Layman´s Report

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


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

- Compilation EI dataset
- Compilation HI dataset
- Unification of EI and HI in the same form
- Statistical analysis – linking of two datasets
- Identification of the chemical elements/compounds with the highest influence on human health
- Elaboration of proposal of limit values for the chemicals identified as influential to human health
- Environmental edification and education
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)

<table>
<thead>
<tr>
<th>GROUNDWATER</th>
<th>SOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>element/component/parameter</td>
<td>symbol</td>
</tr>
<tr>
<td>Water reaction</td>
<td>pH</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>T.D.S.</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>COD₉₅₂</td>
</tr>
<tr>
<td>Water hardness</td>
<td>Ca+Mg</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn</td>
</tr>
<tr>
<td>Ammonium</td>
<td>NH₄</td>
</tr>
<tr>
<td>Fluorides</td>
<td>F</td>
</tr>
<tr>
<td>Chlorides</td>
<td>Cl</td>
</tr>
<tr>
<td>Sulphates</td>
<td>SO₄</td>
</tr>
<tr>
<td>Nitrites</td>
<td>NO₂</td>
</tr>
<tr>
<td>Nitrates</td>
<td>NO₃</td>
</tr>
<tr>
<td>Phosphates</td>
<td>PO₄</td>
</tr>
<tr>
<td>Bicarbonates</td>
<td>HCO₃</td>
</tr>
<tr>
<td>Silica</td>
<td>SiO₂</td>
</tr>
<tr>
<td>Chromium</td>
<td>Cr</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
</tr>
<tr>
<td>Arsenic</td>
<td>As</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Cd</td>
</tr>
<tr>
<td>Selenium</td>
<td>Se</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
</tr>
<tr>
<td>Barium</td>
<td>Ba</td>
</tr>
<tr>
<td>Aluminium</td>
<td>Al</td>
</tr>
<tr>
<td>Antimony</td>
<td>Sb</td>
</tr>
<tr>
<td>Radon</td>
<td>²₂²Rn</td>
</tr>
<tr>
<td>Radium</td>
<td>²³⁵Ra</td>
</tr>
</tbody>
</table>

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

Water hardness distribution in groundwater 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:

# 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/).

## Demographic Indicators

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Description of indicator</th>
<th>Method of calculation</th>
<th>Unit</th>
<th>Mean SR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LEp</td>
<td>life expectancy at birth – population</td>
<td>cumulative calculation of all years of life during lifetime / No. of living persons at the beginning of the year</td>
<td>years</td>
<td>72.60</td>
</tr>
<tr>
<td>2</td>
<td>LEm</td>
<td>life expectancy at birth – men</td>
<td>100 x (number of people aged 60 and over / number of inhabitants)</td>
<td>%</td>
<td>67.44</td>
</tr>
<tr>
<td>3</td>
<td>LEw</td>
<td>life expectancy at birth – women</td>
<td>100 x (number of people aged 60 and over / number of inhabitants)</td>
<td>%</td>
<td>77.07</td>
</tr>
<tr>
<td>4</td>
<td>A60+</td>
<td>proportion of population at age 60 and more</td>
<td>100 x (number of people aged 60 and over / number of inhabitants)</td>
<td>%</td>
<td>15.38</td>
</tr>
</tbody>
</table>

## Crude and Premature Mortality

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Description of indicator</th>
<th>Method of calculation</th>
<th>Unit</th>
<th>Mean SR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>SMRp</td>
<td>population</td>
<td>indirect age-standardized mortality rate of inhabitants to the Slovak standard (19 age groups)</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>SMRm</td>
<td>men</td>
<td>100 x (No. of deaths for selected cause / number of inhabitants)</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>SMRw</td>
<td>women</td>
<td>100 x (No. of deaths for selected cause / number of inhabitants)</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>PYLL100</td>
<td>potential years of lost life</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>4033.0</td>
</tr>
</tbody>
</table>

## Relative Mortality for Selected Cause of Death

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Description of indicator</th>
<th>Method of calculation</th>
<th>Unit</th>
<th>Mean SR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>ReC00-C97</td>
<td>malignant neoplasms</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>212.79</td>
</tr>
<tr>
<td>10</td>
<td>ReC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>76.14</td>
</tr>
<tr>
<td>11</td>
<td>ReC16</td>
<td>malignant neoplasms of stomach</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>45.19</td>
</tr>
<tr>
<td>12</td>
<td>ReC18-C20</td>
<td>malignant neoplasms of colon and rectum</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>24.24</td>
</tr>
<tr>
<td>13</td>
<td>ReC30-C39</td>
<td>malignant neoplasms of respiratory system</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>15.38</td>
</tr>
<tr>
<td>14</td>
<td>ReC64-C68</td>
<td>malignant neoplasms of urinary system</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>11.25</td>
</tr>
<tr>
<td>15</td>
<td>ReC91-C95</td>
<td>all leukaemia</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>13.28</td>
</tr>
<tr>
<td>16</td>
<td>ReC91-C95</td>
<td>all leukaemia</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>6.20</td>
</tr>
<tr>
<td>17</td>
<td>ReC91-C95</td>
<td>all leukaemia</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>14.38</td>
</tr>
<tr>
<td>18</td>
<td>ReC91-C95</td>
<td>all leukaemia</td>
<td>100,000 x (\text{No. of deaths for selected cause / number of inhabitants})</td>
<td>%</td>
<td>213.62</td>
</tr>
</tbody>
</table>

## Potential Years of Lost Life for Selected Cause of Death

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Description of indicator</th>
<th>Method of calculation</th>
<th>Unit</th>
<th>Mean SR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>SMRC00-C97</td>
<td>malignant neoplasms</td>
<td>100,000 x (\text{No. of years of people up to the age of nearly 65 years (deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>27</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>28</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>29</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>31</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>32</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>33</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>34</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>35</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>36</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>37</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>38</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
<tr>
<td>39</td>
<td>SMRC15-C26</td>
<td>malignant neoplasms of gastrointestinal system</td>
<td>100,000 x (\text{No. of deaths at age between 1 to 64 years / number of inhabitants})</td>
<td>years</td>
<td>100</td>
</tr>
</tbody>
</table>

**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/geohalth)

EXAMPLES:

**Deaths per 100 000 inhabitants - diseases of circulatory system**

**RE100-199**

Slovakia: 531.05

(No. of deaths per 100 000 inhabitants)

**Deaths per 100,000 inhabitants - malignant neoplasms**

**ReC00-C97**

Slovakia: 212.79

(No. of deaths per 100 000 inhabitants)

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

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.
Characteristics 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:

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.

More details can be found in paper:

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:


**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.

![Simplified legend](image)

_Simplified legend_
- 1° cluster - good status
- lean to 1° cluster - transition from good to worse status
- lean to 2° cluster - transition from worse to bad status
- 2° cluster - bad status
- extremely bad status

*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](http://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 \( \text{sum}_{\text{neg}} (\Sigma \text{HI: SMR}_{p} – \text{PYLL}_{K00-K93}) \).

Each Slovak municipality is characterized by:

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

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

- Health status level:
  - very good
  - good
  - average
  - impaired
  - unfavourable

**EXAMPLE:**

![Table with data]

<table>
<thead>
<tr>
<th>municipality</th>
<th>health indicators exceeding Slovak mean values &gt;10–50%</th>
<th>health indicators exceeding Slovak mean values &gt;50%</th>
<th>sum_{negHI-SMR}<em>{p}–\text{PYLL}</em>{K00-K93}</th>
<th>health status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geňnica</td>
<td>SMR_{w}, PYLL_{100}, SMRE, SMRI, SMR_{21-25}, PYLLI, PY LL_{21-25}, PYLL</td>
<td>ReC18/20, ReE, ReI12-25, ReI16, SMRE, SMRN</td>
<td>10437.89</td>
<td>average</td>
</tr>
<tr>
<td>Hlceľmanovce</td>
<td>ReC30-39, ReC50, ReC64-68, ReI, SMRI, SMR_{21-25}, PYLLC15-25, PYLLC30-39, PYLLL_{21-25}, PYLL</td>
<td>ReC15/20, ReC18-20, ReC30-39, ReC50-548, ReI, ReI21-25, ReI3-64, ReI, SMR_{63-64}, SMRN, PYLL</td>
<td>9686.33</td>
<td>good</td>
</tr>
<tr>
<td>Hencová</td>
<td>SMRI, PYLLL_{21-25}</td>
<td>ReC, ReC15-25, ReC18-20, ReC30-39, ReC50-548, ReI, ReI21-25, ReI3-64, ReI, SMR_{63-64}, SMRN, PYLL</td>
<td>10441.97</td>
<td>average</td>
</tr>
<tr>
<td>Hrišovce</td>
<td>SMR_{p}, SMW, ReC, ReC19-20, ReC20-24, ReS, SMRC, SMRJ</td>
<td>PYLL100, ReC16, ReC50, ReC64-68, ReE, ReJ, SMRE, PYLLC, PYLLL, PYLL</td>
<td>12894.68</td>
<td>average</td>
</tr>
<tr>
<td>Jaklovce</td>
<td>ReC16-20, ReC30-39, ReI, PYLL</td>
<td>PYLLL_{21-25}</td>
<td>9923.25</td>
<td>good</td>
</tr>
<tr>
<td>Margecany</td>
<td>SMRI, PYLLC15-26</td>
<td>ReC16, PYLL, PYLLL_{21-25}</td>
<td>10129.43</td>
<td>average</td>
</tr>
<tr>
<td>Mnišek nad Hnilcom</td>
<td>SMR_{p}, PYLL_{100}, ReC16, ReE, ReI, SMRE, SMRI, SMRJ, PYLLC, PYLL</td>
<td>ReC64-68, ReE, ReI21-25, ReJ, SMR_{21-25}, PYLL, PYLLL</td>
<td>14404.63</td>
<td>average</td>
</tr>
<tr>
<td>Nálepkovo</td>
<td>SMR_{p}, SMW, PYLL_{100}, ReC50-96, ReE, ReS, SMRC30-39, SMRC81-96, SMRI, SMRN, PYLLC, PYLL</td>
<td>ReC64-68, ReE, ReI, SMRE, SMRI, SMRK, PYLL</td>
<td>12386.12</td>
<td>average</td>
</tr>
<tr>
<td>Prakovce</td>
<td>SMR_{p}, SMW, PYLL_{100}, ReC30-39, SMRC30-39, SMRI, SMRN, PYLLC, PYLL</td>
<td>ReE, SMRE, SMR_{21-25}, PYLL, PYLLL_{21-25}</td>
<td>12392.66</td>
<td>average</td>
</tr>
<tr>
<td>Richnava</td>
<td>SMR_{p}, SMW, PYLL_{100}, ReC16, SMRN</td>
<td>ReC30-39, ReE, ReJ, SMRC30-39, SMRE, SMRC, PYLLC30-39, PYLL</td>
<td>11327.94</td>
<td>average</td>
</tr>
<tr>
<td>Švedlár</td>
<td>ReC30-39, ReC81-96, ReN, SMRC, SMR_{21-25}, SMR_{63-64}</td>
<td>ReC50, SMRC30-39, SMRC81-96, SMRN, SMRC, PYLLC30-39</td>
<td>6738.79</td>
<td>good</td>
</tr>
</tbody>
</table>
Map visualization of health status of Slovak population

Health regionalization of the Slovak Republic – municipalities
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:**

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Environmental indicators exceeding limit values</th>
<th>I_{wq}</th>
<th>Water quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratislava</td>
<td>Mg, Ba</td>
<td>0.000</td>
<td>no pollution</td>
</tr>
<tr>
<td>Banská Bystrica</td>
<td>Mn</td>
<td>0.000</td>
<td>no pollution</td>
</tr>
<tr>
<td>Martinová</td>
<td>Mn</td>
<td>0.000</td>
<td>no pollution</td>
</tr>
<tr>
<td>Nitra</td>
<td>Mg</td>
<td>0.000</td>
<td>no pollution</td>
</tr>
<tr>
<td>Žilina</td>
<td>Mg</td>
<td>0.000</td>
<td>no pollution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Environmental indicators exceeding limit values</th>
<th>I_{sw}</th>
<th>Soil quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratislava</td>
<td>Cr</td>
<td>0.473</td>
<td>low pollution</td>
</tr>
<tr>
<td>Banská Bystrica</td>
<td>Cr</td>
<td>0.339</td>
<td>low pollution</td>
</tr>
<tr>
<td>Martinová</td>
<td>Cr</td>
<td>0.324</td>
<td>low pollution</td>
</tr>
<tr>
<td>Nitra</td>
<td>Cr</td>
<td>0.234</td>
<td>low pollution</td>
</tr>
<tr>
<td>Žilina</td>
<td>Cr</td>
<td>0.641</td>
<td>medium pollution</td>
</tr>
<tr>
<td>Zlaté Moravce</td>
<td>Cr</td>
<td>0.450</td>
<td>low pollution</td>
</tr>
<tr>
<td>Martinová</td>
<td>Cr</td>
<td>0.352</td>
<td>low pollution</td>
</tr>
<tr>
<td>Banská Bystrica</td>
<td>Cr</td>
<td>0.671</td>
<td>medium pollution</td>
</tr>
<tr>
<td>Martinová</td>
<td>Cr</td>
<td>0.399</td>
<td>low pollution</td>
</tr>
<tr>
<td>Nitra</td>
<td>Cr</td>
<td>0.411</td>
<td>low pollution</td>
</tr>
<tr>
<td>Žilina</td>
<td>Cr</td>
<td>0.351</td>
<td>low pollution</td>
</tr>
<tr>
<td>Žilina</td>
<td>U2</td>
<td>st. / na</td>
<td>medium proton</td>
</tr>
</tbody>
</table>

**GEOHEALT LIFE 10 ENVISKO006**

17
Map visualization of groundwater and soil quality in the Slovak Republic

Environmental regionalization of the Slovak Republic – municipalities

GROUNDWATER

SOIL

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

SOIL

Evaluated chemicals and their limit values (Law No. 220/2004 of Coll., sandy-loamy, loamy soil type)
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](http://www.geology.sk/geohealth) (only in Slovak).
**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).

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

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www.geology.sk/geohealthy
CALCIUM - Ca

Health effects on humans

Type of disease

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

**DEFICIT (Hypocalcemia)**
- 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 impairments⁴
- Developmental effects (LD): low birth weight⁵
- Cancer: breast (LD)⁶

Note: Ca in human organism is protective against Pb toxicity (reduced gastrointestinal Pb absorption)⁷ a NO₃ toxicity (reduced risk of gastric cancer)⁷

Minimal risk levels

- not evaluated or not defined

Minimum and maximum necessary levels¹
- recommended daily intake (adult) ¹
  - 1000-1200 mg Ca / day
- upper tolerable intake (adult) ¹
  - 2000-2500 mg Ca / day

Content levels

| Groundwater (mg l⁻¹) | Arithmetic average | Median | Minimum | Maximum | Recommended value*<br>Limit value*<br>Limit value**<br>Not defined |
|----------------------|-------------------|--------|---------|---------|----------------------<br>------------------------<br>------------------------<br>------------------------<br>------------------------|
| Arithmetric average  | 82.9              | 77.1   | 1.0     | 483.7   | >30                  |
| Limit value          | not defined       |        |         |         |                      |

Origin of increased contents

Natural sources
- primary source: weathering of (sedimentary and carbonate) rocks and minerals
- increased Ca contents in groundwater of SR are found mainly in lowlands (higher mineralized waters, presence of CO₂ in water)
- increased Ca contents in soil of SR are found mainly in areas with occurrence of carbonate rocks as bedrock, or in areas where carbonates formsecondary by precipitation from groundwater
- lower Ca contents in groundwater (not exceeding 40 mg l⁻¹ and soils (<7%) 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

References (LD-limited date)

¹OSU 2010. Calcium. Micronutrient Research for Optimum Health, Linus Pauling Institute, Oregon State University.

* in accordance with Slovak guideline for drinking water quality No. 496/2019, **in accordance with Slovak Law No. 220/2004 for soil quality for agricultural use
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 areas 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.

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Katarína Fajčíková
Coordinator for environmental analysis
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# ARSENIC - As

## Health effects on humans

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>Minimal risk levels</th>
<th>Content levels</th>
<th>Origin of increased contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXCESS</strong></td>
<td><strong>Oral exposure (ingestion)</strong></td>
<td><strong>Groundwater (mg L⁻¹)</strong></td>
<td><strong>Natural sources</strong></td>
</tr>
<tr>
<td>Respiratory system: bronchitis, bronchiectasis, bronchopneumonia</td>
<td>chronic exposure (≥ 1 year): 0.0003 mg As / kg / day</td>
<td>Arithmetic average: 0.0026</td>
<td>it forms basically inorganic compounds (As⁴⁺- toxic, As³⁻ less toxic)</td>
</tr>
<tr>
<td>Cardiovascular system: gangrene, Raynaud’s disease, “Blackfoot” disease (necrosis and gangrene)</td>
<td>increased risk for mortality for ischemic heart disease, cardiac failure, increased incidence of cerebrovascular diseases and cerebral stroke, hypertension, thrombosis, atherosclerosis, cyanosis</td>
<td>Median: 0.0005</td>
<td>primary source: weathering of rocks and minerals (mainly sulphides)</td>
</tr>
<tr>
<td>Gastrointestinal system: nausea, diarrhea, irritation, hemorrhage, hematemesis, melena, abdominal pain</td>
<td>lifetime exposure: As is classified as carcinogen for humans based on sufficient evidence from human data (epidemiological studies)</td>
<td>Minimum: 0.000005</td>
<td>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)</td>
</tr>
<tr>
<td>Genotoxic effect: chromos. alteration ¹, ³</td>
<td></td>
<td>Maximum: 4.9</td>
<td>increased As contents in soils of SR are found mainly in areas with occurrence of ore mineralization</td>
</tr>
<tr>
<td>Hematological effects: anemia ¹</td>
<td></td>
<td>Limit value * ⁰</td>
<td></td>
</tr>
<tr>
<td>Liver: cirrhosis, swollen liver</td>
<td></td>
<td>⁰</td>
<td></td>
</tr>
<tr>
<td>Endocrine system: diabetes mellitus ¹, ⁶</td>
<td></td>
<td>⁰</td>
<td></td>
</tr>
<tr>
<td>Skin: keratosis, pigmentation ¹, ²</td>
<td></td>
<td>⁰</td>
<td></td>
</tr>
<tr>
<td>Weight: reduction of body weight ¹</td>
<td></td>
<td>⁰</td>
<td></td>
</tr>
<tr>
<td>Neurological effects: paresthesia, functional denervation, peripheral neuropathy (muscle weakness, numbness of extremities) ¹, ⁵</td>
<td></td>
<td>⁰</td>
<td></td>
</tr>
<tr>
<td>Cancer: skin, liver, bladder, kidneys, prostate ¹, ⁶</td>
<td></td>
<td>⁰</td>
<td></td>
</tr>
</tbody>
</table>

## As occurrence in the geological environment of the Slovak Republic

**Groundwater (mg L⁻¹)**

- Arithmetic average: 0.0026
- Median: 0.0005
- Minimum: 0.000005
- Maximum: 4.9
- Limit value * ⁰: 0.01

**Soils (mg kg⁻¹)**

- Arithmetic average: 16.83
- Median: 7.70
- Minimum: 0.1
- Maximum: 13.040.0
- Limit value ** ²: 25

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**References (LD-limited data)**


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

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**GEOHEALTH LIFE TO ENVIS04S8**
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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Drinking water for public supply</th>
<th>Bottled drinking water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca+Mg</td>
<td>2 – 5 mmol l(^{-1})</td>
<td>2.5 – 5 mmol l(^{-1})</td>
</tr>
<tr>
<td>Ca</td>
<td>50 – 180 mg l(^{-1})</td>
<td>60 – 180 mg l(^{-1})</td>
</tr>
<tr>
<td>Mg</td>
<td>25 – 50 mg l(^{-1})</td>
<td>30 – 60 mg l(^{-1})</td>
</tr>
</tbody>
</table>

More detailed information can be found in technical publications available on the project website [www.geology.sk/geohealth](http://www.geology.sk/geohealth).
**DISSEMINATION**

**Website** ([www.geology.sk/geohealth](http://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:


*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](http://www.geology.sk/geohealth).
Edited by: Fajčíková, K., Cvečková, V., Rapant, S. 2016, State Geological Institute of Dionýz Štúr, Bratislava, Slovak Republic
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.