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Short Report

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Contaminated sites and their impact on health status of residents

(Action A5: „Environmental analysis")

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Abstract

Impact of potentially toxic elements (PTE) on the health status of population has been studied in three historical mining areas of the Slovak Republic. In these areas the health 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 socioeconomic, 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. Based on the assessment of the health status of population using 43 health indicators (the indicators of demographic development and the indicators of health status), no significant difference in the health status of population in contaminated and non-contaminated municipalities has been reported. Therefore, it can be concluded that if groundwater used for drinking purposes are not contaminated in these historical mining areas, the resident population is set to minor danger than has been stated so far.

INTRODUCTION

Connection between geological environment and human health has been known since antiquity. It is either excess or deficiency chemical elements in the environment that accounts for possible negative health effects. Most of the studies in medical geology and geochemistry deal with the influence of higher PTE contents of individual geological components of the environment on the health of local population in geogenically or anthropogenically contaminated areas. Researches focused on impact of increased arsenic contents, particularly in groundwater/drinking water, on human health is a typical example of these studies (Smedley & Kinniburgh 2002, Duker et al., 2005).

Abandoned mining sites are the areas of concern for scientists throughout the world because of a potentially adverse impact of geological environment contamination with PTE upon local population (Wcisło et al., 2002, Peplow and Edmonds 2004, Lim et al., 2008). In these areas there is a higher probability of potential health risks with regard to considerably increased contents of various PTE particularly in soils and groundwater as a result of intense historical mining activities.

In Slovakia there are several abandoned mining sites as a heritage of long-term mining activities carried out in the past (exploitation and processing of Ag-Au-Sb ores, Pb-Zn-Cu ores, Hg ores, brown coal, etc.). The health status of population living in three historical mining areas of the Slovak Republic, where higher PTE contents were observed in geological components of the environment, was compared with that living in adjacent areas of similar socioeconomic character and the same or similar geological structure with low or no PTE contamination. The main objective of this study is to assess how and to what extent the PTE contamination of geological environment might influence health status of residents living in the determined historical mining areas.

MATERIAL

The connection between contaminated geological environment in the selected abandoned mining sites and the health status of local population has been assessed based on the elaboration and analysis of national databases of environmental and health indicators. (Rapant et al., 2013).

The environmental indicators are the contents of chemical elements, components or values of chemical parameters analysed and measured in the environment (Rapant et al., 2013). In this study we evaluate environmental indicators in groundwater and soils as these components of geological environment definitely show the most significant connection with human health.

In addition, it is very likely that PTE contents in groundwater and soils can influence human health to a great extent.

The groundwater is the most important source of drinking water. In Slovakia, it is used as the source of drinking water for more than 90% of Slovak inhabitants. (Klinda and Lieskovská, 2010). The soil is the base of food chain and represents that part of the environment, where human life directly takes place. Crops we eat are grown in soil and meat, eggs, and milk come from animals the life of which is integrally connected with the soil too. Moreover, children but also some adults are known to ingest soil as well. The soil and groundwater chemical contents are determined as "total contents" (way of digestion and sampling methods and chemical analysis according to (Rapant et al.1996, Vrana et al. 1997, Čurlík and Šefčík 1999).

The set of environmental indicators and their mean values for groundwater and soils in the Slovak Republic is summarized in Table 1 (according to Rapant et al., 2013).

Table 1: Characteristics of environmental indicators for the Slovak Republic (mean values).

GROUNDWATER (n=20 339)												
pH	**MIN**	**$ChSK_{Mn}$**	**Ca+Mg**	**Li**	**Na**	**K**	**Ca**	**Mg**	**Sr**	**Fe**	**Mn**	**NH_4**
7.33	629.75	2.18	3.5	0.019	20.34	11.10	93.56	28.29	0.36	0.17	0.12	0.10
F	**Cl**	**SO_4**	**NO_2**	**NO_3**	**PO_4**	**HCO_3**	**SiO_2**	**Cr**	**Cu**	**Zn**	**As**	**Cd**
0.13	32.96	79.32	0.11	38.76	0.20	303.85	18.21	0.0013	0.0026	0.2673	0.0019	0.0010
Se	**Pb**	**Hg**	**Ba**	**Al**	**Sb**		Note: Data except of pH, Ca+Mg in $mmol.l^{-1}$, in $mg.l^{-1}$					
0.0010	0.0014	0.0001	0.0747	0.0297	0.0009							
SOILS (n=10 738)												
Al	**As**	**B**	**Ba**	**Be**	**Bi**	**Ca**	**Cd**	**Ce**	**Co**	**Cr**	**Cu**	**F**
5.90	12.45	65.03	392.78	1.39	0.41	1.46	0.60	64.65	11.77	87.55	26.15	330.98
Fe	**Hg**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**P**	**Pb**	**Sb**	**Se**	**Sn**
2.71	0.24	1.70	0.87	0.08	0.68	0.85	29.29	0.07	29.62	3.69	0.16	4.71
Sr	**V**	**W**	**Zn**	**pH_{H2O}**	**pH_{KCl}**	**carbonates**		Note: macrocomponents in %, microcomponents in $mg.kg^{-1}$				
101.38	79.07	0.92	75.79	6.26	5.52	2.45						

The total number of chemical analyses for groundwater was 20, 339 and for soils 10, 738 chemical analyses. It involves the analyses that have been collected since 1991, when the modern environmental-geochemical mapping of the Slovak Republic started under the IGCP 360 Geochemical Correlation Programme (Darnley et al., 1995). The density of groundwater samples was about one sample per 2.5 km^2 and of soil samples about one sample per 5 km^2.

The health indicators (the indicators health status and demographic development of population) are variables that can express the health status of people in society via direct measurement or observation (Last, 2001). We can say whether the assessed health is good enough or bad, only when a number of areas or time periods are subject to our evaluation. In addition, they must be compared to each other, to standard or published values for larger units within a sufficiently long period of time.

There is no single comprehensive indicator, which would capture all or majority of aspects of population health status. Therefore, a relatively large set of multiple indicators was used in the study.

With regard to sensitivity and especially diversity of the data there is the need for a longer period of time in which health indicators are carefully monitored and evaluated. In our study we used a ten-year period (1994 - 2003) which still seems to be insufficient enough particularly concerning small-sized or problematic municipalities. The data of health indicators were received from the database of the Statistical Office of the Slovak Republic and are guaranteed by the state (www.statistics.sk). We only use the data describing demography and mortality. The data evaluating the incidence of various diseases are not available.

In order to assess the health status of population in contaminated or non-contaminated areas 43 health indicators were selected. It is expected that these indicators can be mostly affected by the geological environment. The list of assessed health indicators with nationwide mean values is given in Table 2.

The selected health indicators describe relevant information on age, and particularly analyse mortality in many different ways. We have deliberately chosen only robust indicators that are stable, not rare and do not alter suddenly. Out of the 43 health indicators subject to assessment we can set aside four of them as positive, i.e. the most favourable values are the highest values. The rest of 39 health indicators can be assigned as negative, i.e. their most favourable values should be as low as possible reaching even zero values.

Table 2 Evaluated health indicators of the Slovak Republic

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 mortality, premature			
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

METHODS

Elaboration of Environmental Indicators

When elaborating and calculating the environmental indicators we adopted such method of geochemical data processing and such representation of environmental indicators so that they can be united with health indicators. Therefore, we had to transform environmental indicators into a form of health indicators, which represent one number for the assessed administrative unit of the Slovak Republic – a municipality or a district. Transformation of the geochemical data on chemical composition of soils and groundwater in the Slovak Republic was realized in the same way. Thus, the environmental indicators were calculated for the basic territorial units of the Slovak Republic – municipalities (2,883 municipalities). Calculations of environmental indicators represented a determination of the mean value of an element/a component for the evaluated territorial administration units (Slovak municipalities) based on the contents of all soils and waters found in a related administration unit using the kriging method (Rapant et al., 2013).

The data for municipalities located in the three areas with historical mining activities were selected from the nationwide geochemical data of environmental indicators for all municipalities in the Slovak Republic and then analysed (293 municipalities in total).

Elaboration of Health Indicators

All health indicators were calculated as a cumulative function for a period of years from 1994 to 2003, i.e. for a ten-year period, when all cases were summed up and all numbers of inhabitants were taken as persons-per-years (number of inhabitants as of December 31 in a pertinent year) for each territorial unit (municipality) assessed.

Calculation methodology and standardization of health indicators was carried out according to recommendations of WHO, Beaghole et al. (1993), Jeníček (1995), Last (2001), Bencko et al. (2003a,b).

Selection of health indicators was based on the International Classification of Diseases by the WHO 10th revision (www.who.int/clasifications/icd/en/). Demographic indicators describing the age composition of municipalities express the average age of the population of the observed municipalities or areas. A percentage of elderly people over 60 years was calculated as 100 times the number of inhabitants aged 60 years and over/number of inhabitants. Indirectly age-standardized mortality indicators were standardized to a Slovak standard (19 age groups). Relative mortality indicators are calculated as the number of deaths per 100, 000 inhabitants (not involving the impact of age of inhabitants). Potential years of life lost are calculated as 100, 000 times the sum of the years of people up to the age of nearly 65 years (deaths at age 1 to 64 years /number of inhabitants. Calculation methods of various health indicators or formulas used to calculate specific health indicators are given in Table 2. Subsequently, from the nationwide data of health indicators the data for municipalities located in the three selected areas with historical mining acitivities were selected and analysed.

Determination of Contaminated/Non-contaminated Areas

It is possible to determine only three regions with historical mining activities, which are large enough to track the impact of contamination by PTE (left after mining activities) on public health in the Slovak Republic – a relatively small country with the total land area of less than 50,000 km^2. The three selected regions are as follows – the Middle Slovak Neovolcanics, the Slovak Ore Mts. and the Upper Nitra region (Fig. 1). The first two regions represent the historical mining areas with ore extraction (from Middle Age). Mining activities in these areas were completed at the end of the twentieth century. The third area is a territory characterized by exploitation of brown coal, which has been mined here since 1909. Currently, brown coal extraction yields reach about 2 million tonnes per year. This coal is preferably used for domestic heating in the region and as a source of combustion in a local power plant. It is characterized with increased contents of arsenic (about 0.8% by weight) and sulphur (about 2% by weight).

Determination of contaminated and adjacent non-contaminated areas in individual regions mentioned above resulted from a fundamental condition of a minimum number of 15 municipalities in each of them.

In addition, the definition of contaminated and non-contaminated areas was based on the limit values for the assessment of soil pollution and drinking water quality valid in the Slovak Republic (Table 3). Contaminated or non-contaminated municipalities were selected based on the PTE contents in soils, since the contents of risk elements in soils are more contrast with their contents in groundwater. Due to relatively high pH of water reaching almost neutral values of the pH scale (as a result of abundant presence of carbonates in the ore veins) PTE mobility is seen as relatively very low. PTE are eliminated from the groundwater and bound in soils and sediments.

Non-contaminated municipalities include the ones with PTE contents in soils not exceeding reference values in case of any assessed element.

Table 3 Assessed elements and their limit values

Soils („A“ reference values of MP SR resolution No. 531/1994-540)															
Element	**As**	**Ba**	**Be**	**Cd**	**Co**	**Cr**	**Cu**	**Hg**	**Mo**	**Ni**	**Pb**	**Se**	**Sn**	**V**	**Zn**
Limit [$mg.kg^{-1}$]	29	500	3	0.8	20	130	36	0.3	1	35	85	0.8	20	120	140
Groundwater (limit values of the Slovak government order No. 496/2010 of Collection of Laws) – drinking water															
Element	**MIN**	**NO_3**	**Cl**	**SO_4**	**F**	**NH_4**	**Na**	**Fe**	**Mn**	**Al**	**As**	**Cd**	**Cr**	**Cu**	**Hg**
Limit [$mg.l^{-1}$]	1000	50	100	250	1.5	0.5	200	0.2	0.05	0.2	0.01	0.003	0.05	1.0	0.001
Element	**Pb**	**Sb**	**Zn**												
Limit [$mg.l^{-1}$]	0.01	0.005	3.0												

The determination of contaminated and non-contaminated areas in the three regions with historical mining activities on the basis of the above criteria is shown in Fig. 1 (Fig. 1). A total of 138 contaminated and 155 non-contaminated municipalities were selected and then compared within individual assessed regions by the concentration level of chemical elements/ compounds in groundwater and soils (environmental indicators) and health status of the population (health indicators).

AREA DESCRIPTION

Geological setting

Geological structure of the evaluated areas is built by various geological-tectonic units and thus it is represented by varied petrographic and geochemical character (Marsina et al., 1999). While the geological environment of the Middle Slovak Neovolcanics is predominantly built by the Neogene volcanics, geological structure in the other two areas is more complicated and contains rocks of diverse geological character.

Eastern part of the Slovak Ore Mts. area is built mainly by the Lower-Paleozoic (Cambrian to Carboniferous) weakly metamorphosed flysch metasediments (metasandstones, metagreywackes, phyllites) and metavolcanics – basaltoid, keratophyre and rhyolite character. Western part is built by dominant the Lower to Upper Paleozoic metamorphic rocks of crystalline basement with signs of migmatization, granitization, especially orthogneisses, paragneisses, migmatites, amphibolites, diorites and metacarbonates. Approximately 5 % of the area is represented by the Mesozoic (carbonatic) sedimentary cover, which consists of the Lower-Triassic quartzite, dolomite and limestone. Mainly metasomatic and ore mineralizations of Fe, Cu, Pb, Zn, Sb, Ag, Au and Hg have been mined in the Slovak Ore Mts. since the Middle Ages.

The Middle Slovak Neovolcanics are predominantly (over 95 %) built by the Neogene volcanics, particularly andesites, basalts (less by rhyolites and dacites), and their pyroclastics. Crystalline rocks (orthogneisses, gneisses, granites) together with the Mesozoic carbonatic rocks having manifestations of scarnization are locally found in the form of xenolithes. In the past the area of the Middle Slovak Neovolcanics was well-known as an important metallogenetic region with exploitation of Au, Ag, Pb, Zn, Cu and Hg ores. Nowadays there is only a limited Au ore mining in the area.

The centre of the Upper Nitra region is represented by the Upper Nitra basin-shaped valley, typical intramontane the Tertiary depression of the Western Carpathians, which is surrounded by core and volcanic mountains. The basin area is built mainly by the Paleogene nummulite sandy limestones and polymict and dolomitic breccias and conglomerates gradually passing into sandstones, siltstones and claystones. It is overlain by flysch sedimentation where mainly sandstones alternate with claystones and siltstones. The Neogene rocks are represented especially by the Eggenburgian sandstones and conglomerates, clays and Badenian volcaniclastics with coal seams being overlaying by basaltic andesites. These predominantly the Tertiary sedimentary units constitute between 40 to 45 % of the studied area. The Mesozoic (mostly carbonates) complexes in surrounding core areas are built mainly by a number of several limestones and dolomites, less by sandstones, shales and quartzites. They cover about 20 % of the investigated area. The crystalline marginal core areas are especially composed by acidic granitoid rocks but less by migmatites and gneisses (about 20% of the evaluated area). About 20% of the studied area, particularly in the Eastern border, is built by neovolcanic rocks – andesites, basalts and pyroclastics.

In the Upper Nitra region (Prievidza, Handlová, Nováky) brown coal and lignite exploitation has been carried out for more than 100 years.

Socioeconomic characteristic

A number of studies analyzing the prevalence of health determinants (especially lifestyle risk factors, as well as poverty, education, employment, ethnicity and housing) in the selected model districts has been carried out in the Slovak Republic in recent years (Vilinová, 2012, Michálek a Podolák, 2007**)**. However, there are no consistent data evaluating health risk factors conditioned by non-optimal lifestyle of the local residents in the studied regions. The epidemiological studies indicate some differences in lifestyle within the districts of the Slovak Republic. Nevertheless, it is difficult to predict these differences when considering adjacent municipalities or those of a similar character in individual areas subject to assessment (rural population, mostly mountainous regions, about the same socio-economic level of the population, a similar lifestyle).

Thus, the lifestyle of people living in contaminated and non-contaminated areas is approximately of the same equality. It seems that comparison of unemployment rates is the most accurate method of how to assess the economic situation of people living in contaminated and non-contaminated areas. According to Table 4, displaying unemployment rate figures in contaminated and non-contaminated areas for the three evaluated regions, it is evident that the unemployment rate is about the same. Moreover, the unemployment rate in the Upper Nitra and the Slovak Ore Mts. regions is slightly higher in the non-contaminated municipalities. Based on this, it is clear that economic level in the assessed areas is practically the same, and apparently accounts for no significant impact on the health of the population in the studied areas.

Fig. 1 Contaminated and non-contaminated areas of the Slovak Republic

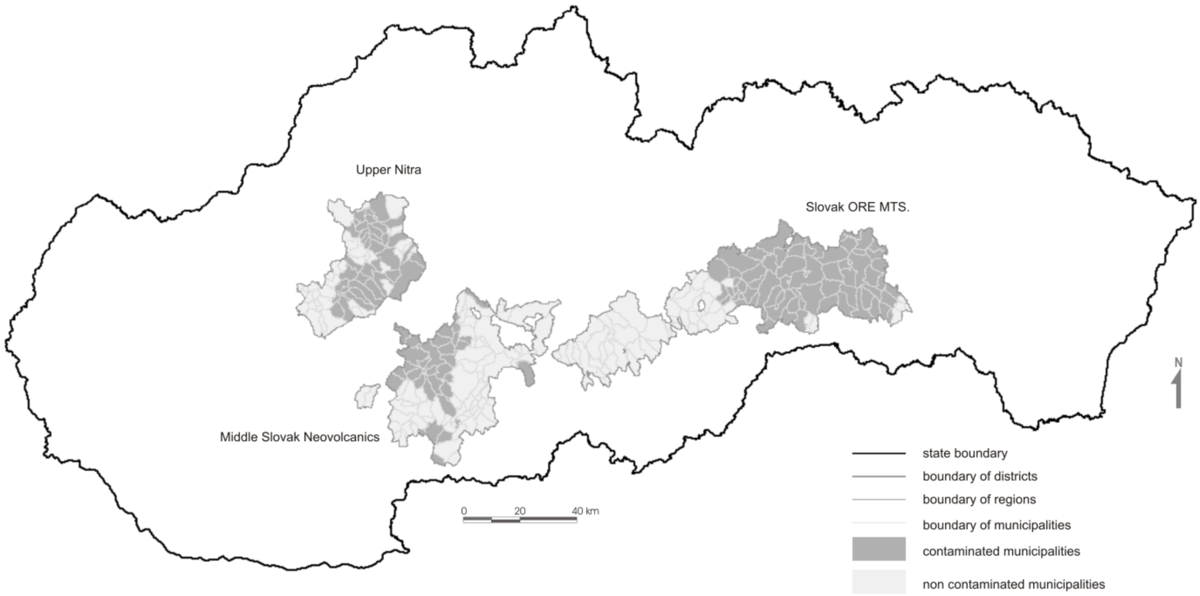

Table 4 Unemployment rates in assessed areas in 2001 and 2011

Region	**unemployment rate in %**			
	Contaminated area		**Non contaminated area**	
	2001	*2011*	*2001*	*2011*
Upper Nitra	19.09	14.81	19.14	15.20
Slovak Ore Mts.	27.32	25.65	32.20	25.78
Middle Slovak Neovolcanics	25.90	23.19	24.21	24.86
Slovak Republic	*2001*		*2011*	
	19.2		13.6	

Source: www. statistics.sk

RESULTS AND DISCUSSION

Basic characteristics of the selected chemical elements in groundwater and soils (environmental indicators) of the studied areas is given in Table 5. The characteristics of population health status in the evaluated contaminated and non-contaminated areas are presented in Table 6.

Table 5 Selected values of environmental indicators in contaminated and non-contaminated areas of the Slovak Republic (mean values for all municipalities)

	MIDDLE SLOVAK NEOVOLCANICS		UPPER NITRA		SLOVAK ORE MTS.	
	Contaminated area	Non contaminated area	Contaminated area	Non contaminated area	Contaminated area	Non contaminated area
Soils						
As	11.03	7.06	32.38	16.90	96.68	13.14
Cd	3.34	0.60	0.24	0.34	0.79	0.31
Cu	35.67	19.18	19.15	17.91	139.89	22.68
Hg	0.16	0.08	0.15	0.10	3.03	0.18
Pb	91.42	29.63	37.65	29.95	118.34	26.26
Sb	2.96	1.53	1.23	0.97	76.79	2.36
Zn	134.14	78.40	88.32	72.75	89.81	74.59
Ca	1.14	0.96	1.47	1.55	0.65	0.91
Mg	0.73	0.59	0.95	0.91	0.69	0.84
carbonates	0.86	1.21	1.74	2.14	0.62	0.22
Groundwater						
As	0.00194	0.00160	0.02096	0.00194	0.01217	0.00165
Cd	0.00139	0.00286	0.00444	0.00818	0.00054	0.00205
Cu	0.00263	0.00239	0.00129	0.00169	0.00413	0.00112
Hg	0.00014	0.00012	0.00015	0.00014	0.00016	0.00013
Pb	0.00198	0.00106	0.00107	0.00193	0.00163	0.00104
Sb	0.00024	0.00021	0.00019	0.00023	0.00941	0.00048
Zn	0.17592	0.25344	0.20046	0.15462	0.12486	0.12066
Ca	43.87	48.98	63.32	93.82	38.33	33.02
Mg	11.75	13.25	18.65	25.72	14.09	9.88
Ca+Mg	1.58	1.77	2.34	3.40	1.54	1.23

Note: contents of elements for groundwater in $mg.l^{-1}$, Ca+Mg v $mmol.l^{-1}$, for soils in $mg.kg^{-1}$, Ca, Mg in %

Table 6 Characteristics of population health status in contaminated and non-contaminated areas

	MIDDLE SLOVAK NEOVOLCANICS		SLOVAK ORE MTS.		UPPER NITRA	
	1*	2*	1*	2*	1*	2*
LEp	71.10	70.99	71.12	71.53	73.55	73.45
LEm	65.78	66.10	66.49	66.99	69.75	69.62
LEw	75.96	75.65	72.88	74.95	77.06	77.13
A60+	18.16	17.89	15.31	16.91	17.87	17.99
SMRp	112.40	112.15	112.25	110.32	94.98	94.38
SMRm	122.67	117.58	115.75	111.37	94.07	91.57
SMRw	105.94	107.21	110.60	109.88	94.74	96.03
PYLL100	5244.41	5049.83	4527.48	4985.29	3485.95	3504.16
ReC	252.60	240.31	211.78	229.03	223.96	238.11
ReC1526	85.26	96.23	70.73	72.94	77.28	94.21
ReC16	14.24	20.72	14.30	15.34	22.60	20.90
ReC1820	27.41	32.32	24.46	20.60	23.02	28.49
ReC3039	55.44	46.94	45.58	51.67	50.09	43.19
ReC50	21.46	29.31	24.51	33.53	23.87	24.96
ReC6468	16.07	8.46	12.02	13.40	9.60	10.98
ReC8196	14.07	13.98	12.75	15.26	11.66	12.74
ReC9195	6.05	8.11	6.13	6.74	4.78	5.21
ReC00D48	241.58	242.61	212.62	229.40	223.83	240.48
ReE	21.52	16.63	17.45	16.49	20.92	14.73
ReI	760.28	668.37	582.93	682.26	613.95	617.30
ReI2125	392.94	310.74	355.31	363.62	288.70	280.75
ReI6364	141.29	108.41	46.26	126.98	55.71	79.70
ReJ	82.12	101.82	73.29	79.76	52.40	49.87
ReK	87.79	74.58	42.05	48.67	52.40	42.30
ReN	17.62	15.99	11.57	17.83	12.21	10.66
SMRC	103.88	100.01	104.66	99.71	93.86	98.75
SMRC1526	98.08	112.33	97.17	88.23	90.88	107.90
SMRC3039	114.40	93.69	110.51	102.84	98.88	83.05
SMRC8196	91.45	92.29	97.83	110.76	79.44	87.30
SMRE	119.57	103.60	131.67	109.24	129.10	89.61
SMRI	119.99	108.75	114.98	116.24	98.25	98.33
SMRI2125	100.30	104.62	137.26	118.20	91.62	86.94
SMRI6364	168.81	140.90	74.89	174.76	75.50	102.84
SMRJ	113.31	146.33	132.39	129.35	77.81	72.34
SMRK	127.85	151.96	99.01	96.85	96.77	82.22
SMRN	114.16	101.85	89.87	118.10	78.32	63.89
PYLLC	1216.72	1101.53	1062.55	1126.65	925.65	975.03
PYLLC1526	306.04	277.58	220.23	272.70	201.33	280.05
PYllC3039	242.30	227.34	200.19	232.48	193.05	151.50
PYllI	1170.12	1182.35	1116.08	1365.40	778.44	839.03
PYLLI2125	578.20	555.64	596.50	728.38	360.04	350.23
PYLLJ	245.71	286.85	272.24	266.66	74.51	71.90
PYLLK	585.14	596.79	391.31	415.26	351.55	219.86
suma_neg	13670,19	13137,34	11679,16	13012,17	9431,74	9461,49

Note: 1* - Contaminated area, 2* Non contaminated area, sum_neg: SMRV - PYLLK

Health status of the population, according to the WHO general declaration, is caused mainly by the four factors as follows: lifestyle (way of life and work) accounts for about 50 % of all factors; genetic factors and the level of health care is attributed to a 10-20 % share; and environment (particularly its geological component) represents about a 20 % share. If we assume that the impact of the first three factors in contaminated and non-contaminated areas of the Slovak Republic is about the same, the decisive influence should be put down to different contamination levels of geological environment by PTE.

In all three regions PTE levels in soils are usually significantly higher in contaminated areas than in non-contaminated areas. The only exception is Cd content in the Upper Nitra region, which is slightly higher in the unpolluted area. This region, however, is especially contaminated by As as a result of brown coal combustion (by atmospheric deposition).With regard to the predominant character of polymetallic mineralization in the Middle Slovak Neovolcanics the most sizeable differences in Cd, Pb, Zn and Cu contents are evident in soils. In the Slovak Ore Mts. (with predominant polymetallic ores and Au-Sb ores) the most significant differences are shown in contents of Sb, Hg, Cu and As in soils.

In case of groundwater we have observed a considerable difference between contaminated and comparative areas only in case of As in the Upper Nitra region. The contents of other PTE in groundwater in contaminated and non-contaminated areas of the assessed regions are, in general, very similar. There is a clear relation to low PTE mobility in groundwater in the given hypergenic conditions mentioned above. In addition, the fact that in geochemical mapping and water sampling we tried to avoid extreme water sources – such as discharge from the drainage tunnels, tailings ponds, etc. – can also play an important role. We haven´t collected extreme soil samples either avoiding waste tips, tailings ponds, remnants of ore treatment plants and other extremely contaminated soil sources.

Based on the results of health indicators (Table 6) it is evident that no significant differences between health indicators in contaminated and non-contaminated areas were observed in any of the three evaluated regions. According to the summary health indicator (suma_neg), the population health status in the Middle Slovak Neovolcanics and Upper Nitra regions are almost exactly the same (between 13,670 and 13,137; between 9,431 and 9,461). Moreover, in the Slovak Ore Mts. the health of the population in a contaminated area (11,679) shows even more favourable figures than in the non-contaminated one (13,012). A very similar situation is described by individual health indicators as well. With regard to the objective of our study, the age indicators (the first four indicators) seem to be of minor importance. They tend to be distorted by population migration, especially moving of young people to big cities because of better job opportunities. They are alike in all three regions for contaminated as well as non-contaminated areas.

The only noticeable difference in these demographic indicators is that the life expectancy in the Upper Nitra region is about 2-3 years longer than in the other two regions. However, it results from the fact that geological environment of carboniferous strata prevails in this region and is more favourable to population health than the silicate rock environment (volcanic rocks, granites, metamorphic rocks) Rapant et al. (2013). In terms of influence of geochemical background of the rock environment on the health of Slovak population it has been proved that rock units of volcanics, granites and metamorphic rocks are much less favourable to human health than carboniferous rocks (limestones, dolomites, flysch sediments).

This stems particularly from the deficient content of Ca and Mg in groundwater/ drinking water in silicate geological units (Rapant et al., 2013). The average contents of Ca, Mg, water hardness and carboniferous composition of soils are significantly higher in the geological environment of the Upper Nitra region than in the other two regions. Moreover, a similar trend – less favourable values of health indicators in the areas of the Slovak Ore Mts. and Middle Slovak Neovolcanics compared to those in the Upper Nitra region – has also been reported in the rest of health indicators. It is reflected in a sizeable difference in sum of negative health indicators (suma_neg), which is by about 2,000 to 3,000 more favourable in the Upper Nitra region than in the other two regions subject to our assessment.

Increased PTP contents are in the world literature associated mainly with cancer (Bako et al., 1982; Fryzek et al., 2001; Cabrera and Gómez 2003). Neither basic indicators of oncological diseases (ReC, SMRC, PYLLC) nor any other specific cancer mortalities according to individual diagnoses (Table 6) show less favourable figures in the areas contaminated with PTE. Mortality due to cardiovascular disease copies a similar trend. We have observed increased mortality in PTE contaminated areas only in case of endocrine system diseases (ReE). Moreover, differences in the mortality become even more evident when taking into account the age of population (SMRE) reaching about 20 % figures in the silicate regions (the Slovak Ore Mts. and Middle Slovak Neovolcanics) but over 30 % in the Upper Nitra region. Adverse effects of PTE on mortality due to diseases of endocrine glands (especially diabetes, thyroid, diseases caused by malnutrition or excessive diet) have been described several times in the world literature (Lai et al., 1994; Gupta et al., 2001). The current level of knowledge, however, does not allow us to assess the impact of PTE on mortality due to diseases of endocrine glands objectively. This issue will be addressed in the next stages of our research using higher statistics, especially neuron networks. The other group indicators (ReK - digestive system, ReJ – respiratory system, ReN - genitourinary system) report no noticeable differences between contaminated and non-contaminated areas.

The contents of macroelements demonstrate more significant influence on the health status of the Slovak population than those of PTE. It is evident that especially deficiency of Ca and Mg in silicate rock environment in groundwater/drinking water accounts for increased incidence of cardiovascular and cancer diseases (Rapant et al., 2013). In addition, the detrimental impact of Ca and Mg deficiency in groundwater/drinking water on cardiovascular diseases has been described many times so far (Shaper et al., 1980, Rylander et al., 1991, Selinus et al., 2005). In the world literature deficient contents of Ca and Mg in groundwater/drinking water have also been associated with an increased occurrence of cancer

(Yang et al., 1999, 2000a, Chiu et al., 2004). Since both diseases are the ultimate cause of deaths in Slovakia, they are most markedly manifested in all the health indicators as well. Therefore, the observed differences in the health status of population in contaminated and non-contaminated areas are mainly linked with different contents of Ca and Mg. For instance, Ca and Mg contents in the Slovak Ore Mts. are significantly higher in contaminated than non-contaminated area, and this is probably the reason for better health of the population living in PTE contaminated area.

Chemical elements in groundwater/drinking water occur mainly in dissolved form, which is the most available form to human beings. Therefore, it is the reason why groundwater/drinking water has probably the major influence on population health, much more considerable than the soils. Regarding the PTE contents in groundwater/drinking water in the evaluated areas, they are predominantly low and about the same even in contaminated and non-contaminated areas reaching levels below the limits of drinking water standards.

The results obtained from the comparison of health indicators between contaminated and non-contaminated areas are staggering and contrary to the current knowledge. In general, poorer health status is predicted in areas contaminated with PTE. Nevertheless, our results suggest that the health status of population in contaminated areas is even slightly better than in non-contaminated ones. We explain this phenomenon as follows: bio-available proportions of PTE in soils in these areas are very low, often well below 5 % (Krčmová and Rapant, 2007, Rapant et al., 2009, Vaculík et al., 2013). Thus, only a small portion of PTE enters the food chain. The PTE contents in groundwater/drinking water are relatively low as well due to neutral to alkaline environment in the area. Even if the local inhabitants use the local groundwater for drinking purposes, there is no increased intake of PTE doses, which would affect their health status.

The increased PTE levels in vegetables grown locally (carrots, potatoes, parsley) were documented in contaminated areas in all evaluated regions showing almost twice as high values as in non-contaminated areas. However, in terms of overall PTE ingestion from food, this proportion of contaminated vegetables is practically very small and almost insignificant (Krčmová and Rapant, 2007, Rapant et al., 2009, Krčmová and Rapant, 2009, Rapant et al., 2010). Moreover, bio-monitoring results (including hair, nails, blood and urine) in the areas subject to our research also manifest slightly increased PTE levels in human materials in contaminated areas when compared to non-contaminated ones (Krčmová and Rapant, 2007, Krčmová and Rapant, 2009, Rapant et al., 2010). These levels, however, are in the vast majority under the set limit values for unpolluted environment and are rarely exceeded only in some municipalities (Rapant et al., 2006).

Thus, it is evident that PTE enter the local food chain and their contents show increased values also in human biological materials. Nevertheless, these contents are probably not high enough to be significantly reflected in the health status of the population. It seems that various adaptive mechanisms are applied in the population living in the contaminated areas resulting into a gradually developed resistance to increased PTE contents. Even in these contaminated areas it is the overall geochemical background, mainly the contents of macroelements, which might crucially affect the health status of the population (probably much more than the PTE contents).

In terms of PTE contents and their impact on the population health status we consider low PTE levels in groundwater as the most relevant fact (Table 5). Groundwater, which is routinely used for drinking purposes in the observed areas, have relatively low PTE levels and are mostly below the drinking water limits.

Thus, we can conclude that the historical areas with recorded PTE contamination in soils, e.g. sediments, but not in groundwater or surface waters used for drinking purposes, represent much lower risk to the health of local people than has been thought about recently.

CONCLUSION

The main aim of this study was to objectively assess the potential impact of PTE on human health in historical mining areas. The health status of population in municipalities situated in contaminated and adjacent non-contaminated areas was compared across three studied regions of the Slovak Republic. Contamination of the studied areas has been documented mainly in soils, while the contents of PTE in groundwater/drinking water were approximately the same and below the limits of drinking water standards.

We found no significant impairment in the health of the population living in the areas with higher PTE contamination compared to non-contaminated areas. Surprisingly, the health status of population in two assessed regions was reported as slightly better in the contaminated area than in the non-contaminated one.

Finally, we can conclude that if groundwater/drinking waters used for drinking purposes show no PTE contamination, the local population inhabiting these historical mining areas might be at much lower risk than has been, in general, reported so far.

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