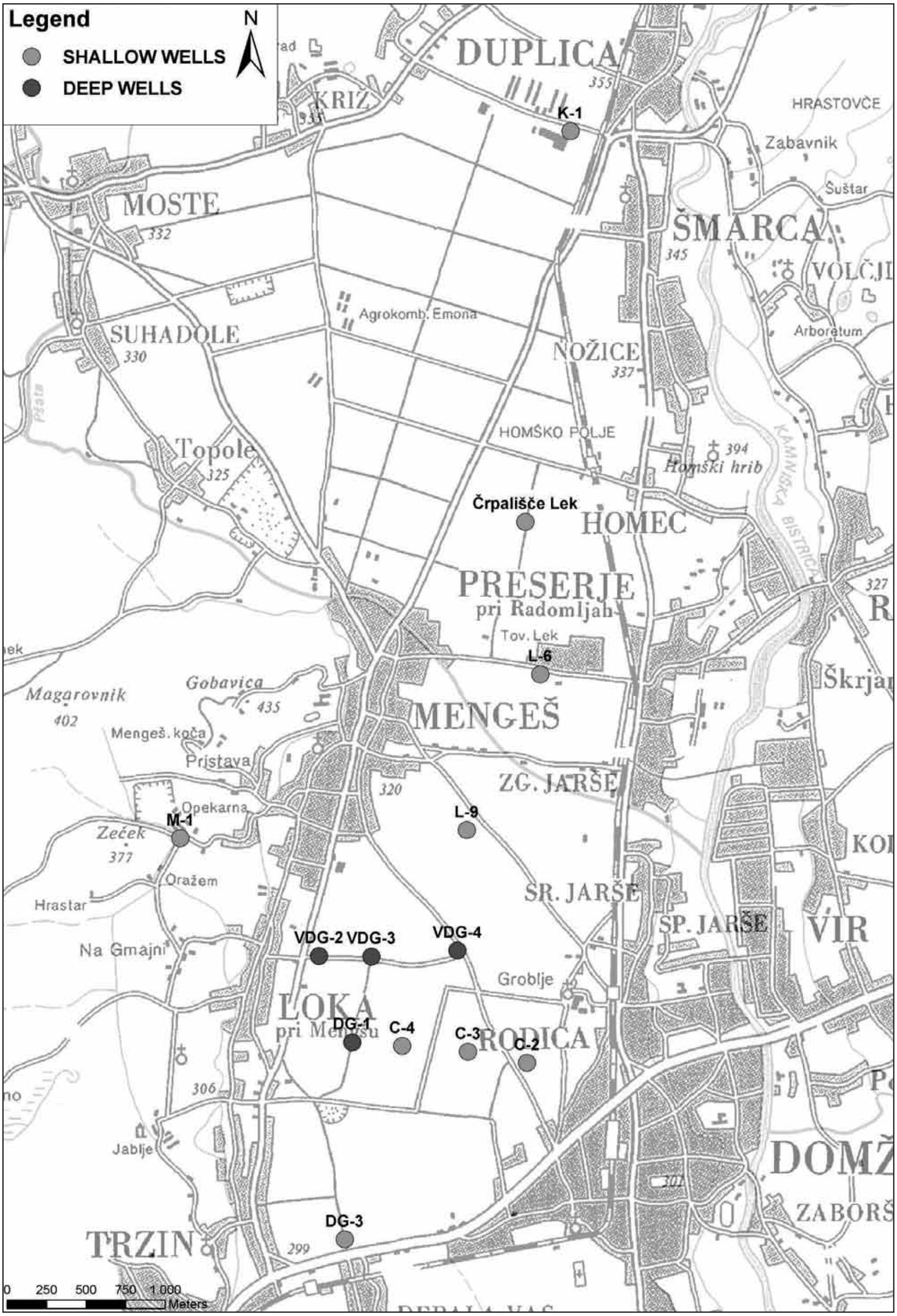


**Figure 1.** Monitoring point locations in the Kamniškobistriško polje

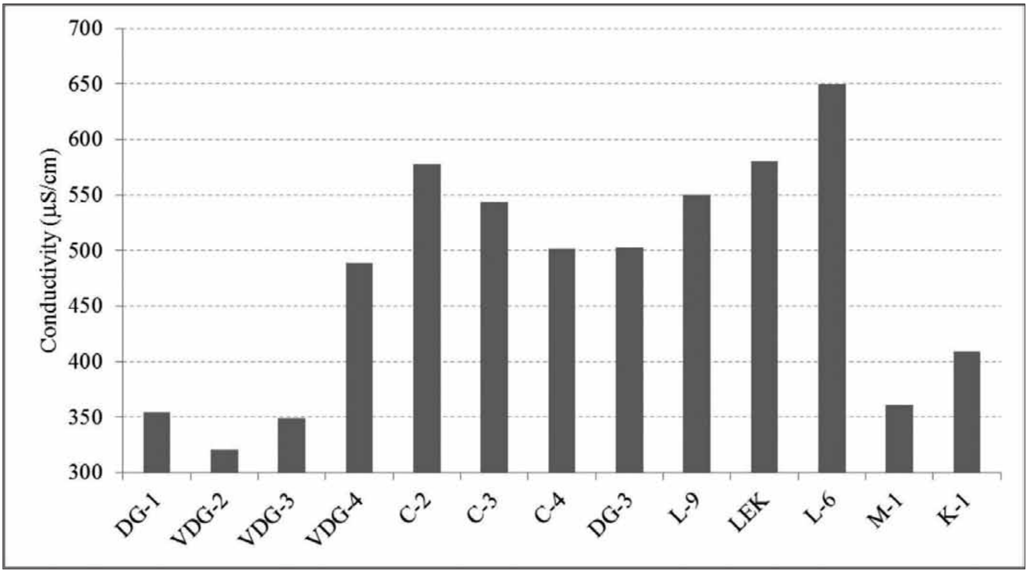


**Figure 2.** Electrical conductivity of groundwater of the Kamniškobistriško polje aquifer

Most values of electrical conductivity in the groundwater of the Kamniškobistriško polje range between 500 µS/cm and 600 µS/cm. Significantly lower values between 300 µS/cm and 350 µS/cm were measured in water from the deep dolomite aquifer, in well M-1, which also comprises the dolomite on the western fringes of the Kamniškobistriško polje, and in piezometer K-1, which is located in the northern part of the Kamniškobistriško polje near Duplica.

The lower values of electrical conductivity in the wells from the lower dolomite aquifer reflect a lesser quantity of dissolved carbonates in groundwater, which indicates that the hydrochemical properties of both aquifers are distinctly different due to their different recharge areas of precipitation.

A deviation from the typical values of electrical conductivity in the lower dolomite aquifer is observed only in the deep well VDG-4, which has a slightly lower value than water from other observation points in the upper Kamniškobistriško polje aquifer, and higher than water from the lower aquifer. Similar characteristics of well VDG-4 are observed also with regard to other hydrochemical and isotope parameters, which are presented further in this report. Thus it can be concluded that water from the lower and upper aquifer of the Kamniškobistriško polje is mixed in this well.

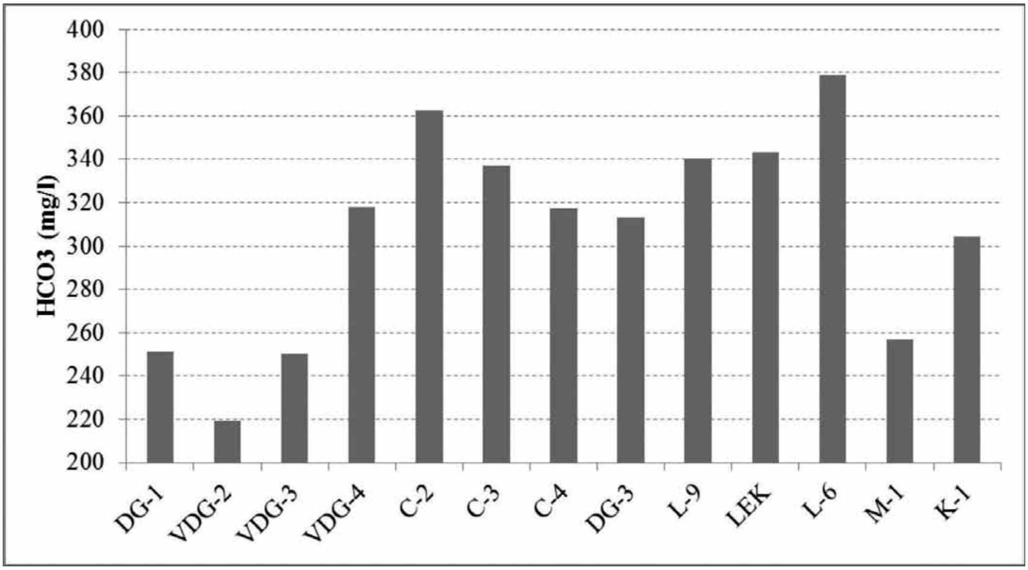


**Figure 3.** Concentration of $HCO_3$ in groundwater from the Kamniškobistriško polje aquifer

**$HCO_3$ in groundwater**

It is evident from Figure 3 that a higher concentration of $HCO_3$ is observed in groundwater from the upper Kamniškobistriško polje aquifer, where $HCO_3$ concentrations range between 300 mg/l and 380 mg/l, whereas water from deep wells in the lower dolomite aquifer shows lower concentrations of $HCO_3$, between 220 mg/l and 250 mg/l. A higher concentration of $HCO_3$ reflects a low-altitude aquifer recharge area in the Kamniškobistriško polje, where the production of soil $CO_2$ is bigger due to a higher average soil temperature. This in turn results also in a higher mineralization of groundwater.

Map on Figure 4 shows spatial characteristics of the $HCO_3$ parameter in groundwater from the Kamniškobistriško polje aquifer.

Because the $HCO_3$ parameter, similar as electrical conductivity, reflects the quantity of dissolved carbonate in water, a considerable degree of correlation between the two parameters may be expected. Figure 5 shows the relation between electrical conductivity and the concentration of $HCO_3$ in groundwater from the Kamniškobistriško polje. The chart also clearly shows the substantial difference between the carbonate chemistry of water from the upper and lower aquifer of the Kamniškobistriško polje.

**Calcium and magnesium**

Figure 6 presents the characteristics of calcium and magnesium distribution in

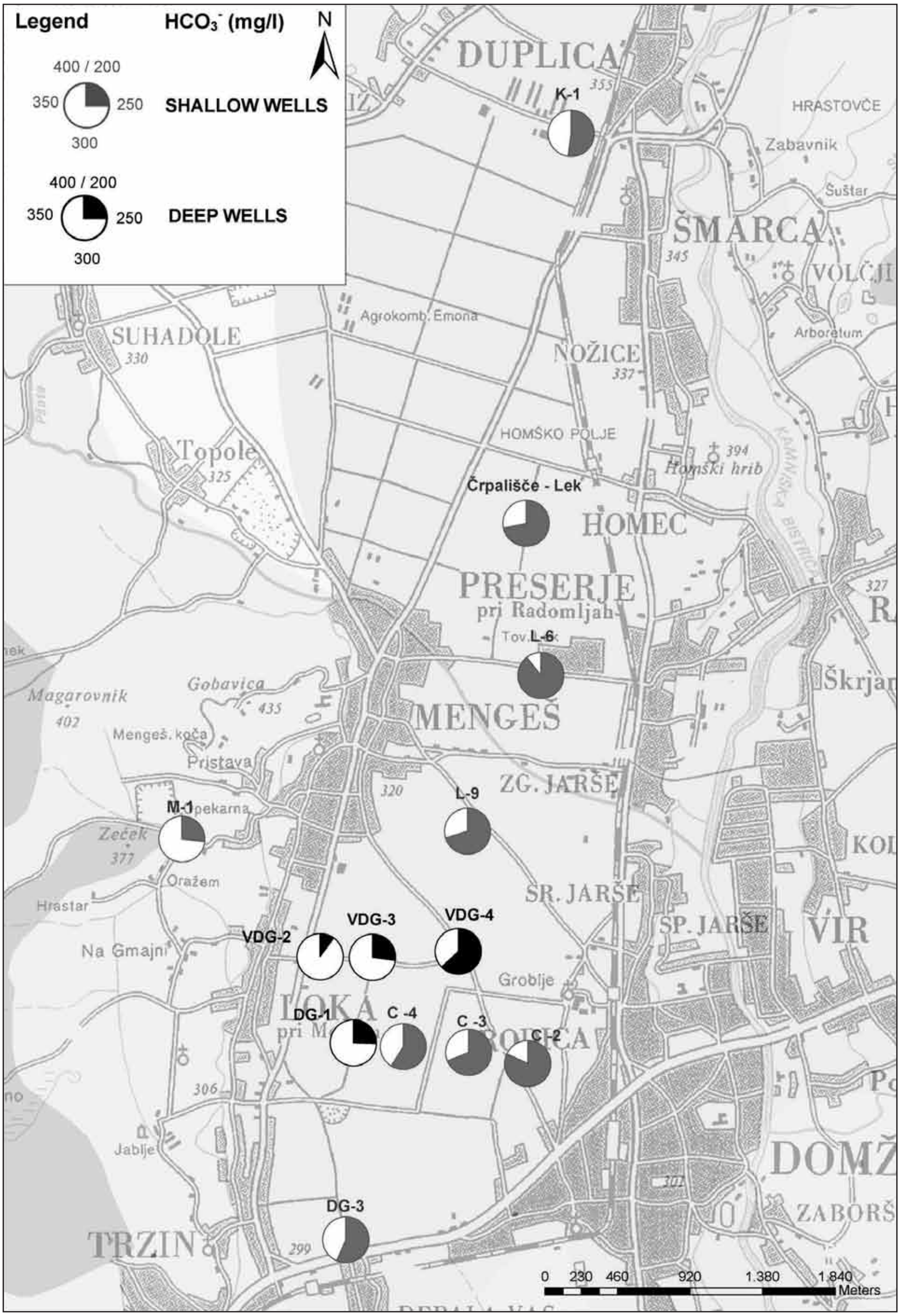


**Figure 4.** Spatial characteristics of $HCO_3$ concentration in groundwater from the Kamniškobistriško polje aquifer

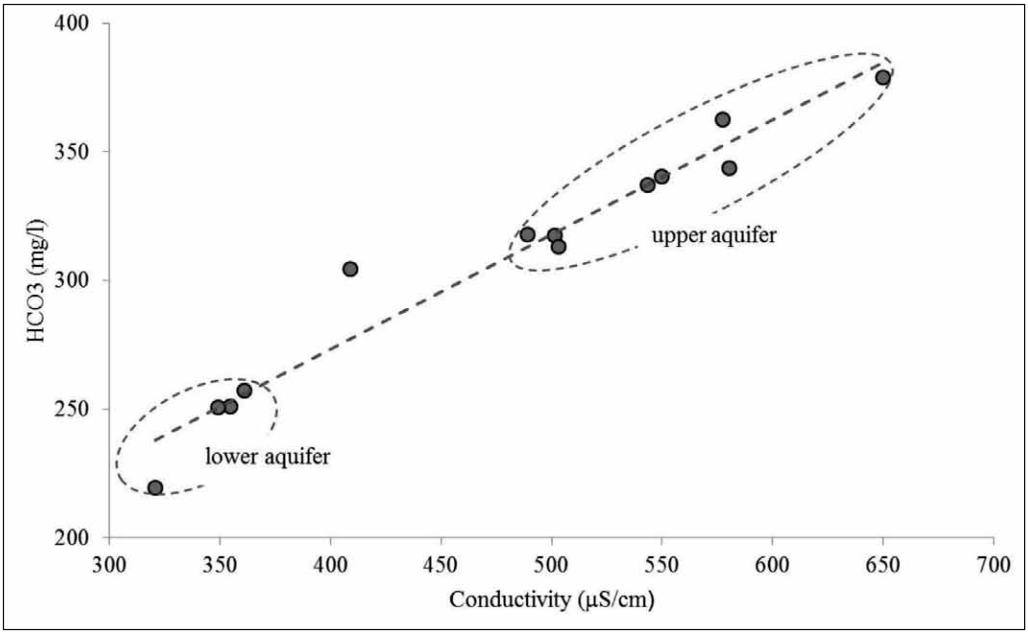


**Figure 5.** Relation between electrical conductivity and $HCO_3$ content in groundwater from the Kamniškobistriško polje

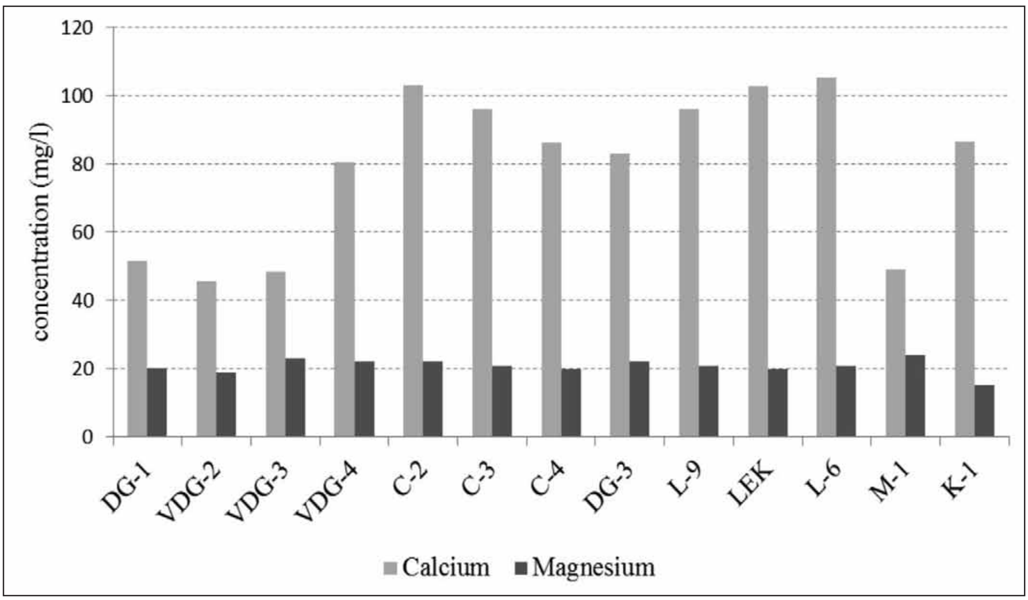


**Figure 6.** Calcium and magnesium content in the Kamniškobistriško polje groundwater

the Kamniškobistriško polje groundwater.

Values of calcium content in groundwater from the lower aquifer are about 50 mg/l, whereas they are considerably higher in the upper aquifer, approximately between 80 mg/l and 110 mg/l.

Compared to calcium, magnesium concentration in groundwater from the Kamniškobistriško polje show a substantially smaller span, from 19 mg/l to 24 mg/l. In this case the difference between groundwater from the upper and lower aquifer is not as pronounced.

The characteristics of the molar ratio between calcium and magnesium in the groundwater of the Kamniškobistriško polje are shown in Figure 7. Most values of the Ca/Mg molar ratio in the upper aquifer lie in the interval between 2.5 and 3.5, which means a marked predominence of calcium from limestone in the aquifer's recharge area. In the lower aquifer the molar ratio is between 1.3 and 1.6, which is close to the theoretical ratio typical of dolomites.

On the basis of these facts it can be concluded that dolomites prevail in the recharge area of the lower aquifer, while the upper aquifer's recharge area is composed of considerably more limestone rocks. We can assume that the lower aquifer mainly recharges in the dolomites outcropping on the western border of the Kamniškobistriško polje in the area of Dobeno, Debeli Vrh and Šinkov Turn.

**Groundwater nitrate**

Nitrates in groundwater usually originate from the use of fertilizers on agricultural areas or from the influence of waste water on the aquifer. Because waste water drainage is regulated in this area, we assume that nitrates in the Kamniškobistriško polje aquifer mostly originate from agricultural activities.

Figure 8 shows average nitrate concentrations in individual monitoring facilities in the area of the Kamniškobistriško polje.

Most nitrate concentrations in the upper Kamniškobistriško polje aquifer lie within the interval between 25 mg/l and 40 mg/l. Markedly lower nitrate concentrations are observed in the lower Kamniškobistriško polje aquifer, where they average at 6 mg/l at the most.

**Sodium and chlorides**

The average concentration of sodium and chlorides in the groundwater of the Kamniškobistriško polje is presented in Figure 10.

The lowest sodium and chloride contents are found in groundwater from the lower Kamniškobistriško polje

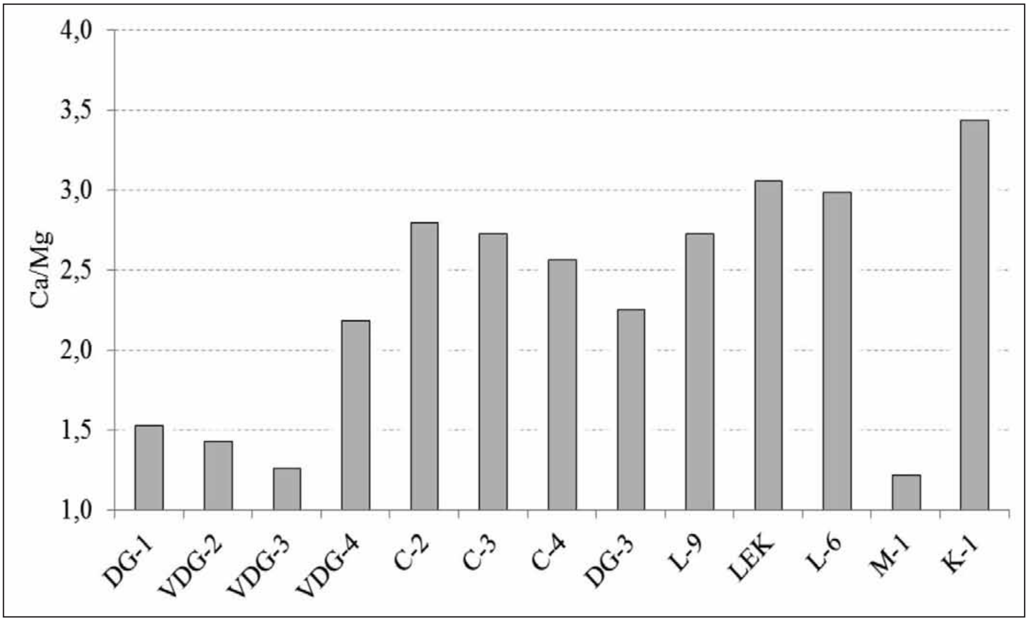


**Figure 7**. Molar ratio between calcium and magnesium in the groundwater of the Kamniškobistriško polje

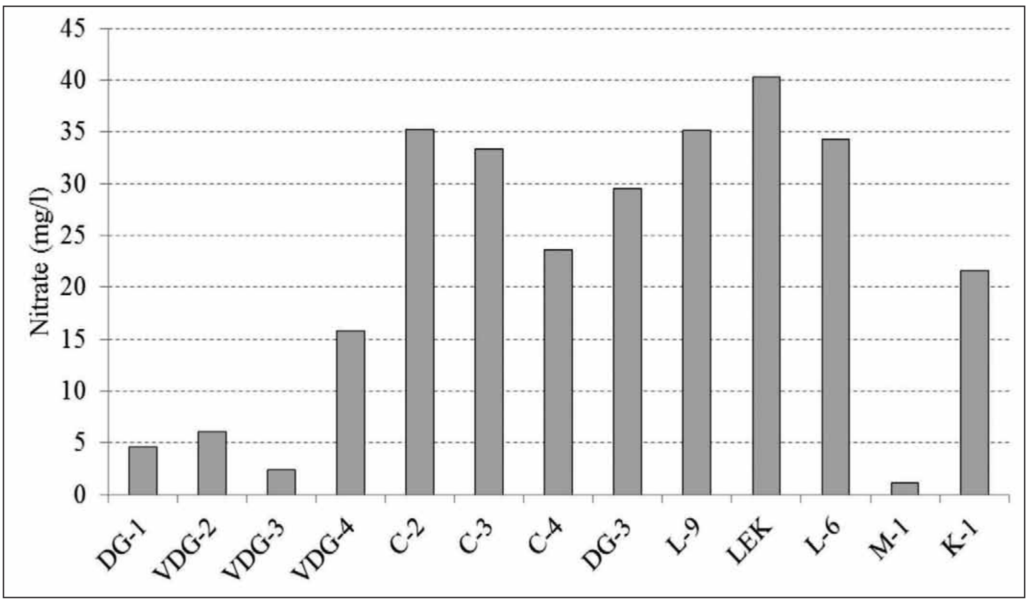


**Figure 8.** Average nitrate concentrations in the groundwater of the Kamniškobistriško polje

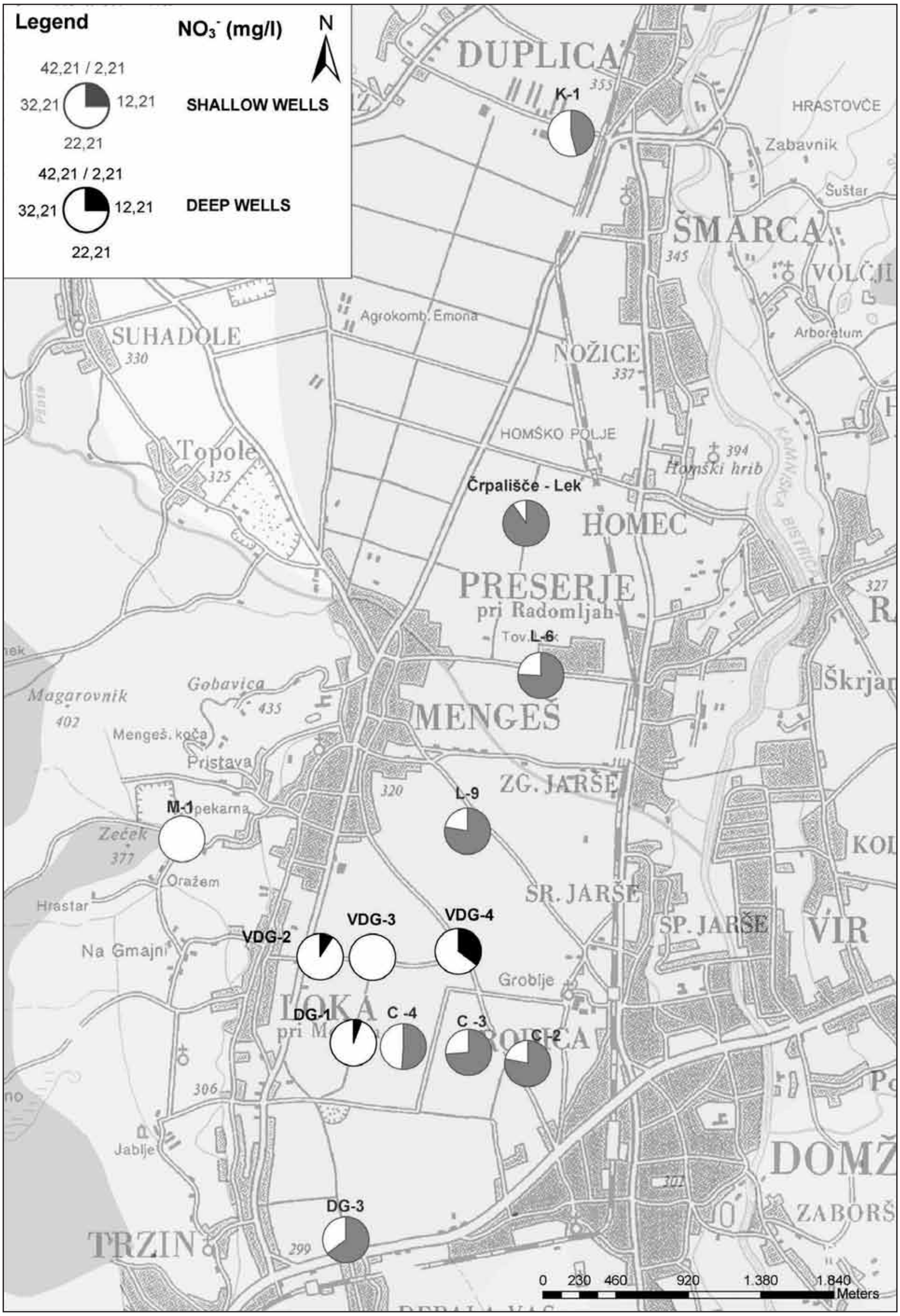


**Figure 9.** Characteristics of spatial distribution of nitrates in the ground-water of the Kamniškobistriško polje

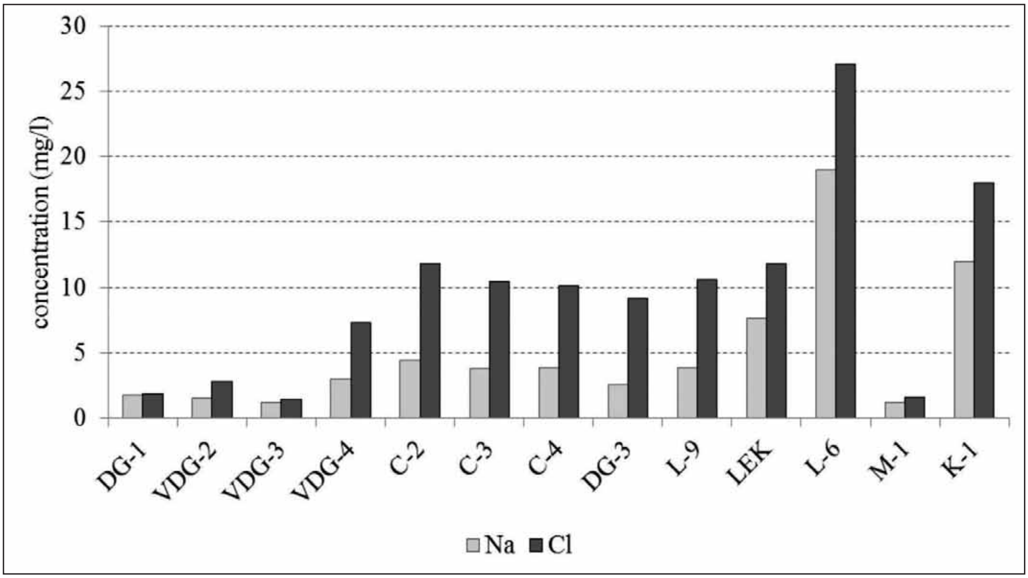


**Figure 10.** Average concentration of sodium and chlorides in the Kamniškobistriško polje aquifer

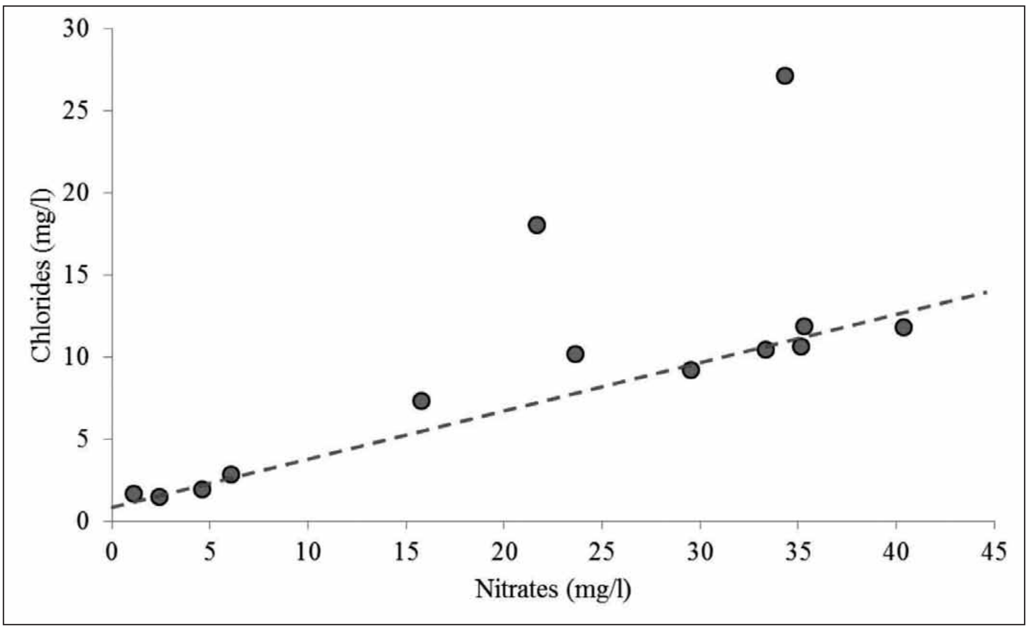


**Figure 11.** Correlation between chlorides and nitrates in groundwater from the Kamniškobistriško polje aquifer

aquifer, the values never exceeding 5 mg/l. A typical chloride concentration is about 10 mg/l.

In some cases also higher chloride concentrations were measured. The highest concentration of chlorides, 27 mg/l, was measured in well L-6 in the central part of the Kamniškobistriško polje. Because the well is located near traffic or parking areas, we suppose that chlorides in this area are mainly a result of salting of roads against frost.

This interpretation is confirmed also by Figure 11 which shows the correlation between chlorides and nitrates in groundwater. On the chart, only the two monitoring points (K-1 and L-6) located in proximity to roads deviate from the regression line in the direction of relatively higher chloride concentration.

## Conclusions

Hydrochemical investigations of groundwater in the area of the Kamniškobistriško polje show that groundwater of the upper gravel aquifer has a fairly different chemical composition than that of the lower dolomite aquifer, which is a result of different recharge areas of both aquifers. The groundwater of the upper aquifer in sands and gravels is more mineralised than groundwater of the lower, dolomite aquifer. This is reflected in a higher electrical conductivity of the water and in the concentrations of $HCO_3$, calcium and magnesium.

The molar ratio between calcium and magnesium in the upper aquifer is higher, which indicates the predominance of limestone over dolomite in the aquifer's recharge area. The molar ratio between calcium and magnesium in the lower aquifer is close to 1, which is typical of pure dolomite recharge areas. We assume that the main recharge area of the lower aquifer is the western border of the Kamniškobistriško polje aquifer in the area of Dobeno, Debeli Vrh and Šinkov Turn, where triasic dolomite prevails.

Also the concentrations of pollutants, such as nitrates and chlorides, are significantly higher in the upper, intergranular, than in the lower, dolomite aquifer. It is assumed that nitrates enter groundwater mostly through agricultural activity, while the application of road salt is the main source of chlorides.

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