Layman´s Report

The Impact of Geological Environment on Health Status of Residents of the Slovak Republic

GEOHEALTH

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

LIFE+ Environment Policy and Governance Project LIFE10 ENV/SK/000086, GEOHEALTH 2011–2016

With financial support by the EU's funding instrument for the environment: Life+ programme and Ministry of Environment of the Slovak Republic

CONTENT

BASIC INFORMATION

Project title: The impact of geological environment on health status of residents of the Slovak Republic

Acronym: GEOHEALTH

Project code: LIFE10 ENV/SK/000086

Location: Slovak Republic

Duration: 01/09/2011 – 31/08/2016

Funded by: EU Life+ programme

Co-funded by: Ministry of Environment of the Slovak Republic

Coordinating Beneficiary: State Geological Institute of Dionýz Štúr

Project manager: Assoc. Prof. Stanislav Rapant, DrSc.

MOTTO: "Chemicals can be present in the environment in excess or in deficit concentrations in relation to the biota and humans. Both cases can be assumed for a certain group of elements as unfavourable from the point of view of potential adverse effects."

BRIEF DESCRIPTION OF THE PROJECT

Geological structure of the Slovak Republic is particularly varied. It reflects different geochemical background that has various influences (positive or negative) on human health. Anthropogenic contamination of geological environment, documented on about 10% of Slovak territory, plays also an important role. Up-to-date surveys suggest that human organism reacts with various health responses on different geological (geochemical) bedrock. Mainly sedimentary and carbonatic rocks emit from geological bedrock essential chemical elements favourable for human health. On the other hand, silicate rocks (volcanics, granitoids and crystalline schists) are characterized by deficit contents of chemical elements necessary for human health. These facts may have influence on the occurrence of areas in the territory of the Slovak Republic (districts, municipalities, group of municipalities) where average lifetime of resident population is significantly lower and where increased mortality from various diseases (30–60%), mainly those cardiovascular and carcinogenic is observed in comparison with average values for the Slovak Republic.
The influence of naturally conditioned geological environment and anthropogenically contaminated geological environment on human health of the Slovak Republic is studied and assessed in this project.

Project objectives: *The main objective of the project is to reduce the negative impact of geological environment on the health status of residents in the Slovak Republic.*

The target objective was reached by solving following partial goals:

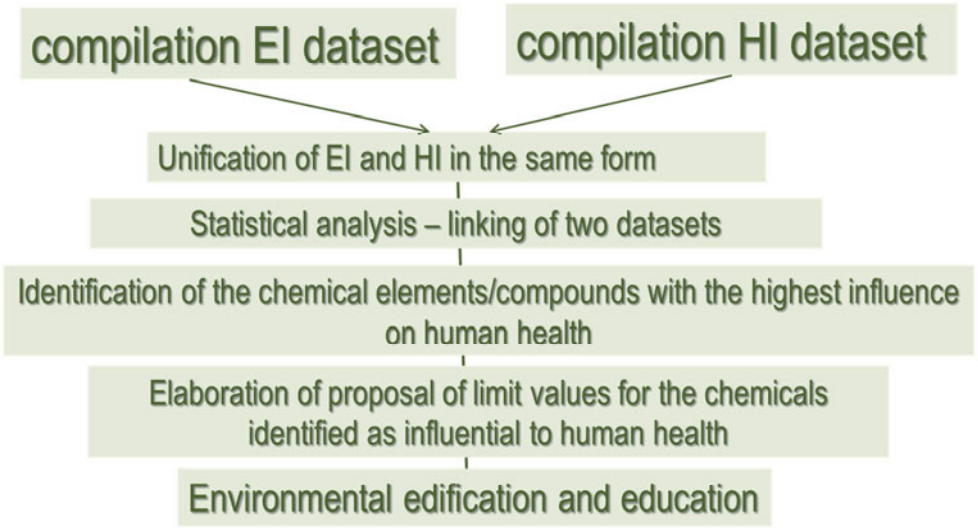
- Compilation of data set of environmental indicators (chemical elements/compounds) for groundwater and soil from the whole territory of the Slovak Republic with the greatest impact on human health,
- Compilation of data set of health indicators for the Slovak Republic (indicators of demographic evolution and health status of residents) which are to the greatest extent influenced by geological environment,
- Linking of data sets of environmental and health indicators and assessment of their relationship,
- Specification and characteristics of the areas with impaired health status of residents in the Slovak Republic due to unfavourable (contaminated) geological environment,
- Environmental analysis, environmental-health regionalization of the Slovak Republic and definition of limit values for chemical elements/compounds in soil and groundwater based on human health effects,
- Elaboration of the proposal of measures to be taken in order to reduce negative impact of geological environment on the health status of residents,
- Implementation of proposed measures into practice.

Key activities:
Action A1: Compilation of data set of environmental indicators
Action A2: Compilation of data set of health indicators
Action A3: Elaboration of environmental and health indicators
Action A4: Linking of environmental and health indicators
Action A5: Environmental analysis
Action A6: Elaboration of the proposal of measures
Action A7: Realization of measures

MAIN IDEA OF THE PROJECT

Linking of geological environment with the health status of inhabitants and searching for response to what extent geological environment is reflected in health status of Slovak population is the main idea of the project.

BASIC METHODOLOGY OF THE PROJECT



A1: COMPILATION OF DATASET OF ENVIRONMENTAL INDICATORS

Groundwater: 20,339 chemical analyses
Soil: 10,738 chemical analyses

for 34 elements/compounds, parameters

through kriging method

the **mean values** for each of 2,883 municipalities of the Slovak Republic were elaborated.

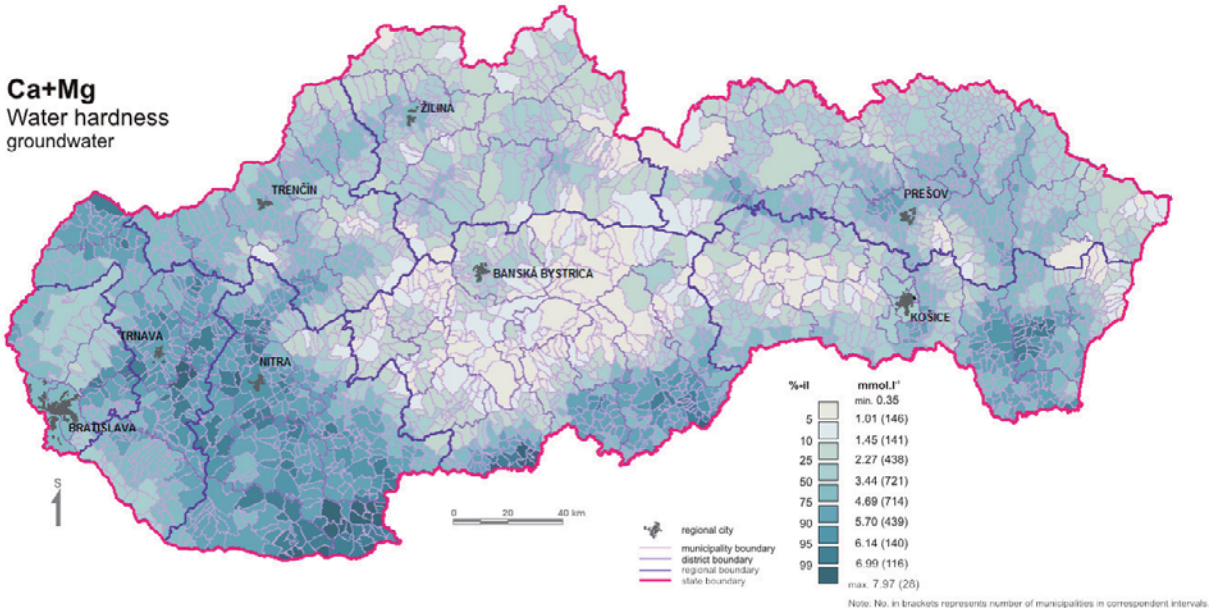
DATA OUTPUT – TABLE FORM AND MAP VISUALIZATION (available at www.geology.sk/geohealth)

GROUNDWATER			*SOIL*		
element/component/parameter	*symbol*	*unit*	*element/component/parameter*	*symbol*	*unit*
Water reaction	**pH**		Aluminium	**Al**	%
Total Dissolved Solids	**T.D.S.**	$mg.l^{-1}$	Arsenic	**As**	$mg.kg^{-1}$
Chemical oxygen demand	**COD_{Mn}**	$mg.l^{-1}$	Barium	**Ba**	$mg.kg^{-1}$
Water hardness	**Ca+Mg**	$mmol.l^{-1}$	Beryllium	**Be**	$mg.kg^{-1}$
Sodium	**Na**	$mg.l^{-1}$	Calcium	**Ca**	%
Potassium	**K**	$mg.l^{-1}$	Cadmium	**Cd**	$mg.kg^{-1}$
Calcium	**Ca**	$mg.l^{-1}$	Cobalt	**Co**	$mg.kg^{-1}$
Magnesium	**Mg**	$mg.l^{-1}$	Chromium	**Cr**	$mg.kg^{-1}$
Iron	**Fe**	$mg.l^{-1}$	Copper	**Cu**	$mg.kg^{-1}$
Manganese	**Mn**	$mg.l^{-1}$	Fluorine	**F**	$mg.kg^{-1}$
Ammonium	**NH_4**	$mg.l^{-1}$	Iron	**Fe**	%
Fluorides	**F**	$mg.l^{-1}$	Mercury	**Hg**	$mg.kg^{-1}$
Chlorides	**Cl**	$mg.l^{-1}$	Potassium	**K**	%
Sulphates	**SO_4**	$mg.l^{-1}$	Magnesium	**Mg**	%
Nitrites	**NO_2**	$mg.l^{-1}$	Manganese	**Mn**	%
Nitrates	**NO_3**	$mg.l^{-1}$	Molybdenum	**Mo**	$mg.kg^{-1}$
Phosphates	**PO_4**	$mg.l^{-1}$	Sodium	**Na**	%
Bicarbonates	**HCO_3**	$mg.l^{-1}$	Nickel	**Ni**	$mg.kg^{-1}$
Silica	**SiO_2**	$mg.l^{-1}$	Phosphorus	**P**	%
Chromium	**Cr**	$mg.l^{-1}$	Lead	**Pb**	$mg.kg^{-1}$
Copper	**Cu**	$mg.l^{-1}$	Antimony	**Sb**	$mg.kg^{-1}$
Zinc	**Zn**	$mg.l^{-1}$	Selenium	**Se**	$mg.kg^{-1}$
Arsenic	**As**	$mg.l^{-1}$	Vanadium	**V**	$mg.kg^{-1}$
Cadmium	**Cd**	$mg.l^{-1}$	Zinc	**Zn**	$mg.kg^{-1}$
Selenium	**Se**	$mg.l^{-1}$	Active soil reaction	**pH_{H2O}**	-
Lead	**Pb**	$mg.l^{-1}$	Exchange soil reaction	**pH_{KCl}**	-
Mercury	**Hg**	$mg.l^{-1}$	Carbonates		%
Barium	**Ba**	$mg.l^{-1}$	Radon	**^{222}Rn**	$kBq.m^{-3}$
Aluminium	**Al**	$mg.l^{-1}$			
Antimony	**Sb**	$mg.l^{-1}$			
Radon	**^{222}Rn**	$Bq.l^{-1}$			
Radium	**^{226}Ra**	$Bq.l^{-1}$			

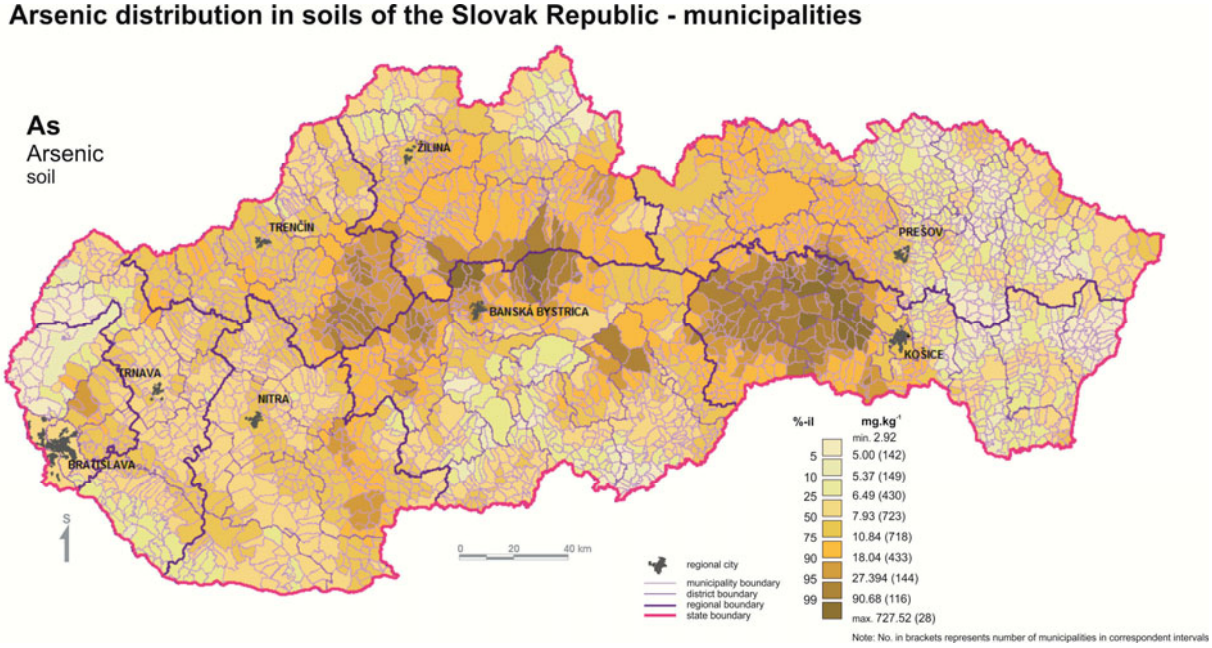
List of evaluated elements/components/parameters in groundwater and soils

EXAMPLES:

Water hardness distribution in groundwater of the Slovak Republic - municipalities



Arsenic distribution in soils of the Slovak Republic - municipalities



All maps are available at www.geology.sk/geohealth.

The methodology of works is described in more detail in the scientific paper:

Rapant, S., Cvečková, Veronika, Dietzová, Z., Fajčíková, K., Hiller, E., Finkelman, R.B., & Škultétyová, S. (2014). The potential impact of geological environment on health status of residents of the Slovak Republic. *Environ. Geochem. Health.* 36, 543-561.

A2: COMPILATION OF DATASET OF HEALTH INDICATORS

The health status of Slovak population was evaluated based on health indicators.
A health indicator is a variable that can express the health status of people in society via direct measurement or observation.

Data source: Statistical Office of the Slovak Republic
Period: 1994–2003, data represent mean value for 10 years

Data characteristics:

- Demographic indicators – describing age structure
- Crude and premature mortality
- Relative mortality from selected causes of death
- Standardized mortality from selected causes of death (Slovak standard, 19 age groups)
- Potential years of lost life for selected causes of death.

Health indicators – causes of death were excerpted from the International classification of diseases (ICD), 10th revision (www.who.int/classifications/icd/en/).

No.	Indicator	Description of indicator	Method of calculation	Unit	Mean SR*
		Demographic indicators describing age structure of municipalities			
1	LEp	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
2	LEm	life expectancy at birth – men			67.44
3	LEw	life expectancy at birth – women			77.07
4	A60+	proportion of population at age 60 and more	100 x (number of people aged 60 and over / number of inhabitants)	%	15.38
		Crude and premature mortality			
5	SMRp	population	indirect age-standardized mortality rate of inhabitants to the Slovak standard (19 age groups)	%	100
6	SMRm	men			100
7	SMRw	women			100
8	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	4033.0
		Relative mortality for selected cause of death			
9	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
10	ReC15-C26	malignant neoplasms of gastrointestinal system			76.14
11	ReC16	malignant neoplasms of stomach			15.20
12	ReC18-C20	malignant neoplasms of colon and rectum			24.24
13	ReC30-C39	malignant neoplasms of respiratory system			45.19
14	ReC50	malignant neoplasms of breast			24.80
15	ReC64-C68	malignant neoplasms of urinary system			11.25
16	ReC81-C96	malignant neoplasms of orgnas for haematopoiesis			13.28
17	ReC91-C95	all leukemia			6.20
18	ReC00-D48	all neoplasms			213.62
19	ReE00-E99	endocrine, nutritional and metabolic diseases			14.38
20	ReI00-I99	diseases of the circulatory system			531.05
21	ReI21-I25	ischaemic heart disease			269.82
22	ReI63-I64	cerebral infarction and strokes			63.57
23	ReJ00-J99	diseases of respiratory system			58.08
24	ReK00-K93	diseases of the digestive system			45.83
25	ReN00-N99	diseases of urinary and reproductive system			13.69
		Standardized mortality for selected cause of death			
26	SMRC00-C97	malignant neoplasms	indirect age-standardized mortality rate of inhabitants to the Slovak standard (19 age groups)	%	100
27	SMRC15-C26	malignant neoplasms of gastrointestinal system			100
28	SMRC30-C39	malignant neoplasms of respiratory system			100
29	SMRC81-C96	malignant neoplasms of organs for haematopoiesis			100
30	SMRE00-E99	endocrine, nutritional and metabolic diseases			100
31	SMRI00-I99	diseases of the circulatory system			100
32	SMRI21-I25	ischaemic heart disease			100
33	SMRI63-I64	cerebral infarction and strokes			100
34	SMRJ00-J99	diseases of respiratory system			100
35	SMRK00-K93	diseases of the digestive system			100
36	SMRN00-N99	diseases of urinary and reproductive system			100
		Potential years of lost life for selected cause of death			
37	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
38	PYLLC15-C26	malignant neoplasms of gastrointestinal system			242.26
39	PYLLC30-C39	malignant neoplasms of respiratory system			186.2
40	PYLLI00-I99	diseases of the circulatory system			866.19
41	PYLLI21-I25	ischaemic heart disease			396.32
42	PYLLJ00-J99	diseases of respiratory system			172.69
43	PYLLK00-K93	diseases of the digestive system			334.80

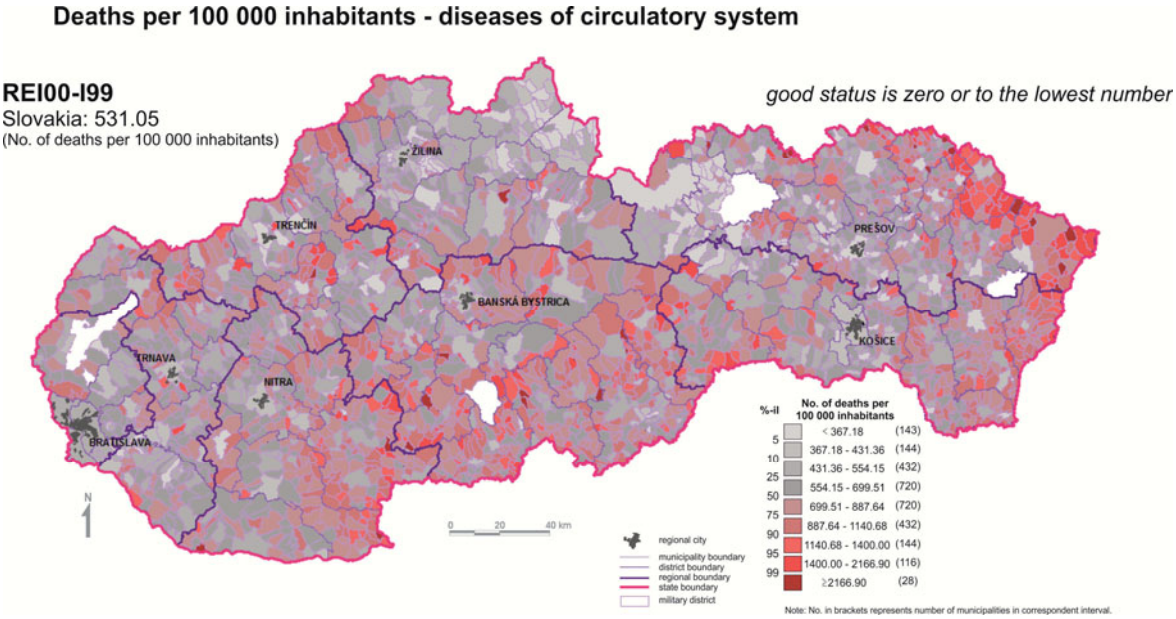
Evaluated health indicators of the Slovak Republic

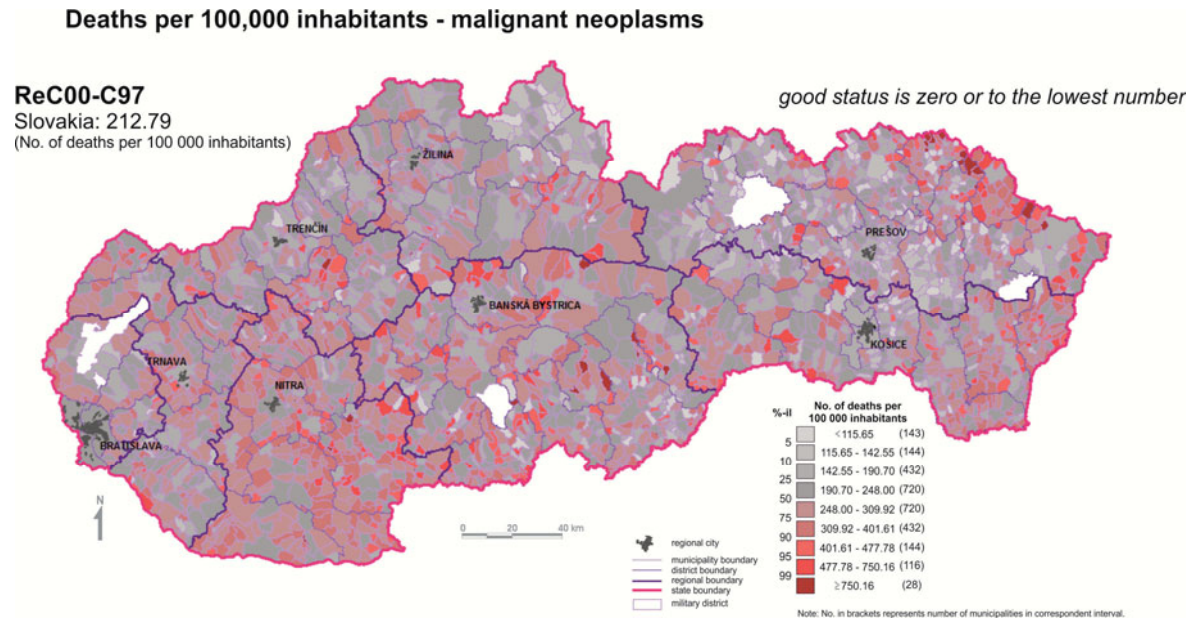
Method of data elaboration:

- ✓ municipalities (2,883)
- ✓ districts (79)
- ✓ whole territory of SR

} Table and map form (available at www.geology.sk/geohealth)

EXAMPLES:





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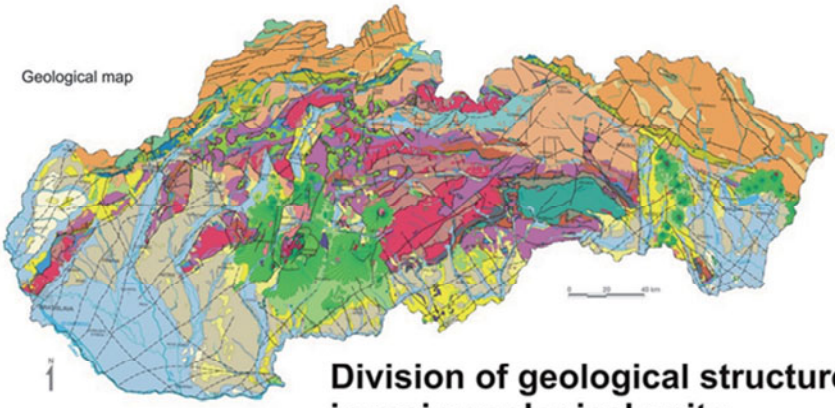
A3: ELABORATION OF ENVIRONMENTAL AND HEALTH INDICATORS

Division of environmental and health indicators according to geological structure:

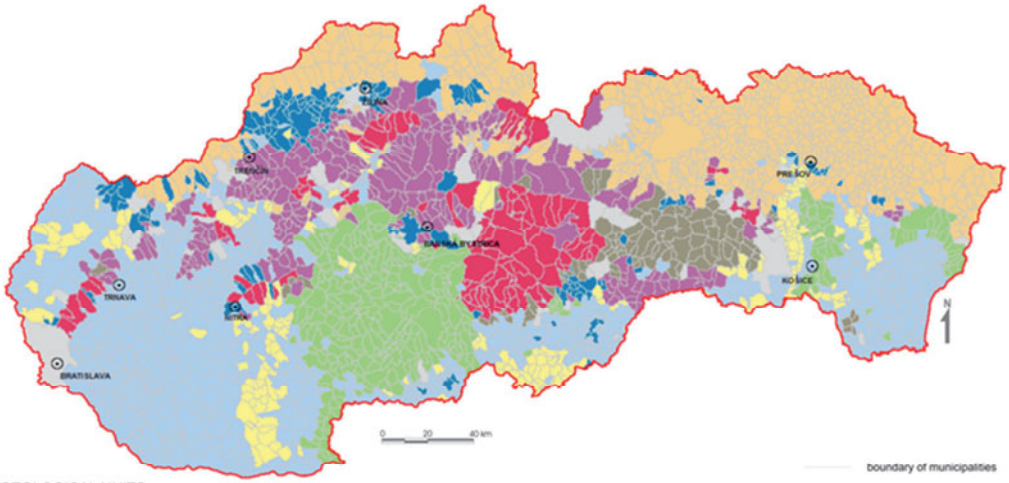
The geological structure of the Slovak Republic is rather complicated. It is characterized by alteration of rocks with various geneses, ages and therefore various mineralogical and petrographic characteristics and variable geochemical background. This is reflected in the variable chemical composition of groundwater/drinking water and soils which can have various impacts on human health.

The territory of the Slovak Republic has been categorized into eight units as follows:

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



GEOLOGICAL UNITS

Quaternary sediments; gravels, sands, loams, rock fractions (940)
Paleogene Flysch; sandstones, shales, claystones (730)
Crystalline; granitoids and crystalline shales (114)
Neogen; clay, claystones, sandstones, conglomerates, sands, gravels (221)
Carbonatic-silicate Mesozoic and Paleogene; carbonates, dolomites, marlstones, sandstones, shales (154)
Paleozoic; metasediments, metavolcanics (100)
Neovolcanics; andesites, basalts, pyroclastics (304)
Carbonatic Mesozoic and basal Paleogene; carbonates, dolomites, conglomerates (269)
Not specified; complicated geology and big cities (51)

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

Charakteristics of health status of residents with respect to geological structure of the Slovak Republic

The data on chemical composition of groundwater and soil (environmental indicators) and indicators of health status (health indicators) were divided into partial datasets according to the geological units for further analysis (Action A4).

Generally, carbonatic rocks were defined as the most favourable rock environments for human health and silicate rocks as the most unfavourable ones.

For more details see paper:

Rapant, S., Cvečková, Veronika, Dietzová, Z., Fajčíková, K., Hiller, E., Finkelman, R.B., & Škultétyová, S. (2014). The potential impact of geological environment on health status of residents of the Slovak Republic. *Environ. Geochem. Health.* 36, 543-561.

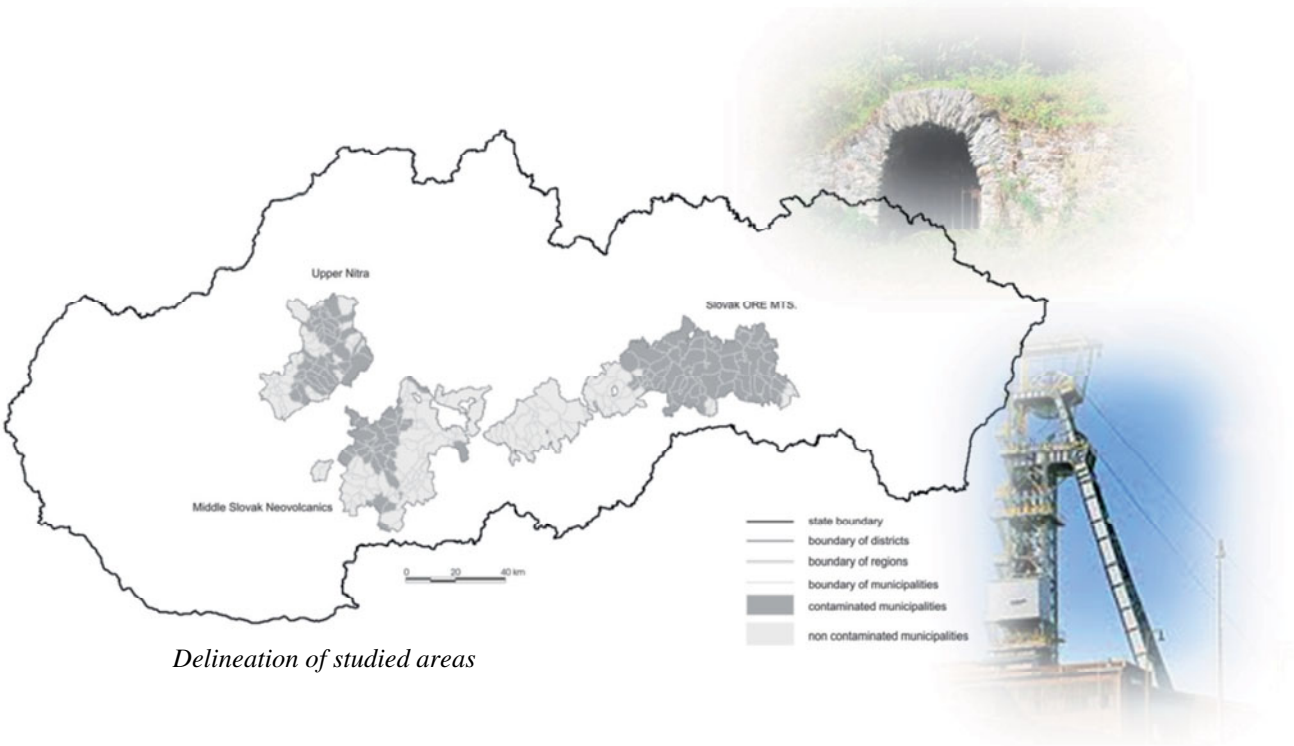
Contaminated and non-contaminated areas in the Slovak Republic and their influence on health status of Slovak population

Impact of potentially toxic elements (PTE) on the health status of population of the Slovak Republic has been studied in two historical mining areas with ore extraction from the Middle Ages (the Middle Slovak Neovolcanics, the Slovak Ore Mts.) and one historical mining area with more than hundred years brown coal mining (Upper Nitra region). In these areas the health status of population living in municipalities with increased PTE contents (As, Pb, Zn, Cu, Cd, Hg and Sb) was compared with that in adjacent municipalities showing low PTE contents. A total of 138 contaminated and 155 non-contaminated municipalities of similar socio-economic, natural and geochemical-geological character were compared. PTE contents in soils of polluted municipalities reported considerably increased levels – between 2 to 10 times higher in contrast to non-contaminated municipalities. On the other hand, PTE contents in groundwater were almost identical both in contaminated as well as non-contaminated areas and in majority of cases were below limit standard values for drinking water.

Main conclusion:

Based on the assessment of the health status of population (using 43 health indicators), no difference in the health status of population in contaminated and non-contaminated municipalities has been reported.

Contents of PTE in geological environment have much lower influence on health status of population in the Slovak Republic than has been, in general, reported so far.



Delineation of studied areas

More details can be found in paper:

Rapant, S., Cvečková, V., Fajčíková, K., Kohút, M. & Sedláková, D. (2014). Historical mining areas and their influence on human health. *European Journal for Biomedical Informatics*, 10(1), 24-34.

A4: LINKING OF ENVIRONMENTAL AND HEALTH INDICATORS

Various mathematical and statistical methods were used for elaboration and linking of datasets of environmental and health indicators.

Artificial neural networks

Through calculations of artificial neural networks for characterizing relationship between **environmental indicators** in groundwater/soils and **health indicators** were defined:

- Order of influence of environmental indicators on single health indicators

- Limit and optimal contents of 10 the most influential environmental indicators in relation to evaluated health indicators

Main conclusion:

Based on the results of artificial neural network calculations Ca, Mg in groundwater and water hardness (Ca+Mg) were identified as the most influential parameters for evaluated health indicators. Other evaluated environmental indicators are found to be less influential.

More details can be found in the following papers:

Rapant, S., Fajčíková, K., Cvečková, V., Ďurža, A., Stehlíková, B., Sedláková, D. & Ženišová, Z. (2015). Chemical composition of groundwater and relative mortality for cardiovascular diseases in the Slovak Republic. *Environ. Geochem. Health*, 37, 745-756.

Rapant, S., Cvečková, V., Fajčíková, K., Dietzová, Z. & Stehlíková, B. (2016). Chemical composition of groundwater/drinking water and oncological disease mortality, Slovak Republic. *Environ. Geochem. Health*, in press (DOI: 10.1007/s10653-016-9820-6)

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. in press

Fuzzy cluster analysis

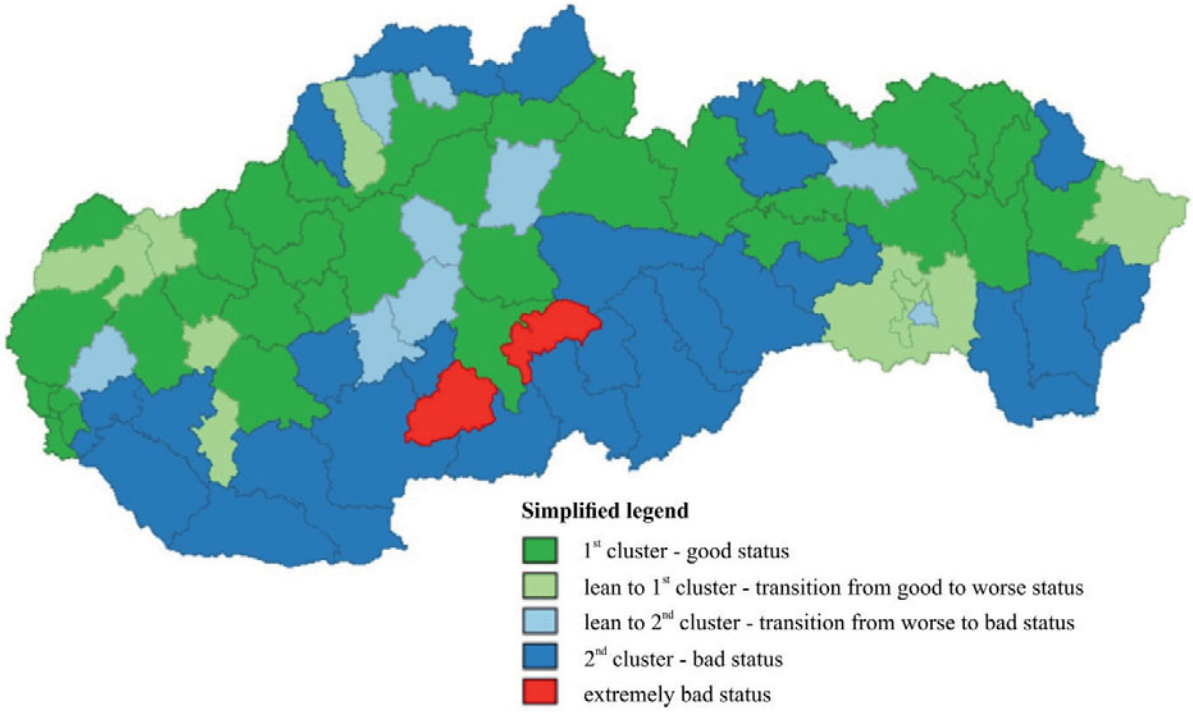
Evaluation of demographic indicators and indicators of health status of population (mortality from selected causes of deaths):

Method of data elaboration:
- ✓ municipalities (2,883)
- ✓ districts (79)

} Table and map form (available at www.geology.sk/geohealth)

Main conclusion:

The territory of the Slovak Republic seems to be divided in two parts. The northern part is characterized with better health status and the southern part is characterized with worse health status of the Slovak population. In general, more favourable health status (lower mortality level) has been observed in bigger cities/municipalities compared to those smaller ones with lower number of inhabitants.
Based on the evaluation of health indicators characterizing mortality from selected causes of deaths, two districts with the most unfavourable health status of residents were defined – Krupina and Detva – both laying on silicate geological bedrock.



Health status of Slovak population as fuzzy cluster analysis of 36 indicators of mortality from selected causes of deaths - DISTRICTS

All results within this action are published on the project website www.geology.sk/geohealth.

A5: ENVIRONMENTAL ANALYSIS

Environmental and health regionalization

Objective: to provide summary information on

- ✓ Quality level of the environment
- ✓ Health status of population

HEALTH REGIONALIZATION

and

ENVIRONMENTAL REGIONALIZATION

- ✓ Groundwater
- ✓ Soil

Method of data elaboration:

- ✓ municipalities (2,883)

} Table and map form (available at www.geology.sk/geohealth)

All results within this action are published on the project website www.geology.sk/geohealth.

Health regionalization

Health regionalization was elaborated based on 39 negative health indicators and their summary expression in the form of sum_neg (Σ HI: SMRp – PYLLK00-K93).

Each Slovak municipality is characterized by:

✓ Health status level:

- very good
- good
- average
- impaired
- unfavourable

Table form includes for each municipality of the Slovak Republic, a list of:

- Health indicators exceeding Slovak mean values in order of 10–50%
- Health indicators exceeding Slovak mean values in order of >50%.

EXAMPLE:

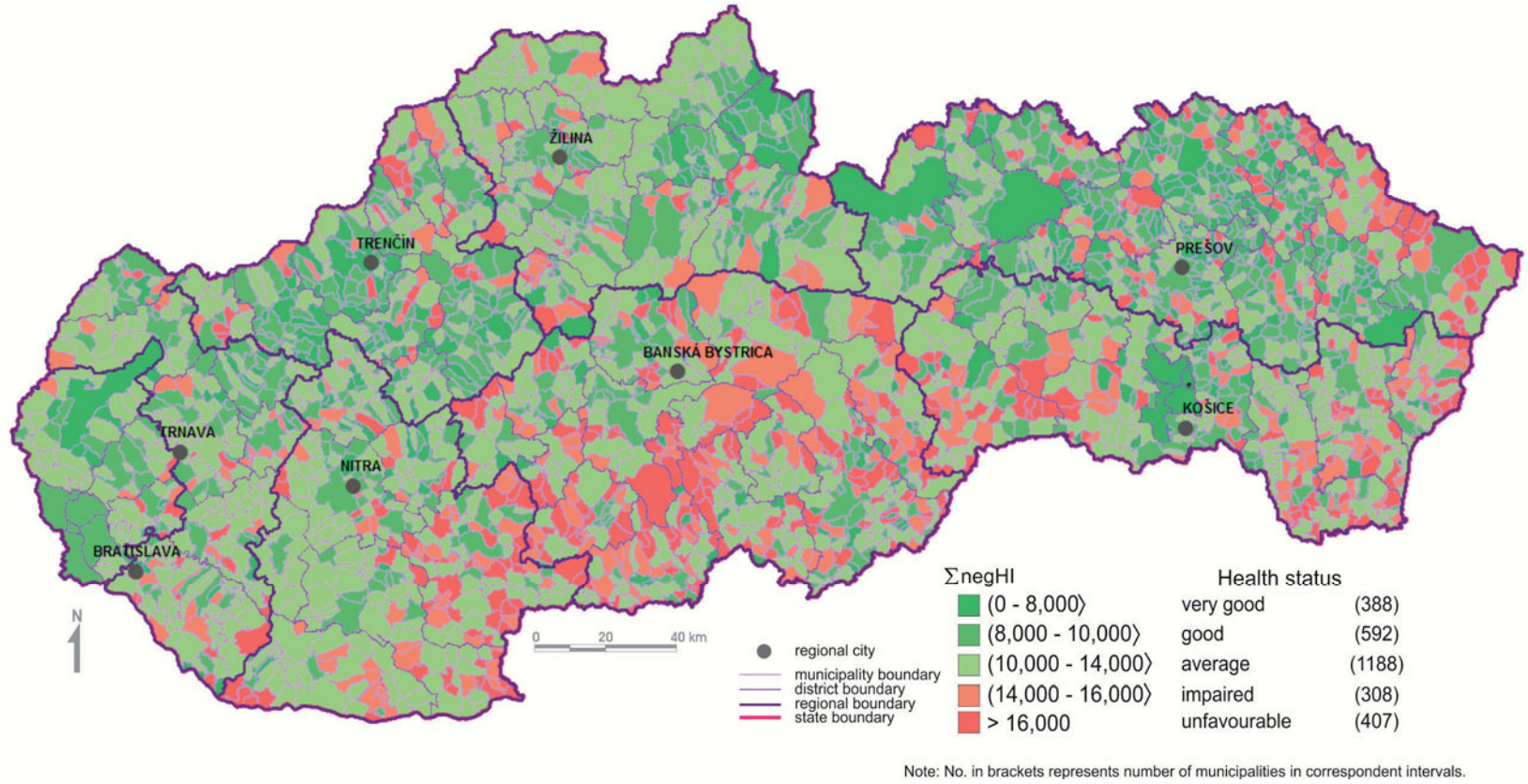
Evaluated health indicators - Košice region

sum_negHI-SMRV-PYLLK00-K99: sum of negative health indicators, health status: very good ≤ 8,000; good >8,000 ≤ 10,000; average >10,000 ≤ 14,000; impaired >14,000 ≤ 16,000; unfavourable >16,000

municipality	health indicators exceeding Slovak mean values 10-50 %	health indicators exceeding Slovak mean values >50%	sum_negHI-SMRp-PYLLK00-K99	health status
district Gelnica				
Gelnica	SMRw, PYLL100, SMRE, SMRI, SMRI21-25, PYLLI, PYLLI21-25, PYLLJ		10437.89	average
Helcmanovce	ReC30-39, ReC50, ReC64-68, ReI, SMRI, SMRI21-25, PYLLC15-26, PYLLC30-39, PYLLI21-25, PYLLK	ReC18-20, ReE, ReI21-25, ReN, SMRE, SMRN	9686.33	good
Henclová	SMRI, PYLLI21-25	ReC, ReC15-26, ReC18-20, ReC30-39, ReC00-D48, ReI, ReI21-25, ReI63-64, ReN, SMRI63-64, SMRN, PYLLI	10441.97	average
Hrišovce	SMRp, SMRw, ReC, ReC18-20, ReC00-D48, ReI, SMRC, SMRJ	PYLL100, ReC16, ReC50, ReC64-68, ReE, ReJ, SMRE, PYLLC, PYLLJ, PYLLK	12864.68	average
Jaklovce	ReC18-20, ReC30-39, ReI, PYLLI	PYLLI21-25	9923.25	good
Kluknava	SMRp, SMRw, ReC, ReC15-26, ReC16, ReC18-20, ReC30-39, ReC00-D48, ReI, SMRI21-25, SMRJ, SMRK, PYLLC30-39, PYLLI, PYLLI21-25	ReC50, ReE, ReI21-25, ReJ, ReK, SMRE, PYLLJ	11892.04	average
Kojšov	SMRm, PYLL100, ReC30-39, ReC64-68, SMRI21-25, SMRJ, PYLLJ	ReC16, ReC18-20, ReC81-96, ReC91-95, ReI, ReI21-25, ReJ, ReK, SMRC81-96, SMRK, PYLLI, PYLLI21-25, PYLLK	14749.39	impaired
Margecany	SMRI, PYLLC15-26	ReC16, PYLLI, PYLLI21-25	10129.43	average
Mníšek nad Hnilcom	SMRm, PYLL100, ReC16, ReE, ReI, SMRE, SMRI, SMRJ, PYLLK	ReC64-68, ReI21-25, ReJ, SMRI21-25, PYLLI, PYLLI21-25, PYLLJ	14046.3	impaired
Nálepkovo	SMRp, SMRm, SMRw, PYLL100, ReC81-96, ReK, ReN, SMRC, SMRC30-39, SMRC81-96, SMRI, SMRN, PYLLC, PYLLK	ReC64-68, ReE, ReJ, SMRE, SMRJ, SMRK, PYLLI	12836.12	average
Prakovce	SMRp, SMRm, SMRw, PYLL100, ReC30-39, SMRC30-39, SMRI, SMRN, PYLLC, PYLLK	ReE, SMRE, SMRI21-25, PYLLI, PYLLI21-25	12392.66	average
Richnava	SMRp, SMRm, SMRw, PYLL100, ReC16, SMRN	ReC30-39, ReE, ReJ, SMRC30-39, SMRE, SMRJ, PYLLC30-39, PYLLJ	11327.94	average
Smolnícka Huta	ReC16, ReE, ReI, ReK, SMRC15-26, PYLLC	PYLL100, ReC, ReC15-26, ReC18-20, ReC64-68, ReC00-D48, ReI21-25, ReN, SMRN, PYLLI, PYLLI21-25, PYLLK	15754.99	impaired
Smolník	SMRp, SMRm, SMRw, ReC, ReC18-20, ReC30-39, ReC81-96, ReC00-D48, ReI, ReI63-64, ReK, ReN, SMRC, SMRC30-39, SMRI, SMRI21-25, SMRK,	PYLL100, ReC64-68, ReC91-95, ReE, ReI21-25, ReJ, SMRE, SMRJ, PYLLI21-25, PYLLJ, PYLLK	17139.09	unfavourable
Stará Voda	SMRm, ReC, ReC00-D48, ReI63-64, SMRC30-39, SMRI, SMRJ	ReC15-26, ReC16, ReC18-20, ReC30-39, ReC81-96, ReC91-95, ReI, ReI21-25, ReJ, ReK, SMRC81-96, SMRI21-25, SMRK, PYLLJ	6280.67	very good
Švedlár	ReC30-39, ReC81-96, ReN, SMRC, SMRI21-25, SMRI63-64	ReC50, SMRC30-39, SMRC81-96, SMRN, PYLLC30-39	8738.79	good

Map visualization of health status of Slovak population

Health regionalization of the Slovak Republic – municipalities



Note: No. in brackets represents number of municipalities in correspondent intervals.

Environmental regionalization

Environmental regionalization was elaborated based on the evaluation of chemical analyses of groundwater (20,339 analyses) and their comparison with the Slovak Drinking Water Standards and the evaluation of chemical analyses of soils (10,738) and their comparison with the Slovak guideline for agricultural soils. Level of pollution of groundwater and soils was evaluated based on calculation of so called index of environmental risk – I_{ER}.

Each Slovak municipality is characterized by:

✓ Level of pollution of groundwater, soils:

- no pollution
- low pollution
- medium pollution
- high pollution
- very high pollution

Table form includes for each municipality of the Slovak Republic, a list of:

- Elements in groundwater and soils exceeding Slovak limit values.

EXAMPLE:

Evaluated environmental indicators - Žilina region

GROUNDWATER

I_{ERgw} - index of environmental risk for groundwater;
groundwater quality: no pollution 0; low pollution >0 ≤ 1; medium pollution >1≤ 5; high pollution >5≤ 10; very high pollution >10; excess of limits for drinking water for Ca, Mg, Ca+Mg - green color value below lower limit, red color higher than upper limit

limit value: NV SR 496/2010

municipality	environmental indicators exceeding limit values	I_{ERgw}	water quality
district Bytča			
Bytča		0.000	no pollution
Hlboké nad Váhom		0.000	no pollution
Hvozdnica		0.000	no pollution
Jablonové		0.000	no pollution
Kolárovice	Mg	0.000	no pollution
Kotešová		0.000	no pollution
Maršová - Rašov		0.000	no pollution
Petrovice	Mg	0.000	no pollution
Predmier		0.000	no pollution
Štiavnik	Mg, Fe	0.118	low pollution
Súľov - Hradná		0.000	no pollution
Veľké Rovné	Mg	0.000	no pollution
district Čadca			
Čadca	Mg	0.000	no pollution
Čierne	Mg	0.000	no pollution
Dlhá nad Kysucou	Mg	0.000	no pollution
Dunajov	Mg	0.000	no pollution
Klokočov	pH, Ca+Mg, Ca	0.000	no pollution
Klubina	Mg	0.000	no pollution
Korňa	Mg, Mn	0.129	low pollution
Krásno nad Kysucou	Mg	0.000	no pollution
Makov		0.000	no pollution
Nová Bystrica	Mg	0.000	no pollution
Olešná	Mg	0.000	no pollution
Oščadnica	Mg	0.000	no pollution
Podvysoká	Mg, Mn	0.046	low pollution
Radôstka	Mg	0.000	no pollution
Raková	Mg, Mn	0.070	low pollution
Skalité	Mg	0.000	no pollution
Stará Bystrica	Mg	0.000	no pollution
Staškov	Mn	0.067	low pollution
Svrčinovec	Mg	0.000	no pollution
Turzovka	Mg	0.000	no pollution

SOIL

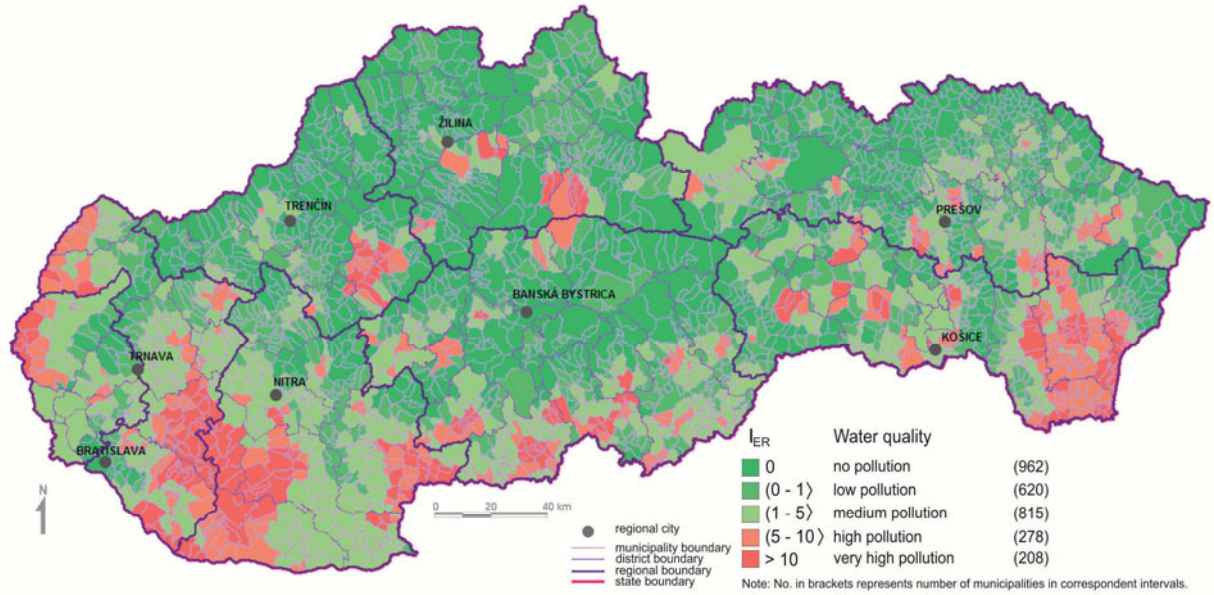
I_{ERs} - index of environmental risk for soil;
soil quality: no pollution 0; low pollution >0 ≤ 1; medium pollution >1≤ 5; high pollution >5≤ 10; very high pollution >10

limit value: law No. 220/2004, sandy-loamy, loamy soil type

environmental indicators exceeding limit values	I_{ERs}	soil quality
Cr	0.473	low pollution
Cr	0.259	low pollution
Cr	0.324	low pollution
Cr	0.234	low pollution
Cr	0.641	medium pollution
Cr	0.403	low pollution
Cr	0.433	low pollution
Cr	0.671	medium pollution
Cr	0.369	low pollution
Cr	0.411	low pollution
Cr	0.351	low pollution
Cr	0.797	medium pollution
Cd, Co, Cr	2.268	high pollution
Cd, Co, Cr	1.791	high pollution
Cr	1.197	high pollution
Cr	1.191	high pollution
Cr	0.188	low pollution
Cr	1.018	high pollution
Cr	0.578	medium pollution
Cr	1.200	high pollution
Cr	0.587	medium pollution
Cr	0.534	medium pollution
Cr	0.428	low pollution
Cr	0.722	medium pollution
Cr	0.911	medium pollution
Cr	0.703	medium pollution
Cd, Co	1.917	high pollution
Cr	0.605	medium pollution
Cr	0.925	medium pollution
Co, Cr	0.851	medium pollution
Cd, Co, Cr	2.482	high pollution
Cr	0.843	medium pollution

Map visualization of groundwater and soil quality in the Slovak Republic

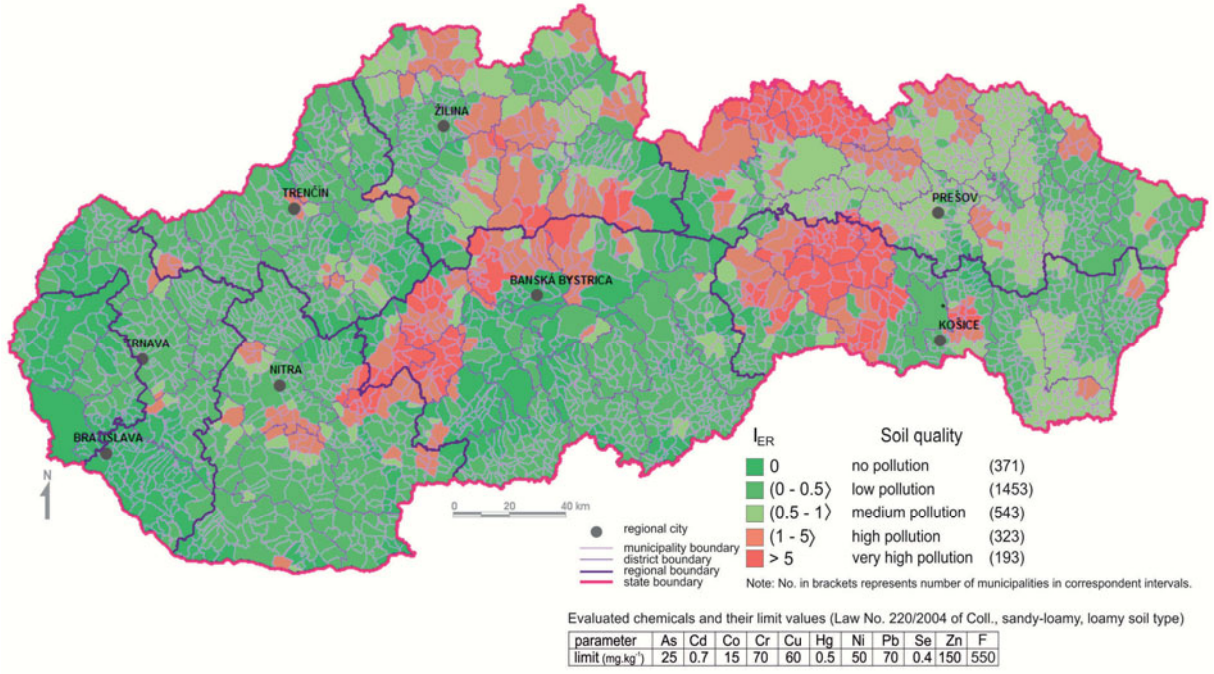
Environmental regionalization of the Slovak Republic – municipalities
GROUNDWATER



Evaluated chemical elements and their limit values (limit value Government regulation No. 496/2010 of Coll.)

parameter	TDS	NO_2	NO_3	Cl	SO_4	As	F	Cd	Cu	Cr	Pb	Hg	Se	NH_4	Al	Mn	Zn	Fe	Na	Sb	COD_{Mn}
limit ($mg.l^{-1}$)	1,000	0.5	50	250	250	0.01	1.5	0.005	2	0.05	0.01	0.001	0.01	0.5	0.2	0.05	3	0.2	200	0.005	3

SOIL



Evaluated chemicals and their limit values (Law No. 220/2004 of Coll., sandy-loamy, loamy soil type)

parameter	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Se	Zn	F
limit ($mg.kg^{-1}$)	25	0.7	15	70	60	0.5	50	70	0.4	150	550

A6: ELABORATION OF THE PROPOSAL OF MEASURES

Recognition of the problem is essential for finding a solution…

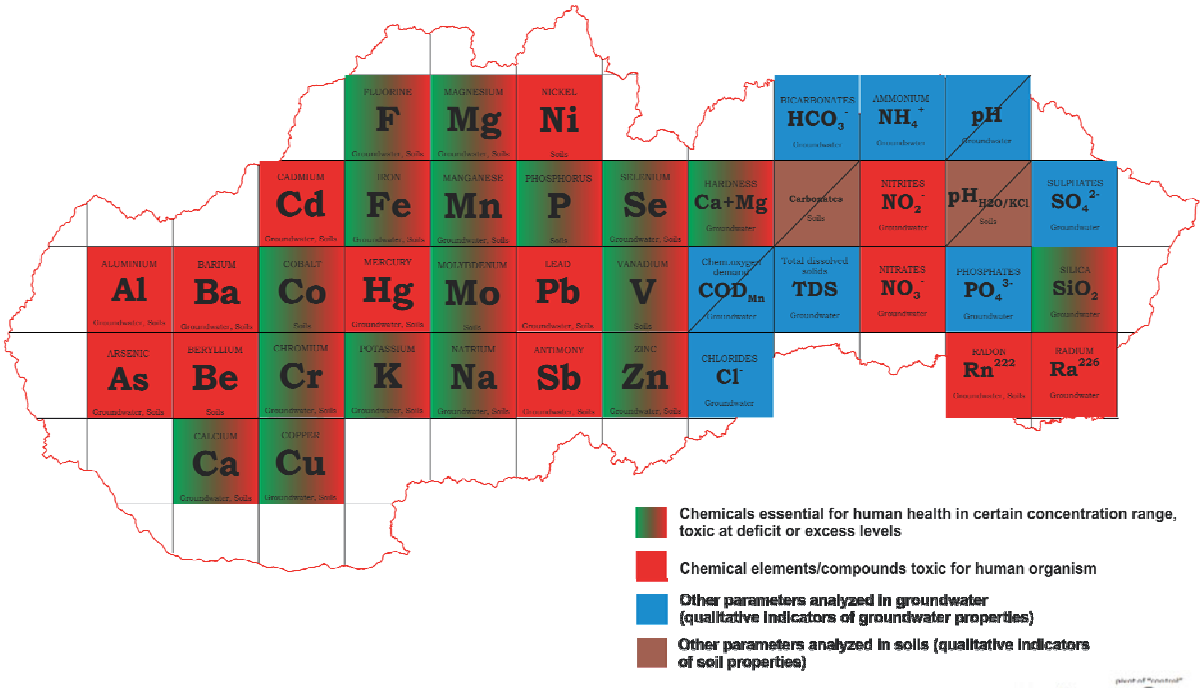
Proposal of measures was elaborated to reduce or eliminate negative impact of geological environment on the health state of Slovak residents. For each of evaluated environmental indicators the factsheet was elaborated, presenting summary information on:

- **Adverse effects on human organism** (due to excess or deficit) and minimal risk levels/recommended intake,
- **Concentration levels in geological environment of the Slovak Republic** (groundwater and soils) and the source of their origin (natural / anthropogenic sources).
- **Proposed measures** to avoid potential health risks.

Method of data elaboration:

✓ 32 chemical parameters in groundwater and 27 parameters in soils

Form of „Factsheets" Cause – effect – measures



Examples of factsheets: CALCIUM, ARSENIC

All factsheets are published on the project website www.geology.sk/geohealth (only in Slovak).

GEOHEALTH

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

CAUSE

Excess – high Ca contents in geological environment (they do not occur in Slovakia)

Deficit – low Ca contents in geological environment

EFFECT

Excess – adverse effects on kidneys, prostate cancer

Deficit – adverse effects on kidneys, cardiovascular, endocrine and musculoskeletal system, neurological and developmental effects, breast cancer

MEASURE

In areas with low Ca contents in drinking groundwater – provision of additional source of Ca (increase consumption of food rich in Ca, Ca ingestion e.g. through drinking of mineral waters, use of vitamin supplements).

CALCIUM

GEOHEALTH

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

www.geology.sk/geohealth/

European Commission

Life

Contact:

State Geological Institute of Dionýz Štúra
Mlynská dolina 1
81704 Bratislava
Slovak Republic

Contact person:
Stanislav Rapant
Project manager
stanislav.rapant@geology.sk
Katarína Fajčíková
Coordinator for environmental analysis
katarina.fajcikova@geology.sk

CALCIUM - Ca

Health effects on humans

Type of disease

EXCESS (Hypercalcemia)[1]

- *Kidneys:* kidney stones (influence of other risk factors e.g. intake of Na, vitamin D…)
- *Cancer:* prostate

DEFICIT (Hypocalcemia)[1]

- *Cardiovascular system:* in association with water hardness (Ca+Mg mmol l^{-1})[1,2,3]
- *Kidneys:* kidney failure
- *Endocrine system:* disturbance of parathyroid function
- *Musculoskeletal system:* osteoporosis
- *Neurological effects (LD):* cognitive impairments[4]
- *Developmental effects (LD):* low birth weight[5]
- *Cancer:* breast (LD)[6]

Note: Ca in human organism is protective against Pb toxicity (reduced gastrointestinal Pb absorption)[1] a NO_3^- toxicity (reduced risk of gastric cancer)[7]

Minimal risk levels

- not evaluated or not defined

Minimum and maximum necessary levels[1]

recommended daily intake (adult)

- 1000-1200 mg Ca / day

upper tolerable intake (adult)

- 2000-2500 mg Ca / day

Ca occurrence in the geological environment of the Slovak Republic

Content levels

Groundwater (mg l^{-1})

Arithmetic average:	82.9
Median:	77.1
Minimum:	1.0
Maximum:	483.7
*Recommended value**	>30
*Limit value**	not defined

Soils (%)

Arithmetic average:	1.5
Median:	0.6
Minimum:	0.01
Maximum:	31.4
*Limit value***	not defined

Origin of increased contents

Natural sources

- primary source: weathering of (sedimentary and carbonatic) rocks and minerals
- increased Ca contents in groundwater of SR are found mainly in lowlands (higher mineralized waters, presence of CO_2 in water)
- increased Ca contents in soil of SR are found mainly in areas with occurrence of carbonatic rocks as bedrock, or in areas where carbonates form secondary by precipitation from groundwater
- lower Ca contents in groundwater (not exceeding 40 mg l^{-1}) and soils (<1%) of SR are found mainly in areas built up by crystalline and Paleozoic rocks, Neovolcanics and partially in flysch belt

Antropogenic sources (of secondary significance)
– industry, agriculture

** in accordance with Slovak guideline for drinking water quality No. 496/2010, **in accordance Law No. 220/2004 for soil quality for agricultural use*

References (LD-limited data)

[1]OSU 2010. Calcium. Micronutrient Research for Optimum Health, Linus Pauling Institute, Oregon State Universit.
[2]Nerbrand, C., Agréus, L., Lenner, R.A., Nyberg, P., Svärdsudd, K. 2003. The influence of calcium and magnesium in drinking water and diet on cardiovascular risk factors in individuals living in hard and soft areas with differences in cardiovascular mortality. BMC Public Health, 3, (1), 1-9
[3]Catling L., Abubakar I., Lake I., Swift L., Hunter P. 2005. Review of evidence for of relationship between incidence cardiovascular disease and water hardness. University of East Anglia and Drinking Water Inspectorate, Norwich, Norfolk, NR47TJ. 142
[4]Jacqmin, H., Commenges, D., Letenneur, L., Barberger-Gateau, P., Dartigues, J.F. 1994. Components of drinking water and risk of cognitive impairment in the elderly. Am. J. Epidemiol., 139, 48-57
[5]Yang, Ch-Y., Chiu, H-F., Chang, CH.-CH., Wu, T-N., Sung, F.-CH. 2000. Association of very low birth weight with calcium levels in drinking water. Environ. Research, Section A, 89, 189-194
[6]Yang, Ch-Y., Chiu, H-F., Cheng, B-H., Hsu, T-Y., Cheng, M-F., Wu, T-N. 2000. Calcium and magnesium in drinking water and the risk of death from breast cancer. Journal of Toxicology and Environmental Health, Part A: Current Issues. 60, (4), 231-241
[7]Yang, Ch.-Y., Cheng, M.-F., Tsai, S.-S., Hsieh, Y.-L. 1998. Calcium, magnesium and nitrate in drinking water and gastric cancer mortality. Jpn. J. Cancer Res., 89, 124-130

GEOHEALTH

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

CAUSE

Excess – high arsenic contents in geological environment (in Slovakia they are present locally in groundwater and soils mainly in historical mining areas but also e.g. in area with coal burning activities)

EFFECT

Excess – adverse effect on respiratory, cardiovascular, gastrointestinal, endocrine system, genotoxic effects, neurological effects, hematologic changes, influence on birth weight, skin, liver, occurrence of cancer diseases

MEASURE

In case of increased arsenic contents in groundwater do not use them for drinking purposes and for irrigation of locally grown plants used for human consumption.
In case of soils do not grow local agricultural plants and do not consume such products or avoid their frequent and regular consumption.

ARSENIC

GEOHEALTH

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

www.geology.sk/geohealth/

Contact:

State Geological Institute of Dionýz Štúr
Mlynská dolina 1
81704 Bratislava
Slovak Republic

Contact person:
Stanislav Rapant
Project manager
stanislav.rapant@geology.sk
Katarína Fajčíková
Coordinator for environmental analysis
katarina.fajcikova@geology.sk

ARSENIC - As

Health effects on humans

Type of disease

EXCESS

- *Respiratory system:* bronchitis, bronchiectasis, bronchopneumonia[1]
- *Cardiovascular system:* gangrene, Raynaud´s disease, "Blackfoot" disease (necrosis and gangrene)[1, 2], increased risk for mortality for ischemic heart disease, cardiac failure, increased incidence of cerebrovascular diseases and cerebral stroke, hypertension, thrombosis, arteriosclerosis, cyanosis[1]
- *Gastrointestinal system:* nausea, diarrhea, irritation, hemorrhage, hematemesis, melena, abdominal pain[1]
- *Genotoxic effect:* chromos. alteration [1, 3]
- *Hematological effects:* anemia[1]
- *Liver:* cirrhosis, swollen liver[1]
- *Endocrine system:* diabetes mellitus[1, 4]
- *Skin:* keratosis, pigmentation[1, 2]
- *Weight:* reduction of body weight[1]
- *Neurological effects:* paresthesia, functional denervation, peripheral neuropathy (muscle weakness, numbness of extremities)[1, 5]
- *Cancer:* skin, liver, bladder, kidneys, prostate[1, 6]

Minimal risk levels

Oral exposure (ingestion)

- chronic exposure (≥ 1 year)[1] : 0.0003 mg As / kg / day
- lifetime exposure: As is classified as carcinogen for humans based on sufficient evidence from human data (epidemiological studies) [6]

As occurrence in the geological environment of the Slovak Republic

Content levels

Groundwater (mg l^{-1})

Arithmetic average:	0.0026
Median:	0.0005
Minimum:	0.000005
Maximum:	4.9
*Limit value**	0.01

Soils (mg kg^{-1})

Arithmetic average:	16.83
Median:	7.70
Minimum:	0.1
Maximum:	13,040.0
*Limit value***	25

Origin of increased contents

Natural sources

- it form basically inorganic compounds (As^{III}-toxic, As^{V} - less toxic)
- primary source: weathering of rocks and minerals (mainly sulphides)
- increased As contents in groundwater of SR are found mainly in areas with occurrence of ore mineralization (crystalline formations), in areas with occurrence of rocks with increased As contents (lydites, claystones of Inner Carpathian Paleogene, Neovolcanics (mainly rhyolites)
- increased As contents in soils of SR are found mainly in areas with occurrence of ore mineralization

Antropogenic sources

- mainly industry (combustion of fossil fuels, metallurgy, ore mining)

** in accordance with Slovak guideline for drinking water quality No. 496/2010, **in accordance Law No. 220/2004 for soil quality for agricultural use*

References (LD-limited data)

[1] ATSDR 2007. Toxicological profile for arsenic. U.S. Department of Health and Human Services, Public health service, Agency for toxic substance and disease registry, Atlanta, Georgia (http://www.atsdr.cdc.gov/toxprofiles/tp2.pdf)

[2] Tseng WP. 1977. Effects and dose-response relationships of skin cancer and Blackfoot disease with arsenic. Environ Health Perspective, 19, 109-119

[3] Kligerman AD., Doerr CL., Tennant AH., Harrington-Brock K., Allen JW., Winkfield E., Poorman-Allen P., Kundu B., Funasaka K., Roop B., Mass M., De Marini D. 2003. Methylated trivalent arsenicals as candidate ultimate genotoxic forms of arsenic: Induction of chromosomal mutations but not gene mutations. Environ Mol Mutagen, 42, 192-205

[4] Lai MS., Hsueh YM., Chen CJ., Shyu MP., Chen SY, Kuo TL., Wu MM., Tai TY. 1994. Ingested inorganic arsenic and prevalence of diabetes mellitus. Am J Epidemiol, 139, 484-492

[5] Rodríguez VM., Jiménéz-Capdeville ME., Giordano, M. 2003. The effects of arsenic exposure on the nervous system. Toxicology Letters, 145, 1-18

[6] IRIS 1998. Arsenic, inorganic. Integrated Risk Information System, U.S. Environmental Protection Agency (http://www.epa.gov/iris/subst/0278.htm)

A7: REALIZATION OF MEASURES

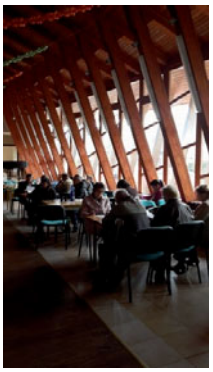
• Edification and Environmental-Health Education

11 informative meetings in selected Slovak municipalities
(With the most unfavourable geological environment)

Residents were explained which risks can be posed by the geological environment and how to avoid them in their everyday life.







• Elaboration of Proposal of Legislative Measures

List of EI and HI which are recommended to be monitored

- Cardiovascular and Oncological diseases (about 75% of all causes of deaths in the Slovak Republic)
- The most influential chemical elements – Ca and Mg in groundwater and water hardness (expressed as Ca+Mg)

Main conclusion:

- We propose increasing the recommended values in the Slovak Drinking Water Guideline for Ca, Mg and Ca+Mg approximately twice their limit values.

Proposed limit values for drinking and bottled water

Parameter	Recommended values Drinking water for public supply	Bottled drinking water
Ca+Mg	2 – 5 mmol l^{-1}	2.5 – 5 mmol l^{-1}
Ca	50 – 180 mg l^{-1}	60 – 180 mg l^{-1}
Mg	25 – 50 mg l^{-1}	30 – 60 mg l^{-1}

More detailed information can be found in technical publications available on the project website www.geology.sk/geohealth.

DISSEMINATION

Website (www.geology.sk/geohealth)

Any media work (press release, TV session, radio reportages, newspaper articles published on the project website)

Workshop, seminar, conference

- International workshop, Bratislava, May – June 2012


- International conference SEGH 2015, Bratislava, June 2015



- Seminar GEOHEALTH 2016, Bratislava, April 2016


Technical publications on the project

Main papers published in international journals:

Rapant S., Letkovičová, M., Cvečková, V., Ďurža, A., Fajčíková, K. & Zach, H. (2013). Linking of environmental and health indicators by neural networks: Case of breast cancer mortality, Slovak Republic. *Open Journal of Geology*, 3, 101-112.

Fajčíková, K., Cvečková, V., Stewart, A., Rapant, S. (2014). Health risk estimates for groundwater and soil contamination in the Slovak Republic: a convenient tool for identification and mapping of risk areas. *Environ. Geochem. Health*, 36, 973–986.

Rapant, S., Cvečková, Veronika, Dietzová, Z., Fajčíková, K., Hiller, E., Finkelman, R.B. & Škultétyová, S. (2014). The potential impact of geological environment on health status of residents of the Slovak Republic. *Environ. Geochem. Health*, 36, 543-561.

Rapant, S., Cvečková, V., Fajčíková, K., Kohút, M. & Sedláková, D. (2014). Historical mining areas and their influence on human health. *European Journal for Biomedical Informatics*, 10(1), 24-34.

Rapant, S., Fajčíková, K., Cvečková, V., Ďurža, A., Stehlíková, B., Sedláková, D. & Ženišová, Z. (2015). Chemical composition of groundwater and relative mortality for cardiovascular diseases in the Slovak Republic. *Environ. Geochem. Health*, 37, 745-756.

Rapant, S., Cvečková, V., Fajčíková, K., Dietzová, Z. & Stehlíková, B. (2016). Chemical composition of groundwater/drinking water and oncological disease mortality, Slovak Republic. *Environ. Geochem. Health,* in press (DOI: 10.1007/s10653-016-9820-6)

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. in press

International conference presentations:

9th ISEG, Aveiro Portugal (July 14-19, 2012)

29th SEGH, Toulouse, France (July 8-12. 2013)

30th SEGH, Newcastle-upon-Tyne, UK (30th July – 4th June, 2014)

32th SEGH, Brussels, Belgium (July 4-8, 2016)

ISEH 2016, ISEG 2016 and Geoinformatics 2016, Galway, Ireland (August 14-20, 2016)

All information is published on the project website www.geology.sk/geohealth.

Edited by: Fajčíková, K., Cvečková, V., Rapant, S. 2016, State Geological Institute of Dionýz Štúr, Bratislava, Slovak Republic

„Highlights“

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 from 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.

Coordinating beneficiary:

ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA
MENTE ET MALLEO

GEOHEALTH

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

Donors:

Life

Ministerstvo životného prostredia Slovenskej republiky