Risk of soil salinization/sodification in the Danube Lowland after the realization of underground sealing walls between Komárno and Štúrovo, Slovakia

Tomáš ORFÁNUS – Anežka ČELKOVÁ – Viliam NAGY

Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovak Republic, E-mail: celkova@uh.savba.sk

Abstract: The paper deals with the evaluation of the characteristics of groundwater (GW) important for the formation and spreading of saline soils and their trends in the alluvium in the left bank-side of the Danube River between Komárno and Štúrovo, Slovakia after underground sealing walls realization for the period from1997 to 2012. The risk that this GW results in salinization/sodification of soils was determined from selected characteristics of GW mineralization (HCO_3^-, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, pH, EC), SAR (sodium adsorption ratio) and from the groundwater level (GWL) regime within the territory.

Keywords: alluvium of Danube River, GW regime, soil salinization/sodification, underground sealing walls

Introduction

In areas with evaporative soil water regime, such as the Danube Lowland in south-western Slovakia or the Eastern-Slovakian Lowland, the main source of salts within soils is the mineralized groundwater (GW) located close to the ground surface. Dissolved salts are transported from the GW table to the soil profile via vertical upward capillary flow of water. Under evaporative soil moisture regime the GW rises up to the root zone of soil profile from where it is deflated by evapotranspiration, and the soluble salts may precipitate and accumulate within upper soil horizons to the same extent as by using of irrigation water with similar chemical composition (Kováčová, 2015; Fulajtár, et al., 1998; Burger and Čelková, 2003). The formation of saline soils is affected especially by total mineralization of GW, their chemical composition and by the groundwater level (GWL) regime. Moreover, utilization of this GW for irrigation leads to further accumulation of salts within the soil profile.

The processes of soil salinization/sodification in the left bank-side of the Danube River between Komárno and Štúrovo can be affected by the system of protective underground sealing walls which were built during the construction of Gabčíkovo – Nagymaros waterworks in Slovakia and finished in 1996. They were constructed to prevent the gravitation outflow of internal waters from the territory of Slovak Republic into the Komárno - Ipeľ river confluence section of Danube and thus may set conditions for increasing of mineralized GW table and subsequent soil salinization/sodification (Burger and Čelková, 2009; Burger, 2012). The aim of this paper is to characterise the chemical status and regime of groundwaters, which are relevant for formation and spreading of saline soils within the left bank alluvium of the Danube River and to determine whether the risk of salinization/sodification of local soils has been increased after the realization of underground sealing walls.

Materials and methods

The GW can be evaluated according to the criteria for the quality of irrigation water. There are various classification schemes used for the assessment of the irrigation water (Allison, et al., 1954; Ayers and Westcot, 1985; Rhoades, et al., 1992). Most of them are based on the assessment categories according to physiological impact on plants or on the quality of soils. We recognize: salinity – the total dissolved solids (expressed as specific electrical conductivity, EC); sodicity – the relative ratio of sodium to the calcium and magnesium (expressed as sodium adsorption ratio, SAR); alkalinity – the content of carbonates and bicarbonates; pH – acid or alkaline medium, and the proportion of specific ions: chlorides, sulphates, nitrates and boron.

As regards of EC, according the American Laboratory Classification System the irrigation water is divided into four classes: low mineralized water (EC < 25 mS m^{-1}); medium mineralized water (25 mS m^{-1} < EC < 75 mS m^{-1}); highly mineralized water (75 mS m^{-1} < EC < 225 mS m^{-1}) and very highly mineralized water (EC > 225 mS m^{-1}). As regards of SAR there are four classes: low sodium water (SAR=0 – 10); medium sodium water (SAR=10 – 18); highly sodium water (SAR=18 – 26) and very highly sodium water (SAR > 26). On the basis of the values of EC and SAR we can determine the risk of soil salinizatin/sodification under the influence of irrigation water or shallow GW.

The chemical composition of water influences the character of saline soils formation. According to concentration of particular ions (Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}, Na^+, Ca^{2+}, Mg^{2+}) the character of soil salinization is determined (the chloride salinization – the limit value of 300 mg l^{-1} Cl^-, the sulphate salinization – the limit value of 250 mg l^{-1} SO_4^2, the soil alkalinity – the concentration of bicarbonates and carbonates anions exceed that of sulphates and chlorides and the ions of Na^+ dominate in the cationic composition (Allison, et al., 1954; Fulajtár, et al., 1998).

The GWL and its fluctuation is another factor affecting the formation and spreading of saline soils. The degree of mineralization of GW in terms of soil salinization/sodification is important only under conditions of capillary rise of mineralized GW to the root zone of soil profile or to the soil surface (Várallyay and Rajkai, 1989; Várallyay, 2011). The "critical" depths of GWL in the areas of medium and high mineralized GW differ for various soil textural classes and range between 1-2.5 m below the soil surface within the studied region (Jambor, et al., 1988).

The values of selected characteristics of GW mineralization (HCO_3^-, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, pH, EC) and monitoring of GW table regime were provided by the Slovak Hydrometeorological Institute in Bratislava. Samples were taken twice a year during the spring and autumn times. Chemical analyses (ion chromatography, AES-ICP, electrometry, gravimetry) were performed by the State Geological Institute of Dionysus Štúr. The SAR values were calculated by the equation: $SAR = Na^+ / \sqrt{Ca^{2+} + Mg^{2+}/2}$, where Na^+, Ca^{2+} and Mg^{2+} are the ions concentrations in mmol.l^{-1} (Allison, et al., 1954).

Definition of the area of interest

The area of interest is located in the south-eastern part of the Danube Lowland in the

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alluvium between Komárno and Štúrovo. The location of the monitoring objects of GW quality is shown in Figure 1. The hydrological regime of GW flow and its quality affects a system of protective measures in the left bank side of Danube River between Komárno and Štúrovo. Protective measures include the reconstruction of dams with the construction of underground sealing walls, construction of seepage and drainage channels and pumping stations. The construction of underground walls was realized in the year 1982 – 1996. There are three so called "windows" omitted in the non – permeable underground walls near the village Iža, Kravany nad Dunajom and Mužla Kendeleš (Figure 1).

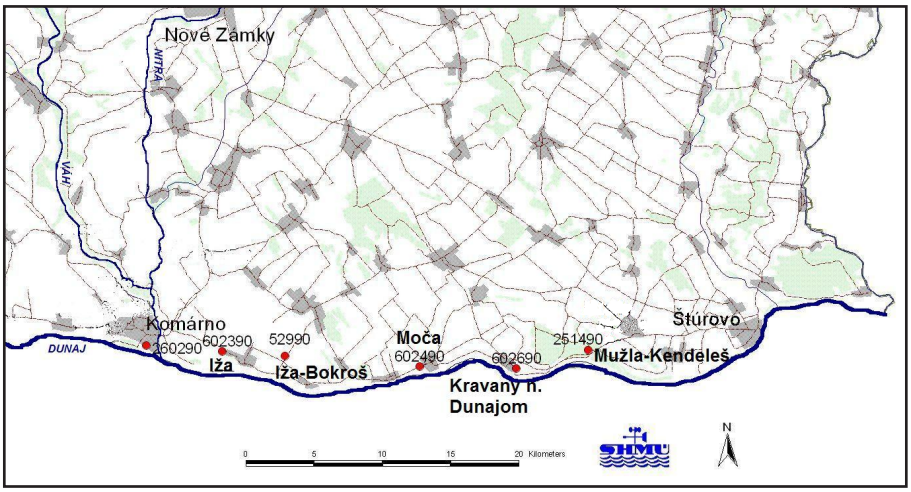

Figure 1. The map of GW quality objects (Komárno 260290, Iža 602390; Iža Bokroš 52990; Moča 602490; Kravany nad Dunajom 602690; Mužla Kendeleš 251490)

Results and discussion

In the GW in the alluvium in the left bank side of Danube River between Komárno and Štúrovo after underground sealing walls realization for the 1997 to 2012 the concentration of bicarbonates ions (HCO_3^-) exceeded that of sulphates (SO_4^{2-}) and chlorides (Cl^-), while Ca^{2+} and Mg^{2+} dominated in the cationic concentrations. HCO_3^-concentrations ranged from 280.6 mg.l^{-1} – 1052.6 mg.l^{-1} and the concentrations of SO_4^{2-} ranged from 37.3 mg l^{-1} – 891 mg l^{-1}. Concentrations of Cl^- in GW were low and ranged between 18.2 mg l^{-1} – 139.0 mg l^{-1} except of Iža where the maximum of Cl^-concentration reached 255 mg l^{-1}. In terms of hydrochemical classification of GW they are the type of calcium-magnesium-bicarbonate and the type of calcium-magnesium-sulphate, with high bicarbonates and sulphates content. Concentrations of Na^+ were low in most monitored objects except of Iža and Iža Bokroš and ranged between 14 mg l^{-1} – 210.3 mg l^{-1}. The pH values ranged from 6.84 – 7.69. The time courses of electrical conductivity values (EC) and sodium adsorption ratio values (SAR) in the monitored GW and their trend lines for 1997 – 2012 are documented in Figure 2.

The EC values ranged from 84.4 mS m^{-1} to 278.0 mS m^{-1}, and showed increasing tendency from 1997 to 2012 in most of the monitored waters. The highest values of EC > 225 mS m^{-1} were measured in Iža. The SAR < 4 values (except of Iža Bokroš where the SAR values

ranged from 2.0 to 6.8), showed an increasing tendency within the objects Iža Bokroš, Moča and Mužla Kendeleš and decreasing tendency in Komárno, Iža and Kravany nad Dunajom (Figure 2).

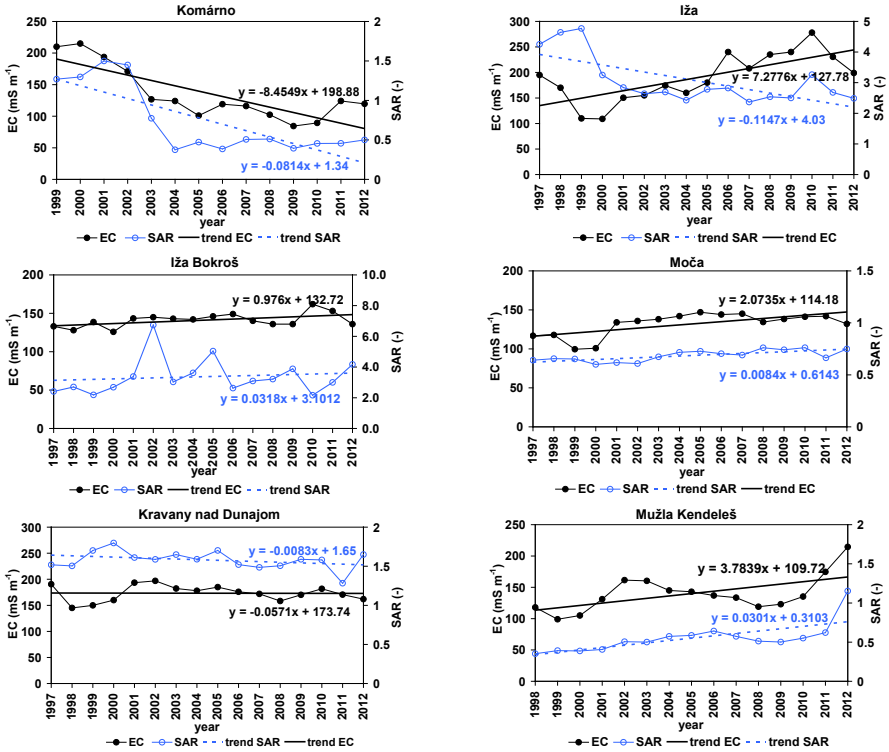

Figure 2. The time courses of the EC and SAR values in GW in the localities of Komárno, Iža, Iža Bokroš, Moča, Kravany nad Dunajom, Mužla Kendeleš and their trend lines from 1997 to 2012

Most of the monitored GW are the highly mineralized waters with a high salinity hazard and low sodium hazard for influenced soils according to criteria of USSL Staff. The GW of Iža and Iža Bokroš can be classified as the water with high to very high salinity hazard and low to medium sodium hazard for soils under influence of GW.

The time courses of the average annual GWL for the 1997 to 2012 period are documented in Figure 3. The depth of GWL under the surface ranged from 2.75 m – 6.80 m, except Iža and Iža Bokroš where it was situated in a depth of 0.52 m – 2.03 m.

Because of existing openings ("windows") in underground sealing walls the trends in average annual GWL for 1997 to 2012 decreased in most monitored wells, except for Iža Bokroš and Mužla Kendeleš where the trend of GWL was increasing.

Thus, in spite of high GW mineralization and its upward trends generally the risk of secondary soil salinization/sodification within the alluvium on the left bank-side of Danube River between Komárno and Štúrovo has not increased. Only within the objects

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of Mužla and Iža Bokroš the realization of underground sealing walls crops really caused the rise of GWL above the critical depths of 0.52 – 2.03 m.

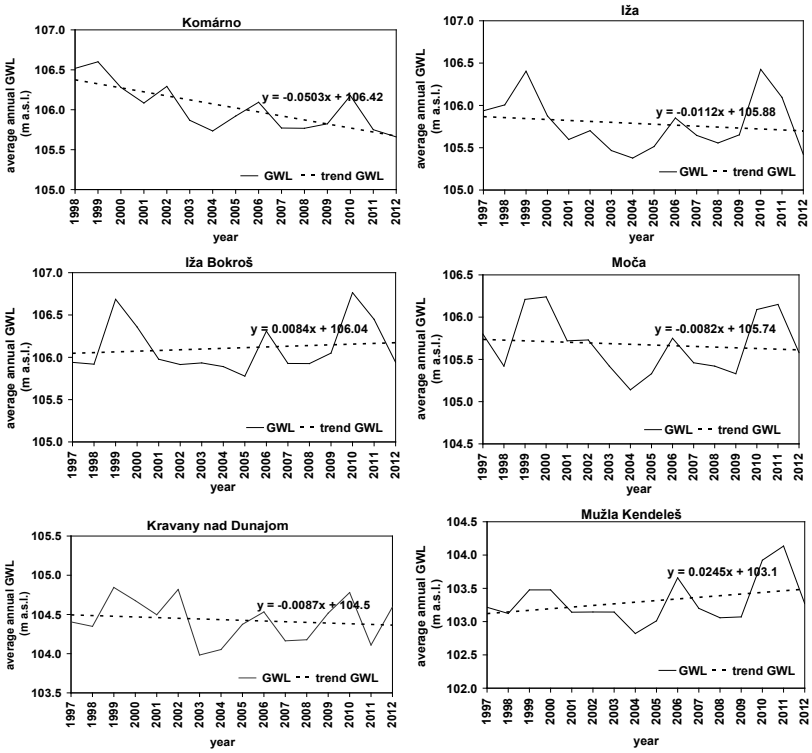

Figure 3. The time course of average annual levels of GW tables in Komárno; Patince; Iža; Iža Bokroš; Moča; Kravany nad Dunajom and Mužla Kendeleš and their trend lines from 1997 to 2012

The risk of secondary soil salinization/sodification under the influence of GW in the area of interest is high with rising trend only in the drainless depressions, then during the floods on Danube through the "windows" in the underground sealing walls and also by using of highly mineralized GW for irrigation (Hraško, 1971; Burger and Čelková 2009).

Conclusions

Finally, we can conclude that after the completion of underground sealing walls construction despite the high mineralization of GW and its upward trends, there was no risk of secondary soil salinization/sodification by means of vertical flow from a GW level to the root zone of soil profile, or on the surface of the soil in most observed localities in the alluvium in the left bank side of Danube River between Komárno and Štúrovo, due to that the GW levels were lower than critical GWL except Iža Bokroš and Iža, where the highly mineralized GW was situated near the surface, and due to decreasing trends in the annual average levels of GWL for 1997 – 2012. Priority attention should be paid to the quality of water for irrigation, which is necessary for optimizing of water and salt regime of soils due to the fact that in studied area the saline soils were already occured. The highly

mineralized GW of the monitored objects is not suitable for irrigation and the use of this water represents a high risk of secondary soil salinization and a low to medium risk of soil sodification.

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