J. Hydrol. Hydromech., *60*, 2012, 1, 57–63
DOI: 10.2478/v10098-012-0005-4

THE RISK OF THE SOIL SALINIZATION OF THE EASTERN PART OF ŽITNÝ OSTROV

VIERA KOVÁČOVÁ, YVETTA VELÍSKOVÁ

Institute of Hydrology, Slovak Academy of Sciences, Račianska 75, 831 02 Bratislava, Slovak Republik;
Mailto: kovacova@uh.savba.sk; veliskova@uh.savba.sk, phone: +421 2/49 268 263

Salinization is an increasing enviromental problem in ecosystems. The assessment of total dissolved solids (TDS), pH, electrical conductivity (EC), exchangeable sodium percentage (ESP), alkalinity and the concentrations of main ions makes possible to identify salinization and alkalization degree. The salt-affected soils occur in the south part and south-east part of Žitný ostrov, where the dry and mild summer climate, evaporation soil water regime and mineralized groundwater create conditions for development of the saline and alkaline soils. Five localities with highly-mineralized groundwater were monitored to evaluate salinity and alkality in the period 1989–2006. At the bottom horizons in localities 1 – 5 evaporative residues (salt content) reached value 0.1 – 0.2 %. In 2006 dry evaporative residues (salt content) was higher than 0.2 %, EC was higher than 250 mS m^{-1} at the bottom horizons in localities 1, 2, 4. The mentioned data allow us to state that salinization and alkalization of soils is developing, it starts from the bottom of soil horizons through middle part of the soil profile up to the top horizons. This phenomenon was observed in all investigated soils in different stages of development.

KEY WORDS**:** Salinization, Alkalization, Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), Electrical Conductivity (EC), Exchangeable Sodium Percentage (ESP).

Viera Kováčová: RIZIKO SALINIZÁCIE PÔDY VO VÝCHODNEJ ČASTI ŽITNÉHO OSTROVA. J. Hydrol. Hydromech., *60*, 2012, 1; 28 lit., 2 obr., 5 tab.

Salinizácia v ekosystémoch je stále významnejší enviromentálny problém. Stanovenie celkového množstva rozpustených látok (TDS), elektrickej vodivosti (EC), sodíkového adsorpčného pomeru (SAR) a obsahu výmenného sodíka (ESP) umožňuje identifikáciu kritického potenciálu salinizácie a degradácie pôdy. Záujmové územie bolo vymedzené vo východnej časti Žitného ostrova, kde suché a horúce klimatické podmienky spolu s vysokomineralizovanými podzemnými vodami sú príčinou translokácie solí do pôdneho profilu. Bolo monitorovaných 5 lokalít v období 1989 – 2006. Namerané údaje poukazujú na vzrastajúci obsah solí, ktorý v r. 2006 dosiahol 0,1 – 0,2 % v celom pôdnom profile vo všetkých monitorovaných lokalitách, hodnoty EC 200 – 400 mS m^{-1} v spodných horizontoch vytvárajú podmienky pre rozvoj zasolených pôd.

KĽÚČOVÉ SLOVÁ**:** salinizácia, alkalizácia, celkové rozpustené látky (TDS), sodíkový adsorpčný pomer (SAR), elektrická vodivosť (EC), výmenné sodíkové percento (ESP).

Introduction

Žitný ostrov – natural conditions, geology and parent materials

Žitný ostrov is the south-west part of Slovakia, where fluvial sedimensts are dominant. In the evapotranspiration regime carbonates in fluvial carbonate sediments have been preserved, formed in alluvial soils of whole alluvial river plains. Parent materials and soil forming processes influenced the occurence prevailingly calcareous soil character. In alluvial areas of lowland rivers Calcaric Fluvisols, in depressions Fluvi-Calcaric Phaeozems, Fluvi-mollic Calcaric Gleysols to Calcaric Gleysols occur. On older alluvial sediments Calcaro-haplic Chernozems are spread. In lower lying southernmost parts with mineralized groundwaters, locally also saline soils are occuring (Fig. 1, 2).

Lowland area is covered by Quaternary cover, and that is why underlying Neogene sediments crop out only locally, in tectonically elevated parts. Their development was influenced in Quaternary period by three basic factors: fluvial and aeolian activities, and solifluction. Extensive alluvial plains originated in descending parts of lowland. Most

spread parent materials are fluvial sediments, loess complexes, aeolian sands and proluvial (slopes) sediments. Their extension, genesis and texture are narrowly connected with geomorphological features of lowlands, particularly territorial tectonic mobility. Contributing factors has also play a role zonal climatic distribution of precipitation-temperature (evapotranspiration – versus perlocation water regime) and groundwater mineralization changes. These factors affect particularly carbonate preservation. Their presence is a significant component part affecting the final character of pedogenetic processes (*Čurlík, Šefčík*, 1999; *Granec, Šurina*, 1999; *Červenka*, 1970; *Šútor, Štekauerová*, 2000; *Burger, Čelková*, 2007, 2009).

The objective of this contribution is to evaluate the state of salinization and alkalization of the soil profile in localities with high-mineralized groundwater.

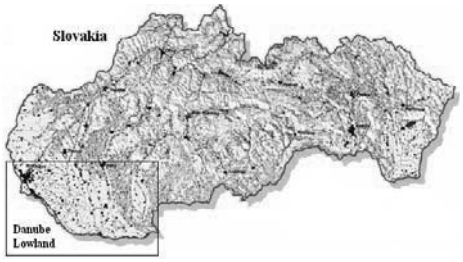
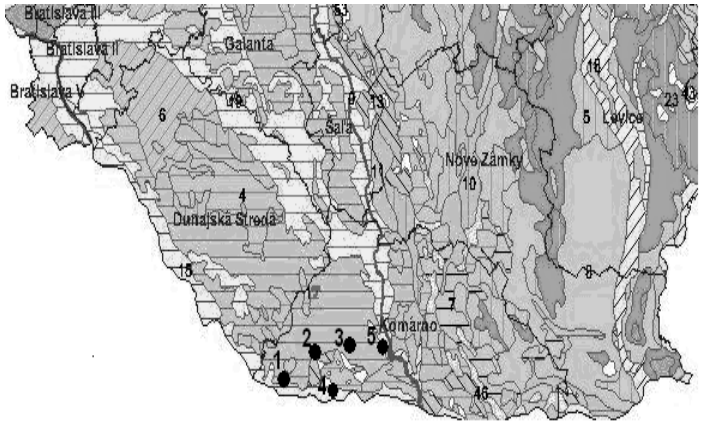


Fig. 1 . Localisation of the studied area.



Legend

Fluvisols calcaric associated with Fluvi-calcaric Gleysols

Fluvi-calcaric Phaeozems developed on calcareous alluvial deposits

Calcaro-haplic-Chernozems, associated with Fluvi-Calcaric Phaeozems and Calcaro-haplic Phaeozems developed on calcareous alluvial deposits

Regosols arenic associated with Arenic-Fluvi-gleyic Phaeozems on alluvial sand (in depressions)

Fig. 2. Dominant soil groups of the area.

Development of saline soils

The salt-affected soils occur in the south part and south-east part of Žitný ostrov. The dry and warm summer climate, evaporation soil water regime and mineralized groundwater create here convenient conditions for development and spreading of the saline and alkaline soils.

These soils are developing slowly from the initial stages to the well developed ones. As a consequence of this long lasting process the slightly and middle saline and alkaline soils as well as typical solonchaks and solonetzes occur in monitored area. The network of monitoring sites therefore respects mentioned fact and the soil in different stages of development are monitored.

Two processes in the development of the salt-affected soils can be recognised:

1. Process of salinization is conditioned by the presence of neutral sodium salts, mainly NaCl and Na_2SO_4. The indicators of salinization are dry evaporative rezidue > 0.2% and electrical conductivity of saturated soil extract EC > 400 mS m^{-1}. Low stage of salinization is running at EC 200 – 400 mS m^{-1} or evaporative rezidue of salts 0.1–0.2 %. The result of salinization processes are middle saline soils and solonchaks.
2. Process of alkalization is conditioned by the presence of alkaline sodium salts, mainly Na_2CO_3, $NaHCO_3$, Na_2SiO_3. The indicators of alkalizaton are exchangeable sodium percentage ESP > 5 % and pH 8 or higher. The result of alkalization processes are middle alkaline soils and solonetz.

In natural conditions both of this processes are represented by different rate and the result is the

mixture of both this processes, one of them is dominant.

The relationship between electrical conductivity and degree of salinity is presented e.g. in *U.S Salinity Laboratory Staff*, 1954; *Recommended Chemical Soil Test Procedures*, 1998; *Burger, Čelková*, 2009.

Groundwater

Groundwater in eastern part of Žitný ostrov is supplied by infiltrating Danube water primarily. Groundwater influenced the soil cover development and some chemical particularities connected with their mineral content and hydrothermic regime (local salinization). Saline soils are widespread in some localities reflecting the predominance of sodium chloride in groundwaters and soil solutions. Sodic soils are subject to severe structural degradation and restrict plant performance through poor soil-water and soil-air relations. Sodicity is shown to be a latent problem in saline-sodic soils where deleterious effects are evident. A classification of soils based on total dissolved solids, electrical conductivity, sodium adsorption ratio, exchangeable sodium and pH is outlined in studies *Barzegar* et al., 1994; *Burger, Čelková*, 2004; *Curtin* et al., 1994a,b; *Feitz* et al., 2002; *Hanes*, 1999; *Kaledhonkar* et al. 2001; *Kováčová*, 2009b.

Sodium is one of the most abundant cations in natural waters. Na^+ cation is very conservative, does not enter oxidation-reduction reactions, cannot be precipitated by chemical reactions, it remains stable in solution. Nevertheless, sodium significantly participates in ion-exchange processes. Cation ion-exchange in common natural waters tends to replace divalent cations in a solution by monovalent cations. Sodium in solids-low waters (below 1 g l^{-1}) occurs in the form of cation Na^+. In solids-richer solutions, the element is combined in several complexes and ion pairs controlled by the type of water chemistry (most frequently $NaCO_3^-$, $NaHCO_3(aq)$ and $NaSO_4^-$). Much sodium gets to soil profile from mineralized waters and through human activities (*Rapant, Vrana, Bodiš*, 1999; *Kováčová*, 2009a; *Burger*, 2007; *Burger, Čelková*, 2009; *Pitter*, 1981; *Richter, Kreitler*, 1993; *Yong* et al., 1992).

State of salinization at Žitný ostrov area

In arid and semi-arid conditions with evapotranspiration regime and mineralized groundwater dissolved ions gets to the upper layers of soil and become the main reason for soil salinization. Measured basic characteristics of groundwater chemical composition indicate, that Na levels in interested area are higher then average (Tab. 1). Sodium content for all investigated groundwaters SR has median 9.1 mg l^{-1} (*Rapant, Vrana, Bodiš*, 1999), but in studies area average sodium content is calculated 21.06 mg l^{-1} (min. 1.1 mg l^{-1}, max. 260.0 mg l^{-1}). Problems of high salinity have been associated with groundwater level and irrigation of soils in arid and semi-arid areas where the soils are generally fragile in structure and susceptible to water logging. Land salinity is closely related to other land degradation processes such as soil erosion, acidification and structural decline. It is estimated that 0.16 % of the soils is salt-affected (the highest part in Komárno – 0.28 %, Nové Zámky – 0.37 %, Šaľa – 0.23% districts). Groundwater quality monitoring results in selected localities leads to the conclusion, that the groundwater quality is worsening and the soil salinization hazard is increasing in the monitored period (*Burger*, 2007; *Burger, Čelková*, 2004, 2009; *Dulovičová, Velísková*, 2007; *Kaledhonkar* et al., 2001).

One of the requirements imposed by the Water Framework Directive (WFD, 2000/60/EC) is to analyse and predict the future changes of surface waters quality. To asses the development of a stream´s pollution one must consider all sources of pollution and understand how water quality evolves over time (*Pekárová* et al., 2009).

Sites description

According to the climatic characteristics this territory belong to warm climatic area. Average annual precipitation sum is ranging from 520 to 650 mm. Number of summer days (temperature > 25 ^oC) is higher than 70 in south-east part of Žitný ostrov. Arid and semi-arid conditions with evapotranspiration regime the mineralized groundwater become the main reason for soil salinization. The salt-affected soils occur in monitored area in the eastern part of Žitný ostrov (Fig. 2), where dry and warm summer climate, evaporation soil water regime and hig-mineralized groundwater (Tab. 1) create conditions for development and spreading of the saline and alkaline soils. These results abduced *Kobza* et al. (2002) too. These soils are developing slowly from the initial stages to the well developed ones. As a consequence of this long lasting process the slightly and middle saline and alkaline soils as well as typical solonchaks and solonetzes occur. In the 5 monitored localities (1 – Veľké Kosihy, 2 –

Okoličná, 3 – Čalovec, 4 – Zlatná na Ostrove, 5 – Kameničná) the soils in different stages of the development were investigated. In the bottom horizons in localities 1, 2, 4, 5 reached evaporative residues (salt content) value 0.1 – 0.2 %, but in year 2006 at all of the soil profile.

The soil types and average groundwater levels in monitored loc. 1–5 are presented in Tab. 2.

T a b l e 1. Basic characteristics of groundwater chemical composition (2006).

Basic statistical characteristics of groundwater chemical composition n = 128			
	Mean	Min.	Max.
pH	7.32	5.76	9.89
TDS [mg l^{-1}]	643.0	49.2	1935.8
Ca^{2+} + Mg^{2+} [mmol l^{-1}]	3.561	0.120	13.021
Conductivity[µS cm^{-1}]	688.1	54.5	2200.0
Free CO_2 [mmol l^{-1}]	0.77	0.12	11.5
Na^+ [mg l^{-1}]	21.06	1.10	260.00
K^+ [mg l^{-1}]	5.53	0.05	114.00
NH_4^- [mg l^{-1}]	0.068	0.025	6.900
Ca^{2+} [mg l^{-1}]	91.93	2.40	352.70
Mg^{2+} [mg l^{-1}]	30.81	0.50	114.55
Fe^{2+} [mg l^{-1}]	0.075	0.005	6.547
Mn^{2+} [mg l^{-1}]	0.069	0.003	2.931
Cl^- [mg l^{-1}]	22.69	1.06	89.00
SO_4^{2-} [mg l^{-1}]	70.70	0.30	1019.00
NO_3^{2-} [mg l^{-1}]	14.88	0.25	39.90
PO_4^{3-} [mg l^{-1}]	0.184	0.005	7.600
HCO_3^- [mg l^{-1}]	353.32	3.05	937.85

T a b l e 2. Soil types and average groundwater levels in monitored localities 1 – 5.

	Locality	Soil type	Average groundwater levels [cm]
1	Veľké Kosihy	Fluvi-calcaric Phaeozems, associated with Calcaric Fluvi-mollic Gleysols and Fluvi-haplic Phaeozems developed on calcareous alluvial deposits	250_a 215_b 198_c
2	Okoličná	Fluvi-calcaric Phaeozems, associated with Calcaric Fluvi-mollic Gleysols and Fluvi-haplic Phaeozems developed on calcareous alluvial deposits	110_a 105_b 101_c
3	Čalovec	Calcaric Fluvi-mollic Gleysols	90_a 95_b 107_c
4	Zlatná na Ostrove	Calcaric Fluvi-mollic Gleysols and Fluvi-haplic Phaeozems developed on calcareous alluvial deposits	325_a 260_b 217_c
5	Kameničná	Calcaric Fluvi-mollic Gleysols	246_a 225_b 215_c

a – 1989, b – 1999, c – 2006

Materials and methods

Soil samples were taken in depths (0–110 cm) from soil profiles (determining the spatial variability of sodicity). The soils were air-dried and passed through a 2-mm sieve. Soluble salts were detected by measuring electrical conductivity (EC). Electrical conductivity (EC) and soluble ions (Na^+, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-} and Cl^-) were determined on saturated-paste extracts. The concentrations of Na^+, Ca^{2+}, Mg^{2+}, K^+ were determined by atomic absorption spectroscopy (AAS); SO_4^{2-} and Cl^- by ionselective electrode.

The basis of the salinization model is the sodium adsorption ratio (SAR) – a relationship between Na^+, Ca^{2+} and Mg^{2+} concentrations that predicts the Na^+ status of the soil exchange complex when the exchange of cations within the soil comes into equilibrium with the soil solution (*Recommended Chemical Soil Test Procedures*, 1998; *US Salinity Laboratory Staff*, 1954). It is given by the following expression:

$$SAR = \frac{Na}{\sqrt{Ca + Mg}}, \quad (1)$$

where ionic concentrations are expressed in mol l^{-1}, SAR in units [mol $l^{-1}]^{0,5}$, but for convenience, units will be omitted hereafter.

Presence of sodium is a potential cause of structural instability when Na occupies more than 10-15% of the exchange sites (*Curtin* et al., 1994a). SAR is related to the exchangeable-Na ratio (ESP) of the soil by the following equation:

$$ESP = k_g SAR, \quad (2)$$

where k_g is the Gapon selectivity coefficient, and ESP – estimated as exchangeable Na/(CEC – exchangeable Na), where CEC is the effective cation-exchange capacity. To predict how much exchangeable Na will accumulate in soil the value of k_g must be known.

Results and discussion

At the beginning of measurement (in 1989) evaporative residues achieved values < 0.1 %, electrical conductivity EC < 250 mS m^{-1} – that is the non-saline stage. During the 1989 – 2006 the values increased gradually due to higher-mineralized groundwater composition (Tab. 2), EC increased in all layers and all monitored localities and achieved values 250 mS m^{-1} < EC < 400 mS m^{-1} – that is defined as slightly saline stage.

In the 5 monitored localities (1 – Veľké Kosihy, 2 – Okoličná, 3 – Čalovec, 4 – Zlatná na Ostrove, 5 – Kameničná) the soils in different stages of the development were investigated. In the bottom horizons in localities 1, 2, 4, 5 reached evaporative residues (salt content) value 0.1 – 0.2 %, but in year 2006 at all of the soil profile.

The presented data measured in year 1989 – – 2006 illustrate the contemporary processes salinization and alkalization in the monitored soils. The alkalization is however more significant and dominant in site No. 4. The mentioned a data allow us to state that salinization and alkalization of soils start from the bottom of soil horizons through middle part of the soil profile up to the top horizons (Tab. 3, 5).

T a b l e 3. Evolution of salinization and alkalization of the soil profiles in monitored sites 1 – 5 (1 – Veľké Kosihy, 2 – Okoličná, 3 – Čalovec, 4 – Zlatná na Ostrove, 5 – Kameničná) in the time period 1989 – 2006.

Loc.	Depth [cm]	Evap. res. [%]			EC [mS m^{-1}]			pH/H_2O			ESP [%]		
		1989	1999	2006	1989	1999	2006	1989	1999	2006	1989	1999	2006
1	0 – 10	0.03	0.07	0.12	49	72	96	7.6	7.2	7.3	1.8	2.1	2.6
	10 – 30	0.08	0.09	0.09	67	60	69	7.8	7.5	7.3	2.5	2.7	3.5
	30 – 50	0.10	0.10	0.13	95	115	128	7.9	7.6	8.1	6.8	7.6	8.5
	50 - 100	0.12	0.15	0.21	213	250	305	7.8	8.0	8.1	7.9	8.2	9.1
2	0 – 10	0.10	0.08	0.15	36	68	95	7.2	7.3	7.2	1.4	1.8	1.9
	10 – 30	0.12	0.06	0.18	59	71	90	7.5	7.6	7.4	3.1	2.4	2.9
	30 – 50	0.15	0.11	0.19	61	108	113	7.4	8.0	7.9	2.7	2.9	8.6
	50 – 100	0.19	0.13	0.22	207	210	215	7.9	8.1	8.2	8.4	8.2	9.7
3	0 – 10	0.06	0.04	0.14	40	56	76	7.1	7.1	7.2	2.6	1.9	1.9
	10 – 30	0.08	0.11	0.17	48	62	70	7.2	7.3	7.4	3.7	3.9	4.2
	30 – 50	0.04	0.06	0.12	75	90	99	7.3	7.4	7.5	5.8	6.2	7.5
	50 – 100	0.05	0.10	0.16	155	180	199	7.5	7.6	7.7	8.3	8.7	9.1
4	0 – 10	0.04	0.11	0.11	51	30	67	7.5	7.3	7.6	1.2	1.1	0.9
	10 – 30	0.05	0.10	0.14	55	40	58	7.2	7.6	7.5	2.8	1.7	1.1
	30 – 50	0.04	0.03	0.10	119	83	115	7.8	8.0	7.5	9.6	7.3	8.2
	50 – 100	0.10	0.16	0.21	242	207	291	8.1	8.1	8.6	9.7	10.1	11.5
5	0 – 10	0.07	0.09	0.11	30	40	50	7.2	7.2	7.4	0.8	1.2	1.4
	10 – 30	0.13	0.14	0.15	57	49	80	7.1	7.3	7.5	1.0	2.5	3.9
	30 – 50	0.09	0.10	0.09	91	56	85	7.2	7.4	7.6	2.7	3.9	4.7
	50 – 100	0.11	0.12	0.16	120	126	170	7.8	7.5	7.9	5.6	8.8	9.5

T a b l e 4. Participation of individual ions in the soil profile in monitored localities 1 – 5 (in 1999).

Loc.	Depth [cm]	Cl^- [mg/ 100g]	SO_4^{2-} [mg/ 100g]	HCO_3^- [mg/ 100g]	NO_3^- [mg/ 100g]	Na^+ [mg/ 100g	K^+ [mg/ 100g]	Ca^{2+} [mg/ 100g]	Mg^{2+} [mg/ 100g]	pH/ H_2O	pH/ KCl
1	0–30	7.5	2	25.6	7.5	22	9.8	24.5	6	7.13	6.15
	30–60	7.4	2	38.2	4.2	26.8	2.3	12.5	7.5	7.36	6.98
	60–90	13.5	3.8	40.3	4	50	1	8.5	6.5	7.22	6.89
	90–110	13.3	15.5	41.2	5.2	63.5	0.8	8.2	7.4	7.22	6.85
2	0–30	8.6	6	135	4.1	4	0.9	20.5	4.2	6.82	6.53
	30–60	11.5	7.4	114	2.9	5.2	0.8	22.4	3.8	6.0	6.45
	60–90	16.2	8.2	195	3.1	5.9	0.8	16.5	3.5	6.72	6.49
	90–110	17	8.1	187	3.5	6.8	0.9	12.7	5	6.95	6.72
3	0–30	28.6	42.5	94.5	3.5	10	1	24	5.9	7.42	7.20
	30–60	23.5	35	90.6	2.9	11.5	0.7	19.5	9.3	7.10	6.73
	60–90	28	18	79	2.2	7	0.6	15.2	7.4	6.92	6.58
	90–110	16	17	85	6.8	18	0.9	13	6.2	7.01	6.79
4	0–30	6.7	44.1	150.9	6.1	68.5	2.8	18.2	4.8	8.6	7.90
	30–60	15.7	69.6	133.8	4.2	97.7	4.2	19.2	2.4	8.2	7.71
	60–90	9.2	64.3	144.2	3.1	98.9	3.1	16.4	1.2	8.3	7.81
	90–110	11.4	65.2	80	2.8	61.6	2.1	12	6.9	8	7.30
5	0–30	15.8	11.0	45.8	5.7	12.1	0.8	28	5.9	7.3	6.9
	30–60	18.5	9.1	92.7	3.2	8.5	1	17.2	7.6	7.2	6.7
	60–90	23.1	19.7	108	2.8	18.9	0.9	21.5	8.9	7.5	7.1
	90–110	20.7	22.1	135	4.6	17.6	1.5	27.5	10.7	7.9	7.5

T a b l e 5. Stage of salinization and alkalization in monitored localities 1 – 5.

1	Veľké Kosihy	slightly solonchak
2	Okoličná	slightly solonchak
3	Čalovec	slightly solonchak, slightly solonetz
4	Zlatná na Ostrove	slightly solonchak, medium solonetz
5	Kameničná	slightly solonchak, slightly solonetz

Differences in data of the evaporative residues (salt content), EC, ESP and pH in individual years support considerable variability in the intensity of saline and alkaline processes within the very small areas. Generally, salinization of the monitored salt-affected soils slightly increase due to mineralization of groundwater. The trendlines of groundwater salinization have increasing character. In groundwater of the eastern part of Žitný ostrov was ascertain salinization risk from middle (medium) to high rate: 75 < EC< 300 mS m^{-1}, 10 < SAR < 38 (*Burger, Čelková*, 2009). A distinct change of an intensity of saline and alkaline processes was confirmed, but it is not hazardeous stage (Tab. 5).

Much sodium gets to soil profile just from mineralized water. Proportion of sodium to the other ions is in Tab. 4.

Summary and conclusion

The salt-affected soils occur in the southern and south-eastern part of Žitný ostrov, where the dry and warm summer climate, evaporation soil water regime and highly-mineralized groundwater create convenient conditions for development of the saline and alkaline soils. As a consequence of this long lasting process the slightly and medium saline and alkaline soils occur in monitored area.

Values of the evaporative residues (salt content), EC, ESP and pH in individual years shows considerable variability of saline and alkaline processes. Generally, the development of monitored salt-affected soils slightly increases due to increasing of mineralization of groundwater in the observed period.

Five localities with highly-mineralized groundwater were monitored to consider salinity and alkality in the period 1989–2006. In localities 1 – 5 evaporative residues (salt content) reached value 0.1 – 0.2 % at the bottom horizons, but in year 2006 all of the soil profiles contained increased values of salts. At the bottom horizons evaporative residues was higher than 0.2 % in 2006, EC in loc. 1, 2, 4 was higher than 250 mS m^{-1} – that is the salinization potential for development of saline soils. Values of ESP > 11 % and pH > 8.5 were measured in

site 4 in year 2006 – the alkalization is dominant there. The mentioned data allow us to state that salinization and alkalization of soils is in progress and start from the bottom of soil horizons through middle part of the soil profile up to the top horizons. During the 1989 – 2006 values of evaporative residues, EC, ESP and pH increased along soil profile.

The objective of this contribution was to estimate the state of salinization and alkalization of the soil in localities with high-mineralized groundwater. The results leads to the conclusion, that the groundwater quality is deteriorating and increased the soil salinization hazard.

Acknowledgements. This research was supported by ITMS 26240120014 Center of excellence for protection and use of landscape and biodiversity supported by the Research & Development Operational Programme funded by the ERDF and APVV-0274-10.

REFERENCES

BARZEGAR R. A., OADES J. M., RENGASAMY P., GILES L., 1994: Effect of sodicity and salinity on disaggregation and tensile strength of an Alfisol under different cropping system. Soil and Tillage Res., *32*, 329–345.

BURGER F., 2007: Modelling and numerical simulation of groundwater flow in the reparian alluial aquifer. J. Hydrol. and Hydromech., *55*, 3, Bratislava, 168–184.

BURGER F., ČELKOVÁ A., 2004: Interaction between surface stream irrigation water and soil from point of view of salinity and sodicity. A. Hydrol. Slovaca, *5*, 1, 112–121.

BURGER F., ČELKOVÁ A., 2007: Origin and mechanisms of the Danube Lowland saline soils and factors underline their formation. A. Hydrol. Slovaca, *8*, 2, 254–271.

BURGER F., ČELKOVÁ A., 2009: Salinization and contamination of the subsurface enviroment. Institute of Hydrology Slovak Academy of Sciences, ISBN 978-80-89139-17-0, pp. 327.

CURTIN D., STEPPUHN H., SELLES F., 1994a: Clay dispersion in relation to sodicity, electrolyte concentration and meachanical effects. Soil Sci. Soc. Am. J., *58*, 955–962.

CURTIN D., STEPPUHN H., SELLES F., 1994b: Structural stability of Chernozemic soils as affected by exchangeable sodium and electrolyte concentration. Can. J. Soil Sci., *74*, 157–164.

CURTIN D., STEPPUHN H., MERMUT A.R., SELLES F., 1995: Sodicity in irrigated soils: Chemistry and structural stability. Can. J. Soil Sci., *75*, 177–185.

ČELKOVÁ A., 2008: Groundwater quality analysis after underground sealing wall realization in the Danube River catchment between Komárno and Štúrovo. A. Hydrol. Slovaca, *9*, 1, 3–13.

DULOVIČOVÁ, R., VELÍSKOVÁ, Y., 2007: Change of Žitný Ostrov channel network aggradation state. J. Hydrol. Hydromech., *55*, 3, 185–198.

FEITZ J. A., LUNDIE S., 2002: Soil Salinization: A Local Life Cycle Assessment Impact Category, J. LCA, *7*, 4, 244–249.

ČERVENKA L., 1970: Influence of the groundwater on constitution saline soils in Slovakia. SAV, Bratislava, pp. 236.

ČURLÍK J., ŠEFČÍK P., 1999: Geochemical atlas of the Slovak Republic: Part V – Soils. Soil Sci. and Conservation Research Institute, Bratislava.

GRANEC M., ŠURINA B., 1999: Atlas of soils SR. VÚPOP Bratislava, pp. 60.

HANES J., 1999: Analysis of sorption attributes of soils. VÚPOP Bratislava, pp. 138.

KALEDHONKAR M.J., TYAGI N.K., van der ZEE, 2001: Solute transport modelling in soil for irrigation field experiments with alkali water. Agricul. Wat. Mngm, *51*, 2, 153––171.

KOBZA J. et al., 2002: Soil monitoring of Slovak Republic. Present state and development of monitored soil properties. ISBN 80-89128-04-1, VÚPOP, Bratislava, 180 s.

KOVÁČOVÁ V., 2009a: The analysis of salinization and alkalization of the soil profile on the South part of Danube Lowland. A. Hydrol. Slovaca, *10*, 1, ISSN 1335-6291, 44 ––54.

KOVÁČOVÁ V., 2009b: Variability of exchangeable ions in unsaturated zone. Collect. from international Scientif. Conf. Hydrogeochemistry 09 – Aktual trends in hydrogeochemistry. Slovak Association of Hydrogeologists, ISSN 978-80-969342-5-6, 160–171.

LEVY G. J., MAMEDOV A. I., GOLDSTEIN D., 2003: Sodicity and water quality effects on slaking og aggregates from semi-arid soils. Soil Sci., *168*, 8, 552–562.

NATIV R., ADAR E., DAHAN O., NISSIM I. 1997: Water salinization in arid regions. J. Hydrol., *196*, 271–296.

PEKÁROVÁ P., ONDERKA M., PEKÁR J., RONČÁK P., MIKLÁNEK P., 2009: Prediction of water quality in the Danube River under extreme hydrological and temperature conditions. J. Hydrol. Hydromech., *57*, 1, 3–15.

PITTER P., 1981: Hydrochemistry. SNTL, Prague, pp. 373.

RAPANT S., VRANA K., BODIŠ D., 1999: Geochemical atlas of Slovakia: Part I – Groundwater, Geological Survey of Slovak Republic, Bratislava.

Recommended Chemical Soil Test Procedures, 1998: North Central Regional Research Publication No. 221, U.S. Department of Agriculture cooperating.

RICHTER B. C., KREITLER Ch. W., 1993: Geochemical Techniques for Identifying Sources of Ground-Water Salinization. EPA, USA, 225.

SUAREZ D. L., 1981: Relation between pH c and sodium adsorption ratio (SAR) and an alternative method of estimating SAR of soil or drainage waters. Soil Sci Soc. Am. J., *45*, pp. 469.

ŠÚTOR J., ŠTEKAUEROVÁ V., 2000: Hydrophysical characteristic of soils at Źitný Ostrov. Institute of Hydrology Slovak Academy of Sciences, Bratislava, Slovakia.

YONG R. N., MOHAMED A. M. O., WARKENTIN B. P., 1992: Principles of Contaminant Transport in Soils. Elsevier Science Publishers B.V., Amsterdam, pp. 327.

U.S. Salinity Laboratory Staff, 1954: Diagnosis and improvement of saline and alkali soil. U.S. Goverment Printing Office. Washington, USD Handbook 60, pp. 160.

Received 21 March 2011
Accepted 19 October 2011