EURASIAN MINERAL WATER: MATHEMATICAL MODELING, CLASSIFICATION AND ASSESSMENT OF THEIR IMPACT ON THE BIOCHEMICAL COMPOSITION OF HUMAN BLOOD

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Abstract. In the article we give the results of comparative analysis of the composition of the Eurasian hydromineral resources and we implement the assessment of their impact on the physiological condition of an organism of the person according to biochemical studies of venous blood. Processing of initial data on the composition and properties of mineral waters chloride-hydrocarbonate, sulphate-hydrocarbonate and chloride-sulphate types and venous blood are made using the method of mathematical modeling, developed by the authors of this article. It is shown that in the balneological impact hydromineral resources on the body hemoglobin and oxygen in the blood increases, glucose decreases, and acid-base pH shifts to high alkalinity.

Keywords: minerals water, blood, modeling, classification.

Introduction

Natural mineral waters are natural resources widely applied in medicine, food industry and a number of other fields of manufacture. The geographical expansion of extraction, bottling and spa applications of medicinal mineral waters and mud, has led to the necessity of a system for monitoring and estimating parameters for: quality, origin, composition and properties of various mineral water and mud.

The biological efficacy of salted - waters systems upon human body is largely dependent on their composition and properties through a mathematical function, usually approximated by statistical methods of the linear regression equation. Nowadays it is important to assess the quality of mineral waters using experimental data of chemical and physic-chemical analysis (total salinity, ionic composition, acid-base balance, conductivity and some other characteristics). Generic requirements for the ionic composition and salinity for the different types of mineral waters given by national standards and data (on separate regional waters) are published in various scientific journals and on Internet sites.

However, until now, the general model of mineral waters` classification has not been developed which allows estimating quantitatively the conformity of regional mineral waters to the reference waters of certain types, groups and classes.

Quoted in the national standards in Russian Federation, CIS and EU tracts of mineral waters are divided into types, groups and subgroups (classes), mostly from the values of total salinity and ionic composition (of salt systems), in certain ranges of concentration, whose boundaries are chosen at random, and that is major disadvantage of existing systems standardization.

The purpose of this work consisted in the establishment of the quantitative dependences connecting composition and properties of the regional Eurasian mineral waters chloride-hydrocarbonate, sulphate-hydrocarbonate and chloride-sulfate type on the basis of a mathematical model developed by us for the classification of mineral waters, using the characteristic parameters calculated from experimental data on the chemical composition of waters [1].

The paper assessed the composition of some mineral waters in Russian Federation, CIS and the EU, the lake brine and squeezed water, medicinal sulphide mud and dark-gray clay sediments underlying dolomite marl, a natural impermeable horizon of salty lakes in Russian Federation and Romania.

The estimated characteristic parameters of the natural waters (Research method)

In order to estimate the applied parameters for water identification, we have been introduced the notions of the “characteristic indicator” of the water and their relation with the chemical composition and total salinity of waters [2].

The phrase “characteristic indicator" refers to those functions of the system, through which, or through whose derivatives, can be expressed in explicit form the composition and mass properties of water-salt systems. In this paper we are talking about Eurasian natural mineral waters of different genesis and metamorphism.

As the initial parameters accepted for the mathematical description of structure of water-salt systems of mineral waters, the following amounts have been entered:

1. $\overline{M}$ - The total mineralization of water, g/dm^3.

The value $\overline{M}$ can be calculated from a known parity in chemistry:

$$\overline{M} = M \cdot C_n, \quad (1)$$

where: M - the gram-equivalent of a salt system of mineral water, g/eqv.; C_n – concentration of salts in solution, eqv/dm^3.

The value M is calculated from equation (1) and is a function of one variable X_i/X_j.

2. The dependence M of the ratio X_i/X_j presented in the form of the equation:

$$M = a(X_i/X_j)^b, \quad (2)$$

where: X_i/X_j - the ratio of equivalent fractions anions $X_{Cl^-}/X_{HCO_3^-}$, $X_{SO_4^{2-}}/X_{HCO_3^-}$ and $X_{Cl^-}/X_{SO_4^{2-}}$**;** *a* and *b* - constants.

The value M adopted by us as the first characteristic indicator that has investigated the water of different ionic composition in a certain sequence in magnitude relations X_i/X_j. Characteristic parameter M is a well-defined value of the salt solution and depends on the nature of dissolved salts, the composition and concentration of ions, forming a salt solution.

We have previously shown that the dilution of the solution with a given value of demineralized water does not change its value. Solutions of different concentrations with similar values X_i/X_j belong to the same subgroup (class) of water. Solutions with close relationships X_i/X_j constitute a certain class of mineralized water.

3. The evaluation study of water supplies of a class of mineralized waters was carried out with characteristic indicator φ, calculated from the equation:

$$\varphi = A\left(\frac{X_i}{X_j}\right)^D, \quad (3)$$

where: A and D are the coefficients *($A=a^2\cdot b$, $D=2b-1$)*.

Characteristic indicator φ can combine mineral water in a separate class of a certain group of mineral waters.

A logarithmic conversation of the equation (3) allows receiving the equation of linear regression for the processing units of the characteristic indicator φ methods of mathematical statistics. In this work the base computer program "Statistics-7" was applied.

Results and discussion

Calculation of characteristic indicator φ of different types of mineral water is made by the equations:

a) chloride-hydrocarbonate type $X_{Cl^-}/X_{HCO_3^-}$ [2]:

$$-\log\varphi\left(Cl/HCO_3\right) = 2.5807 - 1.1524\log\left(X_{Cl^-}/X_{HCO_3^-}\right) \quad (4)$$

b) sulphate- hydrocarbonate type $X_{SO_4^-}/X_{HCO_3^-}$ [4]:

$$-\log\varphi\left(SO_4^{2-}/HCO_3^-\right) = 3.3946 - 1.1301\log\left(X_{SO_4^{2-}}/X_{HCO_3^-}\right) \quad (5)$$

c) chloride-sulfate type $X_{Cl^-}/X_{SO_4^{2-}}$ [5]:

$$-\log\varphi\left(Cl^-/SO_4^{2-}\right) = 3.3096 - 1.0572\log\left(X_{Cl^-}/X_{SO_4^{2-}}\right) \quad (6)$$

Table 1

The values of the characteristic indicator φ of the composition of the some regional Eurasian water depending on the total mineralization and ionic composition.

No.	Mineral water, country	The total mineralization of water, $\overline{M}$, g/dm^3	The ratio X_i / X_j	The value of the characteristic indicator, φ
	Chloride-hydrocarbonate type, $X_{Cl^-} / X_{HCO_3^-}$			
1.	Imperial, Spain	3.921	0.471	907
2.	Isti-Su Verkhnii, Azerbaijan	6.082	0.614	668
3.	Keiser Friedrich Heilquelle, Germany	4.549	0.635	643
4.	Vesuvio, Italy	2.128	0.666	608
5.	Essentuki No.17, Russian Federation	12.057	0.728	549
6.	Biskirchener Karlsalssprudel, Germany	2.788	0.759	523
	Sulphate-hydrocarbonate type, $X_{SO_4^{2-}} / X_{HCO_3^-}$			
1.	Sulphate Narzan, Russian Federation	5.219	0.794	3219
2.	Smirnovskaya, Russian Federation	3.615	0.847	2993
3.	Apenta, Italy	1.847	0.932	2686
4.	Azurra, Italy	0.522	0.935	2676
5.	Ueberkinger, Germany	3.848	0.953	2619
6.	Boario, Italy	0.726	0.996	2492
	Chloride-sulfate type, $X_{Cl^-} / X_{SO_4^{2-}}$			
1.	Krakowianka, Poland	2.714	0.460	4617
2.	Feodosiiskaya, Russian Federation	3.957	0.540	3900
3.	Dax, France	0.987	0.575	3651
4.	Slanic-Moldova No. 5, Romania	0.212	0.658	3168
5.	Lysogorskaya, Russian Federation	18.165	0.744	2784
6.	Don, Russian Federation	2.850	0.791	2610

Table 1 shows the calculated values of the characteristic indicator φ.

This article also considers the possibility of applying the method of mathematical modeling and application of the characteristic indicator of the composition of φ for the estimation of the physiological state of the organism according to biochemical analysis of venous blood of patients of the sanatorium "Techirghiol" (Romania), described in the work [3].

In Tables 2 and 3 it is shown some biochemical indices of chemical composition and properties of blood before and after the adoption of balneological procedures, mud treatment of patients of the sanatorium "Techirghiol". Biochemical blood analysis is made with the device CCXS-6.

With the use of the experimental data (Tables 2 and 3) we calculated characteristic indicator of venous blood of patients of the sanatorium "Techirghiol" (Romania) before and after the Spa treatments with mud.

Characteristic indicator of the ion composition of blood φ* before and after the procedures we calculated by the equation:

1. Original indicator $\varphi^{*,o}$

$$-\log\varphi^{*,o}\left(Cl^- / HCO_3^-\right) = 2.5718 - 1.1506\log\left(X_{Cl^-} / X_{HCO_3^-}\right) \quad (7)$$

2. The value of characteristic indicator φ^* after procedures:

$$-\log\varphi^{*}\left(Cl^- / HCO_3^-\right) = 2.5033 - 1.1349\log\left(X_{Cl^-} / X_{HCO_3^-}\right) \quad (8)$$

In the result of the comparative analysis of composition and properties of Eurasian natural mineral waters using the method of mathematical modeling and introduction of the characteristic indicator of φ we established the quantitative relations linking the evaluation of the integral indicator φ with mineralization and ionic composition of the water of various types and geographical location of the source of mineral water.

Table 2

Biochemical parameters of the chemical composition and properties of human blood before the procedures.

No. of the patient	Ion concentration, mol/dm^3		pCO_2, mmHg	pO_2, mmHg	Glucose, mg/dL	Hemoglobin, g/dL	pH
	HCO_3^-	Cl^-					
1.	29.7526	100.755	48.2975	28.4012	180	14.7940	7.3936
2.	25.6601	105.293	44.2954	42.7791	80	13.6072	7.3669
3.	28.7327	105.032	48.4927	40.0465	87	15.0668	7.3767
4.	29.616	104.683	48.4537	33.3757	103	14.3005	7.4210
5.	26.0374	103.585	40.7284	43.7158	93	13.433	7.4097
6.	27.4314	105.802	48.9607	45.7622	98	14.0599	7.3524
7.	29.4035	107.669	47.4241	42.9389	106	14.2744	7.3964
8.	28.8403	108.196	50.3500	25.8367	123	14.4548	7.3620
9.	28.9969	107.348	48.6241	29.2395	122	14.6029	7.3795
10.	26.9461	108.952	40.9163	51.0594	144	14.4133	7.4226
11.	30.0801	107.939	49.0207	29.7467	91	15.2759	7.3919
12.	26.5423	107.551	40.9486	63.0600	132	18.3332	7.4157
13.	29.2089	104.550	43.8950	32.9255	257	13.7067	7.4271

Table 3

Biochemical parameters of the chemical composition and properties of human blood after the procedures.

No. of the patient	Ion concentration, mol/dm^3		pCO_2, mmHg	pO_2, mmHg	Glucose, mg/dL	Hemoglobin, g/dL	pH
	HCO_3^-	Cl^-					
1.	32.4535	101.8046	48.7149	39.0512	117	14.7940	7.4618
2.	28.1153	105.3554	45.9244	30.0058	75	14.3457	7.3909
3.	25.9409	108.4871	41.3033	54.2744	84	12.7026	7.4020
4.	30.4505	105.2026	49.6929	38.1093	99	13.8033	7.4342
5.	26.8541	103.667	41.7745	57.4177	77	13.2129	7.4121
6.	29.0077	105.7348	49.5124	55.7568	83	14.0599	7.3718
7.	26.7567	108.6529	39.9790	87.7730	108	14.8729	7.4296
8.	25.1097	109.8214	37.6393	45.4035	81	15.2222	7.4282
9.	29.1084	105.4624	43.0842	27.8902	115	13.4303	7.4337
10.	26.6644	107.7174	36.8411	48.0840	108	14.5825	7.4636
11.	29.5132	107.4811	48.8783	36.4002	107	14.5903	7.3849
12.	26.7005	107.6161	38.7008	64.4981	108	18.4041	7.4428
13.	28.3394	105.4173	43.6908	41.7544	210	13.7601	7.4160

Studies have shown that the characteristic composition indicator of water-salt solutions φ determines the identity of the investigated water to a certain class waters of a group and can be used as the basis of identification of regional water and organization of the system of national monitoring.

Application of methods of mathematical modeling and using of characteristic indicator of φ for research of human body fluids, in particular venous blood has shown an opportunity of application of a method for computer diagnostics of the physiological condition of the human body based on the data of biochemical studies of blood [6].

Conclusions

The evaluation of the composition of the Eurasian mineral waters and human venous blood by using the characteristic indicator φ we can make the following conclusions:

1) we suggested mathematical model of water-salt systems regional water and the comparative assessment of their conformity with the reference groups waters chloride-hydrocarbonate, chloride-sulfate and sulfate-hydrocarbonate type;

2) we determined the correspondence of the ion composition of water-salt systems mineral waters chloride-hydrocarbonate type and human venous blood:

$$-\log\varphi(water) = 2.5807 - 1.1524\log\left(X_{Cl^-} / X_{HCO_3^-} \right)$$

and

$$-\log\varphi(blood) = 2.5718 - 1.1506\log\left(X_{Cl^-} / X_{HCO_3^-} \right);$$

3) it is shown that the impact of hydromineral resources and medicinal mud on the human body changes the indicators ionic composition and properties of venous blood: the ratio of chloride and hydrocarbonate ions, acid-base balance, blood oxygenation, the content of hemoglobin, glucose;

4) the characteristic indicator φ allows with a high degree of reliability to conduct computer diagnostics of the physiological state of the human body according to biochemical studies of blood.

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