



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

<sup>1</sup>S. Rapant, <sup>1</sup>V. Cvečková, <sup>1</sup>K. Fajčíková, <sup>2</sup>Z., Dietzová, <sup>3</sup>D. Sedláková, <sup>4</sup>B. Stehlíková



**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 environmental 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 **bioavailability**
- ✓ 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 –  $\text{NO}_3$ , As, Hg, Pb, organic compounds – ***strictly limited in the drinking water guideline***
- ✓ macroelements – essential elements such as Ca, Mg, Na, K,  $\text{SiO}_2$  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)

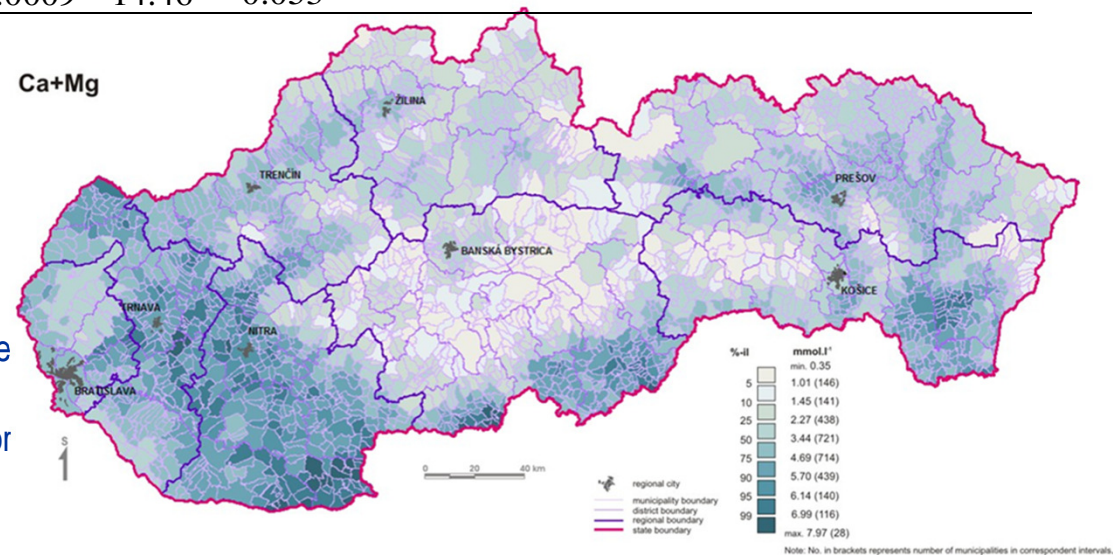
## ENVIRONMENTAL INDICATORS (EI)

Evaluated chemical composition of groundwater and mean Slovak contents

GROUNDWATER (n=20,339)												
<b>pH</b>	<b>TDS</b>	<b>COD<sub>Mn</sub></b>	<b>Ca+Mg</b>	<b>Li</b>	<b>Na</b>	<b>K</b>	<b>Ca</b>	<b>Mg</b>	<b>Sr</b>	<b>Fe</b>	<b>Mn</b>	<b>NH<sub>4</sub></b>
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
<b>F</b>	<b>Cl</b>	<b>SO<sub>4</sub></b>	<b>NO<sub>2</sub></b>	<b>NO<sub>3</sub></b>	<b>PO<sub>4</sub></b>	<b>HCO<sub>3</sub></b>	<b>SiO<sub>2</sub></b>	<b>Cr</b>	<b>Cu</b>	<b>Zn</b>	<b>As</b>	<b>Cd</b>
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
<b>Se</b>	<b>Pb</b>	<b>Hg</b>	<b>Ba</b>	<b>Al</b>	<b>Sb</b>	<b><sup>222</sup>Rn</b>	<b><sup>226</sup>Ra</b>					
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

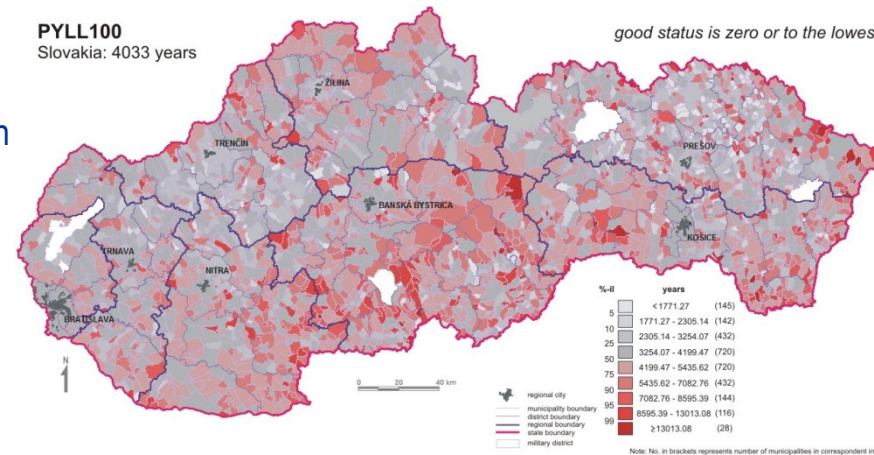
### 5 main groups of HI

- 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

Potential years of life lost per 100 000 of population

PYLL100  
Slovakia: 4033 years

good status is zero or to the lowest number



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



Methodology 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 influential elements  $s_r > 1$ , for non-influential elements  $s_r < 1$



## Results and discussion

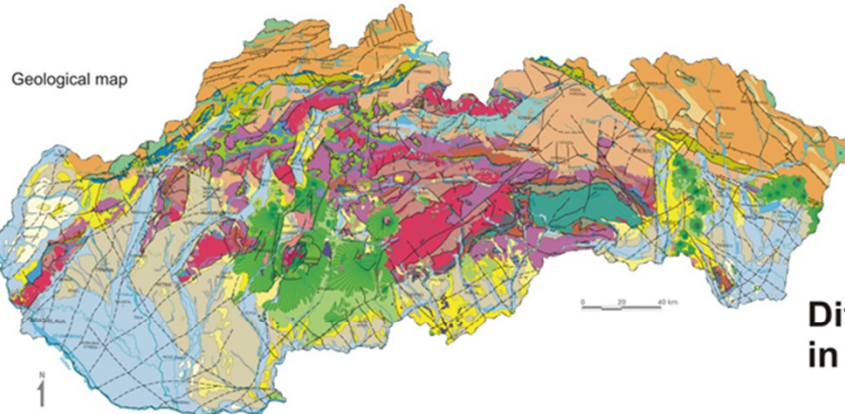
### Division of EI and HI according to various geological environment

Background assumption:

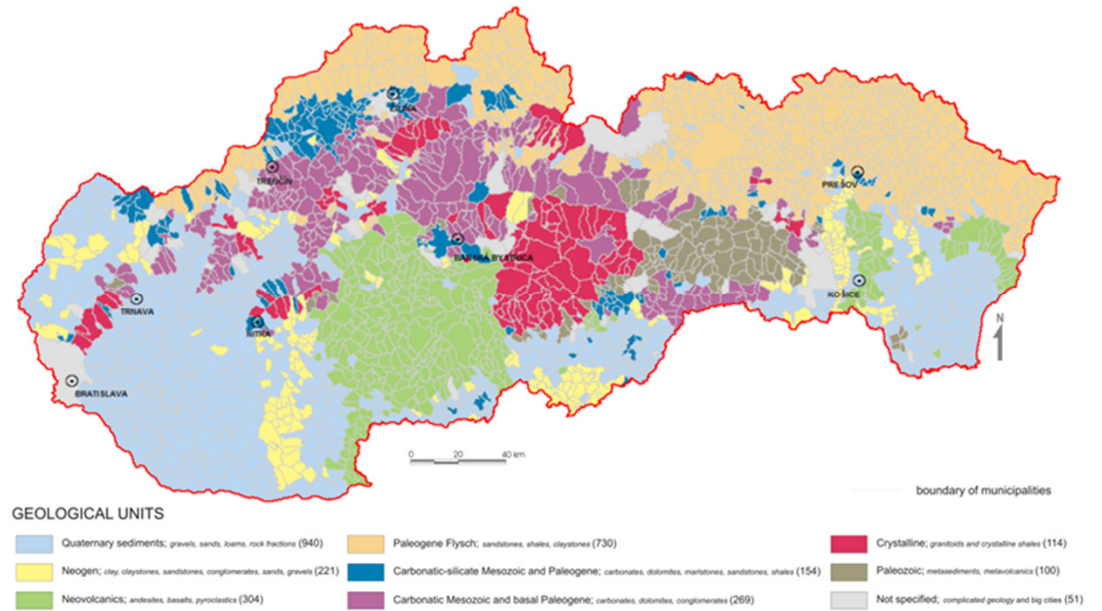
Various geological structure have various influence on human health

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.



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



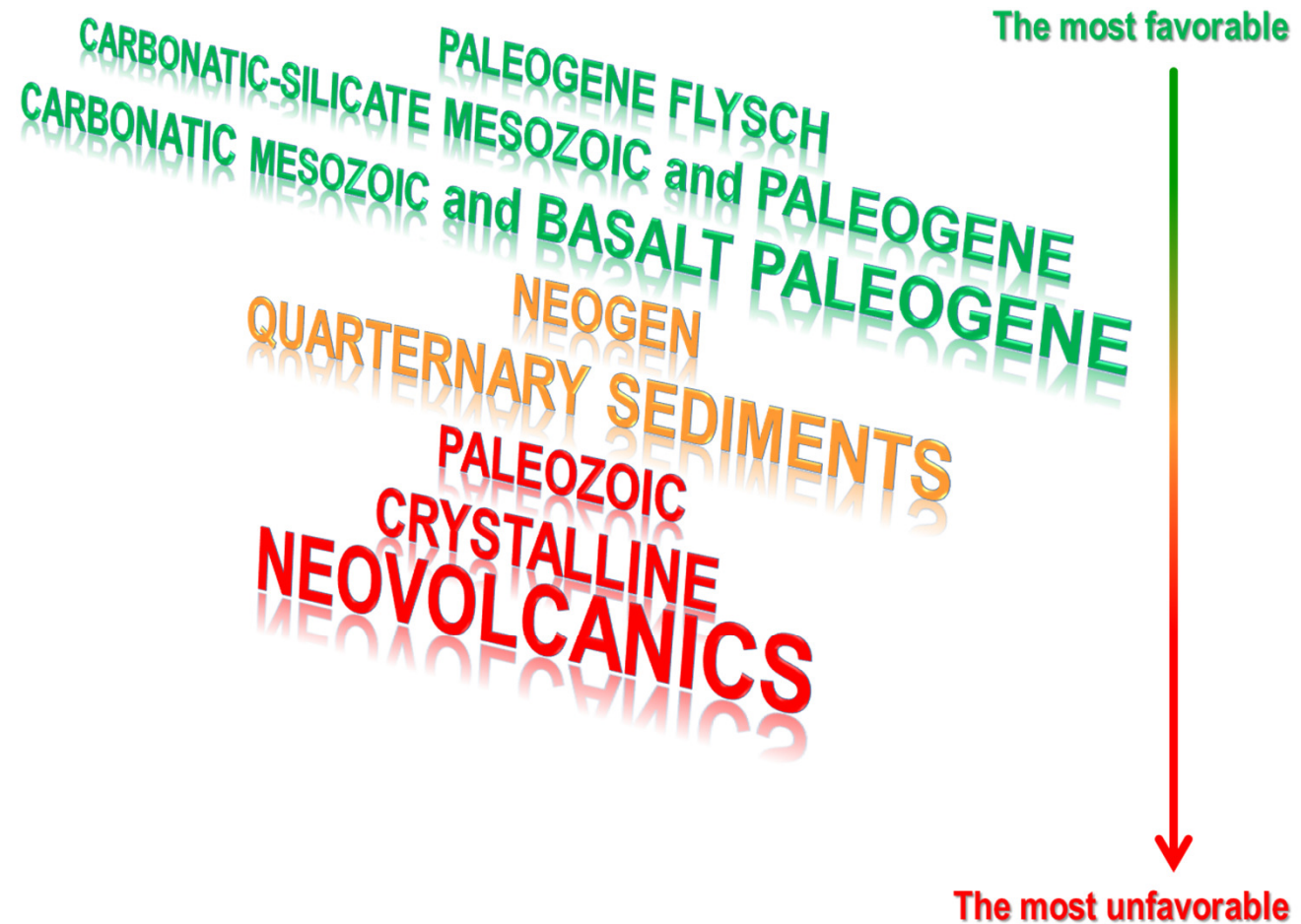
Note: No. in brackets represents number of municipalities in correspondent geological units.





Results and discussion

Characteristics of geological units according to their favourableness to human health





## Results and discussion

### Division according to geology

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

Geological unit/district	<b>1</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>Krupina</b>	<b>Bardejov</b>	<b>SR</b>
Parameter	n = 100	n = 154	n = 727	n = 309	n = 36	n = 86	
<b>TDS</b> [mg l <sup>-1</sup> ]	302.27	586.79	524.64	439.73	362.34	484.79	629.75
<b>Ca+Mg</b> [mmol l <sup>-1</sup> ]	1.68	3.45	3.02	2.11	1.58	2.75	3.50
<b>Na</b> [mg l <sup>-1</sup> ]	8.53	12.79	12.74	16.09	13.12	10.34	20.34
<b>Ca</b> [mg l <sup>-1</sup> ]	43.15	99.86	88.53	56.13	42.01	80.75	93.56
<b>Mg</b> [mg l <sup>-1</sup> ]	14.70	23.27	19.67	17.14	12.96	17.98	28.29
<b>Cl</b> [mg l <sup>-1</sup> ]	13.18	21.24	17.14	21.66	13.81	13.77	32.96
<b>SO<sub>4</sub></b> [mg l <sup>-1</sup> ]	45.65	65.38	62.72	49.70	22.42	44.96	79.32
<b>NO<sub>3</sub></b> [mg l <sup>-1</sup> ]	18.02	21.72	16.19	26.44	16.49	14.84	38.76
<b>HCO<sub>3</sub></b> [mg l <sup>-1</sup> ]	138.29	323.63	287.65	191.51	174.23	282.12	303.85
<b>As</b> [mg l <sup>-1</sup> ]	0.00863	0.00135	0.00079	0.00241	0.0018	0.00114	0.00192
<b>Se</b> [mg l <sup>-1</sup> ]	0.00063	0.00074	0.00068	0.00086	0.0006	0.00068	0.00097
<b>Pb</b> [mg l <sup>-1</sup> ]	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.)**





## Division according to geology

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

Geological unit/district	<b>1</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>Krupina</b>	<b>Bardejov</b>	<b>SR</b>
Health indicator	n = 100	n = 154	n = 727	n = 309	n = 36	n = 86	
<b>LE</b>	71.47	72.75	73.69	71.11	69.95	74.07	72.60
<b>PYLL100</b>	4360.96	3985.46	3874.38	4586.18	5609.07	3140.73	4033.00
<b>ReC00-C97</b>	209.46	195.96	177.99	236.28	243.23	175.32	212.79
<b>ReI00-I99</b>	569.73	505.07	463.32	638.78	889.20	492.82	531.05
<b>ReJ00-J99</b>	70.21	57.44	54.42	81.98	81.11	26.62	58.08
<b>ReK00-K93</b>	41.39	42.40	34.22	66.88	75.68	25.39	45.83
<b>SMRC00-97</b>	101.78	95.18	95.03	102.91	99.73	91.20	100
<b>SMRI00-I99</b>	111.73	98.86	100.03	108.50	131.06	100.71	100
<b>SMRJ00-J99</b>	124.81	100.61	109.39	126.34	116.33	50.50	100
<b>SMRK00-K93</b>	94.92	94.23	84.31	130.61	150.20	62.63	100
<b>PYLLC00-C97</b>	1053.42	921.47	909.88	1097.32	1121.6	808.8	1005.20
<b>PYLLI00-I99</b>	1052.18	937.66	831.99	1050.95	1518.2	779.9	866.19
<b>PYLLJ00-J99</b>	274.92	146.28	229.74	202.67	259.2	231.1	172.69
<b>PYLLK00-K93</b>	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 coefficients 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub> & 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 <sub>3</sub>	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 <sub>4</sub>	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 <sub>3</sub>	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 <sub>2</sub>	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

$s_r$  – coefficient of sensitivity,  
R<sup>2</sup> – 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<sup>-1</sup>, Ca+Mg  
in mmol l<sup>-1</sup>)

Order	Parameter	$s_r$	R <sup>2</sup>	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 <sub>Mn</sub>	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 <sub>3</sub>	1.012	0.993	250.79	does not exist	does not exist	does not exist	concave parabola	16.57	592.05
9	SO <sub>4</sub>	1.003	0.522	31.42	185.32	does not exist	does not exist	concave parabola	9.38	319.50
10	NO <sub>3</sub>	1.003	0.832	does not exist	71.45	does not exist	does not exist	concave parabola	1.33	227.09



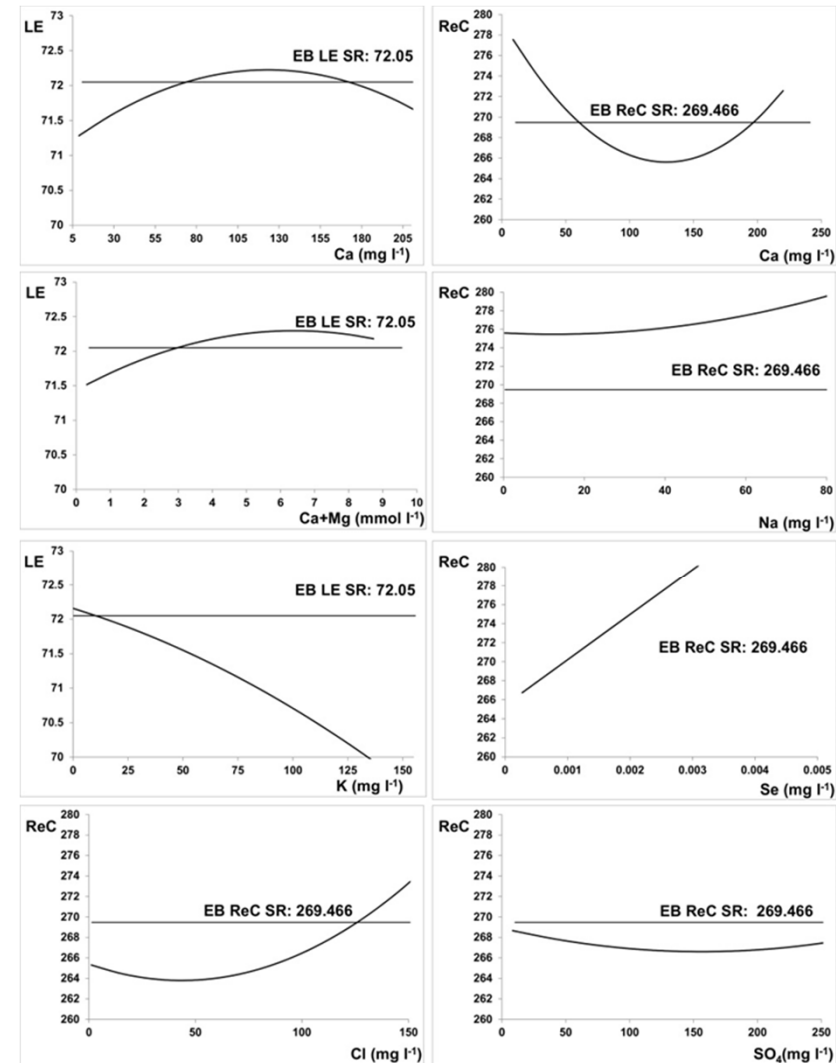


## Results and discussion

### ANN

- ✓ The most influential parameters are Ca+Mg, Ca, Mg, TDS, HCO<sub>3</sub>, SO<sub>4</sub>, Cl, NO<sub>3</sub>
- ✓ Potentially toxic elements and parameters of natural radioactivity are not influential
- ✓ Influential elements are grouped into 3 categories:
  - Ca+Mg, Ca, Mg
  - TDS, HCO<sub>3</sub>
  - SO<sub>4</sub>, Cl, NO<sub>3</sub>
- ✓ 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



--- Limit critical values (intersect of the average of health indicators for Slovakia)

----- Optimal limit values (peak of parabola ± standard deviation)

EB SR: empirical Bayesian balanced average for Slovakia





## **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 ( $< 1,5 \text{ mmol.l}^{-1}$ )

### **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

<b>Socio-economic characteristics<sup>a</sup></b>	<b>Krupina</b>	<b>Bardejov</b>	<b>SR</b>
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
<b>Health-care characteristics<sup>b</sup></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
<b>Lifestyle characteristics<sup>c, d</sup></b>			
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

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



Results and discussion

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

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, diarrhea)

- ✓ 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:

<b>Mg</b>	minimum 20 – 30 mg.l <sup>-1</sup>
<b>Ca</b>	minimum 40 – 80 mg.l <sup>-1</sup>
<b>water hardness</b>	2 – 4 mmol.l <sup>-1</sup>

- ✓ 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
<b>LE</b>	1	<b>Ca+Mg</b>	2.98	does not exist	not defined	does not exist	0.35	7.97
	2	<b>Ca</b>	73.95	172.21	85.56	160.60	9.83	201.01
	3	<b>Mg</b>	18.13	does not exist	does not exist	does not exist	2.45	97.75
<b>PYLL100</b>	1	<b>Ca+Mg</b>	2.87	6.67	3.21	6.33	0.35	7.97
	2	<b>Ca</b>	79.40	169.74	87.05	162.09	9.83	201.01
	3	<b>Mg</b>	20.44	83.24	33.82	69.87	2.45	97.75
<b>ReC00-C97</b>	3	<b>Ca+Mg</b>	1.73	5.85	2.23	5.34	0.35	7.97
	4	<b>Ca</b>	60.56	196.84	91.18	166.21	9.83	201.01
	8	<b>Mg</b>	25.66	35.83	12.72	48.77	2.45	97.75
<b>ReI00-I99</b>	1	<b>Ca+Mg</b>	2.90	9.10	4.40	7.60	0.35	7.97
	2	<b>Ca</b>	does not exist	89.40	does not exist	does not exist	9.83	201.01
	3	<b>Mg</b>	24.30	95.80	42.00	78.10	2.45	97.75
<b>ReJ00-J99</b>	1	<b>Ca+Mg</b>	3.20	11.67	5.88	8.99	0.35	7.97
	2	<b>Ca</b>	93.08	does not exist	does not exist	does not exist	9.83	201.01
	3	<b>Mg</b>	28.63	does not exist	83.99	120.05	2.45	97.75
<b>ReK00-K93</b>	1	<b>Ca+Mg</b>	does not exist	4.08	0.41	3.53	0.35	7.97
	4	<b>Ca</b>	17.74	127.58	35.14	110.18	9.83	201.01
	7	<b>Mg</b>	does not exist	33.54	does not exist	10.65	2.45	97.75
<b>SMRC00-C97</b>	2	<b>Ca+Mg</b>	does not exist	4.17	does not exist	does not exist	0.35	7.97
	3	<b>Ca</b>	104.07	does not exist	does not exist	does not exist	9.83	201.01
	1	<b>Mg</b>	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
<b>SMRI00-I99</b>	1	<b>Ca+Mg</b>	not defined	not defined	not defined	not defined	0.35	7.97
	2	<b>Ca</b>	not defined	not defined	not defined	not defined	9.83	201.01
	3	<b>Mg</b>	does not exist	65.85	does not exist	does not exist	2.45	97.75
<b>SMRJ00-J99</b>	6	<b>Ca+Mg</b>	3.27	does not exist	does not exist	does not exist	0.35	7.97
	3	<b>Ca</b>	90.03	does not exist	does not exist	does not exist	9.83	201.01
	4	<b>Mg</b>	25.81	does not exist	does not exist	does not exist	2.45	97.75
<b>SMRK00-K93</b>	1	<b>Ca+Mg</b>	0.99	2.16	0.99	2.16	0.35	7.97
	2	<b>Ca</b>	not defined	not defined	not defined	not defined	9.83	201.01
	3	<b>Mg</b>	does not exist	29.67	does not exist	does not exist	2.45	97.75
<b>PYLLC00-C97</b>	1	<b>Ca+Mg</b>	not defined	not defined	not defined	not defined	0.35	7.97
	3	<b>Ca</b>	93.17	194.91	106.52	181.56	9.83	201.01
	4	<b>Mg</b>	not defined	not defined	not defined	not defined	2.45	97.75
<b>PYLLI00-I99</b>	1	<b>Ca+Mg</b>	5.70	8.88	5.73	8.85	0.35	7.97
	3	<b>Ca</b>	150.76	does not exist	164.04	does not exist	9.83	201.01
	3	<b>Mg</b>	56.20	82.78	56.20	82.78	2.45	97.75
<b>PYLLJ00-J99</b>	4	<b>Ca+Mg</b>	does not exist	4.06	does not exist	does not exist	0.35	7.97
	2	<b>Ca</b>	does not exist	121.18	does not exist	does not exist	9.83	201.01
	3	<b>Mg</b>	does not exist	47.63	does not exist	does not exist	2.45	97.75
<b>PYLLK00-K93</b>	1	<b>Ca+Mg</b>	does not exist	4.84	0.73	3.84	0.35	7.97
	2	<b>Ca</b>	17.58	173.05	57.80	132.83	9.83	201.01
	3	<b>Mg</b>	does not exist	37.27	does not exist	does not exist	2.45	97.75
<b>Mean values</b>		<b>Ca+Mg</b>	<b>2.95</b>	<b>6.15</b>	<b>2.95</b>	<b>5.83</b>	<b>0.35</b>	<b>7.97</b>
		<b>Ca</b>	<b>78.03</b>	<b>155.61</b>	<b>89.61</b>	<b>152.29</b>	<b>9.83</b>	<b>201.01</b>
		<b>Mg</b>	<b>28.45</b>	<b>54.51</b>	<b>48.33</b>	<b>79.91</b>	<b>2.45</b>	<b>97.75</b>

### Limit values

defined by Slovak guideline  
for drinking water (Anon  
2010)

*Ca > 30 mg l<sup>-1</sup>*

*Mg 10 – 30 mg l<sup>-1</sup>*

*Ca+Mg 1.1 – 5.0 mmol l<sup>-1</sup>*







Proposed limit values for groundwater used for drinking water public supply

Parameter	Recommended levels
Ca+Mg	2 – 5 mmol . l <sup>-1</sup>
Ca	50 – 180 mg . l <sup>-1</sup>
Mg	25 – 50 mg . l <sup>-1</sup>



## 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

# Thank you for your attention

This research has been performed within the project  
Geohealth (LIFE10 ENV/SK/000086)



## Acknowledgement

Project is financially supported by the EU's funding instrument for the environment: Life+ programme and Ministry of the Environment of the Slovak Republic.



All materials are available on the project website [www.geology.sk/geohealth](http://www.geology.sk/geohealth)