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Influence of chemical composition of groundwater/drinking water on health status of inhabitants of the Slovak Republic

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GEOHEALTH

The impact of geological environment on health status of residents of the Slovak Republic.

Introductory remarks

HEALTH STATUS OF POPULATION depends on:

50 %	lifestyle
10 – 20 %	level of health-care
10 – 20 %	genetic factors
20 %	environment

We are searching for the 20% rate of ennvironmental factors

Assuming that first three factors are roughly similar, the environment, mainly geological structure, chemical composition of soils and mainly chemical composition of groundwater/drinking water can have higher influence than those mentioned 20%, mainly in highly contaminated and geologically unfavourable areas.

Introductory remarks

Generally, there are three main exposure routes for the input of chemical elements to human organism:

- ✓ INGESTION (oral exposure)
- ✓ INHALATION
- ✓ DERMAL CONTACT

among them INGESTION is certainly the most significant

We evaluate in relation to human health

SOILS

GROUNDWATER/DRINKING WATER

Introductory remarks

SOILS

Basis of the food chain

- ✓ Chemical elements in soils are present in various forms/species ~ their transfer to plants,

  or food chain depends on their **bioavailabilty**

- ✓ Foodstuffs nowadays ~ of **global** origin

- ✓ Various chemical elements/compounds

- ✓ Chemical elements are strongly bound in food (complex organic compounds) and only some of chemical elements is transferred to human organism

Introductory remarks

GROUNDWATER/DRINKING WATER

- ✓ Contents of chemical elements are limited in the drinking water guideline
- ✓ classic contaminants – NO_3, As, Hg, Pb, organic compounds – ***strictly limited in the drinking water guideline***
- ✓ macroelements – essential elements such as Ca, Mg, Na, K, SiO_2 dominantly ***non-limited or only as recommended values***
- ✓ Chemical elements in water are present in soluble forms and therefore are directly bioavailable to human organism
- ✓ In contrast to food (of global origin) humans are drinking the same water during their life or while they are moving to the another place
- ✓ They are daily exposed approximately to the same dose of chemical elements through water ingestion
- ✓ In case of essential elements ***long-term and cumulative deficiency or excess*** may occur

Materials

Data on chemical composition of groundwater ENVIRONMENTAL INDICATORS (EI)

Data on health status and demographic growth of population HEALTH INDICATORS(HI)

Materials

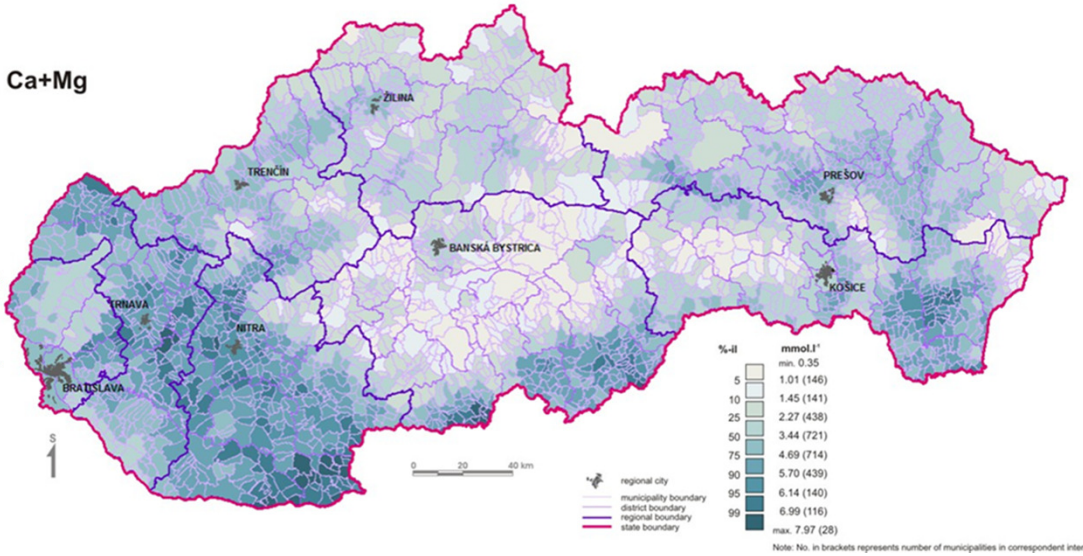
ENVIRONMENTAL INDICATORS (EI)

Evaluated chemical composition of groundwater and mean Slovak contents

GROUNDWATER (n=20,339)												
pH	**TDS**	**COD_{Mn}**	**Ca+Mg**	**Li**	**Na**	**K**	**Ca**	**Mg**	**Sr**	**Fe**	**Mn**	**NH_4**
7.33	629.75	2.18	3.5	0.019	20.34	11.10	93.56	28.29	0.36	0.17	0.12	0.10
F	**Cl**	**SO_4**	**NO_2**	**NO_3**	**PO_4**	**HCO_3**	**SiO_2**	**Cr**	**Cu**	**Zn**	**As**	**Cd**
0.13	32.96	79.32	0.11	38.76	0.20	303.85	18.21	0.0013	0.0026	0.2673	0.0019	0.0010
Se	**Pb**	**Hg**	**Ba**	**Al**	**Sb**	**^{222}Rn**	**^{226}Ra**					
0.0010	0.0014	0.0001	0.0747	0.0297	0.0009	14.46	0.053					

Chemical composition of groundwater/drinking water - EI

- ✓ Compiled database of 20,339 groundwater sample
- ✓ Analysed scale – 34 elements/compounds
- ✓ Data are elaborated into form of mean contents for each of evaluated 2,883 Slovak municipalities
- ✓ Data are elaborated in map and table form for municipalities/districts/regions/SR

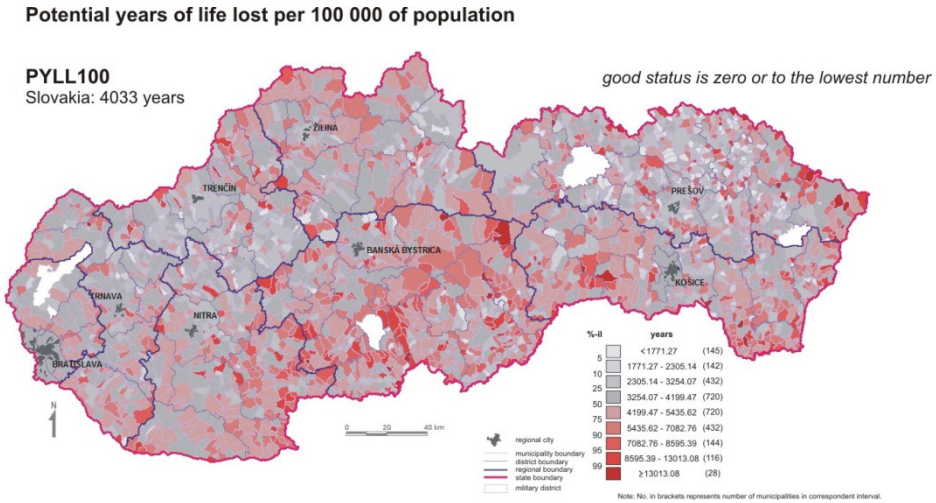


HEALTH INDICATORS(HI)

Materiál

Health indicator is a variable that expresses health status of inhabitants in society through direct measure or observation (Last, 2001)

- ✓ Data source Statistical office of the Slovak Republic
- ✓ Evaluated period 10 years (1994-2003)
- ✓ (means values for 1994 – 2003)
- ✓ HI – compiled in accordance with International classification diseases (ICD, 10th revision)
- ✓ HI – one numerical value for each of 2,883 Slovak municipalities
- ✓ Data are elaborated in map and table form for municipalities/districts/regions/SR



5 main groups of HI

- Demographic indicators
- Premature mortality
- Relative mortality for selected cause of deaths
- Standardized mortality for selected cause of deaths
- (19 age groups, Slovak age standard)
- Potential years of lost life for selected cause of deaths

4 main groups of causes of deaths

CVD	50 %
OD	25 %
GS	6 – 8 %
RS	5 – 6 %
Total cca	85 %

Evaluated health indicators of the Slovak Republic (data recalculated according to No. of inhabitants in municipalities)

Health Indicator	Description of indicator	Method of calculation	Units	Mean SR*
Demographic indicators describing age structure of municipalities				
LE	life expectancy at birth – population	cumulative calculation of all years of life during lifetime / No. of living persons at the beginning of the year	years	72.60
Premature mortality				
PYLL100	potential years of lost life	100,000 x [the sum of the years of people up to the age of nearly 65 years (deaths at age between 1 to 64 years) / number of inhabitants]	years	4033.00
Relative mortality for selected cause of death				
ReC00-C97	malignant neoplasms	100,000 x [No. of deaths for selected cause / number of inhabitants]	No. of deaths per 100,000 inhabitants	212.79
ReI00-I99	diseases of the circulatory system			531.05
ReJ00-J99	diseases of respiratory system			58.08
ReK00-K93	diseases of the digestive system			45.83
Standardized mortality for selected cause of death				
SMRC00-C97	malignant neoplasms	indirect age-standardized mortality rate of inhabitants to the Slovak standard (19 age groups)	%	100
SMRI00-I99	diseases of the circulatory system			100
SMRJ00-J99	diseases of respiratory system			100
SMRK00-K93	diseases of the digestive system			100
Potential years of lost life for selected cause of death				
PYLLC00-C97	malignant neoplasms	100,000 x [the sum of the years of people up to the age of nearly 65 years (deaths at age between 1 to 64 years) / number of inhabitants]	years	1005.20
PYLLI00-I99	diseases of the circulatory system			866.19
PYLLJ00-J99	diseases of respiratory system			172.69
PYLLK00-K93	diseases of the digestive system			334.80

Health indicators are classified according to International classification of diseases (ICD), 10th revision (http://www.who.int/classifications/icd/en/), * mean for the Slovak Republic for the period 1994 – 2003

Metodhodology of work

- ✓ **Division of EI and HI according to various geological environment**
- ✓ **Statistical analysis**
  - Linear correlation
  - Spearman correlation
- ✓ **Calculation of Neural networks (ANN)**

Why ANN?

- Our data are not normally distributed
- They are of relevance of everyday life
- They are often spoiled by errors, sometimes incomplete
- We cannot suppose the existence of linear function between them
- Use of standard regression analysis (linear and Spearman correlation coefficient) could lead to wrong conclusions
- Through ANN we are able to identify the influence of single chemical elements in groundwater / soils on health indicators
- Through ANN we are able to derive limit values (minimum necessary as well as maximum allowable) for single chemicals in relation to their influence on health indicators
- Reliability of ANN is characterized by correlation coefficient R
- Statistical significance of ANN is characterized by coefficient of determination R^2
- The level of influence of chemicals on health indicators is characterized by sensitivity coefficient (sensitivity rate) s_r, for infuential elements $s_r > 1$, for non-influential elements $s_r < 1$

Results and discussion

Division of EI and HI according to various geological environment

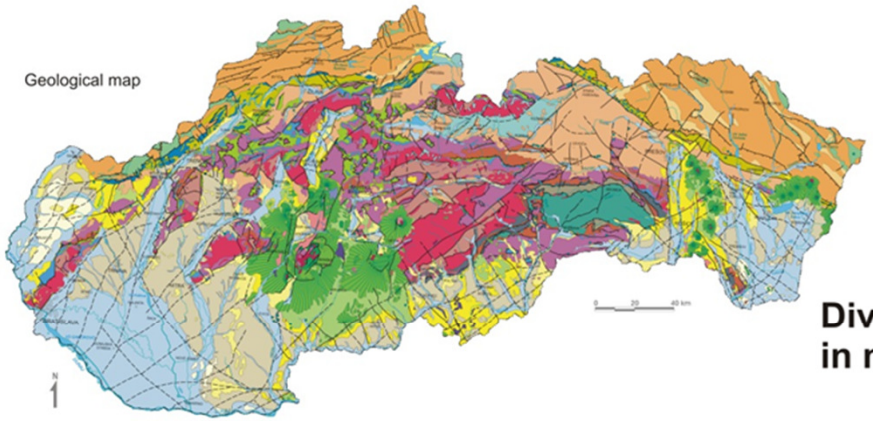
Background assumption:

Various geological structure have various influence on human health

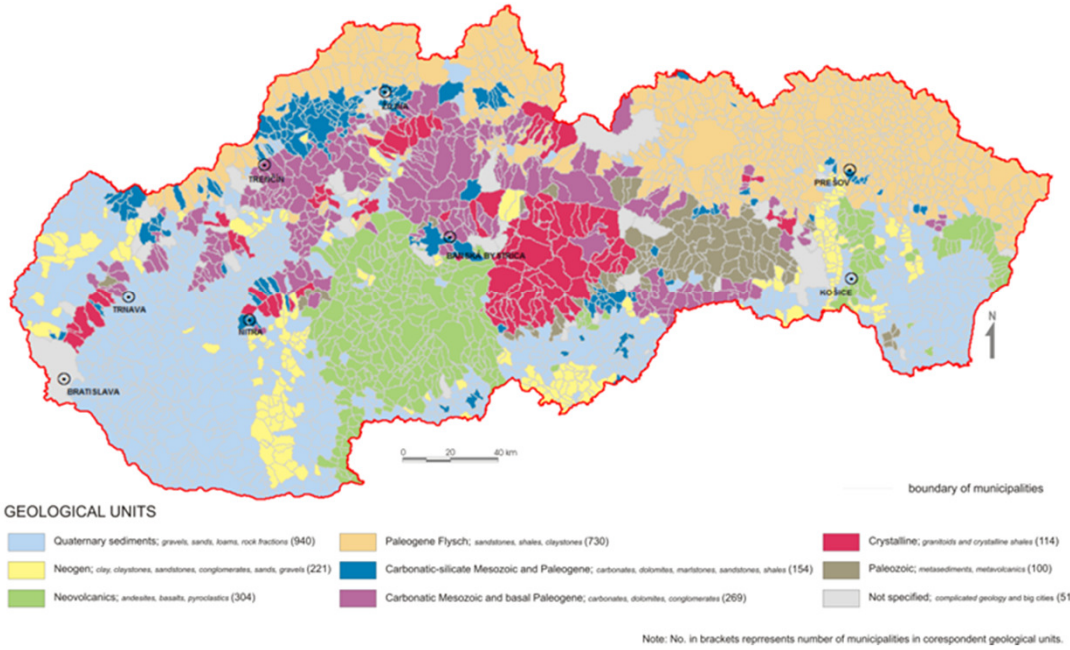
Geological structure of the Slovak Republic divided into eight main units:

1. Paleozoic: mostly metasediments, metavolcanics,
2. Crystalline: mostly granites, gneisses and migmatites,
3. Carbonatic Mesozoic and basal Paleogene: mainly limestones, dolomites, carboniferous conglomerates,
4. Carbonatic-silicate Mesozoic and Paleogene: mainly marl, marly limestones, dolomites, sandstones and shales,
5. Paleogene Flysch: mainly sandstones, shales, claystones,
6. Neovolcanic rocks: mainly andesites, basalts and their volcanoclastics,
7. Neogene: mainly clays, claystones, conglomerates, sands, gravels,
8. Quaternary: mainly gravel, sand, clay, rock fragments.

Results and discussion

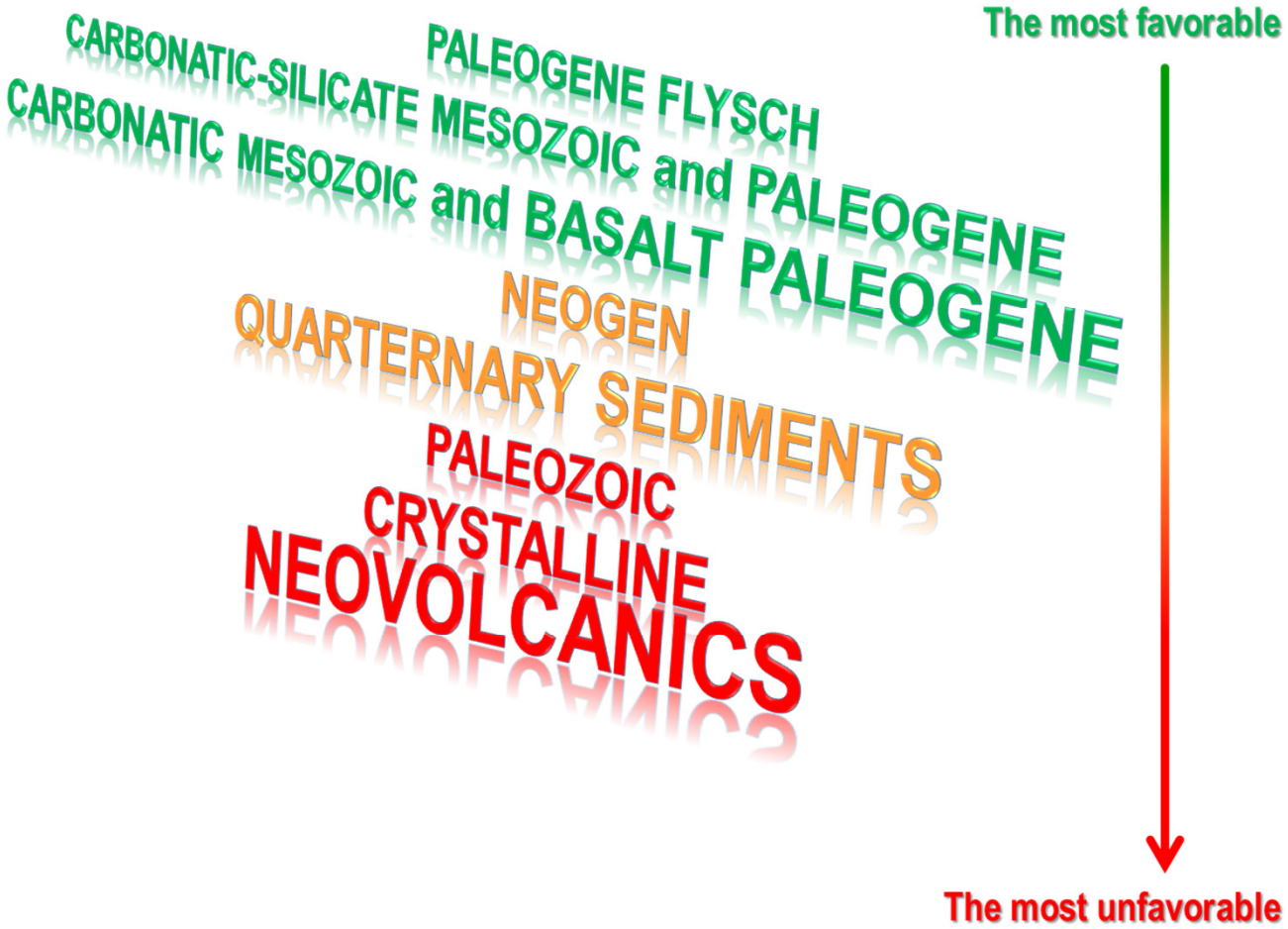


Division of geological structure of the Slovak Republic in main geological units



Results and discussion

Characteristics of geological units according to their favourableness to human health



Results and discussion

Mean values for selected chemical elements/parameters in groundwater in selected areas of the Slovak Republic

Geological unit/district Parameter	1 n = 100	4 n = 154	5 n = 727	6 n = 309	Krupina n = 36	Bardejov n = 86	SR
TDS [mg l^{-1}]	302.27	586.79	524.64	439.73	362.34	484.79	629.75
Ca+Mg [mmol l^{-1}]	1.68	3.45	3.02	2.11	1.58	2.75	3.50
Na [mg l^{-1}]	8.53	12.79	12.74	16.09	13.12	10.34	20.34
Ca [mg l^{-1}]	43.15	99.86	88.53	56.13	42.01	80.75	93.56
Mg [mg l^{-1}]	14.70	23.27	19.67	17.14	12.96	17.98	28.29
Cl [mg l^{-1}]	13.18	21.24	17.14	21.66	13.81	13.77	32.96
SO_4 [mg l^{-1}]	45.65	65.38	62.72	49.70	22.42	44.96	79.32
NO_3 [mg l^{-1}]	18.02	21.72	16.19	26.44	16.49	14.84	38.76
HCO_3 [mg l^{-1}]	138.29	323.63	287.65	191.51	174.23	282.12	303.85
As [mg l^{-1}]	0.00863	0.00135	0.00079	0.00241	0.0018	0.00114	0.00192
Se [mg l^{-1}]	0.00063	0.00074	0.00068	0.00086	0.0006	0.00068	0.00097
Pb [mg l^{-1}]	0.00142	0.00121	0.00125	0.00134	0.0018	0.00094	0.00136

1 – Paleozoic, 4 – Carbonatic-silicate Mesozoic and Paleogene, 5 – Paleogene Flysch, 6 – Neovolcanic rocks, SR – mean for the Slovak Republic, n = number of municipalities in evaluated geological unit/district

Significant differences are observed mainly in case of **calcium, magnesium, total mineralization** (T.D.S.)

Results and discussion Mean values for health indicators in selected areas of the Slovak Republic

Geological unit/district Health indicator	1 n = 100	4 n = 154	5 n = 727	6 n = 309	Krupina n = 36	Bardejov n = 86	SR
LE	71.47	72.75	73.69	71.11	69.95	74.07	72.60
PYLL100	4360.96	3985.46	3874.38	4586.18	5609.07	3140.73	4033.00
ReC00-C97	209.46	195.96	177.99	236.28	243.23	175.32	212.79
ReI00-I99	569.73	505.07	463.32	638.78	889.20	492.82	531.05
ReJ00-J99	70.21	57.44	54.42	81.98	81.11	26.62	58.08
ReK00-K93	41.39	42.40	34.22	66.88	75.68	25.39	45.83
SMRC00-97	101.78	95.18	95.03	102.91	99.73	91.20	100
SMRI00-I99	111.73	98.86	100.03	108.50	131.06	100.71	100
SMRJ00-J99	124.81	100.61	109.39	126.34	116.33	50.50	100
SMRK00-K93	94.92	94.23	84.31	130.61	150.20	62.63	100
PYLLC00-C97	1053.42	921.47	909.88	1097.32	1121.6	808.8	1005.20
PYLLI00-I99	1052.18	937.66	831.99	1050.95	1518.2	779.9	866.19
PYLLJ00-J99	274.92	146.28	229.74	202.67	259.2	231.1	172.69
PYLLK00-K93	369.48	340.66	287.97	491.26	693.29	211.84	334.8

1 – Paleozoic, 4 – Carbonatic-silicate Mesozoic and Paleogene, 5 – Paleogene Flysch, 6 – Neovolcanic rocks, SR – mean for the Slovak Republic, n = number of municipalities in evaluated geological unit/district

- All HI are markedly more unfavourable in silicate geological units (1, 4) and in the Krupina district built up by neovolcanics
- The most significant differences are observed in case of gastrointestinal and respiratory system, even about 300%

Results and discussion

Statistical analysis

PEARSON AND SPEARMAN CORRELATION
between EI and HI
for entire geological environment

- ✓ Correlation cofficients are very low (- 0,01 ~ + 0,01)
- ✓ For Ca+Mg dominantly with high statistical significance
- ✓ for HI of various causes of deaths – negative correlation coefficients (impairment of health status at deficit contents)
- ✓ for HI – LE positive correlation coefficients (human life gets longer)

r – Pearson correlation coefficient
R – Spearmanov correlation coefficient
P – value – significance level
P = 0,05 – verified dependance (+),
P = 0,01 – high dependance (++),
P = 0,001 – very high dependance (+++)

Parameter	Linear correlation			Spearman correlation		
	r	P	significance	R	P	significance
Ca+Mg & LE	0.140	0.000	+++	0.181	0.000	+++
NO_3 & LE	-0.021	0.392	-	0.069	0.005	++
As & LE	0.020	0.411	-	-0.078	0.001	++
Ca+Mg & PYLL100	-0.130	0.000	+++	-0.187	0.000	+++
NO_3 & PYLL100	-0.001	0.960	-	-0.077	0.002	++
As & PYLL100	-0.017	0.484	-	0.083	0.001	+++
Ca+Mg & ReC00-C97	-0.085	0.000	+++	-0.134	0.000	+++
NO_3 & ReC00-C97	-0.050	0.043	+	-0.112	0.000	+++
As & ReC00-C97	-0.001	0.960	-	0.080	0.001	++
Ca+Mg & ReI00-I99	-0.083	0.001	+++	-0.151	0.000	+++
NO_3 & ReI00-I99	-0.031	0.198	-	-0.092	0.000	+++
As & ReI00-I99	-0.013	0.586	-	0.030	0.224	-
Ca+Mg & ReJ00-J99	-0.108	0.000	+++	-0.138	0.000	+++
NO_3 & ReJ00-J99	-0.057	0.020	+	-0.111	0.000	+++
As & ReJ00-J99	-0.003	0.912	-	0.090	0.000	+++
Ca+Mg & ReK00-K93	-0.049	0.047	+	-0.119	0.000	+++
NO_3 & ReK00-K93	0.075	0.002	++	-0.038	0.116	-
As & ReK00-K93	0.001	0.959	-	0.171	0.000	+++
Ca+Mg & SMRC00-	-0.033	0.175	-	-0.038	0.119	-
NO_3 & SMRC00-C97	0.012	0.618	-	-0.004	0.861	-
As & SMRC00-C97	0.006	0.798	-	0.086	0.000	+++
Ca+Mg & SMRI00-I99	-0.023	0.351	-	-0.046	0.061	-
NO_3 & SMRI00-I99	0.077	0.002	++	0.052	0.034	+
As & SMRI00-I99	-0.014	0.578	-	0.039	0.112	-
Ca+Mg & SMRJ00-J99	-0.066	0.007	++	-0.084	0.001	+++
NO_3 & SMRJ00-J99	-0.010	0.693	-	-0.056	0.023	+
As & SMRJ00-J99	0.004	0.871	-	0.081	0.001	+++
Ca+Mg & SMRK00-	-0.039	0.112	-	-0.088	0.000	+++
NO_3 & SMRK00-K93	0.105	0.000	+++	0.007	0.780	-
As & SMRK00-K93	0.018	0.456	-	0.168	0.000	+++
Ca+Mg & PYLLC00-	-0.079	0.001	++	-0.095	0.000	+++
NO_3 & PYLLC00-C97	-0.028	0.258	-	-0.042	0.086	-
As & PYLLC00-C97	-0.001	0.971	-	0.106	0.000	+++
Ca+Mg & PYLLI00-	-0.084	0.001	+++	-0.121	0.000	+++
NO_3 & PYLLI00-I99	0.042	0.083	-	0.002	0.929	-
As & PYLLI00-I99	-0.020	0.421	-	0.091	0.000	+++
Ca+Mg & PYLLJ00-	-0.025	0.302	-	-0.079	0.001	++
NO_3 & PYLLJ00-J99	0.009	0.715	-	0.004	0.856	-
As & PYLLJ00-J99	-0.006	0.806	-	0.058	0.018	+
Ca+Mg & PYLLK00-	-0.041	0.092	-	-0.079	0.001	++
NO_3 & PYLLK00-K93	0.079	0.001	++	0.006	0.800	-
As & PYLLK00-K93	0.028	0.248	-	0.156	0.000	+++

Results and discussion

Neural networks (ANN)

Coefficients of sensitivity and order of influence for 10 the most influential elements/parameters in groundwater in relation to health indicators according to calculations through ANN

Parameter	1		2		3		4		5		6		7		8		9		10		11		12		13		14		xP
	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	s_r	P	
Ca+Mg	1.419	1	1.115	1	1.027	3	1.370	1	1.590	1	1.057	1	1.003	3	1.677	1	1.001	6	1.180	1	1.044	1	1.046	1	1.003	4	1.169	1	1.92
Mg	1.153	3	1.027	3	1.005	8	1.150	3	1.255	3	1.009	7	1.004	1	1.291	3	1.002	4	1.065	3	1.004	4	1.002	6	1.004	3	1.063	3	3.92
Ca	1.246	2	1.048	2	1.013	4	1.211	2	1.346	2	1.015	5	1.003	2	1.387	2	1.003	3	1.108	2	1.008	3	1.006	3	1.004	2	1.100	2	2.62
TDS	1.086	4	1.003	5	1.074	1	1.053	4	1.008	4	1.015	6	1.001	8	1.018	4	1.016	1	1.051	4	1.016	2	1.002	7	1.010	1	1.028	4	3.92
HCO_3	1.012	8	1.013	4	1.034	2	1.026	5	1.005	5	1.023	4	1.002	4	1.006	5	1.005	2	1.028	5	1.002	5	1.010	2	1.003	6	1.012	5	4.38
SO_4	1.004	9	1.002	7	1.0094	5	1.009	7	1.001	8	1.006	8	1.001	10	1.001	10	1.001	5	1.006	8	1.001	10	1.003	5	1.001	7	1.003	9	7.77
Cl	1.003	11	1.002	9	1.007	6	1.027	6	1.001	9	1.029	2	1.001	5	1.001	11	1.000	13	1.021	6	1.002	6	1.002	8	1.001	8	1.003	8	7.85
NO_3	1.003	10	1.001	11	1.006	7	1.004	8	1.001	10	1.003	9	1.001	11	1.002	6	1.001	8	1.004	9	1.001	8	1.001	11	1.001	11	1.001	10	9.31
SiO_2	1.002	13	1.002	8	1.001	12	1.003	10	1.000	17	1.027	3	1.001	6	1.001	14	1.000	11	1.014	7	1.000	13	1.001	9	1.000	21	1.008	6	10.77
Na	1.0434	7	1.001	12	1.003	9	1.002	9	1.000	16	1.002	12	1.001	12	1.001	13	1.000	14	1.001	13	1.001	7	1.003	4	1.001	9	1.000	19	11.31
K	1.0732	6	1.000	15	1.000	17	1.001	12	1.000	20	1.000	17	1.001	20	1.001	15	1.000	16	1.000	17	1.000	14	1.001	10	1.000	13	1.000	28	16.00

s_r – coefficient of sensitivity, P – order of influence, xP – arithmetic mean of order of influence for all evaluated health indicators, 1 – LE, 2 – PYLL100, 3 – ReC00-C97, 4 – ReI00-I99, 5 - ReJ00-J99, 6 - ReK00-K93, 7 - SMRC00-C97, 8 - SMRI00-I99, 9 - SMRJ00-J99, 10 - SMRK00-K93, 11 - PYLLC00-C97, 12 - PYLLI00-I99, 13 - PYLLJ00-J99, 14 - PYLLK00-K93

Results of calculations of ANN and derived limit values for 10 the most influential chemical elements/parameters in groundwater of the Slovak Republic in relation to LE

Order	Parameter	s_r	R^2	Limit content		Optimal content		Evaluated function of dependence	Contents*	
				LL	UL	LL	UL		min	max
1	**Ca+Mg**	1.419	0.997	2.98	does not exist	does not exist	does not exist	concave parabola	0.35	7.97
2	**Ca**	1.246	0.975	73.95	172.21	does not exist	does not exist	concave parabola	9.83	201.01
3	**Mg**	1.152	0.975	18.13	does not exist	does not exist	does not exist	concave parabola	2.45	97.75
4	**TDS**	1.086	0.899	358.46	does not exist	does not exist	does not exist	concave parabola	87.30	1412.30
5	**COD_{Mn}**	1.081	0.994	does not exist	2.27	does not exist	does not exist	straight line	0.75	7.48
6	**K**	1.073	0.964	does not exist	9.85	does not exist	does not exist	straight line	0.27	153.15
7	**Na**	1.043	0.977	does not exist	24.07	does not exist	does not exist	concave parabola	0.71	119.69
8	**HCO_3**	1.012	0.993	250.79	does not exist	does not exist	does not exist	concave parabola	16.57	592.05
9	**SO_4**	1.003	0.522	31.42	185.32	does not exist	does not exist	concave parabola	9.38	319.50
10	**NO_3**	1.003	0.832	does not exist	71.45	does not exist	does not exist	concave parabola	1.33	227.09

s_r – coefficient of sensitivity,
R^2 – coefficient of determination,
LL – lower limit,
UL – upper limit,
*minimum – maximum contents of chemical elements/parameters in groundwater of the Slovak Republic (units in mg l^{-1}, Ca+Mg in mmol l^{-1})

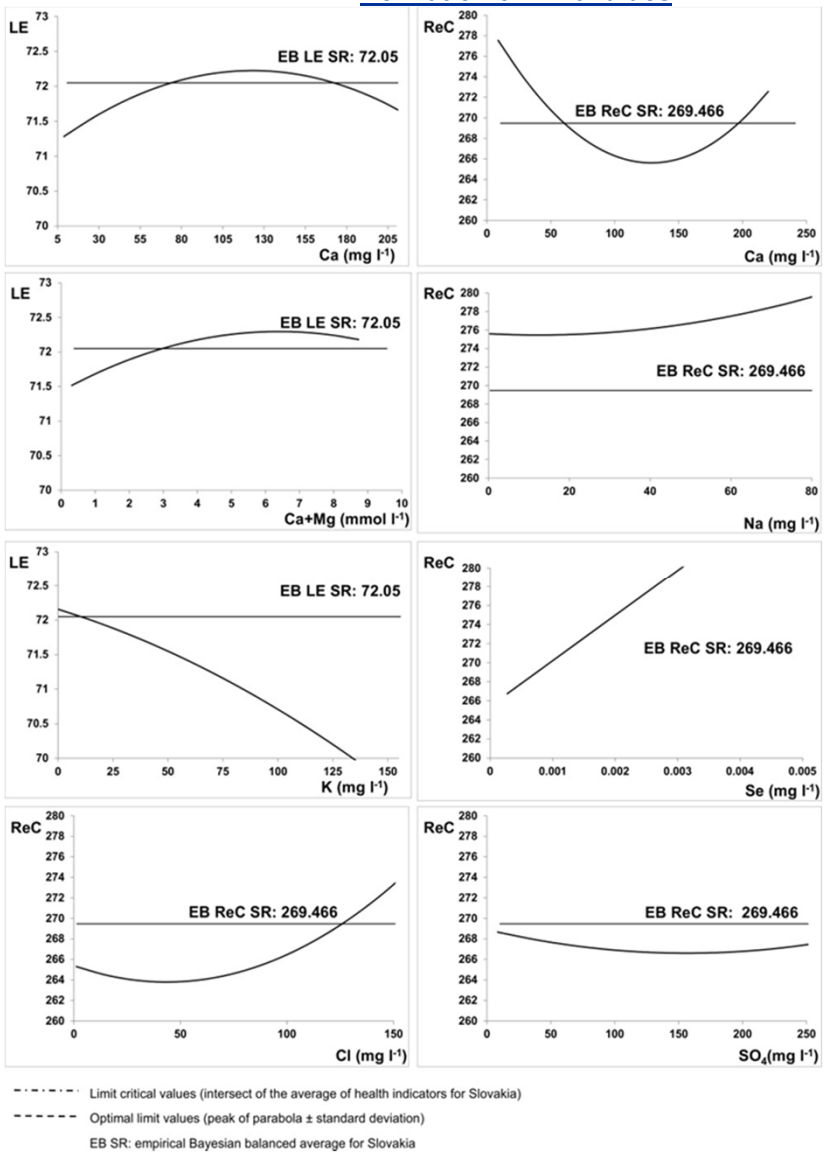
Results and discussion

ANN

- ✓ The most influential parameters are Ca+Mg, Ca, Mg, TDS, HCO_3, SO_4, Cl, NO_3
- ✓ Potentially toxic elements and parameters of natural radioactivity are not inluential
- ✓ Influential elements are grouped into 3 categories:

  Ca+Mg, Ca, Mg
  TDS, HCO_3
  SO_4, Cl, NO_3
- ✓ The highest influence (s_r more than 1 – 2 orders higher) have Ca+Mg, Ca, Mg
- ✓ Similar relationships were documented for all evaluated HI (not reviewed in this presentation)
- ✓ With decrease of Ca and Mg contents mortality increases
- ✓ With increasing levels of Ca+Mg, Ca, Mg the human life gets longer

Derivation of limit values



Literary findings and knowledge on the influence of Ca and Mg and water hardness on human health

CARDIOVASCULAR DISEASES

Relationship between deficit Ca and Mg drinking water contents and low water hardness and CVD was described in many studies from all over the world

ONCOLOGICAL DISEASES

Relationship between deficit Ca and Mg drinking water contents and low water hardness and OD was described:

Japan – Sakamoto et al., 1997
Taiwan – prof. Yang (10 works)
Slovakia – Rapant et al., 2014, 2016

DISEASES OF GASTROINTESTINAL SYSTEM

Relationship between deficit Ca and Mg drinking water contents and low water hardness and diseases of GS was described only in one Russian (non referenced) study Lutai (1992) reporting increased incidence of diseases of stomach and dodecadactylon in relation to soft water (< 1,5 mmol.l^{-1})

DISEASES OF RESPIRATORY SYSTEM

We did not find any reference in world literature reporting association between mortality/incidence of diseases of RS and Ca, Mg in water or water hardness

In case of GS and RS we observe the most significant differences in relative and standardized mortality (almost more than 300 %)

Results and discussion

Impact of other factors (except of water)

MORTALITY FOR ONCOLOGICAL DISEASES depends also by a series of other factors:

- Level of contamination of other compounds of the environment (air, soils)
- Socio-economic conditions
- Rate of Gypsy population
- Level of health-care
- Lifestyle

Such data are not available for particular Slovak municipalities but are available only for selected areas and districts.
We mention them for two evaluated districts Bardejov and Krupina

Results and discussion

Review of selected socio-economic, health-care and lifestyle characteristics for Krupina and Bardejov districts compared with the Slovak Republic

Socio-economic characteristics[a]	**Krupina**	**Bardejov**	**SR**
Level of registered unemployment (% of population)	16.95	19.6	*12.29*
Average nominal monthly salary in Euro	694	614	*957*
Rate of gypsy nationality (% of population)	2.1 - 4	4.1 - 8	*2*
Health-care characteristics[b]			
No. of physicians posts per 10,000 population - adults (age 18+ years)	4.36	3.40	*4.32*
No. of physicians posts per 10,000 population - children and adolescents (age 0-17 years)	6.86	7.44	*9.87*
Lifestyle characteristics[c, d]			
Regular physical activity in average (% of population)	45	39.5	*58.5*
Regular eating habits (% of population)	75	49	*68*
Smoking (% of population)	25	43	*19.5*
Excessive alcohol intake (% of population)	9.8	11	*6.8*

[a]Statistical office of the Slovak Republic (www.statistics.sk), [b]NHIC 2013, [c]Data source for Krupina district: Kosmovský et al., 2015, [d]Data source for Bardejov district and the Slovak Republic: EHES – European Health Examination Survey (www.ehes.info), SR – Slovak Republic

Results and discussion

PROPOSAL OF LIMIT VALUES FOR INFLUENTIAL ELEMENTS
(Ca, Mg, Ca + Mg)

The importance of HI

LE	100 %
PYLL	100 %
CVD	50 %
OD	25 %
GS	6 – 8 %
RS	5 – 6 %

- ✓ We cannot define the levels mathematically, for about half of the HI the limit value does not exist (decreasing or increasing element content has no influence on HI) or cannot be defined
- ✓ In defining limit values we also have to take into account the potential adverse health effects of very hard water (kidney stones, diarhea)
- ✓ sensory water properties – unfavourable taste, formation of coatings on surface of coffee or tea glasses and loss of aromatic substances from food and beverages by binding on Ca carbonate
- ✓ Technological water properties : corrosive effects
  incrustation
- ✓ Most authors recommend:

Mg	minimum 20 – 30 $mg.l^{-1}$
Ca	minimum 40 – 80 $mg.l^{-1}$
water hardness	2 – 4 $mmol.l^{-1}$

- ✓ In literature higher significance is reported for Mg than Ca (we are not able to define limit values from our data)
- ✓ Upper limit values for Ca, Mg and water hardness we consider to be of less significance, such contents practically do not occur in the territory of the Slovak Republic and generally they are not used for drinking purposes

Our derived limit values for Ca, Mg contents and water hardness (Ca+Mg) for single health indicators

Health indicator	Order	Element	Limit content		Optimal content		Contents*	
			LL	UL	LL	UL	min	max
LE	1	Ca+Mg	2.98	does not exist	not defined	does not exist	0.35	7.97
	2	Ca	73.95	172.21	85.56	160.60	9.83	201.01
	3	Mg	18.13	does not exist	does not exist	does not exist	2.45	97.75
PYLL100	1	Ca+Mg	2.87	6.67	3.21	6.33	0.35	7.97
	2	Ca	79.40	169.74	87.05	162.09	9.83	201.01
	3	Mg	20.44	83.24	33.82	69.87	2.45	97.75
ReC00-C97	3	Ca+Mg	1.73	5.85	2.23	5.34	0.35	7.97
	4	Ca	60.56	196.84	91.18	166.21	9.83	201.01
	8	Mg	25.66	35.83	12.72	48.77	2.45	97.75
ReI00-I99	1	Ca+Mg	2.90	9.10	4.40	7.60	0.35	7.97
	2	Ca	does not exist	89.40	does not exist	does not exist	9.83	201.01
	3	Mg	24.30	95.80	42.00	78.10	2.45	97.75
ReJ00-J99	1	Ca+Mg	3.20	11.67	5.88	8.99	0.35	7.97
	2	Ca	93.08	does not exist	does not exist	does not exist	9.83	201.01
	3	Mg	28.63	does not exist	83.99	120.05	2.45	97.75
ReK00-K93	1	Ca+Mg	does not exist	4.08	0.41	3.53	0.35	7.97
	4	Ca	17.74	127.58	35.14	110.18	9.83	201.01
	7	Mg	does not exist	33.54	does not exist	10.65	2.45	97.75
SMRC00-C97	2	Ca+Mg	does not exist	4.17	does not exist	does not exist	0.35	7.97
	3	Ca	104.07	does not exist	does not exist	does not exist	9.83	201.01
	1	Mg	does not exist	33.50	does not exist	does not exist	2.45	97.75

Table continued

Health indicator	Order	Element	Limit content		Optimal content		Contents*	
			LL	UL	LL	UL	min	max
SMRI00-I99	1	**Ca+Mg**	not defined	not defined	not defined	not defined	0.35	7.97
	2	**Ca**	not defined	not defined	not defined	not defined	9.83	201.01
	3	**Mg**	does not exist	65.85	does not exist	does not exist	2.45	97.75
SMRJ00-J99	6	**Ca+Mg**	3.27	does not exist	does not exist	does not exist	0.35	7.97
	3	**Ca**	90.03	does not exist	does not exist	does not exist	9.83	201.01
	4	**Mg**	25.81	does not exist	does not exist	does not exist	2.45	97.75
SMRK00-K93	1	**Ca+Mg**	0.99	2.16	0.99	2.16	0.35	7.97
	2	**Ca**	not defined	not defined	not defined	not defined	9.83	201.01
	3	**Mg**	does not exist	29.67	does not exist	does not exist	2.45	97.75
PYLLC00-C97	1	**Ca+Mg**	not defined	not defined	not defined	not defined	0.35	7.97
	3	**Ca**	93.17	194.91	106.52	181.56	9.83	201.01
	4	**Mg**	not defined	not defined	not defined	not defined	2.45	97.75
PYLLI00-I99	1	**Ca+Mg**	5.70	8.88	5.73	8.85	0.35	7.97
	3	**Ca**	150.76	does not exist	164.04	does not exist	9.83	201.01
	3	**Mg**	56.20	82.78	56.20	82.78	2.45	97.75
PYLLJ00-J99	4	**Ca+Mg**	does not exist	4.06	does not exist	does not exist	0.35	7.97
	2	**Ca**	does not exist	121.18	does not exist	does not exist	9.83	201.01
	3	**Mg**	does not exist	47.63	does not exist	does not exist	2.45	97.75
PYLLK00-K93	1	**Ca+Mg**	does not exist	4.84	0.73	3.84	0.35	7.97
	2	**Ca**	17.58	173.05	57.80	132.83	9.83	201.01
	3	**Mg**	does not exist	37.27	does not exist	does not exist	2.45	97.75
Mean values		**Ca+Mg**	**2.95**	**6.15**	**2.95**	**5.83**	**0.35**	**7.97**
		Ca	**78.03**	**155.61**	**89.61**	**152.29**	**9.83**	**201.01**
		Mg	**28.45**	**54.51**	**48.33**	**79.91**	**2.45**	**97.75**
Limit values defined by Slovak guideline for drinking water (Anon 2010)			***Ca > 30 mg l^{-1}***		***Mg 10 – 30 mg l^{-1}***		***Ca+Mg 1.1 – 5.0 mmol l^{-1}***	

Proposed limit values for groundwater used for drinking water public supply

Parameter	Recommended levels
Ca+Mg	2 – 5 mmol l^{-1}
Ca	50 – 180 mg l^{-1}
Mg	25 – 50 mg l^{-1}

Conclusion

- health status of the population in the Slovak Republic is significantly influenced by the chemical composition of the groundwater/drinking water, in particular, by the Ca, Mg contents and water hardness (Ca+Mg)
- At deficit contents of these parameters mortality for CVD, OD, GS, RS is increasing
- At their higher contents human life gets longer

MAIN CONCLUSION

It is reported that the population of the Slovak Republic, living in the silicate geological environment (granites, crystalline schists, volcanics), shows significantly worse health status (increased mortality for selected diseases) and shorter life expectancy as a result of deficit contents of calcium and magnesium in geological environment, mainly in drinking groundwater. It is very likely that populations of other EU countries may face similar problems as well. Moreover, we find it necessary to keep people living in such unfavourable geological environment informed in order to carry out convenient measures (additional supply of Ca and Mg from other sources) to avoid these risks.

More details can be found in paper:

Rapant, S., Cvečková, V., Fajčíková, K., Hiller, E. & Sedláková, D. (2016). Impact of chemical composition of groundwater/drinking water on health status of inhabitants in the Slovak Republic and proposal of limit values for the influential elements. Environ. Geochem. Health, in press

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GEOHEALTH
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