Hydrogeology and hydrogeochemistry in the alluvial aquifer of the Zagreb area (Croatia)

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Abstract: The aquifer of the Zagreb area is composed of gravel and sand. East of Zagreb the thickness of the aquifer reaches its maximal thickness, about 100 m. The first results of hydrogeochemical research, which is directed on the research of the different parts of the aquifer, especially the deep parts that can be used for water supply, are presented in this paper. Results show that there is an aquifer stratification with regard to the hydrogeochemical conditions in the different parts of aquifer. This is particularly emphasized with distance from the Sava River.

Key words: alluvial aquifer, hydrogeochemical parameters, isotope distribution, hydrogeochemical conditions

Introduction

Zagreb aquifer is the most important source for water supply of city of Zagreb, where from about 5.5 m^3/s of groundwater is pumped. It is a part of hydrogeological system situated within the Sava basin. Due to its great importance, it has been intensively explored, mainly from hydraulical point of view. In this paper the preliminary results of investigations of hydrogeochemical and isotope indicators in groundwater that have been done since 2000, are presented. Groundwater samples have been taken in various hydrological conditions at 15 piezometric wells (Figure 1) at various depths. The isotope composition of groundwater along the depth of the aquifer was analyzed on three locations (piezometric wells ČDP-23, ČDP-9, JP-10). The main ions, elementary composition, stabile isotopes of oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$), radioactive isotopes of hydrogen (tritium, ^{3}H) and carbon (^{14}C) and the dissolved organic carbon (DOC) are analyzed. The goal of these investigations is the estimation of origin and dynamics of aquifer recharge and the interconnection among its individual parts, which reflects at the estimation of possibility for usage and vulnerability of groundwater.

General hydrogeological features

Zagreb aquifer is made of Quaternary sediments, which are distinguished by horizontal and vertical exchange of various lithological units (Velić et al., 1999). It is composed of Pleistocene and Holocene gravel-sand sediments where the pebbles and grains of limestone and dolomite are prevailing (Figure 1). Within the older (Pleistocene) aquifer the semi permeable silt-clay interbeds, which are partially eroded in the middle part of the basin, are located. The

Scientific paper

aquifer is of exceptionally high permeability. The average hydraulic conductivity is about 2000 m/day. The groundwater flow velocity, determined by tracing with radioactive isotope ^{131}J, is 9-9.15 m/day. Semi permeable deposits composed of silt, sand and clay lay above the gravel-sand aquifer. The thickness of these deposits is as a rule 1-2 m. The groundwater levels are below the overlaying deposits, so the aquifer is of the unconfined. The river Sava has cut its river-bed into gravelly aquifer, so it is in the direct hydraulic connection with the groundwater. At almost the whole considered area the river Sava is recharging the aquifer, which is even more emphasized by intensive water pumping at big pumping sites (Fig. 1).

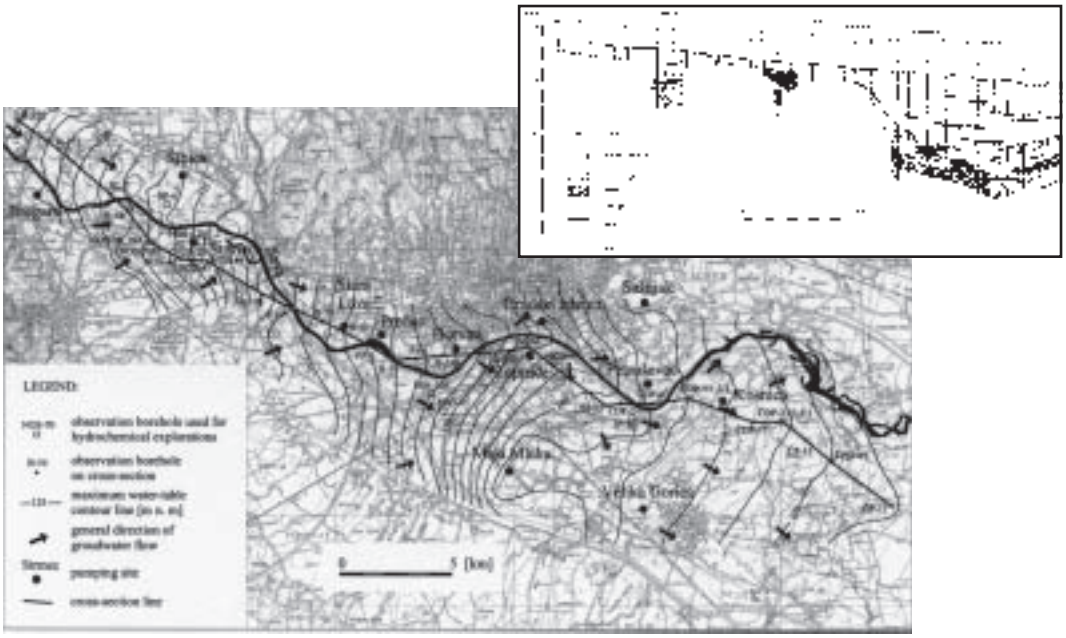

Figure 1. Longitudinal lithological cross-section of the Zagreb aquifer

GENERAL HYDROGEOCHEMICAL DATA AND ISOTOPE DISTRIBUTION

In accordance to the petrographical and mineralogical composition of sediments that build the aquifer, the groundwater belongs to Ca^{2+}-HCO_3^- type with significant portion of Mg^{2+}. The decrease of Ca^{2+} and HCO_3^- content along the aquifer depth at the piezometric wells ČDP-9 and ČDP-23, which is the consequence of lower contribution of soluble matter from the weathering zone, has been noticed. The groundwater temperature in the period from 2000 to 2002 was about 10-16 °C. As a rule, at all the piezometric wells the increase of temperature was recorded from December to February, after that the water temperature was gradually decreasing up to September next year. Conductivity varies between 400 and 1000 μS/cm, and greater values than this have been recorded at the individual piezometric wells downstream from groundwater pollutant. Generally it could be concluded that the values of conductivity are decreasing with the aquifer depth. Groundwater from Zagreb aquifer is, according to pH values, neutral to slightly basic. The content of oxygen dissolved

in the water varies from values lower than 1mg/l to 10 mg/l. Due to low oxygen concentration the dissolving of the manganese oxides and iron oxides from sediments is enabled and in accordance with that the concentration of manganese and/or iron in the groundwater in individual zones of inflow areas of pumping sites Strmec, Petruševec and Črnkovec is increased. The tritium activity in the groundwater of Zagreb aquifer varies from 6 to 22 TU, and ^{14}C activity varies from 82 to 104 % of the present carbon (pmC). Activity distribution of these isotopes along the aquifer depth on both locations shows that the whole quantity of water is the result of present recharge, so in its prevailing part, it is the result of precipitation infiltration in last 50 years (IAEA, 1983). The increase of activity concentration of ^{3}H along the aquifer depth on the piezometric wells ČDP-9 and ČDP-23 (Figure 2) can be the result of groundwater tracing during the 80-ies in the last century. Taking into account the hydrological conditions during the groundwater sampling it has been observed that the highest activity of ^{3}H was noticed at lower groundwater levels (September, 2001), while at higher groundwater levels the lower ^{3}H activity was noticed, which indicates the inflow of water with lower ^{3}H activity, hence the contemporary water.

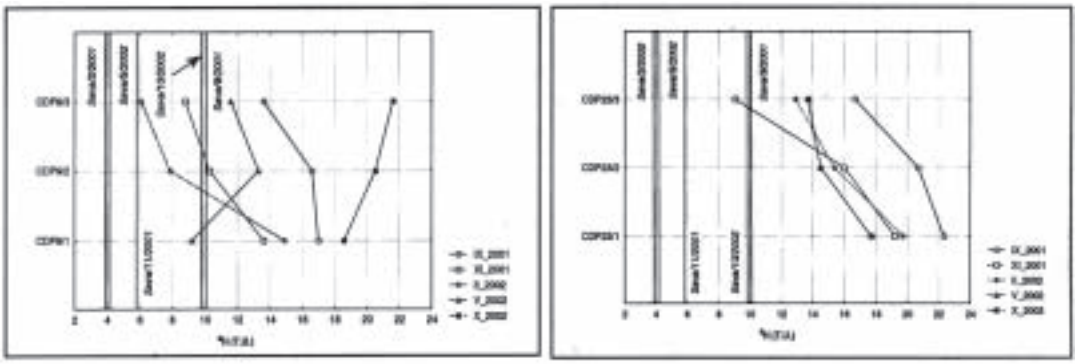

Figure 2. The distribution of ^{3}H activities in the groundwater along the depth in Zagreb aquifer

In the Zagreb aquifer groundwater the content of stable hydrogen isotope ($\delta^{2}H$) varies from -57 to 66 ‰, and the content of oxygen ($\delta^{18}O$) varies from -9.6 to -8.7 ‰ (Fig. 3). The values of ratio between these isotopes in the water from piezometric well JP-10 are the most similar to the values in samples from the river Sava. In that part the aquifer recharges from the river Sava (Fig. 1). Generally it could be said that the determined variations along the depth at the piezometric well ČDP-9 reflect the simultaneous influence of infiltration from the river Sava and from precipitation. The range of measurement deviation points to high velocity of groundwater flow and the water exchange in some parts of the aquifer. Thereby, the dynamics of exchange isn't connected to the depth.

According to the concentration of tritium activity, somehow calmer medium has been determined along the depth of piezometric well ČDP-23, where the shallower parts are more under the influence of local recharge, while with the depth this influence decreases. In the same time, the values of ratio between stable isotopes are more negative then above mentioned. Deeper parts of groundwater at this location are pauperised with heavier isotope, which points at more expressed regional flow.

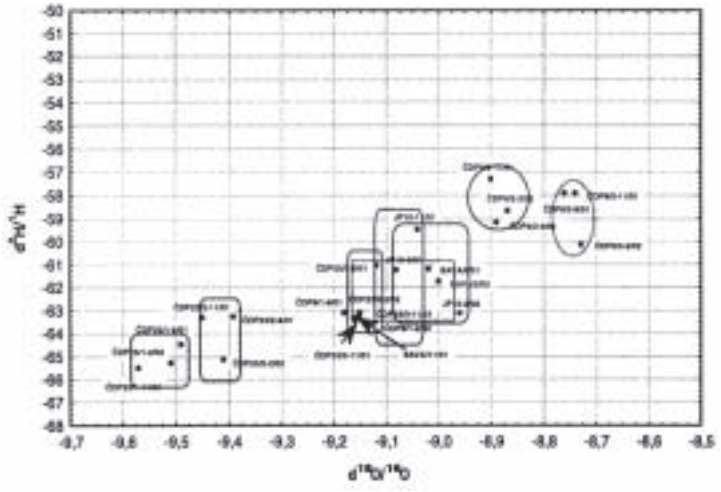

Figure 3. Ratio $\delta^{18}O$ and $\delta^{2}H$ in the groundwater of Zagreb aquifer

CONCLUSIONS

Zagreb aquifer is the main source for water supply of city of Zagreb. It is composed of non-cohesive gravel-sand deposits of Quaternary age, in which the aquifer with exceptionally high permeability was formed. In this paper only the preliminary results of hydrogeochemical investigations that have been made since 2000 in this area, are shown. The values of basic hydrogeochemical and isotope indicators of groundwater (temperature, electrolytic conductivity, main ions, isotope composition) indicate the stratification of aquifer along the depth. Hydrogeochemical conditions and the distribution of isotope composition point at different time of recharge and retain the contact between groundwater and the rock mass. However, besides that, it could be concluded that the whole quantity of water is the result of present recharge, hence in it's most part it is the result of recharge in the last 50 years, which is favorable circumstance for the using of groundwater. In favor of this are the data of tritium activity in the groundwater, which is from 6 to 22 TU, ^{14}C activity from 82 to 104 % of present carbon (pmC) and the content of stabile hydrogen isotope ($\delta^{2}H$) from -57 to 66 ‰, and oxygen from -9.6 to 8.7 ‰.

REFERENCES

IAEA (1983): *Guidebook on Nuclear Techniques in Hydrology*, Techical report series No. 91, International Atomic Energy Agency, Vienna.

VELIĆ, J., SAFTIĆ, B. & MALVIĆ, T. (1999): Lithologic Composition and Stratigraphy of Quaternary Sediments in the Area of the "Jakuševec" Waste Depository (Zagreb, Northern Croatia). *Geol. Croatica,* Vol. 52/2, pp. 119-130, Zagreb.