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Characteristic of Balneologically Active Components and Microflora under Extreme Conditions of Mineral Waters of the Mongolian People's Republic

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Characteristic of balneologically active components and microflora under extreme conditions of mineral waters of the Mongolian People's Republic[1])

Mineral waters, being a component of the biogeosphere, play in important part in the redistribution of many specific elements, thereby providing for the direct or indirect influence on biological processes: on activity of different kinds of bacteria and on high organisms as well.

Complex investigations of chemical and microbiological compositions, directed on the study of hydromineral solutions formation conditions and of physiological effect of solutions on human organism, were carried out by the authors for the first time for mineral waters of MPR.

It is known, that the pecularities of mineral water formation, connected with a considerable depth, a high temperature, a high CO_2 gassaturation and transitional-reductive conditions (in the absence of or at minimum amount of dissolved oxygen) leave their respective mark on a species composition of microorganism present. The study of such interconnection represents an obvious value not only for the solution of a problem of chemical composition of mineral waters. The revelation of the relationship between dissolved organic matter composition and the bacteria present allows to approach the study of metamorphization of silt deposits in lakes and seas and also to investigate the changes in minerals of sedimental deposits in time.

As it was previcusly noted, cold carbonate and nitric thermal mineral waters of MPR were used as a subject of study. Apart from macrocomponent composition, the quantitative characteristics of the most important physiologically active components such as iron, fluorine, dissolved silica, arsenic, iodine etc. were investigated, microflora was also studied.

Nitric thermal waters with the mineralization up to 0.8 g/l of hydrocarbonate-sulfate and sulfate-hydrocarbonate nitric composition are spread over west regions of the Mongolian People's Republic. Forming their chemical composition on a considerable depth under the influence of high temperatures and pressure, the hydrothermal solutions are enriched with components the migration conditions of which depend directly or indirectly on temperature. Such components are fluorine, silicon, and calcium. The presence of high concentration of fluorine (up to 24.5 mg/l) and dissolved silica (up to 213 mg H_4SiO_4/l) in thermal waters should be considered to be the characteristic feature of the waters. Oxygen is absent or observed in minimum concentrations. The most important component, which specifies geochemical situation of hydrothermal solutions and therefore the conditions of migration of many elements, is dissolved hydrogen sulfide, the presence of which is observed in all thermal waters studied. In a weak alkali state of hydrothermal solutions, all dissolved hydrogen sulfide is practically in a hydrosulfide form, H5. Since the H5 concentration comes up to 16 mg/l in many deposits, the given hydrotherms may be characterized as hydrosulfide ones. The intensive deposition of sulfur is observed at the places of discharge of hydrothermal solutions greatly enriched with hydrogen sulfide.

As the microbiological analysis of thermal waters showed, the temperature factor played an essential part in development of different groups of bacteria.

The strict dependence between temperature and overal amount of bacteria was not found

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out, but it was observed that at the water temperatures from 20 to 55 °C, the overall number of bacteria was higher (155–325 thousand col/ml) than in hydrothermal solutions with the temperatures from 55 to 92 °C.

For the waters with high temperature (50 °C and higher), the high quantity of saprophytes (4500–5440 col/l) is typical; this may be connected with the presence of easily decomposing dissolved organic substances (1.2–7.9 mg. Corg/l). Phenol-oxidizing bacteria (when phenol content is from 0.006 to 0.046 mg/l) were found in all springs. Denitrifying bacteria are developed very weakly or they are not present at all. Metaneforming bacteria were observed in small quantities only in the waters of deposits of art and Khuzhirte. Their absence in the waters of other hydrotherms may be connected with the presence of dissolved oxygen (even at minor concentration of it), the bacteria of a given type being able to develop in the absolute absence of oxygen. In all cases, the weak growth of thion- acid bacteria was observed.

Cellulose-fermenting aerobes were found in the waters of all studied objects; anaerobes and sulfate-reducing bacteria were completely absent.

It is quite possible that a temperature barrier of 45–50 °C has a depressing influence on the development of such groups of bacteria as sulfate-reducing, metane-forming, denitrifying ones, and favors the more intensive growth of others, for example phenol-oxidizing bacteria. This conclusion is, however, possible to be ararrived at under the complex consideration of temperature and geochemical conditions, as well as the chemical composition of aqueous solution and analysis of not only quantitative contents of different components but also the forms of their migration. The latter factor is especially important in the study of a composition of dissolved organic substances and of bacteria present in the aqueous solution.

The determination of all these pointed out interrelations would allow to approach the elucidation of the role of the microbiological component in the formation of chemical composition of different types of natural waters distiguished by their genesis.

This may be exemplified by the results of complex study of the largest field of thermal waters in Shargalzhut on the territory of MPR. This field is unique both in the occurrence of the most important specific components and in their reserves. By the present time, 153 places of thermal water discharge with the temperature from 52 to 92 °C have been registered.

The detail study of this unique hydrothermal field makes it possible to establish the availability of the interconnection between the temperatures of individual discharges and the contents of hydrosulfide-ions (pair correlation coefficient, $r = 0.53$). The relationship between the thermal water temperature and hydrosulfide contents shows that the origin of hydrosulfides is chemical in a greater degree than biochemical, since, as it is known, the optimum conditions of bacterium activity are observed at temperatures from 50 to 60 °C, the activity gradually attenuating with the further increase in temperature. And though according to data on microbiological analysis, the bacterial life develops even at temperatures up to 100 °C, the activation of activity of bacteria was not observed at the temperatures from 60 to 100 °C. It should be noted that sulfate-reducing bacteria were not discovered in the waters of Shargalzhut field.

The group of sulfide-oxidizing bacteria is of great interest. This fact may explain the availability of considerable connection between contents of sulfates and hydrosulfide-ions in the waters of Shargalzhut field; the fact shows the possibility of a partial enrichment of hydrothermal solutions with sulfats at the expense of the vital activity of bacteria.

As a whole, the development of bacteria in waters of Shargalzhut field is very weak: from 3 to 35 col/ml; ammonifying bacteria were found only in minute quantity; phenol-oxidizing bacteria were found only in a spring with the temperature of 82.5 °C; this is the most high temperature spring among other ones subjected to microbiological analysis.

Cold carbonic acid waters of Mongol People's Republic are mainly located in the east regions of the country and partially in the south, in the north parts of the desert of the Gobi. This type of waters is quite various in chemical composition, in the extent of mineralization, and in the quantity of physiologically active components as well. The regular change of chemical composition of cold carbonic acid waters of Mongolia from the north to the south is characteristic of them. Hydrocarbonate alkali-earthe waters with mineralization up to 2 g/l exist in the north regions of the province, and these waters give, southward, place to sulfate – hydrocarbonate sodic ones with the mineralization of 2–5 g/l, whereas the cold carbonic-

acid waters of hydrocarbonate-chloride and chloride-hydrocarbonate sodic composition with a mineralization of 7–13 g/l were found out in the north regions of desert of Gobi. Weakly oxidizing conditions of formation, and the absence or presence of oxygen only in small quantities give rise to favourable conditions for an intensive migration of various micro-elements iron in particular.
The wide abundance of this element in rocks and the favourable geochemical conditions of these waters favour the accumulation of iron in quantities up to 30 mg/l, the most part of carbonic-acid waters being allowed to be characterized as ferrugious ones.
The presence of carbonic acid is the main reason of accumulation of calcium in carbonate waters of MPR may be recommended for internal use without any limitations.
soluble Ca F_2 formation. That is why the fluorine ion contents are relatively low in carbonate waters and constitude from 0.02 to 2.2 mg/l, by virture of which all carbonate waters of MPR may be recommended for internal use without any limitations.
The concentrations of other elements are the following: boron 0.25–13.58 mg/l, bromine 0.20–2.72 mg/l, arsenic 0.001–0.040 mg/l; iodine was not detected in most of waters or only traces of it were found.
In the case of dissolved silica, the temperature is the main factor of accumulation of this material in hydrothermal solutions, whereas in carbonate waters, the intensity of silicon accumulation should be connected with the significant amounts of dissolved carbonic acid, in the presence of which, the leaching of rocks increases and, consequently, the concentration of components (including silicon) also increases in the solution.
The presence of silica in quantities from 37 to 113 mg H_2SiO_4/l in carbonate waters seems to be stipulated by this factor. It is known, that carbonate waters are formed in the depths, which are to a considerable degree less than the depths of hydrothermal solution formation. Therefore the microbiological composition of carbonate waters is essentially affected by surface waters. The presence of higher contents of bacteria (up to 447 thousand col/ml) in carbonate waters as compared with that in hydrothermal solutions should be connected with their nature of formation.
For carbonate waters, higher contents of saprophytes are also characteristic. The intensive development of sulfate-reducing bacteria was observed almost in all springs investigated. Phenol-oxidizing bacteria are very weakly developed.
The spring of Urdyn-Tokhoi, having hydrocarbonate-sodic composition and located on the territory of thermal water occurrence, is an exeption. The presence of a great quantity of phenol- oxidizing bacteria (100 col/ml) in the composition of this spring, the absence of sulfate-reducing bacteria, and the weak development of thionacid and methan-forming bacteria make it possible to speak about some common features of genesis of the cold carbonate spring of Urdyn- Tokhoi and the thermal water fields located on the given territory.
Recently, it was established that organic substances, organic and free amino acids in particular, dissolved in natural waters, play an important part in physiologic influence on the human organism.
Carbonate mineral waters of hydrocarbonate-sodic composition, nitric sulfate-sodic hydrotherms, and cold hydrogen-sulfide waters are the most enriched with organic acids.

Summary

The distribution of amino acids is irregular in mineral waters. Their content is minimum in cold carbonate waters of hydrocarbonate sodic composition, the highest amino acid concentration does not exceed 0.640 mg N/l.
Hydrothermal solutions are enriched with amino-acids to the greatest extent, the amino acids contents coming up to 0.780 mg N/l in hydrotherms of sulfate-sodic composition. In thermal waters enriched with hydrosulfides, amino acids are present in quantities up to 1.710 mg N/l.

Zusammenfassung

Mineralwässer sind wichtige Bestandteile der Biogeosphäre. Die darin enthaltenen spezifischen Komponenten bedingen ihre Wirksamkeit in biologischen Prozessen, die die Ent-

stehung und Lebenstätigkeit von der Mikroflora bis zu den höheren Organismen beeinflussen.

Von den Autoren sind praktisch alle Lagerstätten und Erscheinungen der Mineralwässer der MVR untersucht worden. Gemeinsam mit weiteren charakteristischen Parametern und Komponenten wurden die wichtigsten biologisch aktiven Bestandteile Eisen, Silizium, organische Stoffe, Schwefelwasserstoff, Fluor, Brom, Jod, Arsen, Bor u. a. bestimmt und die Mikroflora studiert.

Die vorhandenen Kriterien zum Gehalt von biologisch aktiven Komponenten in den Mineralgewässern stützen sich auf ihre physiologische Beeinflussung.

Zur Vereinfachung ist die Charakteristik der obenerwähnten Komponenten für kohlensaures kaltes Wasser und Stickstoff-Hydrothermalwasser angegeben.

Kohlensaures Mineralwasser: Die Mikroflora besteht aus einer geringen Menge von Saprophyten, phenoloxidierenden und dinitrifizierenden Bakterien. Das Wasser des Chalzan-uul-Brunnens weist einen gesteigerten Gehalt an sulphatreduzierenden Bakterien auf. Der Gehalt von biologisch aktiven Komponenten im kohlensauren Wasser liegt niedriger als die in der UdSSR bekannten Werte. Die mittlere Konzentration in mg/l beträgt: Bor – 0,3–0,4; (im Chalzan-uul – 136), Brom – 0.4, Jod – 0.08, Arsen – 0,01. Die gesteigerten und hohen Konzentrationen von Eisen – 30 mg/l, Fluor – bis 2,2 mg/l, gelöster Kieselerde – bis 90 mg/l, verdienen besondere Aufmerksamkeit.

Die hohen Konzentrationen von Eisen und Silizium erlauben es, eine große Zahl der kohlensauren Wässer als eisenhaltig und kieselhaltig zu bezeichnen, wobei dieses Wasser höchst günstig ist bei der Heilung einer Reihe von inneren Erkrankungen.

Nach dem Gehalt an biologisch aktiven Komponenten unterscheidet sich das stickstoffhaltige Thermalwasser stark von kohlensaurem Wasser. Es weist meistens Hydrosulphide bis zu 17 mg/l auf, der Borgehalt ist auf 1,5 mg/l gesteigert. Keine Quelle hat Jod aufgewiesen; die Bromkonzentration ist niedriger als in kohlensaurem Wasser.

Nach der Kationenzusammensetzung des Thermalwassers ist der Kalziumionengehalt nicht groß. Die Anwesenheit von fluorhaltigen Gesteinsschichten, die hohe Wassertemperatur und die Abwesenheit antagonistischer Elemente begünstigen das Auftreten von Fluoriden, deren Konzentration 23 mg/l erreicht. Eine charakteristische Besonderheit der Thermalwässer ist der hohe Gehalt an gelöster Kieselerde (über 150 mg/l H_4SiO_4).

Die Mikroflora dieses Wassers ist reich an Saprophyten, phenoloxidierenden und zellulosezersetzenden Anaerobiern.

Eine wichtige physiologische Wirkung auf den Organismus erfolgt durch gelöste organische Stoffe, insbesondere organische und freie Aminosäuren. Besonders reich an organischen Säuren sind kohlensaure Mineralwässer von einer Hydrokarbonat-Natrium-Zusammensetzung, stickstoffhaltige Sulphat-Natrium- und Chlorid-Natrium-Thermalwässer, aber auch schwefelwasserstoffhaltige Wässer.

Die Verteilung von freien Aminosäuren in den Mineralwässern ist ungleichmäßig. Im kohlensauren Hydrokarbonat-Magnesium-haltigen Wasser ist deren Gehalt minimal, im Hydrokarbonat-Natrium-haltigen maximal (durchschnittlich 0,640 mg N/l).

Hydrothermalwässer enthalten auch bedeutende Konzentrationen freier Aminosäuren, die in Sulphat-Natrium-haltigen Wässern 0,780 mg N/l erreichen. In hydrosulphidhaltigen Wässern erreicht ihr Gehalt 1,710 mg N/l.

Резюме

Минеральные воды являются важнейшей составной частью биогеосферы. Наличие в них специфических компонентов обусловливает их поведение в биологических процессах, влияющих на генезис и жизнедеятельность от микрофлоры до высших организмов Авторами обследованы практически все месторождения и проявления минеральных вод МНР. Наряду с прочими характерными параметрами и компонентами определялись главнейшие биологически активные составляющие: железо, кремний, органические вещества, сероводород, фтор, бром, иод, мышьяк, бор и другие, изучалась микрофлора.

Содержание и распределение этих компонентов в различных типах вод неодинаково, зависит от многих факторов и, прежде всего, от геологической обстановки формирования.

Имеющиеся критерии по содержанию биологически активных компонентов в минеральных водах основаны на их физиологическом действии.

В целях упрощения характеристика вышеуказанных компонентов приводится для углекислых холодных вод и азотных гидротерм.

Микрофлора углекислых минералных вод представлена небольшим количеством сапрофитов, фенолокисляющих и динитрифицирующих бактерий. В воде скважины Халзан-ул повышено содержание сульфатредуцирующих бактерий. Содержание биологически активных компонентов в углекислых водах ниже критериев, принятых в СССР. Средние концентрации их в мг/л равны: бора — 0,3—0,4 в воде Халзан-ул — 136), брома — 0,4, иода — 0,08, мышьяка — 0,01.

Обращают на себя внимание повышенные и высокие концентрации железа — 30 мг/л, фтора — до 2,2 мг/л, растворенного кремнезема — до 90 мг/л.

Повышенные концентрации железа и кремния позволяют отнести большинство углекислых вод к железистым и кремнистым, весьма благоприятным при лечении ряда внутренних заболеваний.

Азотные термальные воды по содержанию биологически активных компонентов резко отличаются от углекислых. Для большинства из них характерно наличие гидросульфидов (до 17 мг/л), повышенное содержание бора (до 1,5 мг/л); иод не обнаружен ни в одном источнике; ниже, чем в углекислых водах, концентрация брома.

В катионном составе термальных вод невелико содержание ионов кальция. Наличие фторсодержащих пород, высокая температура вод и отсутствие элементов-антагонистов благоприятствует накоплению фторидов, концентрация которых достигает 23 мг/л. Характерной особенностью термальных вод является присутствие в них высоких содержаний растворенного кремнезема (более 150 мг H_4SiO_4/л).

Микрофлора этих вод богата сапрофитами, фенолокисляющими и целлюлозоразлагающими анаэробами.

Важное физиологическое воздействие на организм оказывают растворенные органические вещества, в частности, органические и свободные аминокислоты. Наиболее обогащены органическими кислотами углекислые минеральные воды гидрокарбонатного натриевого состава, азотные сульфатно-натриевые и хлоридно-натриевые термы, а также сероводородные воды.

Распределение свободных аминокислот в минеральных водах неравномерно. В углекислых гидрокарбонатно-натриевых водах их содержание минимально, максимальное — в гидрокарбонатно-натриевых (среднее — 0,640 мг N/л).

Гидротермы содержат более высокие концентрации свободных аминокислот, достигающие в сульфатно-натриевых водах 0,780 мг N/л. В гидросульфидных водах содержание их достигает 1,710 мг N/л.