Unsaturated zone of Zagreb aquifer

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Abstract. Unsaturated zone of unconfined Zagreb aquifer system has never been investigated in detail. For the purpose of water flow and solute transport modelling, unsaturated zone profile and pedological burrow at location Kosnica were excavated. Sediments and soil are described in detail, boundary conditions are determined, main hydrogeological processes selected and field measurement of different parameters important for model calibration started.

Key words: unsaturated zone, geochemical processes, modelling, field data acquisition, Zagreb, Croatia.

Introduction

Groundwater quality of unconfined aquifer systems depends strongly on land use and unsaturated zone characteristics which influence water flow and solute transport. An understanding of how metals can migrate through the vadose zone is necessary for environmental professionals to predict the impact that contamination may have on human health and the environment. Subject of this study is unsaturated zone of Zagreb aquifer where high concentrations of several toxic metals in soils and sediments are found. The goal of the study is assessment of impact of land use on groundwater quality, by modelling water flow and solute transport at Kosnica site.

Case study description

Area of investigation is situated in northwest Croatia (Fig. 1). The broader area (Fig. 1) consists of a large alluvial plain bordered in the north and northwest by a mountain range, Mt Žumberak and Mt Medvednica. The region is characterized by large variability in lithology, pedological features and land use.

The mesorelief of the investigated area abounds in numerous meanders of the Sava River, inundated fluvial cones and numerous bowl-shaped depressions. From the geomorphologic aspect, there are two marked features, one being the raised sealed terrace of the Sava and Holocene terrace. The climate of Zagreb is classified as a moderately continental climate (Cfwbx in Köppen climate classification system).

Geology of the Zagreb aquifer area is represented mainly by Quaternary sediments. Lower Pleistocene deposits are predominantly composed of clayey silts / silty clays with sporadic lenses and interbeds of gravelly-sands, up to thickness of few decimeters (Velić & Durn, 1993). While the lower and middle part of Middle Pleistocene unit is predominantly composed of sands, the upper part comprises silt and clay sized material (Velić & Durn, 1993; Velić & Saftić, 1996). The Upper Pleistocene unit is characterized by frequent lateral changes of gravels, sands, silts and clays. The Holocene is composed gravels and sands in which limestone cobbles prevail.

The thickness of unsaturated zone in Zagreb area varies from 8 meters in NW part to 2 meters in SE part (Fig. 2). The upper part of this zone is composed mainly of silty to sandy material, while the lower part consists of gravels. In some parts this material was intersected with clay layers. Predominantly three pedologic units developed on theese sediments: Fluvisols, Stagnic Podzoluvisols (Pseudogley) and Eutric Cambisols (Sollitto *et al.*, 2010).

Numerous studies of lateral and vertical metal distribution in soils have been made in the area of Zagreb and Zagreb County (Namjesnik, 1994; Miko *et al.*, 2001; Romić, 2002; Romić & Romić, 2003; Romić *et al.*, 2004, 2005; Sollitto *et al.*, 2010). These studies show elevated concentration of metals in topsoils, as well as increase of cadmium, iron, manganese, and

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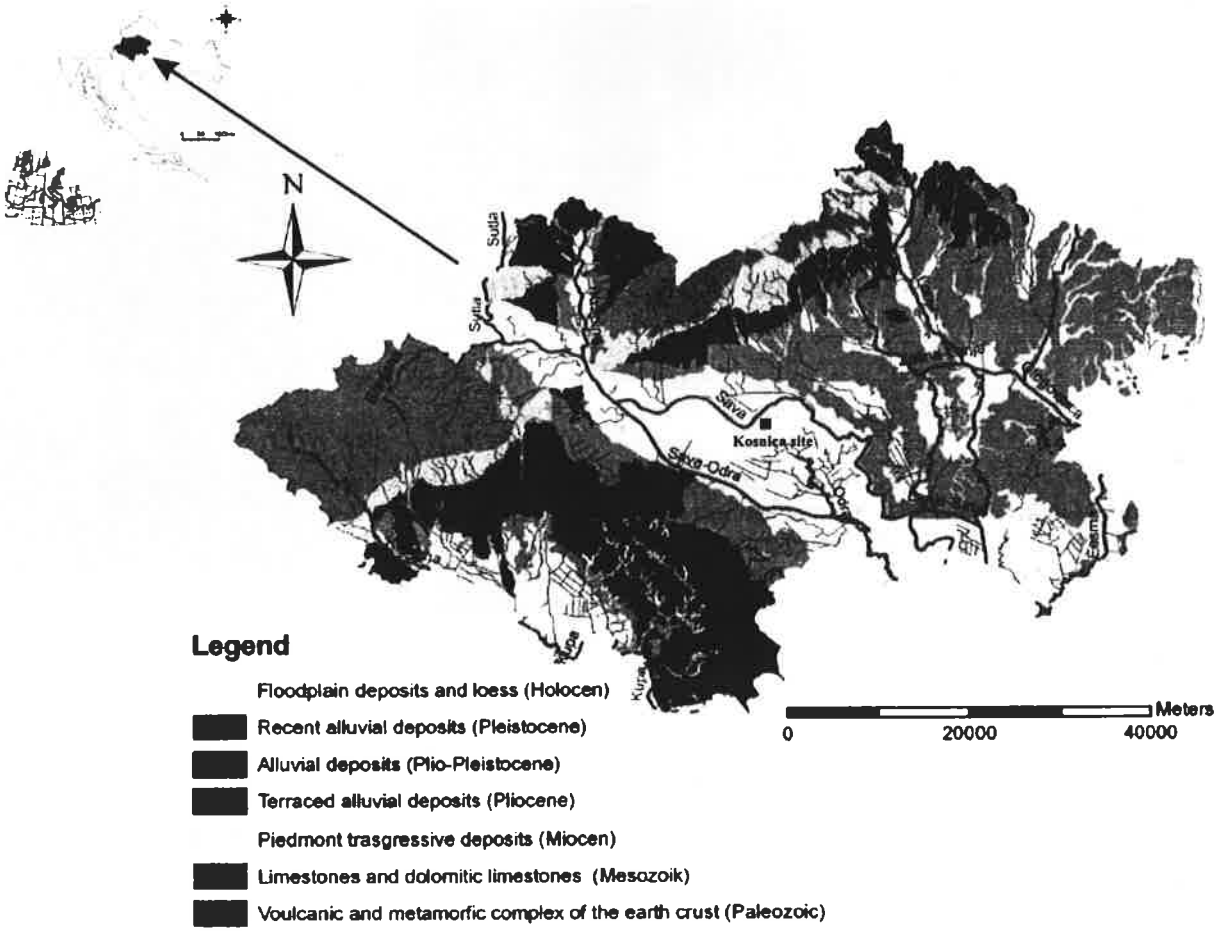

Fig. 1. Simplified geological and geomorphological map of Zagreb area according to SOLLITTO *et al.* (2010).

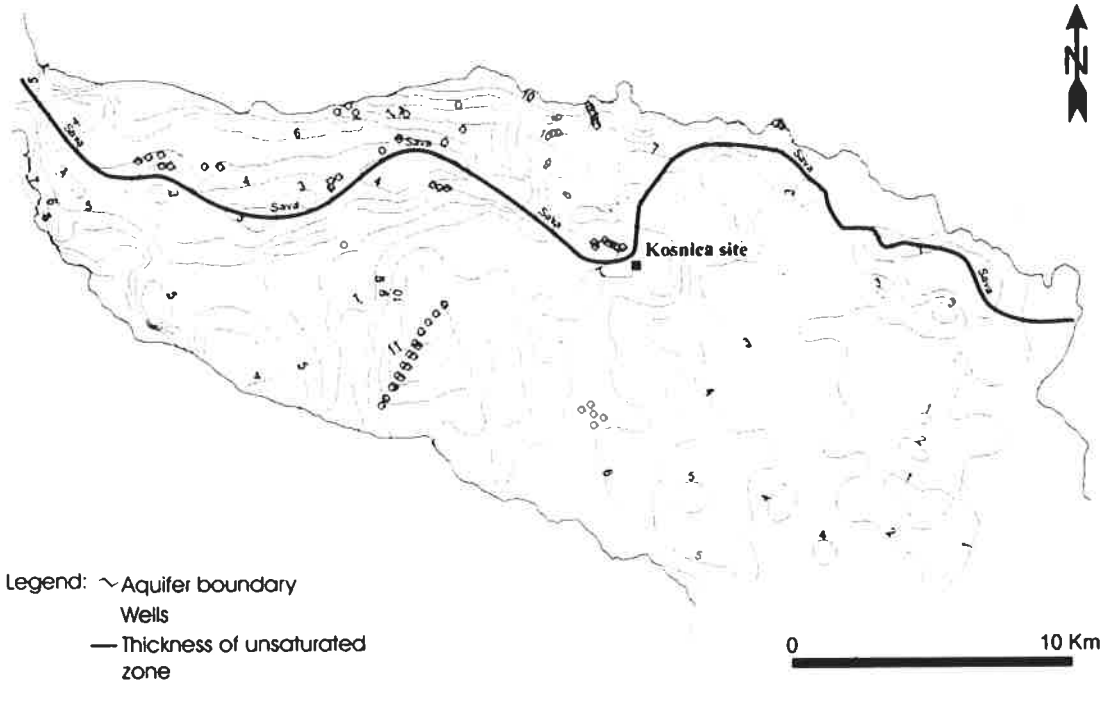

Fig. 2. Isopach map of unsaturated zone.

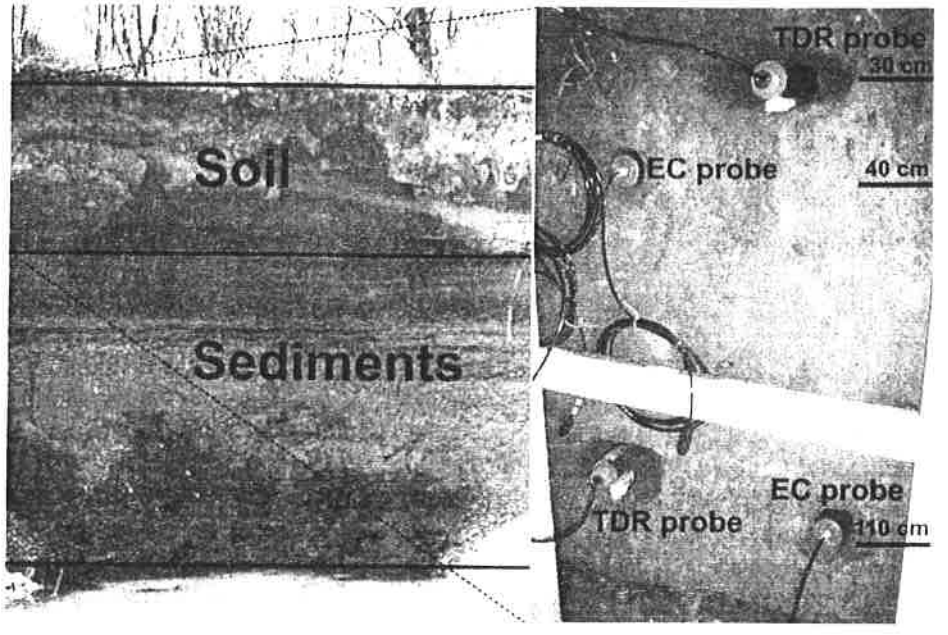

Fig. 3. Investigated pedological burrow with equipment for data acquisition.

nickel with depth. ROMIĆ & ROMIĆ (2003) emphasized that the distribution of trace elements in soils of investigated area is primarily controlled by: (a) geology, (b) industrial impact (traffic, heating plants, chemical industry and airports) and (c) external factors (some trace elements are brought by the Sava River, which has been exposed to intensive pollution by mining, industries and towns in its upper course). A portion of trace metals is introduced by wind, blown from the industrial region of north Italy (ANTONIĆ & LEGOVIĆ, 1999).

Flow and transport modeling in unsaturated zone

Location of investigated profile (Fig. 3) is located in second zone of sanitary protection of the water abstraction site Kosnica, about eight hundred meters from Sava river (Fig. 2). Detailed characterization (chemical, mineralogical and sedimentological) of sediments and soils is still in progress. Lower part of profile consists of gravels with sand component, while upper part is dominated by gravels with silty to sandy material. Stagnosols (Pseudogley) is developed of the top of unsaturated zone profile. The profile is consists of following soil horizons: O-A horizon; AC-C horizon; 2C/Cl horizon; 3Cl horizon and 4Cl/Cr horizon.

Modeling water flow and solute transport will be performed using Hydrus 1D software (ŠIMUNEK *et al.*, 1998). Advection, dispersion and sorption are main processes which will be modeled. Boundary conditions for water flow model are atmospheric conditions (upper) and free drainage (lower), while for solute transport are flux (upper) and zero concentrations gradient (lower). Monitoring of parameters such are water content, electrical conductivity, pressure heads and concentrations of metals in percolating water) is necessary for calibration of models. Thitherto, pedological burrow (Fig. 3) two meters in depth was made, instruments installed and measurement started. Transport model will be used for particle tracking metals (cadmium, lead and zinc). Contaminated water will be spill on the top of the pedological burrow. The solutions will be prepared from $Pb(NO_3)_2$, ZnO and CdO. Leachate collection will be analyzed using AAS for detection of selected metals. Historical climate data has been obtained from the surrounding meteorological stations.

Conclusion

For the purpose of water flow and solute transport modelling of unsaturated zone above unconfined Zagreb aquifer, profile and pedological burrow at location Kosnica were excavated. Sediments and soil are described in detail, boundary conditions are determined, main processes selected and field measurement of different parameters important for model calibration started. The goal of this investigation is assessment of impact of land use on groundwater quality. The results of this study can contribute to better understanding how metals migrate through the unsaturated zone and affect sanitary protection zones of Zagreb aquifer.

Acknowledgments

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