Carpathian Journal of Earth and Environmental Sciences, February 2011, Vol. 6, No. 1, p. 229 – 240

CHARACTERIZATION OF THE SOIL DEGRADATION IMPACT OF WASTE THERMAL WATERS ON THE SOUTHERN GREAT HUNGARIAN PLAIN (CASE STUDY ABOUT THE RISK OF SEWAGE THERMAL WATER SEEPAGE ON SOIL MEDIUM)

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Abstract: In the course of our work the chemical composition of thermal water utilized in the Southern Great Hungarian Plain and disposed to the environment was investigated from the viewpoint of soil and groundwater degradation. Temporary disposal of these sewage thermal waters are executed in cooling pools and released across ground channels into natural surface waters afterwards. During this process the waste water infiltrates into the soil, altering soil and groundwater parameters.

It can be claimed that thermal water is characterized by pollutants of Hg, As, Cd and Pb, which can get to the groundwater across the soil. In most cases, ammonium concentration and Na % have also exceeded the limit value. From the thermal water with high Na%, Na^+ gets to the groundwater and raises its Na^+-rate. Ammonium content of thermal water transforms into nitrate on the surface during utilization and then appears in the groundwater, as well. In the soils close to the channel, alkalinization and salt accumulation is characteristic.

We focused on a selected sample area, Cserkeszőlő in order to present in detail manifestation of the waste thermal water effects in particular regard to the salinzation-sodification-alkalinization processes. The characteristic changes are represented on Chernozem and Phaeozem soil types of this sample area. It was concluded that the high total salt content of the seeping used thermal water facilitated salt accumulation in other horizons of both soil types. Alkalinization of above-mentioned soil degradation processes also could be detected. ESP values of soils have not attained the hazardous value, so sodification has not appeared yet.

Keywords: thermal water, soil degradation, human-induced salt accumulation

1. INTRODUCTION

Hungary is on the cutting edge of having thermal water reservoirs. Besides Italy and France, Hungary has the highest amount of thermal water in Europe. The exploitation and utilization of this natural resource is very diverse (balneotherapy, drinking water, mineral water) (Árpási, 2001; Árpási, 2009). The usage of thermic-characteristic in thermal water is widespread in agriculture (e.g. heating green houses of horticultural estates, drying crops etc). In industry, it is used as heating medium or technology water. Municipal use has also been increasing in many spheres, mainly for hot water supply and heating (Fig. 1). The complex utilization of thermal water has successfully been realized in some towns (Hódmezővásárhely, Szeged, Szentes) (Szanyi et al, 2010).

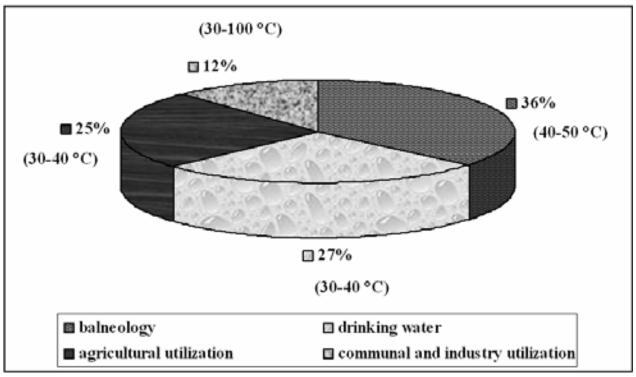

Figure 1. Use of thermal water in different sectors according to the temperature in Hungary (Árpási, 2001)

More than 70% of territory of Hungary contains thermal water due to high geothermal gradient originating from good heat-conducting deposits and the thinned crust in Carpathian Basin. This value is the highest in the Great Hungarian Plain whereas it is a bit lower around mountains and hills. The majority of the active 950 thermal water wells in Hungary (Szanyi, J., 2010) are situated in the southern of the Great Hungarian Plain (Fig. 2), so this region was selected for our investigations.

More and more spas and wellness centers have played important role in progressive Hungarian tourism. However, this results in increased exploitation of thermal water which becomes waste water after use. This means continuous load as these establishments operate all the year. Their sewage water may not be reinjected to the reservoir strata since it has been polluted during the bathing. However, in the practice, as a most frequent treatment, this polluted water is piped into cooling pools and then across ground channels into surface waters.

In addition, the greenhouse farming is very popular in the southern part of the Great Hungarian Plain owing to excellent productivity conditions on this region. The thermal water used in greenhouses has just periodically required waste water management since this water is utilized exclusively in winter. After circulation of thermal water used for energetic purposes (e.g. heating) within a closed pipe system, it could be pumped back. This procedure will be compulsory in the case of thermal wells established after 2010 (1995. LVII. Water Management Act 15. § (3)). The management of these waters is going to happen in the above-mentioned way till then.

Owing to high amount of exploited thermal water (0.5 million m^3/day) (Hungarian Geological Survey, 2002) and its extensive utilization, environmental problem of water placement after utilization and its inspection has became a very current topic till now.

To estimate these effects, it is important to evaluate composition of thermal waters in the investigated region. Varsányi (1989, 1994) studied the origin, chemical evolution, and movement of subsurface waters in the Southern Great Hungarian Plain. She claimed that calcite and dolomite dissolution as well as albite weathering have together resulted in chemical composition of these waters. In addition, the oxidative conversion of the organic matter has had an important role. Based on spatial changes of the total hardness and Na^+ concentration, the author detected ion exchange processes indicating the direction of water movement in the subsurface waters. In accordance with above-mentioned, two water movement systems could be identified.

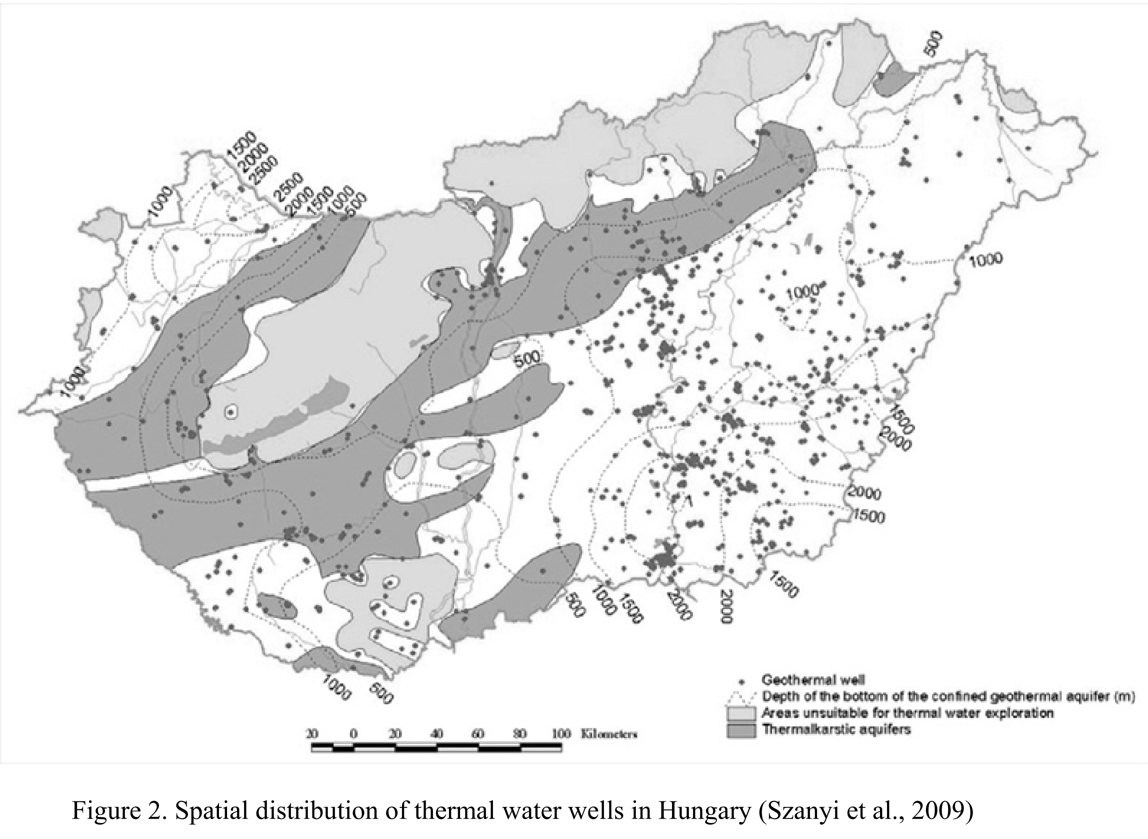

Figure 2. Spatial distribution of thermal water wells in Hungary (Szanyi et al., 2009)

In Hungary, widespread method of waste thermal water treatment is to discharge it into uninsulated channels and cooling pools. In this case, this sewage water continuously infiltrates into the soil and evaporates, as well. Change both in concentration conditions and composition can be noticed along the canal. Potential pollutants in the water can enter the groundwater-soil system, and can induce negative changes. The effects on the soil could be eliminated by the isolation of the channels. In this respect, in 2004, Kahlown and Kemper carried out experiments on insulations of different materials and thickness in order to examine cost-effectiveness of the investment. In 1998, Simonic and Ozim's experiments proved that organic contaminants can be eliminated with activated carbon treatment. The removal of additional harmful ions can be achieved using ion exchange resins (Pohl, 2006, Tokmachev et al., 2008, Xu, 2005). Reduce in the salinity can be executed with the help of rather expensive reverse osmosis techniques (Greenlee et al., 2009). In some places (e.g. Sárvár), medicinal salt, thermal bath crystal are produced using evaporation. In most cases, however, the water flows into the canal without any pre-cleaning processes.

Cultivation close to ground channels can aggravate the problem in many cases. Beside the leakage effects, we have to take the potential irrigation into account, which can alter soil parameters resulting in lower soil quality, and form soil conditions unsuitable for arable land cultivation (Szilassi et al., 2010).

Several studies research effects of irrigation with saline water on cultivated soils (Beltrán, 1999; De Clercq et al., 2008, Mandal et al., 2008) and different plants (Minhas, 1996; Gawad et al., 2005; Gupta et al., 1998; Bayuelo-Jiménez et al., 2003, Sharma and Minhas, 2005; Marcu, 2005; dell'Aquila and Tedeschi, 2005). The effects of water flowing in the canal can exert influence on the quality and quantity of the crop across the soil and groundwater.

Our goal is to determine typical pollutants of thermal waters in the Great Hungarian Plain. During our work, the soil, groundwater and thermal water data (2003-2008) of 25 establishments, leaching the used thermal water into ground channels and finally running into natural surface water, have been processed. One of these establishments, Cserkeszőlő Spa is selected to present the effects of waste thermal water leakage on different genetic soil types.

2 SAMPLE AREAS

The environmental reports about sample sites in the Great Hungarian Plain have been created by Szmektit Bt., Szeged (2003-2007). These documents contain data about horticultural estates, spas and wells supplying block of flats and hospital with heat alike (Table 1).

Table 1. The list of sample plots

Sample area	Number of sample sites	Spa	Horti-cultural estate	Other
Apátfalva	1		1	
Csanytelek	1		1	
Csengele	2		2	
Cserkeszőlő	1	1		
Csongrád	3	1	2	
Fábián-sebestyén	1		1	
Hódmező-vásárhely	3	1	1	1
Kakasszék	1		1	
Makó	1			1
Ópusztaszer	2		2	
Szentes	6		6	
Szentlászló	1		1	
Sziksósfürdő	1	1		
Tiszakécske	1		1	

We focus on Cserkeszőlő of above-mentioned sample sites. The investigated area is located in the Tiszazug region of the Great Hungarian Plain. It is an alluvial fan flat formed on floodplain with Holocene moulding formations (Pécsi, 1990). This area has very variable soil types. Two main soil types are investigated: Chernozem and Phaeozem (WRB, 2007). The adjacent areas have been cultivated for a long time. In Cserkeszőlő, the spa has been operating since 1952, the water requirement of which is supplied by two medicinal water wells (depth$_1$: 2311 m, water temperature$_1$: 82°C, year of plantation$_1$: 1938; depth$_2$: 1159 m, water temperature$_2$: 67 °C, year of plantation$_2$: 1975) and three cold ones. Mixed water of these wells gets out to the nature and infiltrates into the soil. This water runs 9.5 km across ground canal and get into the Körös River as ultimate recipient.

3. METHODS

3.1. Sample method

The sampling scheme of all the sample sites in the environmental reports was the same. Thermal water samples were taken from the direct outflow of the well. Information on surface water sample was gained from the data of the sample points nearest to the flowing of the thermal water into the ground channel. The soil and groundwater parameters are determined from these soil cores in accordance with sampling scheme. In environmental reports soil samples were taken directly from soil part located above the groundwater.

Besides above-mentioned data, we focused one of this region (Cserkeszőlő) in order to gain exact information on effects of waste thermal water on soil properties. Spatial location of the sample points were selected here to indicate horizontal and vertical effects of the thermal water channels. Therefore, we sampled the different sections of the channel, near and far from the canal line (Fig. 3). With the help of these sample points, it is possible to identify what degree the effect of leaching waste thermal water on soil is. Variable soil types can be observed in the sample area. The upper and lower section of the channel can be characterized with Calcic Luvic Chernozem (Siltic) and Endosalic Calcic Luvic Phaeozem (Siltic), respectively (FAO, 2006). Being the high soil diversity, the features of the changes by infiltration on different genetic soil types can be compared. In the course of sampling in Cserkeszőlő, we examined water flowing in ground channel, groundwater and soil, as well. The cores were created and samples were taken in every 20 cm from surface to groundwater in each sample points with the help of Eijkelkamp-type hand drill. The groundwater was sampled after the final groundwater level, and then stored in refrigerator.

3.2. Laboratory method

Table 2 presents water and soil parameters that were measured in laboratory for the environmental reports. The measurements, based on the current Hungarian standards, were carried out in an accredited laboratory.

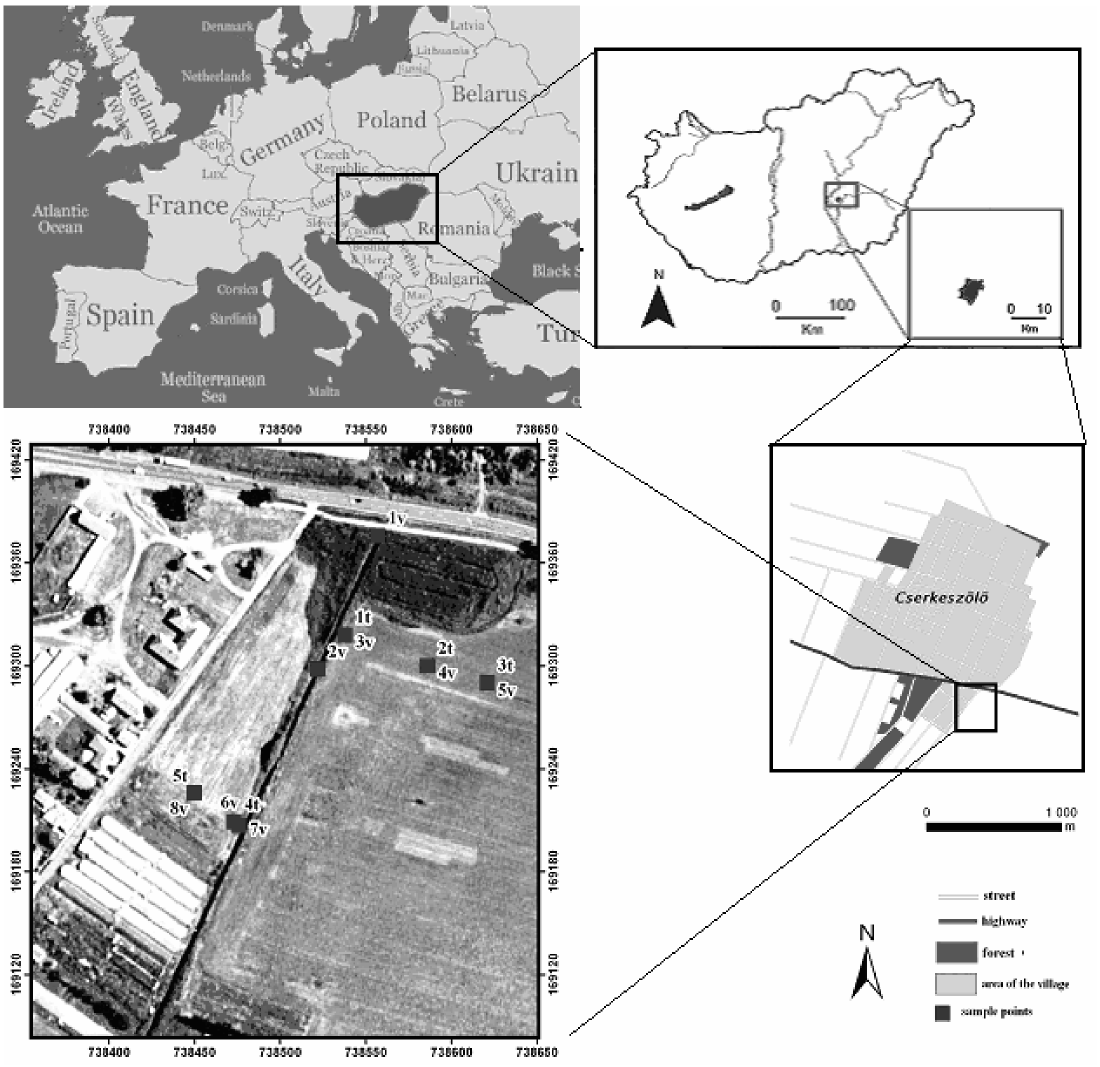

Figure 3. Location of the Cserkeszőlő investigation area sample points

Table 2. Summary table of laboratory measurements for the environmental reports

Thermal water	Water of the channel	Groundwater	Soil
pH	pH	pH	pH (H_2O)
Total salt content	Total salt content	Total salt content	Total salt content
NH_4^+-N	NH_4^+-N	NH_4	NH_4-N
NO_3^--N	NO_3	NO_3	NO_3-N
Phenol index	Phenol index	Phenol index	Phenol index
Total Mn	Total Mn	Total phenol	Humus cont.
Fe	Fe		Soda content
COD	COD		$CaCO_3$ cont.
Total As	Total As	Total As	Total As
Total Cd	Total Cd	Total Cd	Total Cd
Total Co	Total Co	Total Co	Total Co
Total Cr	Total Cr	Total Cr	Total Cr
Total Cu	Total Cu	Total Cu	Total Cu
Total Hg	Total Hg	Total Hg	Total Hg
Total Ni	Total Ni	Total Ni	Total Ni
	Total P	Total P	
Total Pb	Total Pb	Total Pb	Total Pb
Total Zn	Total Zn	Total Zn	Total Zn
		SO_4	
Sulphides (total S - SO_4^--S)	Sulphides (total S - SO_4^-- S)	S	S-value
PO_4^{3-}	PO_4^{3-}	PO_4^{3-}	
Na %	Na%	Na %	

The minimum, maximum, mean and standard deviation values of the measured data have been calculated and compared with the limit values in the regulation of the Ministry of Environment and Water No. 28/2004. This regulation differentiates energetic and balneological use of thermal water in the case of directly discharging into periodic watercourses as ultimate recipient. Emission limit values of waste water directly discharged to surface water are defined in the collective decree of the Ministry of Environment - Ministry of Agriculture and Regional Development No. 9/2002 and its amendment No. 219/2004 in the 1st annex. Limit values are determined by the joint regulation of the Ministry of Environment, Ministry of Public Health No. 6/2009 in order to preserve the quality of the subsurface water and the geological formations. The parameters of Cserkeszőlő (Table 3.) were measured according to the current Hungarian Standard

4 RESULTS

4.1. The composition and potential environmental risk of thermal waters in the Southern Great Hungarian Plain

Waste thermal water in ground channel has high temperature, high salt content, and in some cases it has been contaminated with geogen and/or anthropogenic material yet.

Table 3. Catalog of analyzed parameters of Cserkeszőlő samples

Water Samples	Soil Samples	Regulation	Type of Instrument and Measurement Technology
pH	pH (H_2O)	MSZ-08-0206-2:1978 2.1.,MSZ 21470-2:1981 5	WTW inoLab pH 720
TSC with EC measurement	TSC with EC measurement	MSZ-08-0206-2:1978 2.4	OK-104 conductometer
cation composition (Ca^{2+}, Mg^{2+}, Na^+, K^+)	cation composition (Ca^{2+}, Mg^{2+}, Na^+, K^+)	K^+: MSZ 20135:1999. 4.1., 4.2., 5.3., 6., Na^+: MSZ-08-0213-1:1978 2.1.3, MSZ-08-0213-2:1978 1.8,Ca^{2+}: MSZ-08-0213-1:1978 2.1.3., MSZ-08-0213-2:1978 1.6.1, Mg^{2+}: MSZ-08-0213-1:1978 2.1.3., MSZ-08-0213-2: 1978 1.7.1	Atom absorption and Emission Flame Spectrophotometry type Perkin Elmer 3110
anion composition (Cl^-, HCO^{3-}, CO_3^{2-}, SO_4^{2-})	anion composition (Cl^-, HCO_3^-, CO_3^{2-}, SO_4^{2-})	CO_3^-, HCO_3^{2-}: MSZ 448/11-86, Cl^-: MSZ 448/15-82, SO_4^{2-}: Wieslawa Ewa Krawczyk (1997)	Titration, Helios Gamma UV-VIS spectrophotometer
Na% (calculated)	ESP (calculated)		
SAR (calculated)	SAR (calculated)		
	$CaCO_3$ content	MSZ-08-0206-2:1978 2.1	Scheibler-type calcimeter
	Na_2CO_3 content	MSZ-08-0206-2:1978 2.3	Titration
	Humus content	MSZ 21470-52: 1983 2.	Helios Gamma UV-VIS spectrophotometer
	Texture	MSZ-08-0205:1978 5.1., 5.2	yarn test of Arany
	Porosity		method of stationary priming
	Bulk density		gravimetric

TSC: Total salt content, MSZ: Hungarian Standard

Depending on the quality, condition, texture, leakage factor of the soil, this water on the complete section of the channel can infiltrate to groundwater, too. Thereafter, depending on climate conditions pollutants and salts migrate with the groundwater corresponding to seasonal dynamic of the groundwater.

At the time of drought, groundwater rich in salt accumulates salts in the B horizon or close to the surface due to the increased evaporation. The leaching is the characteristic process during the humid period. Consequently, the salts accumulate vertically according to their solubility in the deeper horizons of the soil profile. Salts and other pollutants originating from thermal water can be transported from the canal line towards the surrounding areas by horizontal groundwater movements.

The seepage in ground channels as treatment method raises several problems: the salt accumulation, human induced salinisation/secondary salinisation, and negative effects on soil fertility of other pollutants leaking from the thermal water into the soil. Alkalinization is the same dangerous as above-mentioned processes, because Na^+ may become the dominant one of adsorbed ions; hence the clay minerals disintegrate and migrate along the profile. In addition, on alkaline pH the functions of soil microorganisms have been inhibited, the micronutrients have precipitated and plant nutrient intake decreased.

Sewage thermal waters exert influence directly on the soil medium in contact with them, indirectly on the groundwater and last but not least on the natural surface waters alike. Used thermal water periodically discharged into rivers through channels may affect the quality of the water in the river. According to the categories of the irrigation water quality, water of these rivers can be only optionally suitable for irrigation in particular seasons, as total salt, total dissolved solid, nitrate, ammonia, phosphate, Na^+ and K^+ content as well as pH increases due to the entering sewage thermal waters. As a result of that, eutrophication can be detected.

In the case of infiltration in ground channels, potential soil degradation, salinization and sodification of the soil on the surrounding areas have to be counted on due to very high salt, Na^+ and Mg^{2+} concentration in thermal water. Consequently, negative soil physical properties are typical (e.g. strong swelling capability, high amount of non-available water content, peptization, slightly water permeability) as Na^+ causing adverse soil properties on soil colloid has exchanged Ca^{2+} creating the positive ones (Filep & Füleky, 1999). It is very difficult to reverse this process since Na^+ binds stronger to the surface than Ca^{2+}. The rise of the concentration of exchangeable Na^+ originates from the quantity and quality of salts in the soil solution.

It is important to consider not only the impacts on soil but the changes in surface waters, as recipients. Nevertheless, temperature rise as potential problem can intensify the velocity of hydrobiological and chemical processes and organic matter production. Oxygen solubility in water, however, decreases. Thus, concentration of dissolved oxygen in water can meet oxygen demand of the organisms no longer so they perish. The proliferation of aquatic plants starts in water body owing to more intensive nutrient-supply. The water surface is getting covered from sun radiation by the high amount of seaweed. Due to the reduced radiation and oxygen supply, the anaerobic processes become predominant. The above-mentioned changes might be dangerous since natural biological balance can be disturbed by their effects.

The high-temperature thermal water flowing in ground channel exerts influence not only on the surface recipient but also the groundwater. It can enhance the temperature of surrounding groundwater by some °C. Therefore, we have to pay more attention to chemical and physical parameters of the waste thermal water to be emitted into the environment in order to avoid these adverse changes.

According to our studies, it can be claimed that the thermal water on the Great Hungarian Plain contain Hg, As, Cd and Pb as typical contamination which can reach the groundwater across the soil (Table 4.). Besides, ammonium ion can be regard as potential contaminant since its great part is transformed to nitrite by nitrifying bacteria and this latter one in contacting with oxygen results in nitrate. The slight amount of the later ones is retained by soils depending on their buffer capacity, the higher amount of them, however, infiltrate into the groundwater. The phenol is in the thermal water until it reaches the surface and evaporates owing to its volatility afterwards. Consequently, phenol concentration of the sewage water continuously decreases along the ground channels due to volatilization into the atmosphere. The sulphides under aerobic conditions on the surface oxidize to sulphates and leak towards the groundwater. The phosphate in surface water and groundwater is not of thermal water origin; it is presumably flowed into the canal from surrounding fertilized agricultural areas by run off. Besides, the high Na % and SAR values are one more essential problem: the high proportion of the Na^+ compared to the other exchangeable cations can degrade physical conditions of soil.

Table 4. The potential pollutants of thermal waters in the Great Hungarian Plain

Thermal water	Min.	Max.	Mean	Std. Dev.	9/2002 D. (mg/l)	6/2009 D. (mg/l)	N (pc)	ALV (pc)	%
pH	6.9	8.7	8	0.4	6-9	*	22	0	0
NH_4^+-N (mg/l)	0.23	15.66	6.19	4.17	10	*	24	20	**83.33**
Ammonium (mg/l)	0.5	17.9	8.1	5.5	0.5	*	11	10	**90.9**
Nitrate (mg/l)	0.8	6.3	1.5	1.8	25	*	9	0	0
TSC (mg/l)	158	2675	1424	709	*	3000	21	0	0
Na %	80.66	99.2	94.9	4.05	*	45 % e	23	23	**100**
Na %	80.66	99.2	94.9	4.05	*	95% b	23	13	**56.52**
KOI (mg/l)	1.09	1249	75.91	269.47	150	*	21	1	4.76
Total Hg (mg/l)	0.00001	0.04	0.02	0.02	0.01	*	19	17	**89.47**
Total As (mg/l)	0.001	0.067	0.032	0.022	0.5	*	21	13	**61.9**
Total Cd (mg/l)	0.00005	0.01	0.00534	0.00414	0.05	*	19	9	47.37
Total Ni (mg/l)	0.0002	0.03	0.0112	0.00899	1	*	19	1	5.26
Total Pb (mg/l)	0.0005	0.07	0.0362	0.0309	0.2	*	19	10	**52.63**

e- energetical utilization, b- balneology utilization, * there is no limit value, D.: Decree, TSC: Total Salt content, N: Total number of datas, ALV: Above the limit value

Table 5. The summary result of the hazardous parameters

Investigated Parameter	Thermal water (mg/l)			Groundwater (mg/l)			Soil (mg/kg)		
	N (pc)	ALV (pc)(1)	%	N (pc)	ALV (pc) (2)	%	N (pc)	ALV (pc)(3)	%
pH	22	0	0	19	0	0	23	11	47.83
NH_4^+-N	24	20	**83.33**	0	*		24	1	4.17
NO_3	9	0	0	25	5	20	0	0	0
Phenol index	19	4	21.05	17	*		14	0	0
Total As	21	13	**61.9**	13	6	46.15	14	1	7.14
Total Hg	19	17	**89.47**	13	13	**100**	14	1	7.14
Total Ni	19	1	5.26	13	1	7.69	14	1	7.14
PO_4	12	1	8.33	23	9	39.13	0	0	0
Na %	23	$23^e/13^b$	**$100^e/56.5^b$**	20	14	**70**	-	-	-
(ESP) Na_S%	-	-	-	-	-	-	7	*	-
Total Cd	13	2	15.38	19	9	47.37	14	0	0
Total Pb	13	4	30.77	19	10	**52.63**	14	0	0
COD	21	1	4.76	0	0	0	0	0	0

(1)regulation of the Ministry of Environment and Water No. 28/2004, collective decree of the Ministryof Environment - Ministry of Agriculture and Regional Development No. 9/2002 and its amendment No. 219/2004 in the 1st annex; (2), (3) joint ordinance of the Ministry of Environment, Ministry of Public Health No. 6/2009; *there is no limit value, N: Total number of datas, ALV: Above the limit value, e-energetical utilization, b-balneology utilization.

The high Na^+ concentration originating from thermal water can reach the groundwater. In instance of soils, our results are compared with also average values due to few available limit values. It can be claimed that in some cases the investigated soils had slightly solonchak character due to salt accumulation. The total salt content transcended 0.05%.

In accordance with our experiences, sodification effect of Na^+ can often be observed in the investigated region. The peptization of soil colloids is getting underway at 5 Na_S% over vigorous effect of Na^+. Consequently, these soils have become swelling during wet period and cracking during the dry one so their water management system has deteriorated (Filep & Füleky, 1999).

It can be seen that peculiar pH of all studied parameters has exceeded the limit value: it fells into the category strongly alkaline in the case of 47.8% of the samples (Table 5).

4.2. Case study on environmental effect of thermal water

The Na % is especially hazardous parameter of thermal water in Cserkeszőlő (Table 6). Predominance of Na-ion compared to the other exchangeable ones can give rise to sodification of the soil. The original total salt, Na % content of thermal water in Cserkeszőlő is 3658.9 mg/l and 96.69 %, respectively. However, this water is diluted by cold water wells of the spa.

Table 6. Main parameters of thermal water, surface water and groundwater

	Original thermal water composition I. well	**Original thermal water composition II.well**	**Mixed thermal water**	**Water in the channel**	**Ground-water**	**Ground-water**	**Ground-water (control)**	**Ground-water**	**Water in the channel**	**Ground-water (control)**
			1 v	**2 v**	**3 v**	**4 v**	**5 v**	**6 v**	**7 v**	**8 v**
pH	n.d.	n.d.	7.94	7.98	7.83	7.95	8.08	8.27	8.15	8.12
TSC (mg/l)	3659	n.d.	874	867	**1248**	**1913**	**1768**	**3032**	863	**2431**
TSC (%)	n.d.	n.d.	0.1	0.09	0.13	0.21	0.19	0.33	0.1	0.27
CO_3^{2-} (mg/l)	n.d.	n.d.	0	5.21	0	69.04	44.29	50.08	26.71	67.74
HCO_3^- (mg/l)	1380	1170	662.2	647.7	838.4	741.7	803.9	1240	1287	704.6
Cl^- (mg/l)	181	10	120	128	170	466.4	406.4	554.4	49	593.6
SO_4^{2-} (mg/l)	< 25	< 25	3.91	5.74	53.13	78.96	69.35	246.1	8.81	154
Ca^{2+} (mg/l)	6.6	4.7	1.27	1.4	358.7	376.3	364.3	8.86	1.11	335.5
K^+ (mg/l)	12.2	6	6.04	6.77	5.6	4.31	2.96	2.2	11.88	2.73
Mg^{2+} (mg/l)	0.7	1	1.55	1.63	97.55	156.4	5.61	11.14	1.46	73.5
Na^+ (mg/l)	570	410	573.9	518.6	489.1	632.5	633.3	634.4	428.3	633.7
SAR	**56.35**	**44.79**	**80.75**	**70.56**	5.91	6.91	9.02	**33.47**	**62.8**	8.16
Na %	**96.69**	**97.23**	**98.48**	98.14	51.43	54.08	62.94	96.62	96.74	60.62

n.d. – no data, TSC : Total salt content

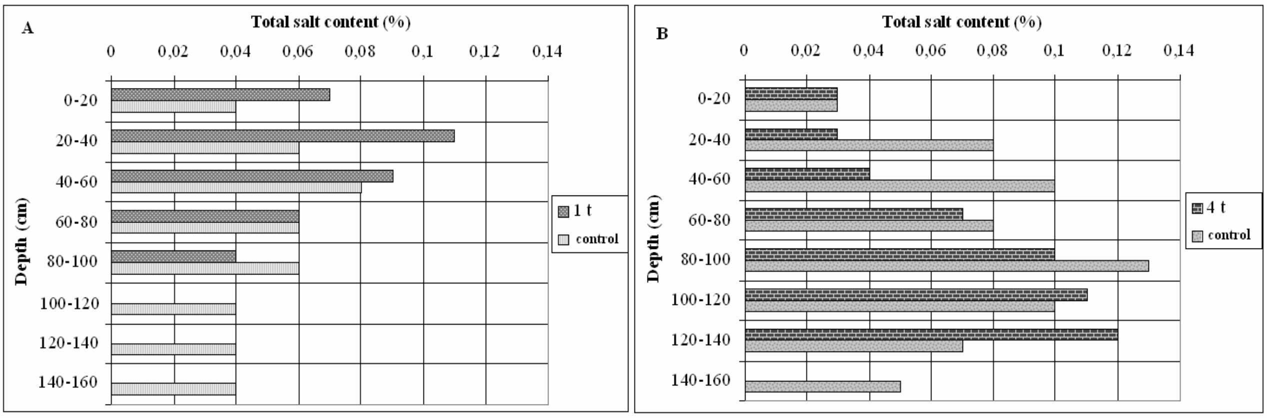

Figure 4. The salt profiles of the Calcic Luvic Chernozem (Siltic) soil (A) and the Endosalic Calcic Luvic Phaeozem (Siltic) (B) soil compared to the control ones.

Therefore, the total salt content of this mixed water flowing into the unlined ground channel decreases to 874 mg/l, whereas Na^+ increases to 98.47 %. Consequently, infiltration of this water into soil is able to induce salinization/sodification. SAR values exceeds limit value 10 in the thermal water, in the water flowing in unlined ground channel and in the groundwater of the profile situated in the lower section of the channel alike. Thus, sodificating effect of these waters on the soils is very considerable in these areas. Beside Na%, total salt content is also significant parameter in the groundwater. It has exceeded 1000 mg/l in all cases; above this value the water is able to induce salt accumulation in the soil. Moreover, its reaction shifted toward alkaline pH values, as well.

The salt concentration and pH values in the groundwater of Chernozem soil (3v, 4v, 5v) are less than those in the one of Phaeozem soil (6v, 8v).

Overall, on this sample area, both the thermal water and groundwater exert sodificating effect on soils and can also facilitate salt accumulation. This is also supported by the salt and ESP profiles of the soils located close to channel line and ones of the control points. Besides these parameters, the pH distribution along the profile is researched if alkalinization in the soil is.

According to our experiences, it can be established that salt accumulation is noticed in Calcic Luvic Chernozem (Siltic) profile near the channel (Fig. 4. A). Maximal salt content (0.11%) is located between 20 and 40 cm in the A-horizon. In this horizon, the increased amount of $CaCO_3$ and Na_2CO_3 also contribute to the total salt content. This salt accumulation can be signed in also the control soil profile (at the depth of 20-100 cm) 50 meters far from the channel.

Leaching of the salts from the upper soil horizon can be examined: it can become more intensive in the case of control profile 3 t since this horizon is ploughed up easing the infiltration of the precipitation.

Slight salt accumulation occurs in the profile of Endosalic Calcic Luvic Phaeozem (Siltic) on the lower section of the channel (Fig. 4 B). Maximum value of total salt content is 0.12 % at the depth of 120-140 cm, directly above the groundwater table, in the fluctuation zone. Soda content has increased in this lower part of the soil profile, $CaCO_3$ content, however, has not exceeded that of the control profile so main part of the total salt content is composed of Na-salts

Horizons between 60 and 140 cm fell into category of the slightly solontchak, whereas whole profile is slightly solontchak excepting the upper 20 cm of the control point. In profile 4 t, the salt amount of horizons beneath 100 cm exceeds that of the control profile. This salt accumulation, originates from groundwater of high total salt content and high Na %. As the groundwater closer to the channel has much more total salt content than the distant one, it can be assessed that seeping thermal water results in plus salt and Na^+ content. Thermal water leakage raises both the level of the groundwater table and total salt content. Over the higher water permeablity capacity of Phaeozem soil, the water transporting salt and the groundwater of high salt content can incorporate at the 80-140 cm depth. That is why the amount of salts increases in this horizon.

The Calcic Luvic Chernozem (Siltic) soil has good adsorption features due to its clayey-loam, loam texture, 20-30 % of clayey particles, moderate humus content, and very good carbonate supply. Na^+ of high amount can bind to binding sites owing to the high proportion of clay particles in the upper 20 cm of the profile. There is negative correlation between the soda and the ESP values (Exchangable Sodium Percentage) along the profile over competition for Na^+. If the Na^+ precipitates in carbonate form as soda, it can not adsorb to the ion binding sites and vice versa. Distribution of ESP is similar to that of the total salt content along the soil profile, except for the horizons between 20 and 40 cm where Na^+ is precipitated as soda increasing the total salt content and decreasing the amount of exchangeable Na^+ in the soil.

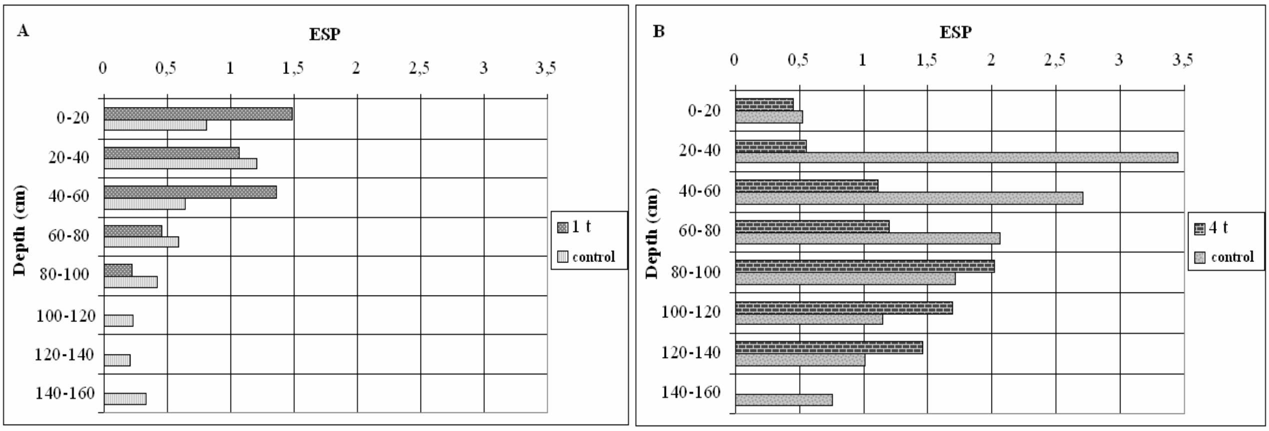

Figure 5. The ESP profiles of the Calcic Luvic Chernozem (Siltic) soil (A) and the Endosalic Calcic Luvic Phaeozem (Siltic) (B) soil compared to the control ones

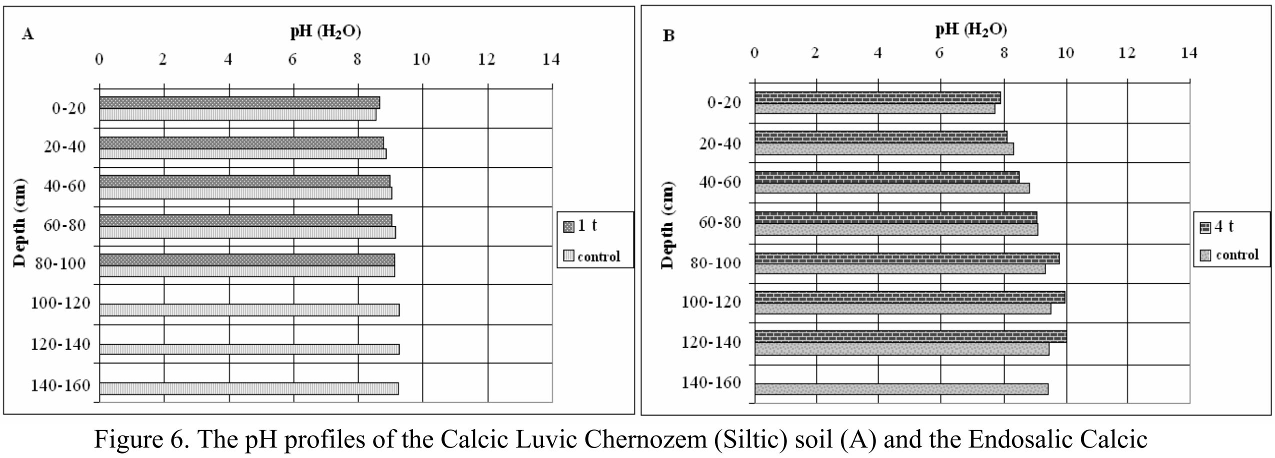

Figure 6. The pH profiles of the Calcic Luvic Chernozem (Siltic) soil (A) and the Endosalic Calcic Luvic Phaeozem (Siltic) (B) soil compared to the control ones

Compared to control profile, increased amount of Na^+ can be found at the depth of 0-20 cm and 40-60 cm (Fig. 5. A), but it is not too significant (<1.5 %). We do not count on soil degradation unless ESP value is higher than 6 %. Therefore, ESP of the soil do not hit the critic value, physical degradation has not been able to generate by seepage of Na-ions from used thermal water yet. The thermal water has an effect on sample points located next to the channel: total salt content, ESP values in the groundwater and total salt in the soil increases. Thus, Na^+ in soil does not accumulated in risky rate, but amount of it in groundwater is significant. On the other hand, groundwater has a high Na % and SAR rate, as well (Table 6). In the long run, Na-ion can deteriorate the quality of the soil getting in touch with groundwater. Thanks to the humic acids, reaction becomes lower in the topsoil, and tardily mobile carbonate besides the easily soluble soda also starts to migrate in the Endosalic Calcic Luvic Phaeozem (Siltic) soil. Thus, leaching of $CaCO_3$ and Na_2CO_3 content can be noticed from the topsoil. Owing to alkaline hydrolysis of these salts, the pH value increases to 10 at the bottom of the soil profile. On the lower section of the channel, Endosalic Calcic Luvic Phaeozem (Siltic) soil with mainly sandy silt texture and very high humus content is typical (Fig. 5 B). Na^+ leaching to the substrata is confirmed by the maximum of ESP values at the depth of 80-140 cm. Thus, accumulation zone of Na-ion is in the B-C horizon, and in the top of the C horizon in this soil profile. Here, a sandy loam and clayey loam strata in the profile can be observed. Thus, in this horizon, the amount of clays, the proportion of fine soil particles increased, specific surface became larger. Consequently, more Na^+ can accumulate due to the increased number of specific ion adsorbent posts. Although, maximum of ESP values is at the depth of 80-100 cm, but it has not attained the limit of 6 % on the lower section of the channel, either.

The Calcic Luvic Chernozem (Siltic) soil has alkaline, strongly alkaline reaction. The pH increases from the topsoil toward the bottom in the soil (Fig. 6 A). Above mentioned Na_2CO_3 hydrolyzes in alkaline way so it raises pH values. On the lower section of the channel, reaction of the soil is alkaline, strongly alkaline (Fig. 6 B).

5. Conclusions

Thanks to the large quantity of available thermal water reservoirs in Hungary, this natural resource has been exploited in an intensively way. Temporary disposal of sewage thermal water after utilization is executed in cooling pools and it is released across ground channel into natural surface waters afterwards. In our work, effects of the thermal water infiltrating from ground channels on soils are examined. It can be assessed that thermal water on the Great Hungarian Plain can be characterized by high concentration of ammonium, As, Cd, Pb and Hg, as well as high Na %. The latter two are also able to reach the groundwater. In the soils close to the channels, alkalinization and salt accumulation is peculiar.

On the selected sample area, Cserkeszőlő, the effects of thermal water seepage can be summarized as follows:

- the groundwater table has risen, and its salt and Na^+ content enhanced by infiltration (mainly in Phaeozem, due to its coarser texture and less adsorption capacity);
- salts and Na^+ can be transported by the groundwater flow towards the adjacent areas and appear in the control samples as well;
- salt accumulation in different horizons of the diverse soil types (Chernozem-A horizon, Phaeozem-C horizon) is manifested;
- indirect alkalinization effect can be detected: alkaline hydrolyzing salts infiltrate from the seeping thermal water to the groundwater and rises its pH. Thus, the alkaline groundwater induces alkalinization in the soil, so the rate of alkalinization have not depended on the distance from the channel;
- sodification effect (based on ESP values) is not considerable.

As some pollutants can get into groundwater and migrate within groundwater bodies, thus the effects can be observed even in the control profiles located 50 m from the channel line. In the case of agricultural cultivation on the surrounding areas of ground channels, it is essential to preserve soil quality, fertility and prevent yield reduction. The thermal water disposal on majority of sample plots has been carried out for decades, so it is relevant question when the soil buffer capacity depletes and fertility decline is irreversible. It is very important to study these effects and realize the right defensive actions on more areas near the channels in order to preserve fertility.

Acknowledgement

We would like to express our thanks to the Szmektit Bt., wherefore provided information. In addition, thank to everyone, who played a part in the sampling works and laboratory measurements. Featured thanks go to Károly Barta, to Tamás Fábian, to István Fekete and to Ibolya Tápai. In addition, we would like to thank Zsuzsanna Ladanyi for the assistance in preparing the figures.

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Received at: 15. 06.2010
Revised at: 24. 11. 2010
Accepted for publicationat: 26. 11. 2010
Published online at: 27. 11. 2010