MAIN CHARACTERISTIC COMPOSITION OF SOME GROUND AND ARTESIAN WATERS IN THE SOUTH BETWEEN DANUBE-TISZA REGION OF HUNGARY

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Abstract: *The use of waters from different origin is essential in the cultivation in the Danube-Tisza Interfluve, so the quality of irrigation water should be far considered. In our study we represent the results of the investigation of surface, ground and deeper artesian water samples originated from the Danube-Tisza Interfluve. Based on the depth of the samples we made three categories. Water samples were collected and analyzed in the laboratory of Faculty of Horticulture (Kecskemét College). High EC and iron content seemed to be a potential source of problems during irrigation. Main cations shown in the samples were calcium and sodium, followed by magnesium whereas potassium was the lowest macro cation. Among the accompanying anions, hydrogen carbonate content was the highest in most samples, followed by chloride. Ion content (EC) decreased with depth significantly, and was strongly and positively related with Mg^{2+}, Na^{+}, K^{+}, NO_3^{-}, Cl^{-} and HCO_3^{-} ions. The concentration of ions containing nitrogen or phosphor were low in usual. Phosphate content was related only with arsenic content.*

Key words*: ground water, artesian water, surface water, irrigation, main chemical composition*

INTRODUCTION

The southern part of the Great Hungarian Plain is the largest horticultural area of the country. Annual precipitation is low - about 500-550 mm - in this area, and moreover, it has an extreme distribution. The climate in Hungary will probably turn to a more Mediterranean direction, with increasing water demand and the possibility of more frequent extreme events. This would result in the reduction of soil moisture and groundwater recharge . [5]

Another trait of Hungarian geography is that the country strongly depends on the river outflow arriving from other countries, and about 96% of the surface waters are of foreign origin. [3] Groundwater use for irrigation is increasing, and nowadays it exceeds the amount of surface water used. More than 95 per cent of the drinking water is supplied from groundwater and the rest is bank-filtered water, primarily from Danube. In the loose soils, especially in the Danube-Tisza Interfluve, it is easy to drill wells; so many wells were drilled in the twentieth century for domestic use and agricultural activities, as well.

Regarding the use of surface and ground water we should consider Water Framework Directive. This requires the Member States of the European Union to improve the quality of surface and ground water into good status, and sustain their good condition. Concerning artificial and heavily modified water bodies the target is to achieve the good ecological potential instead of the good ecological status. In Hungary, serious losses of crop occur in cultivation due to the drought regularly. Development of irrigation systems, water retention and economic use of water sources are in the center of attention. Surface, subsurface and deep waters – used as irrigation water – can contribute to the nutrient supply as well.

One of the most serious consequences of the climate change tendencies is that less water would be present for increased water demand. [2] Using EU funds, surface or ground irrigation water would be transferred to the land of the farmers, and it should be ensured that the water is used up.

In our study we show the main components of some artesian and ground waters collected in the southern part of the Great Hungarian Plain, primarily in Kecskemet and surroundings.

MATERIALS AND METHODS

Water sample collection. The collection of samples took place between 2007 and 2015 in the Danube-Tisza Interfluve, from ground waters of different wells. Based on the depth of the sampling points, we divided the samples into three categories: Group 1: 5-30 meters, Group 2: 31-70 meters and Group 3: 71-275 meters. Number of samples in the groups was 63, 58 and 12, respectively, a total of 133 samples. The place of origin was mainly Kecskemét and its surroundings. The rules of sampling were the following: collection of water sample from drilled wells after streaming a few minutes, sample collection containers washed out with well-water, and closed tight immediately after sampling. After a longer storage the results of the investigation were not reliable. Taking of samples and the scope of the tests were made taking into account the relevant legislation.

Water sample tests. Analytical testing methods were made in the Soil and Plant Testing Laboratory of Faculty of Horticulture (Kecskemét College). Our laboratory uses standard methods for analysis. Examination of pH was made by potentiometer, while electric conductivity (EC) was measured by laboratory conductometer.

Main macro and microelement contents were measured by optical emission spectrometer (ICP-AES method). Main measured macro elements were Ca^{2+} , Mg^{2+}, Na^{+}, K^{+}. Usual microelements measured were Fe, Mn, and As, while Cu and Zn were measured only casually. N content of samples was determined in the form of the dominant inorganic ions. Ammonium and nitrate content were measured spectroscopic method. Among accompanying anions PO_4^{3-}, SO_4^{2-} ions were analyzed by ICP-OES method. Investigation of chloride was made by argentometric titration, whereas carbonate and hydro-carbonate ions were analyzed by neutralization titration. The methods are based on widely accepted standards. German hardness was estimated on the concentration of calcium and magnesium.

The number and the ratio of concentrations over or under limit for sprinkling water, stated in Hungary, were estimated using the abovementioned measured parameters. For estimating changes in the concentration of the nutrients Student's two-pair t-probe was applied. Relations between variables were estimated by calculating correlation coefficients, and statistically significant relationships were also emphasized, based on the widely available Critical Values for Pearson's Correlation Coefficient table (under 0.05, 0.01 and 0.001 levels). [1]

RESEARCH RESULTS

Average depth in the three depth categories of the ground waters was 20.9, 46.4 and 156 m, respectively.

Among the results, the highest occurrence of over limit concentrations for sprinkling water was achieved in the case of iron and electrical conductivity. In the deepest samples (Group 3) the occurrence of high ammonium concentrations became the most characteristic change compared to Group 1 and 2. High sodium, manganese, hydro-carbonate, nitrate and chloride concentrations decreased with increasing depth. We did not detect extremely high pH, calcium, magnesium cuprum, zinc, boron and phosphate levels in our samples (Figure 1). In the case of hydro carbonate, the regulation defines lower threshold limit (30 mg/l). Too low concentration of hydro-carbonate was not characteristic in our examined samples (except one sample, in Group 1). The highest extremities of iron and arsenic levels were shown in the middle-depth group. Nitrate level was high in 6.35% and 1.72% of the samples of Group 1 and Group 2, respectively.

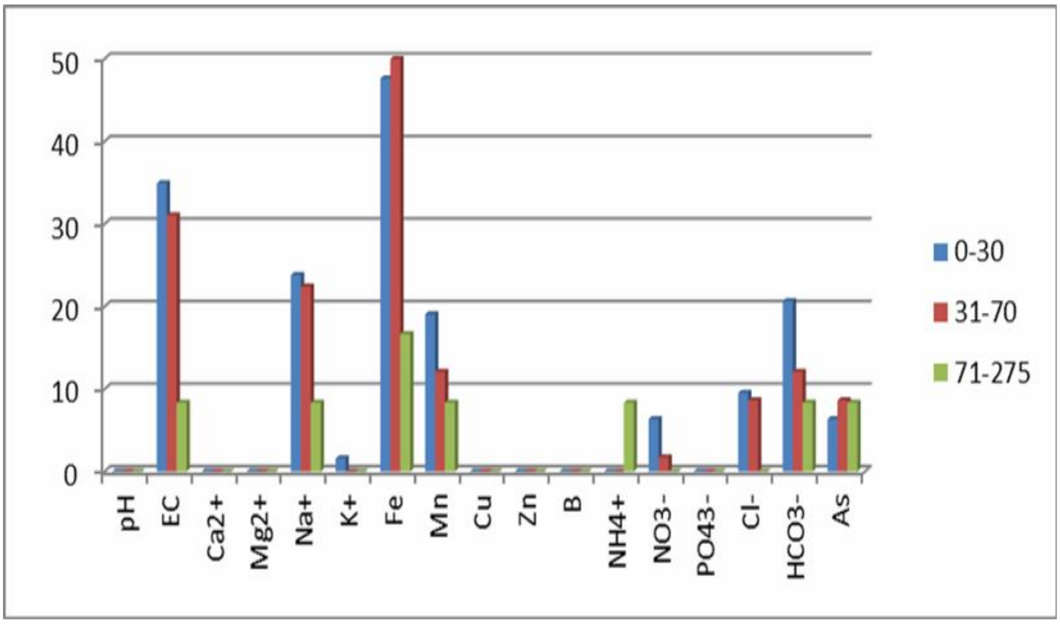

Figure 1. The occurrence of over limit concentrations in ground water samples (expressed in %) regarding the main elements and ions

Main macro elements in water samples were calcium and sodium, followed by magnesium and potassium. Regarding changes with increasing depth, detailed results are shown in Table 1. Positive or negative trends of correlations and significant correlation levels between depth and the analyzed parameters are shown in the table. Stronger relationships are highlighted with dark grey.

Table 1

Tendencies of changes of main measured components in water samples

	Group 1	**Group 2**	**Group 3**
pH	-	+	-
EC	-	-	-
Ca^{2+}	+	**- <0.05**	+
Mg^{2+}	-	-	+
Na+	-	+	-
K^+	-	-	+
Fe	**+ <0.05**	-	-
Mn	+	-	+
NH_4^+	-	-	-
NO_3^-	-	-	+
PO_4^{3-}	+	+	+
Cl^-	**- <0.01**	-	+
HCO_3^-	+	-	-
As	+	+	+

We also tracked the relations between changes in the level of the measured parameters. The results of the examinations of Group 1 are shown in Table 2. Green background in a cell shows a significant correlation coefficient, the darker the green color, the stronger the correlation.

Table 2

Correlation coefficients among parameters in water samples Group 1

	pH	EC	Ca^{2+}	Mg^{2+}	Na+	K^+	Fe	Mn	NH_4^+	NO_3^-	PO_4^{3-}	Cl^-	HCO_3^-	As
pH	1.000	-0.011	-0.346	-0.188	0.255	0.023	-0.245	-0.051	0.106	-0.024	0.059	0.178	0.023	0.360
EC	-0.011	1.000	0.039	0.689	0.797	0.565	0.053	0.301	0.107	0.514	-0.065	0.644	0.748	-0.191
Ca^{2+}	-0.346	0.039	1.000	0.365	-0.273	0.075	0.095	0.137	-0.051	0.378	-0.266	0.052	0.017	-0.263
Mg^{2+}	-0.188	0.689	0.365	1.000	0.321	0.327	0.161	0.333	-0.016	0.479	-0.231	0.359	0.582	-0.298
Na^+	0.255	0.797	-0.273	0.321	1.000	0.289	-0.142	-0.028	0.165	0.170	0.147	0.671	0.786	0.017
K^+	0.023	0.565	0.075	0.327	0.289	1.000	-0.012	0.567	0.043	0.896	-0.028	0.341	0.328	-0.126
Fe	-0.245	0.053	0.095	0.161	-0.142	-0.012	1.000	0.369	-0.081	-0.297	-0.083	-0.123	0.039	-0.045
Mn	-0.051	0.301	0.137	0.333	-0.028	0.567	0.369	1.000	0.083	0.687	-0.044	0.063	0.163	-0.161
NH_4^+	0.106	0.107	-0.051	-0.016	0.165	0.043	-0.081	0.083	1.000	0.039	0.063	0.443	-0.019	-0.095
NO_3^-	-0.024	0.514	0.378	0.479	0.170	0.896	-0.297	0.687	0.039	1.000	-0.111	0.338	0.302	-0.233
PO_4^{3-}	0.059	-0.065	-0.266	-0.231	0.147	-0.028	-0.083	-0.044	0.063	-0.111	1.000	-0.110	-0.002	0.667
Cl^-	0.178	0.644	0.052	0.359	0.671	0.341	-0.123	0.063	0.443	0.338	-0.110	1.000	0.498	-0.250
HCO_3^-	0.023	0.748	0.017	0.582	0.786	0.328	0.039	0.163	-0.019	0.302	-0.002	0.498	1.000	-0.095
As	0.360	-0.191	-0.263	-0.298	0.017	-0.126	-0.045	-0.161	-0.095	-0.233	0.667	-0.250	-0.095	1.000

The level of significance: 5% 1% 0.1%

In Group 1 pH, ammonium and phosphate was the least related with other components. EC was strongly related with Mg^{2+}, Na^+, K^+ cations and NO_3^-, Cl^- and HCO_3^- anions. Na^+ was strongly related with Cl^- and HCO_3^- .

Table 3 shows correlation coefficients between parameters in Group 2.

Table 3

Correlation coefficients among parameters in water samples Group 2

	pH	EC	Ca^{2+}	Mg^{2+}	Na+	K^+	Fe	Mn	NH_4^+	NO_3^-	PO_4^{3-}	Cl^-	HCO_3^-	As
pH	1.000	-0.134	-0.395	-0.299	0.170	0.179	-0.340	-0.307	-0.261	-0.090	-0.045	-0.110	0.121	0,271
EC	-0.134	1.000	0.422	0.801	0.809	0.438	0.558	0.266	0.666	0.197	-0.047	0.846	0.654	-0,024
Ca^{2+}	-0.395	0.422	1.000	0.490	-0.040	0.174	0.653	0.304	0.685	0.426	-0.131	0.487	-0.061	-0,122
Mg^{2+}	-0.299	0.801	0.490	1.000	0.374	0.345	0.644	0.483	0.625	0.173	-0.178	0.686	0.387	-0,137
Na^+	0.170	0.809	-0.040	0.374	1.000	0.409	0.160	-0.030	0.411	0.056	0.105	0.616	0.784	0,077
K^+	0.179	0.438	0.174	0.345	0.409	1.000	0.220	0.003	0.021	0.117	-0.078	0.325	0.493	0,117
Fe	-0.340	0.558	0.653	0.644	0.160	0.220	1.000	0.359	0.829	-0.190	0.014	0.720	0.124	0,185
Mn	-0.307	0.266	0.304	0.483	-0.030	0.003	0.359	1.000	0.351	-0.109	-0.010	0.252	-0.018	-0,206
NH_4^+	-0.261	0.666	0.685	0.625	0.411	0.021	0.829	0.351	1.000	0.537	-0.090	0.593	0.296	-0,340
NO_3^-	-0.090	0.197	0.426	0.173	0.056	0.117	-0.190	-0.109	0.537	1.000	-0.004	0.033	0.026	0,207
PO_4^{3-}	-0.045	-0.047	-0.131	-0.178	0.105	-0.078	0.014	-0.010	-0.090	-0.004	1.000	-0.117	0.074	0,561
Cl^-	-0.110	0.846	0.487	0.686	0.616	0.325	0.720	0.252	0.593	0.033	-0.117	1.000	0.335	-0,258
HCO_3^-	0.121	0.654	-0.061	0.387	0.784	0.493	0.124	-0.018	0.296	0.026	0.074	0.335	1.000	-0,281
As	0.271	-0.024	-0.122	-0.137	0.077	0.117	0,185	-0.206	-0.340	0.207	0.561	-0.258	-0.281	1.000

The level of significance: 5% 1% 0.1%

The correlation of EC and other parameters became notably stronger in Group 2 than in Group 1. Phosphate was not related with other components, except arsenic, in Group 2 and 3, as well. Regarding nitrogen containing ions, relations with nitrate were more characteristic in Group 1, while ammonium form was more significant in Group 2. We found particularly strong relations in Group 2, between iron and Ca/Mg/Cl/NH_4.

The number of samples in Group 3 was too low to get any statistically significant results, but the tendencies showed slight decreases in pH, sodium, iron and ammonium, in an almost significant manner, whereas magnesium and calcium levels tended to increase.

The decrease in EC with decreasing depth was significant (1019 vs. 681 µS cm-1; $p<0.05$), and the deviation of the level also decreased. Hardness of the samples was in the medium hard range, which slightly decreased with depth (from 20.5 to 15.8 German hardness, non significant).

CONCLUSIONS

In our study we emphasize that the quality of surface waters and ground waters should be controlled and regularly monitored. [4] The use of inadequate quality sprinkling water sources and the pollution of water should be avoided as having a negative impact on the conditions of cultivation.

Surface water quality is often not tested regularly, so we do not have enough data of this field. The examinations certainly involve costs, but for the correct consumption and use of the waters, and also to comply with the Water Framework Directive, we are required to do more water quality tests.

The EU Water project draws attention to preparation, development and implementation of efficient irrigation developments; the protection of groundwater reserves, and the use of surface waters, if it is possible. Aquifer systems can only be used for micro irrigation. The criterion of good quantity status is that the quantity of water taken out does not exceed the stock of waters that can be utilized.

The other formulation of recommendations is the reduction of nitrate pollution. The Nitrate Directive and the Good Agricultural Practice defines the minimum requirements in the field of the reduction of nitrate pollution. Protection of waters against pollution caused by nitrates from agricultural sources is supported by the Action Plan.

In the Danube-Tisza Interfluve, physical quality and chemical composition of the soils and the underlying rocks also have a wide variety. Waters which were measured in our study, derived from porous or basin-type cold water bodies. In our region the average thickness of the quaternary complex is 200-500 m.

The results of our study confirmed the following statements:

- Deviation of the concentration of some parameters decreased with depth in ground waters taken.
- The ratio of over limit concentrations also decreased with depth, except ammonium and sulphate.
- The highest extreme levels were reached in the case of iron in all groups, followed by EC, reflecting high concentration of saline components. High level of sodium was also significant.
- EC decreased with depth significantly.
- Phosphorus is one of the least mobile elements. Phosphate content stayed in the low concentration range, and seemed not to be related with other components, except arsenic.
- High nitrate level was not characteristic in our samples, about 6% of the samples of Group 1 and decreased thereafter.

It is a special feature of groundwater in the Great Plain that different salts are dissolved in the most diverse concentration. Salt content of these waters usually exceeds 1000 mg l^{-1}. Sodium-hydro-carbonate is the most frequent salt in our region. Composition of water samples is varied because of the water flows beneath the surface, moving up and down. The waters investigated are of medium hardness, potassium content is expressly low because of the minor clay content. Our results showed that increased EC and iron levels may cause the most problems during the use of ground waters for irrigation in agricultural cultivation. Iron and manganese content should be avoided under drip irrigation because of the risk of clogging. However, higher content of iron and manganese in waters (1.5 mg l^{-1})

is not a problem from the plant nutrition perspective. High sodium content of our samples may contribute to the formation of saline soils in cultivation.

Our results emphasize the importance of water analysis and the discussion of the test results.

REFERENCES

1. **FISCHER, R. A., F. YATES**, 1963, Statistical tables for biological, agricultural and medical research, Pearson Education Limited
2. **MEZŐSI G., BATA, T., MEYER, B., C., BLANKA, V., LADÁNYI, ZS.,** 2014, Climate Change Impacts on Environmental Hazards on the Great Hungarian Plain, Carpathian Basin, International Journal of Disaster Risk Science 5(2). pp 136-146.
3. **SOMLYÓDY, L., SIMONFFY, Z.,** 2004, Water in Hungary: with Tradition and Unique Problems to the EU. Begegnungen, Schriftenreihe des Europa Institutes Budapest, Band 25: 127-145.
4. **SOMLYODY L., BRUNNER, P. H., KROISS, H.,** 1999, Nutrient balances for Danube countries: A strategic analysis, Water Science and Technology 40 (10), 9-16.
5. **PÁLFAI, I.,** 2000, Az alföld belvízi veszélyeztetettsége és aszályérzékenysége. In: A víz szerepe és jelentősége az Alföldön. A Nagyalföld Alapítvány kötetei 6. 85-95.