Historical Mining Areas and Their Influence on Human Health

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Abstract

Aims: 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 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).

Methods: The contents of PTE were analysed in groundwater/ drinking water and soils. The health status of resident population was evaluated based on 43 health indicators classified according to the international classification of diseases (ICD, 10th revision), including mainly those indicators characterizing mortality on cardiovascular and oncological diseases. 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.

Results: 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.

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

Keywords

historical mining areas, potentially toxic elements, health indicators, health status

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1 Introduction

The connection between the geological environment and human health has been known since antiquity. Both excess and deficiency chemical elements in the environment can result in possible negative health effects. Most of the studies in medical geology and public health deal with the influence of potentially toxic elements (PTE) from geological materials (rocks, soil, water, stream sediments, ambient dust, etc.) in the environment on the health of local population in geogenically or anthropogenically contaminated areas. Research focused on the impact of increased arsenic contents, particularly in groundwater/drinking water, on human health is a typical example of these studies [1, 2]. Another important topic of concern is the historical mining sites throughout the world because of the potentially adverse impact on the local population of the mobilized geological materials containing PTEs [3, 4, 5, 6]. 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 historical 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 historic mining areas of the Slovak Republic, where higher PTE contents were observed in geological components of the environment, was compared with the health status of people 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 was to assess how, and to what extent, the PTE contamination of the geological environment might influence the health status of residents living in the selected historical mining areas.

2 Material

The connection between the contaminated geological environment in the selected historical mining sites and the health status of the local population has been assessed based on the data from national databases of environmental and health indicators [7].

The environmental indicators are the contents of chemical elements, components or values of chemical parameters analysed and measured in the environment [7]. 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 [8]. In addition, it is probable that PTE contents in groundwater and soils can influence human health to a great extent.

In Slovakia, groundwater is used as the source of drinking water for more than 90% of Slovak inhabitants [9]. 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 and also some adults are known to ingest soil as well. Thus, there are numerous ways that people can be exposed to the trace elements in soil. The soil and groundwater chemical contents are determined as "total contents" (way of digestion and sampling methods and chemical analysis [10, 11, 12].

The set of environmental indicators and their mean values for groundwater and soils in the Slovak Republic is summarized in Table 1 (according to [7]).

The total number of chemical analyses for groundwater was 20, 339 and for soils 10, 738. The data included 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 [13]. 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 [14]. We can say whether the assessed health is good 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 and to standard or published values for larger units within a sufficiently long period of time (i.e. decades).

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 minimally sufficient particularly concerning small-sized or problematic municipalities (military districts). The data of health indicators were obtained from the database of the Statistical Office of the Slovak Republic [15]. We only used the data describing demography and mortality. The data evaluating the incidence of specific 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 affected by the geological environment. The list of assessed health indicators with nationwide mean values is given in Table 5.

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 four (1 to 4 in Table 5) are considered as positive, i.e. the most favourable values are the highest values. The remaining 39 health indicators are negative, i.e. their most favourable values should be as low as possible reaching even zero values.

3 Methods

3.1 Elaboration of Environmental Indicators

When elaborating and calculating the environmental indicators we adopted the 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 conducted 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 or component for the evaluated territorial administration units (Slovak municipalities) based on the contents of all soil and water samples

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

GROUNDWATER (n=20 339)												
pH	**T.D.S.**	**COD_{Mn}**	**Ca+Mg**	**Li**	**Na**	**K**	**Ca**	**Mg**	**Sr**	**Fe**	**Mn**	**NH_4**
7.33	629.75	2.18	3.5	0.019	20.34	11.10	93.56	28.29	0.36	0.17	0.12	0.10
F	**Cl**	**SO_4**	**NO_2**	**NO_3**	**PO_4**	**HCO_3**	**SiO_2**	**Cr**	**Cu**	**Zn**	**As**	**Cd**
0.13	32.96	79.32	0.11	38.76	0.20	303.85	18.21	0.0013	0.0026	0.2673	0.0019	0.0010
Se	**Pb**	**Hg**	**Ba**	**Al**	**Sb**		Note: Data except of pH in $mg.l^{-1}$, Ca+Mg in $mmol.l^{-1}$					
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						

found in a related administration unit using the kriging method [7].

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).

3.2 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 and the 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 [16, 17, 18, 19].

Selection of health indicators was based on the International Classification of Diseases by the WHO 10th revision [20]. 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 per number of inhabitants. Indirect 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 the age of the 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 per number of inhabitants. Calculation methods of various health indicators or formulas used to calculate specific health indicators are given in Table 5. 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.

3.3 Determination of Contaminated/Non-contaminated Areas

It is possible to determine the influence of PTEs from abandoned mining sites on human health only in three regions with historical mining activities, 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 the Middle Ages. 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 since 1909. Currently, brown coal extraction yields reach about 2 million tonnes per year. This coal is primarily used for domestic heating in the region and as a source of fuel in a local power plant. The coal is characterized an extremely high content of arsenic (about 800 ppm by weight) and sulphur (about 2% by weight).

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

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 2). Contaminated or non-contaminated municipalities were selected based on the PTE contents in soils, since the contents of health risk elements in soils are of higher variability than in groundwater. Due to relatively high pH of water reaching almost neutral pH values of (as a result of abundant presence of carbonates in the ore veins) PTE mobility is seen as relatively very low. Under these conditions PTEs are removed from the groundwater and bound in soils and sediments.

Table 2: 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	**TDS**	**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												

Non-contaminated municipalities include those with PTE contents in soils not exceeding reference values for any of the assessed elements.

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. 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).

4 Area Description

4.1 Geological Setting

The geologic structure of the evaluated areas is composed of various geological-tectonic units and thus is represented by rocks of varied petrographic and geochemical character [21]. While the geological environment of the Middle Slovak Neovolcanics consists predominantly of Neogene volcanics, geological structure in the other two areas the geology is more complicated and contains rocks of diverse geological character.

The eastern part of the Slovak Ore Mts. area consists mainly of Lower-Paleozoic (Cambrian to Carboniferous) weakly metamorphosed flysch metasediments (metasandstones, metagreywackes, phyllites) and metavolcanics – basaltoid, keratophyre and rhyolite character. The western part consists dominantly of 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 %) consists of 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

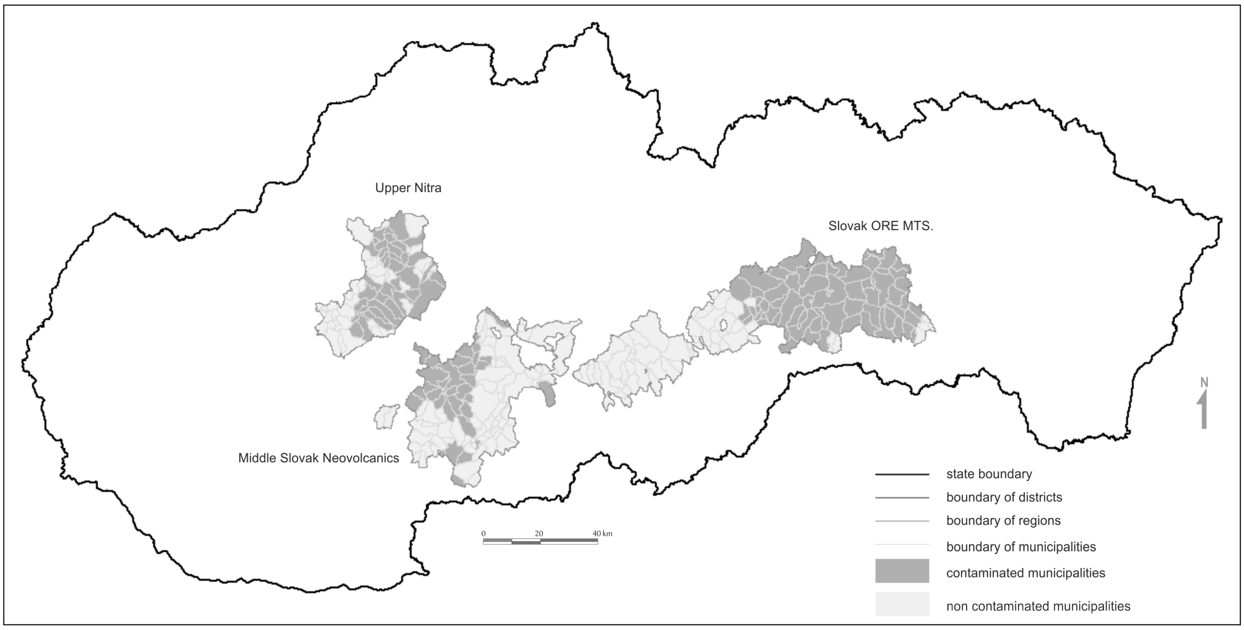

Figure 1: Contaminated and non-contaminated areas of the Slovak Republic.

Table 3: 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

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 consists mainly of 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 Tertiary sedimentary units constitute between 40 to 45 % of the studied area. The Mesozoic (mostly carbonates) complexes in surrounding core areas consist mainly of a number of limestones and dolomites with andstones, shales and quartzites covering about 20 % of the investigated area. The crystalline marginal core areas are primarily composed of acidic granitoid rocks with about 20% of the area covered by migmatites and gneisses. About 20% of the studied area, particularly in the Eastern border, consists of 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.

4.2 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 districts has been carried out in the Slovak Republic in recent years [22, 23]. 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 similar. It seems that comparison of unemployment rates may be the most accurate method of assessing the economic situation of people living in contaminated and non-contaminated areas (Table 3). According to Table 3, displaying unemployment rate figures in contaminated and non-contaminated areas for the three regions, it is evident that the unemployment rate is about the same comparing data for 2001 and 2011. 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.

5 Results and Discussion

Basic characteristic of the selected chemical elements in groundwater and soils (environmental indicators) of the studied areas is given in Table 4. The characteristics of population health status in the evaluated contaminated and non-contaminated areas are presented in Table 6.

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 are about the same, the decisive influence should be put down to geological factors and 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, Pb and As in soils.

In case of groundwater we have observed a considerable difference between contaminated and non-contaminated 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 water sources such as discharge from the drainage tunnels, tailings ponds, etc., can also play an important role. We haven´t collected soil samples from waste tips, tailings ponds, remnants of ore treatment plants and other extremely contaminated soil sources, too.

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 regions. According to the summary health indicator (sum_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 the 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). In terms of the influence of the geochemical background of the rock environment on the health of the Slovak population it has been proven that rock units of volcanics, granites and metamorphic rocks are much less favourable to human health than carboniferous rocks (limestones, dolomites, flysch sediments) Rapant et al. [7].

This stems particularly from the deficient content of Ca and Mg in groundwater/ drinking water in silicate geological units [7]. 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 the sum of negative health indicators (sum_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 PTE contents are in the world literature associated mainly with cancer [24, 25, 26]. 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 has a similar trend. We have observed increased mortality in PTE contaminated areas only in the 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 [27, 28]. 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) show 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 [7]. In addition, the detrimental impact of Ca and Mg deficiency in groundwater/drinking water on cardiovascular diseases has been described many times so far [29, 30, 31]. In the world literature deficient contents of Ca and Mg in groundwater/drinking water have also been associated with an increased occurrence of cancer [32, 33, 34]. 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, considerably much more 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 surprising and contrary to the current assumptions. In general, poorer health status is predicted in areas contaminated with PTE. Nevertheless, our results suggest that the health status of populations in both, contaminated and non-contaminated areas is at the same level or slightly better in contaminated areas. We explain this phenomenon as follows: the bio-available proportions of PTE in soils in these areas are very low, often well below 5 % [6, 35, 36]. Thus, only a small portion of the 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 [6, 35, 37, 38]. Moreover, biomonitoring 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 areas [35, 37, 38]. These levels, however, are in the vast majority under the set limit values for unpolluted environment and are rarely exceeded only in some municipalities [39].

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 reflected in the health status of the population. It seems that various adaptive mechanisms can apply in the population living in the contaminated areas. 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 4). Groundwater, which is routinely used for drinking purposes in the observed areas, has relatively low PTE levels and is mostly below the drinking water limits.

Thus, we can conclude that the historical areas with recorded PTE contamination in soils or 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.

6 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, no significant differences between the health status of population living in contaminated areas and that living in non-contaminated areas were observed. 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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Table 4: 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 5: 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

Table 6: Characteristics of population health status in contaminated and non-contaminated areas (data recalculated according to number of inhabitants in respective municipalities).

	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
sum_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