Potential Influence of Geochemical Background on the Health State of Population of the Slovak Republic

RAPANT, S.[1], KHUN, M.[2], JURKOVIČ, Ľ[2]. and LETKOVIČOVÁ, M.[3]

[1]Geological Survey of the Slovak Republic, Mlynská dolina 1, 817 04 Bratislava
[2]Department of Geochemistry, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava
[3]ENVIRONMENT, P.L.C., Dlhá 8, 949 01 Nitra

Abstract. The paper presents possibilities for using geochemical databases for solving problems of the influence of geological environment contamination on the health state of people. Using statistical methods it was confirmed that significant correlation exist between chemical elements in stream sediments of Slovakia (analysed for As, B, Be, Bi, Ca, Co, Cr, Cu, Hg, Mn, Sb and Se) and demographic and medical indicators of the health state of population of the Slovak Republic (e.g. PYLL – potentially lost years of life; POD-2500 – low birth weight expressed in percentage from all born children per 100 000 inhabitants, CaUMR – mortality rate due to all types of malignancy per 100 000 inhabitants; HUO – gross mortality of inhabitants; etc.).

Key words: medical geology, geochemistry and health, Slovakia

Introduction

Along the life style (the way of life and work), genetic factors and the level of health care the environment is one of the critical factors influencing the health state of population and thereby also the quality of life and life expectancy of people. Its significance and influence rises especially in polluted regions where even a geographically important occurrence of increased sickness rate can appear.

Geographical factors of extension of some diseases are known virtually since the existence of medicine as a science. Already in the 4th century A.D. the Chinese were familiar with the influence of environmental factors on the human health, especially related to an endemic occurrence of struma. Despite the fact that the medical science knows long ago that the sickness rate of some diseases in some individual parts of the world is different, the medical geography or geographical medicine as a science originated virtually just in the first decades of the 20th century. Of course, during the study of spread of various diseases, in geographical terms, some connections have been sought particularly related to climatic or topographic factors. However, in most cases the connection of geography and medicine can not explain the causality between significant geographical differences and spread of some diseases. In order to resolve this causality responsibly it is absolutely necessary to use geochemical information. Than, in this manner, the space for independent scientific field – medical geochemistry has been opened.

Chemical elements and their relationship to diseases

The relationship between the geochemical background and the human is far closer than generally supposed. A state of illness of a human occurs if the balance between the organism and factors of external environment is disturbed. This can happen due to the influence of endogenous factors (state of organism of an individual human) as well as due to the effect of exogenous factors (the influence of environment). Then, geomedical research can be applied here. Medical geochemistry deals with the application of geochemistry and geochemical mapping to the health state of plants, animals and humans.

Medical geochemistry, as a branch of geomedicine, is a scientific field that deals with the influence of chemical composition of geochemical environment of natural and anthropogenous origin, waters, soils, recent sediments and rocks to the human and animal health in the context of external environmental factors (Khun, 1992).

Nowadays, a great amount of examples exist in literature where the causal relation between an excess or a lack of chemical elements in geochemical environment and an increased occurrence of some diseases has been shown on various world and slovak localities. In the table 1 selected examples are presented, processed based on several literature sources (Zýka, 1975, Fergusson, 1990; Bencko at al, 1991; Khun, 1992; ATDSR, 1992; Thorton,1993; Alloway-Ayres, 1993; Škárka – Ferenčík, 2000; WHO, 1996 and others). Apparently, the table shows that nowadays the influence of the excess of individual ele-

Table 1 The influence of deficiency or excess of chemical elements in geochemical environment on the occurrence of some diseases

	Deficiency	Excess
Al	–	– Alzheimer disease
As	– insufficient hair growth – enlargement of spleen	– skin, lungs cancer – terratogenic effects – skin diseases
B	–	– alimentary canal diseases
Ba	–	– mechanic damage of lungs – stomach cancer – nerves poison – influence on the central nerve system
Be	–	– „Urov disease„ – beryliosis – professional or long-time exposures – carcinogenity, elephantiasis
Ca	– bones deformations – cardiovascular diseases (water hardness)	– uric acid stones – atherosclerosis, hyperthension – related to the water hardness (Ca+Mg) – inverse relation of mortality from these diseases to water hardness
Cd	– growth reduction	– prostate cancer – environmental carcinogen
Ce	–	– positive correlation with skin cancer and other malignant melanomas
Co	– anaemia – avitaminosis	– thyroid diseases (Co / I ratio)
Cr	– diabetes	– carcinogenity, especially in a professional exposure – lungs cancer related to Cr content in asbestos
Cu	– anaemia	– Cu – toxicosis – relation of Cu content in water to athersosclerosis
F	– defects in bones and teeth evolution (caries)	– spottiness of teeth (fluorosis) – relation to hearth diseases in areas with high F content
Fe	– anaemia	–
Hg	– unknown	– relation between Hg and I contents in environs with spread of struma – disorders of central nerve system – acute toxic – effect on saddles, liver – environmental carcinogen
K	–	– virtually intoxic – possible influence on hyperthension
Li	– relation between deficiency in drinking water and atherosclero-sis	– assumed „protective„ functions
Mg	– deficiency is related to phatogenesis of cancer – „anticarcinogenic„ influence – cardiovascular diseases (water hardness)	– anaesthesia – relation to cardiovascular diseases (Ca+Mg)
Mn	– skeleton deformations	– shakiness of limbs – defective hearing
Mo	– teeth defectiveness – caries	– diseases of alimentary canal at livestock – reduction of growth
Na	–	– cardiovascular diseases
Ni	– skin diseases	– carcinogenity (tetracarbonyl Ni, Ni in asbestos)
P	– rachitis	– minor relation between geochemical distribution of P and diseases
Pb	–	– sclerosis multiplex – carcinogenity in relation to Pb content in soils – positive correlation between Pb content in drinking waters and mortality from cardiovascular diseases
Rn	–	– lungs and windpipe cancer – cardiovascular diseases
Sb	–	– professional exposure – poisonings, skin and eyes damage, respiratory problems – long-time exposures – respiratory problems, cardiovascular diseases, gastrointesti-nal defects
Se	– Keshan disease – endemic myocarditis, can cause progress of tumours in animal systems, sterility	– alimentary canal defects skin hyperpigmentation, changes on nails
Sn	– reduced growth	– indirect influence (at professional exposure)
Sr	–	– diabetes – „Urov„ disease – negative correlation between Sr content in environment and mortality from cardio-vascular diseases – increased Sr content in cancerous tissues
Ti	–	–
V	– cardiovascular diseases	– negative influence at professional exposure only
W	–	– negative influence at professional exposure only
Zn	– strong reduction of growth – bad curability of wounds	– increased mortality from cancer (predominantly stomach)
Zr	– decrease in number of red corpuscles	– relation to elephantiasis

Ca+Mg (water hardness)	– negative effect of soft water on cardiovascular system – positive correlation between water hardness and some forms of cancer
NO_3^-	– alimentary methemoglobinemia – carcinogenic effect of nitrates metabolites – nitrites, nitrosamines

ments, especially toxic metals, on the occurrence of diseases is much more known, proved and evaluated than the influence of the deficiency of chemical elements. In industrially developed countries the cases of diseases resulting from primary and simple deficiency of trace elements are relatively rare, because the consummation of food from various parts of the state or even continents guarantees the minimum necessary reception of all elements. The influence of the deficiency is manifested especially locally in developing countries, where the majority of food is provided by the population itself from local sources.

Environmental geochemistry and medical geochemistry in Slovakia

Based on the extensive geochemical mapping of the territory of the Slovak Republic, carried out in the 1990's by means of geochemical atlases and environmental-geochemical maps (Vrana et al ,1997; Rapant et al.,1999), several areas with extensive contamination of waters, soils, sediment, rocks, especially by toxic elements but also by major elements as well as organic pollutants, have been documented. These areas include mainly the regions with historical mining of mineral raw materials as well as regions with highly developed industry and agriculture. In several of these areas concentration of various harmful (including carcinogenic, mutagenic and toxic) elements and materials are known in such concentrations that a reasonable suspicion exists about the highly negative impact of the polluted environment on the human health. A representation of the global environmental load of the Slovak Republic by toxic elements is clear from the figure 1 – *Distribution of the degree of stream sediments contamination in Slovakia.* Spišsko-gemerské rudohorie Mts. region is one of the areas where the geochemical environment is characterised by high concentrations of toxic elements, but furthermore also for example by pollution from alkaline emissions from magnesite industry, contamination from agriculture and other anthropogeneous activities. Just this region was selected as a pilot area, where the Geological Survey of the Slovak Republic in collaboration with several other environmentally oriented organisations nowadays elaborates and tests the methodology of evaluation of the geochemical environment contamination in relation to the health state of population (Rapant et al., 1998). Within the framework of this project methodological procedures of connecting geochemical data with demographic and medical data are elaborated and evaluated. Apart from the total content of elements in individual environmental components, also the forms of their occurrence are monitored – speciations, their bioavailability and toxicity. Concentrations of major elements, toxic elements, but also selected organic macro- and micropolutants are evaluated and correlated. In collaboration with the State Health Institute, Košice the achieved results are processed and evaluated by direct medical monitoring on people living in the most contaminated areas.

Study of the health state of population is in focus of many scientific fields, among those geology and geochemistry has an important place. Geological structure determines the character and mode of exploitation of a country, while on the other hand it governs also its chemical composition. In Slovakia medical-geological research appears in a limited amount already for more than 50 years. The extensive study of an endemic struma occurrence in relationship to the geochemical environment, performed by Podoba in years 1949-1953 (Podoba, 1962) can be presented perhaps as the first work with implication of medical geochemistry in Slovakia. Deficient areas related to iodine content, which significantly correlated with the occurrence of endemic strum, have been determined. Among the more recent studies the medical-geochemical research in the Žiarska kotlina region has to be mentioned (Khun et al., 2000), where the health state of the monitored children population was related to the potential negative influence of the geochemical background (e.g. fluorine content in soil and sediments, concentration of nitrates in drinking water, etc.).

The problem of the negative impact of a polluted environment on the human health is complicated not only from the practical but also from the human and social point of view. Industrial evolution gives birth to an increase of social and economic standard of people, but on the other hand it usually determines the deterioration of the state of environmental contamination and consequently the increase of the negative impact of geochemical background of a country on the human health. Generally it is assumed that the environment of life (and work) participates approximately with 20 % on the health state of people. The life style (the way of life and work) is the most important with about 50 % of participation. Genetic factors represent 20 % and the level of the public health service has 10 % of influence. However, in heavily polluted areas the contribution of the environment to the health state of population can be markedly higher.

Demographic and medical indicators

Health and diseases have a very broad scale of characteristics and features that can be used as indicators. Generally, health state indicators, as well as indicators related to some exposure, have to satisfy some requirements. They have to be relevant in term of the health policy and they have to by simple and understandable, well reflecting state changes, and also they have to have a goal and a threshold value. Moreover they must be able to merge into relational units in information systems. Due to scientific conditions of construction and application of health indicators, their theoretical justification and their validity are based on international standards. Characteristics of the human health are influenced besides the risk factor itself also by the duration of exposure. On the other hand, apart from the risk factors, duration of exposure and their intensity, the ability of an organism to compensate damages in organism, that could lead to an apparent (clinic) injury or a disease, work in the opposite way.

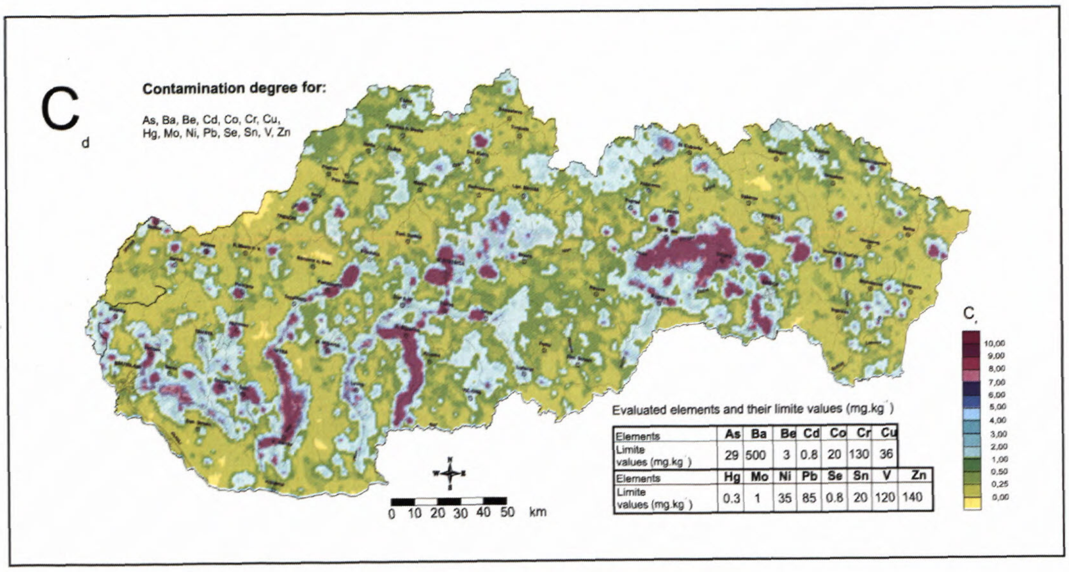

Fig. 1 Map of the degree stream sediments contamination in Slovakia.

Moreover, the level of the medical care has also a significant role. All these mutually combining and variably interfering components will be manifested in the health of population.

All medical and demographic data, used in the current medical-geochemical research in Slovakia, represent data validated by the National Institute of Health of the Slovak Republic. Data used in calculations represent average values from a five-year period, namely for the years 1993 –1997. The distribution of selected health state indicators in 79 counties and in 2 873 health-regional units of Slovakia is shown in figure 2.

Health state of population indicators, used below, could be divided into following main groups:

- demographic data
- reproduction health of population data
- total mortality rate
- mortality rate due to malignancy
- chronic diseases of lungs
- cardiovascular diseases

In all of the above groups several individual groups are evaluated in terms of the age and sex and various separate diagnosis are followed. The health state of population of the Slovak Republic is evaluated in 2 873 medical-territorial units (MTU) that according to the character of settlement could be divided in the following way:

towns (≥10 000 inhabitants)	*72 MTU*
country (<10 000 inhabitants)	*2 801 MTU*
country – villages with <500 inhabitants	*1 208 MTU*
country – villages with 500 – 1 999 inhabitants	*1 298 MTU*
country – villages with 2 000 – 9 999 inhabitants	*295 MTU*

Linking of health state indicators and geochemical data

In evaluation of the potential influence of a geochemical environment we come out of an assumption that increased concentrations of contaminants in environment are negatively manifested in the health state of population, i.e. they are manifested in an increase of values of unfavourable health indicators or in changes of links among them. Hence these changes have to be quantified at least by a few of the followed set of health state indicators and they have to show a statistical dependency among the evaluated variables.

Valid linking of databases is conditioned by the application of convenient statistical methods and correct databases. Correlation coefficients are used for the expression of tightness of a stochastic relation between two random variables, representing the characters being evaluated. Classic pair coefficient expresses the extent of the linear stochastic relation. However, the relation between studied characters naturally could have also a different character. The most classic correlation coefficient is sensitive towards possible extreme values. Due to the above reasons we have selected the Spearman serial correlation coefficient for the analysis of dependency of studied features - the element content in geochemical environment and the indicator of the health state:

$$\rho = 1 - \frac{6}{n(n^2 - 1)} \sum_{i=1}^{n} (d_i - s_i)^2 ,$$

where

n is the range of the selected set,

d_i ($i = 1, 2, ..., n$) are series of the first character,

s_i ($i = 1, 2, ..., n$) are series of the second character.

For $n \geq 8$ we use H_0 for the verification of the validity of the zero hypothesis: $\rho = 0$ test statistics

$$t = \frac{|\hat{\rho}|\sqrt{n-2}}{\sqrt{1-\hat{\rho}^2}},$$

that has asymptotically the division of Student with (n-2) degrees of freedom.

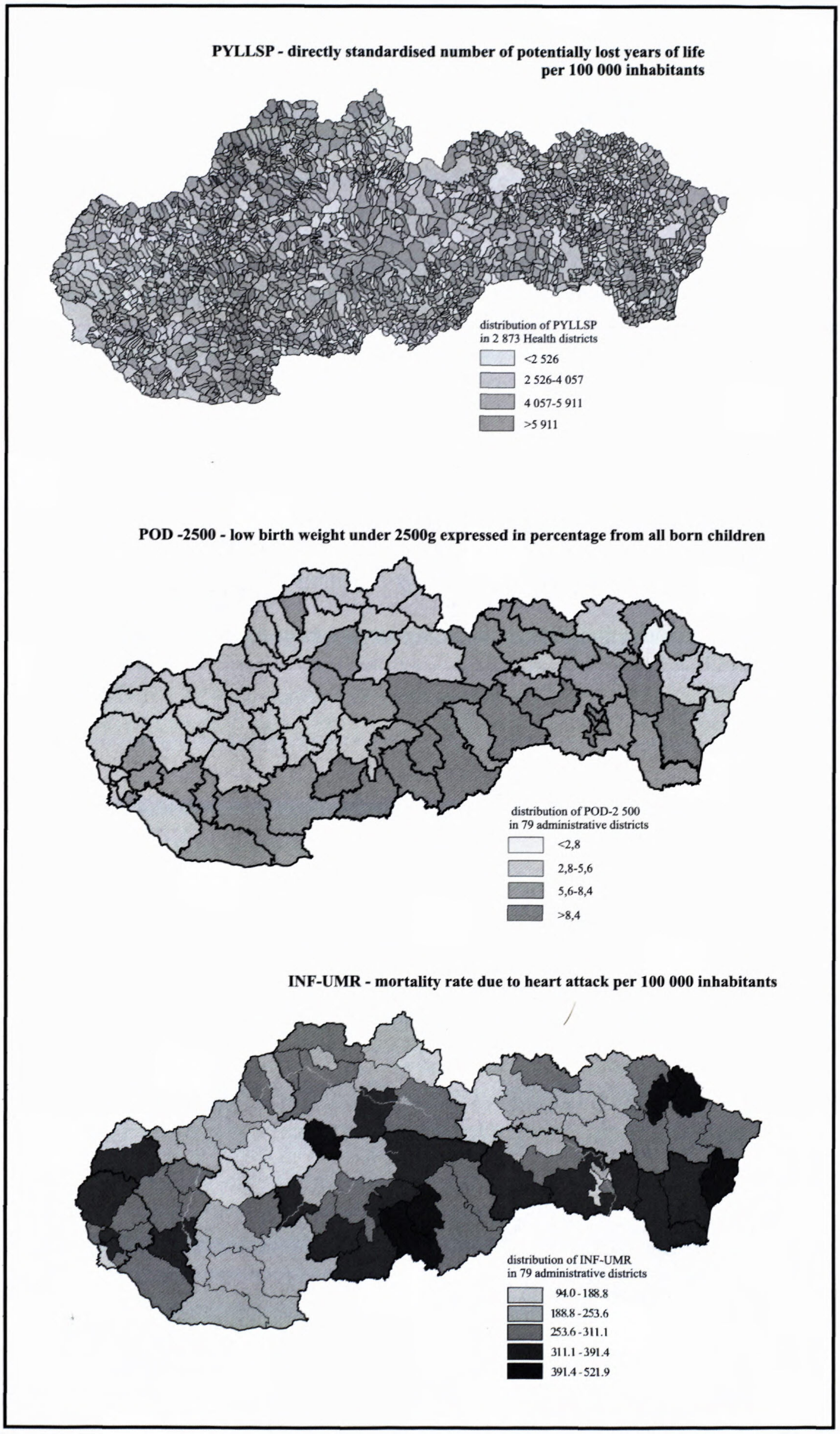

Fig. 2 Distribution of selected indicators of health state for 79 administrative counties and 2 873 health-regional units

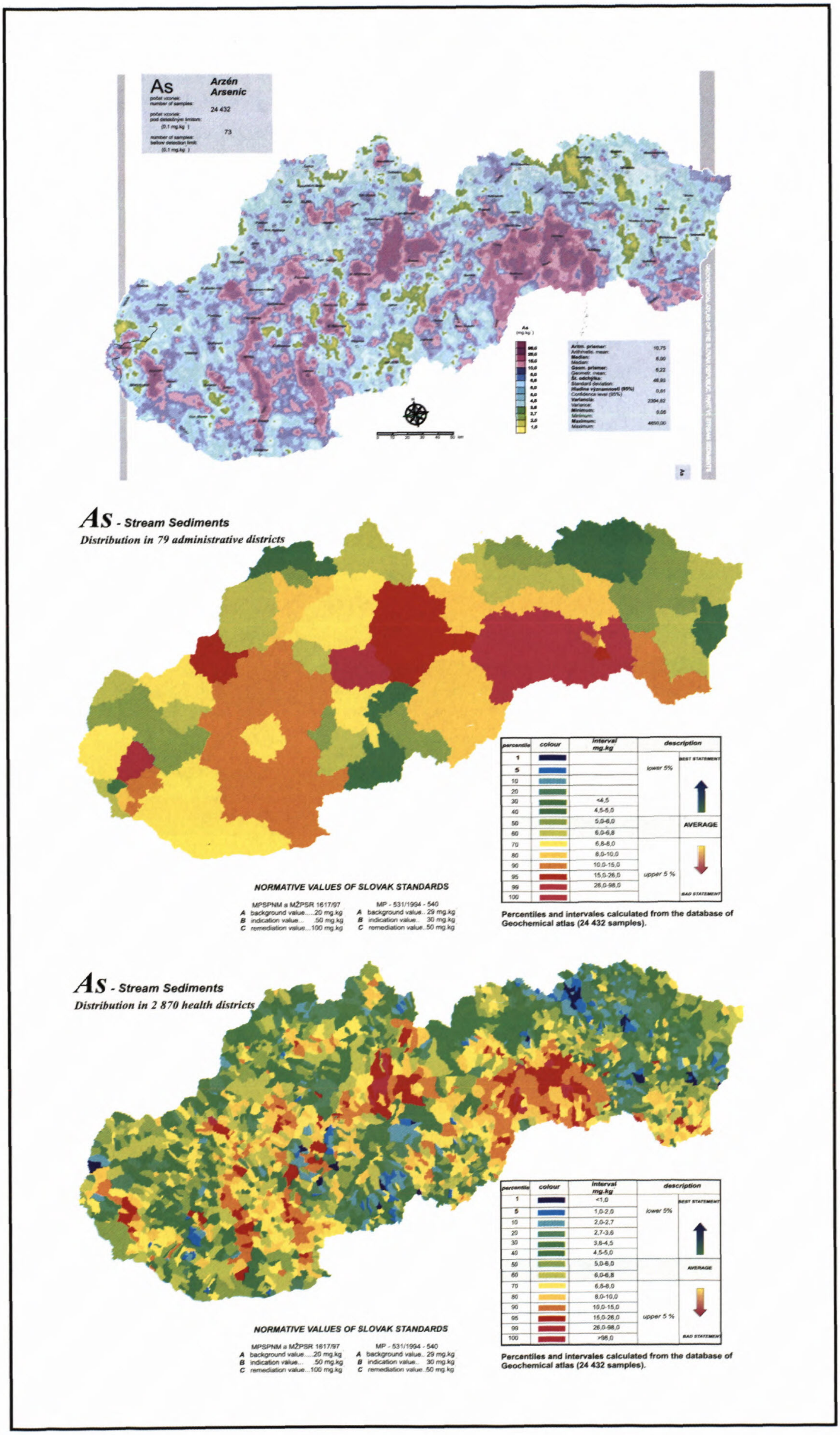

Fig. 3 Data transformation from Geochemical atlas of stream sediments into 79 administrative counties and 2 873 health-regional units

The zero hypothesis is rejected at the confidence level α if the test statistics value t is bigger or equal at the most to value 1-α of the quantile χ^2 division with (n-2) degrees of freedom. Then we say that values of studied characters do not (significantly) correlate.

If the same series of the first character d_i (i = 1, 2, ..., n), or second character s_i (i = 1, 2, ..., n) occur, it is necessary to perform a correction during the calculation of the Spearman correlation coefficient as well as the test statistics.

Dependencies between indicators of the health state and concentrations of a chemical element are regarded as stochastically confirmed if the calculated values of confidence level α reach less than 0.05. The following empirical evaluation is used to express a proof for the calculated relations:

$\alpha \leq 0.001$	very high dependence	+++
$\alpha \leq 0.01$	high dependence	++
$\alpha \leq 0.05$	proved dependence	+

Achieved results and their discussion

The evaluation of the methodology of searching stochastic dependencies between geochemical data and indicators of the health state of population was performed on nine chemical elements ***As, B, Be, Ca, Cr, Cu, Hg, Sb and Se*** in stream sediments of Slovakia and on four health indicators – ***PYLL*** (directly standardised number of *potencially lost years of life*), ***POD-2500*** (low birth weight expressed in percentage from all born children), ***Ca-UMR*** (mortality rate due to all types of malignancy per 100 000 inhabitants) and ***INF-UMR*** (mortality rate due to heart attack per 100 000 inhabitants).

Geochemical databases and databases of demographic and health indicators were unified in equivalent forms according to administrative and health-regional units (fig. 3). Average concentrations of chemical elements from points falling within individual administrative units have been calculated. In this manner they have been processed for 79 administrative counties and 2 873 health-regional units in a graphic as well as in a database form. In first approach relations of nine chemical elements in stream sediments and four indicators of the health state of population have been statistically tested for the whole Slovak Republic (2 873 MTU) and all studied groups of town and country inhabitants.

Values of calculated Spearman correlation coefficients, confidence levels α together with empirical evaluation of provableness of the studied features for 2 799 health-regional units of country inhabitants, are shown in table 2. The achieved results show that significant correlation has been confirmed statistically between the distribution of several chemical elements and the occurrence of individual indicators of the health state. In some cases, the high confidence level of correlation, together with literature knowledge of the influence of individual chemical elements on the human health, indicates that the presented stochastic relations could be regarded for causal in several cases, e.g. the distribution of As vs. POD-2500 and PYLL, Sb vs. POD-2500, Cu vs. PYLL and others.

Considering the variability of features and reasons related to the health state of population (apart from the geochemical background) the correlation coefficient values are relatively low. If nation-wide data are recalculated (2 801 correlated variables) the values reach only about 0.1 or less (table 2). In addition to the correlation coefficients values the confidence value α of calculated coefficients also represents the significance and dependence between correlated features and sets. Higher values of correlation coefficients have been recorded for calculations of 79 counties. (table 3). Directly in the pilot area of the Spišsko-Gemerské Rudohorie Mts., where regarding the relatively high degree of contamination of the geological component of the environment the influence of the geochemical environment on the the health state of population can be expected to be higher, correlation coeficients reach values 0.3–0.5 (table 3) beside values of α less than 0.001. Within the area of the Spišsko-Gemerské Rudohorie Mts. the causality of negative influence of increased chemical elements concentrations in geochemical environment on the health state of population is confronted with common geochemical and medical studies in one of the most contaminated villages of the area – Zlatá Idka. In this village primarily the Sb and As contents are increased (geo-induced) in all parts of the geological environment – ground and surface waters, sediments, soils as well as in forest biomass. The State Health Institute, Košice (Dietzová, 2000) concurrently monitors As and Sb contents in biological materials of people (blood, urine, hair and nails) and moreover it traces concentrations of these elements in locally grown vegetables and fruits. In several cases an overrun of particular biological limits of the followed toxic metals was recorded in biological materials of people.

The performed calculations of geochemical and medical-demographic data for individual groups of inhabitants unequivocally show that the usage of parameters for country inhabitants is the most suitable for the evaluation of the characteristic of the potential influence of geochemical background on the health state of population.

Furthermore, it is probable that chemical elements, regarding their relations to individual health indicators, could be divided into:

„Causal elements„ (e.g. Cd, Hg, As, Sb,...) – with proved relationship between health indicators and excess or deficiency of a chemical element in the geochemical background and

„Indicating elements„ (e.g. Bi, Be,...) – with high stochastic dependence thanks to the geochemical relationship with causal elements.

Conclusions

The solving of problems of the influence of geochemical background on the health state of population is currently just in the stage of verification of preliminary results and processing of methodical procedures. Proposed methodical principles of linking geochemical data with medical and demographic indicators of the health

Table 2 Spearman correlation coefficients, confidence levels α and significance of relations dependencies of selected chemical elements in river sediments of Slovakia and indicators of the health state of population of the Slovak Republic – country inhabitants (2 801 MTU)

		N	Spearman S	t(N-2)	α	significance
As	*PYLL*	2 801	0.04994	2.64465	0.00822	++
As	*PODM_2500*	2 801	0.06317	3.34734	0.00083	+++
As	*CA_UMR*	2 801	0.04062	2.15011	0.03163	+
As	*INF_UMR*	2 801	0.06326	3.35220	0.00081	+++
B	*PYLL*	2 801	0.01940	1.02594	0.30501	
B	*PODM_2500*	2 801	0.00560	0.29593	0.76731	
B	*CA_UMR*	2 801	0.02940	1.55569	0.11990	
B	*INF_UMR*	2 801	-0.03000	-1.58733	0.11255	
Be	*PYLL*	2 801	0.06899	3.65751	0.00026	+++
Be	*PODM_2500*	2 801	0.06196	3.28309	0.00104	++
Be	*CA_UMR*	2 801	-0.05499	-2.91272	0.00361	++
Be	*INF_UMR*	2 801	-0.01335	-0.70611	0.48018	
Ca	*PYLL*	2 801	-0.01496	-0.79128	0.42885	
Ca	*PODM_2500*	2 801	-0.01740	-0.92052	0.35738	
Ca	*CA_UMR*	2 801	0.06251	3.31256	0.00094	+++
Ca	*INF_UMR*	2 801	0.04396	2.32739	0.2002	+
Cr	*PYLL*	2 801	-0.02395	-1.26692	0.20529	
Cr	*PODM_2500*	2 801	0.00848	0.44871	0.65367	
Cr	*CA_UMR*	2 801	0.03710	1.96349	0.04969	+
Cr	*INF_UMR*	2 801	-0.04647	-2.46040	0.01394	+
Cu	*PYLL*	2 801	0.07227	3.83238	0.00013	+++
Cu	*PODM_2500*	2 801	-0.00652	-0.34477	0.73030	
Cu	*CA_UMR*	2 801	0.02094	1.10744	0.26820	
Cu	*INF_UMR*	2 801	0.03612	1.91156	0.05603	
Hg	*PYLL*	2 801	0.03577	1.89295	0.05847	
Hg	*PODM_2500*	2 801	0.05922	3.13737	0.00172	++
Hg	*CA_UMR*	2 801	0.01713	0.90587	0.36508	
Hg	*INF_UMR*	2 801	0.08620	4.57603	0.00000	+++
Sb	*PYLL*	2 801	0.01521	0.80426	0.42132	
Sb	*PODM_2500*	2 801	0.07654	4.05987	0.00005	+++
Sb	*CA_UMR*	2 801	0.00421	0.22277	0.82373	
Sb	*INF_UMR*	2 801	0.03594	1.90206	0.05727	
Se	*PYLL*	2 801	-0.00192	-0.10170	0.91900	
Se	*PODM_2500*	2 801	-0.04736	-2.50745	0.01222	+
Se	*CA_UMR*	2 801	0.05568	2.94949	0.00321	++
Se	*INF_UMR*	2 801	0.00687	0.36352	0.71624	

$\alpha \leq 0.001$ very high dependence +++
$\alpha \leq 0.01$ high dependence ++
$\alpha \leq 0.05$ proved dependence +

state of population are currently being elaborated in all geochemical environments (soils, waters, sediments) and in much broader range of chemical elements and indicators of the health state of population. Thereafter, they will be a basis for working-out analyses of the environmental risk and in the most critical areas for analyses of the health risk. In addition, results of special laboratory work, mainly the assessment of the occurrence of evaluated toxic elements and toxicity tests (acute and chronic) on samples of waters, soils and sediments, will be used.

The proven significant relation between medical and environmental-geochemical parameters could provide a very important tool for the environmental analysis in decision processes. The outlined approach for the evaluation of the influence of geochemical background on the health state of population will provide a possibility to discover health risk in time. Even if the risk can not be entirely avoided, their consequences can be minimised at least.

Table 3 Statistic relation between chemical elements contents in river sediments and indicators of the health state of population

Element	Health indicator	R	α	***Significance***
		79 counties of Slovakia		
Co	*PODM_2500*	0.001	0.973	
	HÚO	0.391	0.000	+++
	PPÚO	0.351	0.002	++
	PYLL	0.376	0.001	+++
Mn	PODM_2500	0.325	0.004	++
	HÚO	0.314	0.006	+
	PPÚO	0.332	0.003	++
	PYLL	0.368	0.001	+++
		82 MTU of the Spišsko-gemerské rudohoria Mts.		
As	*PPÚO*	0.472	0.000	+++
	UMR_ZNP	0.335	0.002	++
	PYLL	0.284	0.009	++
	PODM_2500	0.090	0.419	
Bi	*PPÚO*	0.454	0.000	+++
	UMR_ZNP	0.148	0.182	
	PYLL	0.198	0.074	
	PODM_2500	-0.02	0.799	

Note: R – Spearman order correlation coefficient; α - confidence level; PYLL (directly standardised number of potentially lost years of life); PODM_2500 (percentage of children with birth weight under 2500g); HÚO (gross mortality rate of population); PPÚO (percentage of untimely deaths of inhabitants over 65 y.); UMR_ZNP (mortality rate due to lungs malignancy per 100 000 inhabitants)

Literature

Alloway, B. J. & Ayres, d. c. 1993: *Chemical Principles of Environmnetal Pollution.* Blackie Academic and Professional, 291 p.

Augustín, J. & Zejda, R. 1991: *Cancer incidence and geochemical factors in the environment.* The Sci. Tot. Environment, 106, p. 155–163.

ATSDR – Agency for Toxic Substance and Disease Registry, 1992: Toxicological Profile for Antimony. U.S. Public Health Service, U.S. Department of Health and Human Service. Atlanta. GA, 245 p.

Bencko, V., Cikrt, M. & Lener, J. 1995: *Toxické kovy v životním a pracovním prostředí člověka.* GRADA Publishing. Praha, 282 p.

Bodiš, D. & Rapant, S. eds., 1999: *Geochemical Atlas of Slovak Republic-part VI.- Stream sediments.* Monography, Geol. Survey of Slovak Republic, Bratislava, 145 p.

Bodiš, D. & Rapant, S. 2000: *Environmental Geochemistry and Environmental-Geochemical Mapping of the Slovak Republic.* Slovak Geol. Magazine. 1/2000. GS SR, Bratislava. p. 5–16.

Dietzová, Z. 2000: *Odhad zdravotného rizika z arzénu a antimónu prítomného v životnom prostredí u obyvateľov obce Zlatá Idka.* Manuskript ŠZÚ Košice.

Fergusson, J. E. 1990: *The Heavy Elements: Chemistry, Environmental Impact and Health Effects.* Pergamon Press. 614 p.

Khun, M., 1992: Medical geochemistry. Temporary teaching texts. Manuscript. Department of Geochemistry, Faculty of Natural Sciences, Comenius University, Bratislava, 66 p (in Slovak).

Khun, M., Jurkovič, Ľ. & Urminská, J. 2000: *Medical Geochemistry: A Brief Outline oh the Problems and Practical Application in the Region of Žiarska kotlina Basin.* Slovak Geol. Magazine. 1/2000. GS SR, Bratislava, p. 17–26.

Letkovičová, M., Stehlíková, B, Smatanová, K. & Ďurov, M. 2000: The evaluation of potential influnce of geochemical environment on the health state of population in region SGR – Analysis of indicators of demographical development and health state of population in SGR. Partial report, Manuscript. ENVIRONMENT, a.s. Nitra (In Slovak).

Podoba, J. 1962: *Endemicka struma na Slovensku.* Vyd. SAV, Bratislava, 187 p.

Rapant, S., Bodiš, D., Mackových, D. Mjartanová, H. Čížek, V. & Pramuka, S. 1998: The evaluation of potential influnce of geochemical environment on the health state of population in region SGR. Project of geological works. Manuscript. GS SR, Bratislava (In Slovak).

Rapant, S., Rapošová, M., Bodiš, D., Marsina, K. & Slaninka, I. 1999: *Environmental–geochemical mapping program in the Slovak Republic.* Journal of Geochemical Exploration. 66 (1999). p. 151–158.

Škárka, B. & Ferenčík, 2000: *Biochémia.* Slovak academic Pres, spol. s r. o., Bratislava.

Thorton, I. 1993: *Environmnetal geochemistry and health in the 1990s: a global perspective.* Applied Geochemistry. Supp. Issue, No 2, p. 203–*210.*

Vrana, K., Rapant, S., Bodiš, D., Marsina, K., Lexa, J., Pramuka, S., Maňkovská, B., Čurlík, J., Šefčík, P., Vojtaš, J., Daniel, J. & Lučivianský, L. 1997: *Geochemical Atlas of Slovak Republic at a scale 1 : 1 000 000.* Jurnal of Geochemical Exploration, 60, p. 7–37.

Zýka, V. 1975: *Vliv anomálniho geochemického prostředí na rozšíření zhubných novotvarů.* Sbor. Geol. Věd., Technol. Geochem. Praha. 201 p.

WHO – World Health Organisation, 1996: Arsenic – Guidelines for drinking water quality. In: Health criteria and other supporting information. 2nd ed. Vol. 2., Geneva, p. 156–167.