CHAPTER 1

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THE IMPORTANCE OF BIOGEOCHEMISTRY IN ENVIRONMENTAL PROTECTION AND GREEN GROWTH

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The questions of heterogeneity, organised character and optimum condition of the biosphere, its functioning and transformation always were and remain central scientific problems, for they are directly bound up with cognition of nature of life as a planetary and cosmic phenomenon, with a historical estimation of a role of the living matter in the past, present and future, with definition of a place and role of the person in evolution of the Earth and with forecasting assessment of biogeocenosis development. In this article attention is paid on importance of a biogeochemistry in development of ecological researches, questions of geochemical ecology and concept of biogeochemical provinces directly bound up with the analysis of a present condition and evolution of the biosphere.

Keywords: *Environmental protection, Green growth, Ecosystem, Biosphera, Biogeochemistry, Trace elements, Technogenesis, BGC provinces, Biogeochemical endemics, BGC investigations*

INTRODUCTION

In current conditions of man-made transformation of nature, the principle of adequacy of the materials and technologies used to productivity and resources of the biosphere is of cardinal importance. The biogenic migration of chemical elements is not unlimited. It strives to maximize its manifestation within certain limits corresponding to the homeostasis of the biosphere as the main property of its sustainable development and organization. It is the creation and implementation of the environmentally acceptable technologies in agriculture and industry that was proclaimed by the UN Conference on Environment and Development (Rio de Janeiro,

1992) as one of the main conditions for achieving sustainable development of the world community.

The deficiency or excess of vital, as well as the accumulation of toxic chemical elements, radionuclides in the body of animals depend on modern technologies and features of biogeochemical cycles of elements. The imbalance of biologically active elements in the environment negatively affects plants, animals and humans, causing diseases (microelementoses). In addition, biogeocenotic connections between organisms are disrupted, biodiversity and abundance are reduced.

Currently, the biological role of most trace elements has been studied in sufficient depth. There are technologies for correcting a number of microelementoses of plants, animals and humans. At the same time, the work of Russian scientists, especially A.P. Vinogradov (1938, 1960) and V.V. Kovalsky (1977), played a certain role in the development of the doctrine of trace elements. The development of V.I. Vernadsky's biosphere ideas resulted in the emergence of concepts of biogeochemical provinces, biogeochemical zoning and geochemical ecology. It is these directions that underlie the methodology of biogeochemical study of the taxon of the biosphere.

Now, biogeochemistry included a system of knowledge, and become a systemic science of the elemental composition of living matter and its role in the migration, transformation and concentration of chemical elements and their compounds in the biosphere, of geochemical processes involving organisms, their interaction with the geochemical environment and geochemical functions of the biosphere (Ermakov et al., 2012).

The current stage of the evolution of the biosphere is a stage of correction of man-made human activity and the beginning of the emergence of reasonable resource-saving noospheric technologies. This is quite fully documented by a huge array of data and thousands of publications. Nevertheless, the effect of interaction between macro- and microelements and the influence of the technogenic component on the biogeochemical cycles of chemical elements falls out of the attention of researchers. This article concerns the problem of biogeochemistry – – a relatively new scientific direction of geochemistry and biology, which appeared in Russia at the beginning of the twentieth century.

METODOLOGY OF THE ECOLOGY BGC INVESTIGATIONS

The methodology of revealing and studying BGC provinces is based on complex (quantitative regional and local) comparative research of migration of chemical elements in all links of a BGC food chain, from rocks of the lithosphere through soils, soil microorganisms, air, water, plants, forages, foodstuff to an organism of animals and human being. Thus, a biomass, space of a dwelling of organisms, energy and biological reactions (concentration of elements, metabolic disorders, synthesis of biologically active compounds, activity of specific ferments, adaptive and pathological changes, diseases), bound up with features of a local BGC cycles of separate chemical elements of chemical elements and aspects of biological action of the latter - to definite stages in study of a BGC provinces.

BGC activity of microorganisms and plants regulating speeds of flows of matters and determing a homeostasis of the biospheric ecosystems is the key moment in formation of biogenic migrating flows of atoms of chemical elements and their associations during a mass-exchange in the system lithosphere-hydrosphere-atmosphere. Their accumulation for the majority of chemical elements by a soil microflora is ecologically interconnected (Gradova et al., 2013). Thus, the biomass of soil microorganisms (in particular of fungi) sometimes exceeds a biomass of plants and absorbs huge masses of chemical elements, creating original depot. This blockading is extremely heavy for a number of toxic metals (Pb, Cd, Hg and others) and it is realised, probably, by metallothioneines, which supplement a stock of sulphides of metals in soils during the destruction process (Gradova et al., 2020).

BGC researches include the analysis of a various cartographic material, geological and geochemical conditions of the project area, information about geobotany and geochemistry of landscapes, plant pathology, morbidity of animals and man, quantitative calculation of a biomass and revealing of characteristical biological reactions bound up with structure and composition of geochemical environment. Use of landscape geochemistry methods (landscape – geochemical division and description of a researched taxon of the biosphere), and also statement of special works bound up with development of rehabilitation measures (use of special technologies, means of' a detoxification and correction of microelementhoses) with attraction of the appropriate experts is expedient during study of BGC provinces of azonal character. Originally both geochemical and technogenic anomalies, and data of distribution of microelementhoses or endemic diseases can be basis of revealing of provinces. However further it is necessary to aspire to the complex decision of biogeochemical problems. The correlation between levels of chemical elements or their associations and pathological condition of organisms requires comprehensive all-round study, for the expediency and efficiency of the preventive offers depends on it (Ermakov et al., 2018).

The sampling of territories can be survey (on typomorphous elements), and also more detailed, as in prospecting geochemistry depending on soluble tasks. Method of the conjugate sites with the detailed description of associations and ecogroups of plants is used the most frequently. Research of soils, chemical structure of which is formed as a consequence of complex interaction of soil forming rocks, natural waters, atmospheric precipitation and activity of microorganisms, plants and numerous inhabitants of soils borrows one of central places. As a rule, BGC estimation of territory includes lateral and vertical study of migration and allocation of chemical elements, their various forms, relationship with single components of soils, including organic matters. The coefficients of biological accumulation of elements (Kb) in system soil - hay harvests of plants - biomass of microorganisms, coefficients of a concentration (Kc) and dispersion (Kd) relatively dark (average for the lithosphere) or background concentration of chemical elements in soils and general kind of rocks, and also various correlation of concentration of chemical elements in separate parts of BGC food chain have the great importance.

The investigation of biogeochemical endemias is associated with the development of methods of biogeochemical indication of the ecological state of taxons of the biosphere. The method is based on the differentiation of the chemical composition of organisms, their organs and tissues depending on the geochemical features of the habitat, food and feed (Opekunova, 2016; Yusupov et al., 2016; Ermakov et al., 2018). The use of biogeochemical indication for environmental assessment of ore, industrial and agricultural territories is especially effective (Ermakov et al., 2002, 2007, 2012, 2015, 2018).

Comparative analysis of the following biogeochemical parameters of an alive organism inhabiting in conditions of various zones has the great importance also for development of a fundamental biogeochemistry (Ermakov et al., 2020; Tyutikov, 2020).

The estimation of a microbe soil complex and involving of considered elements in biogenic migration by various taxonometric groups of microorganisms or microbe soil biomass received on special soil medium with natural concentration, balances and forms of chemical elements is essential stage of BGC researches (Ermakov et al., 2012). It is possible to find the detailed description of methodology of revealing and study of BGC provinces and their ecological estimation in special manuals (Criteria..., 1992).

So, it is necessary to have the following information for the characteristic of BGC provinces:

- detailed geological and physico-geographical description of area;

    - the description of soil - plant complex, parameters of landscape geochemistry and basic technogenic sources;
- BGC spectra of macro- and ME in BGC food chains (rocks, soils, waters, air, microorganisms, plants, animals and other organisms);
- levels of the contents of biologically active forms of chemical elements and associations in BGC food chain, including the forms of migration in a liquid phase and coefficients of water migration;
- concentrations of the elements in atmospheric and soil air and in atmospheric precipitation;
- the description and analysis of biological reactions of organisms (accumulation of chemical elements and their forms, biochemical disorders, analysis of activity of test ferments, adaptive reactions, morphological changes, signs of specific diseases);
- the differential analysis of a pathology of man and animals;
- various coefficients (Kb, Kc, Kd) and parameters of biogenic migration (Ma , Fm) and others;
- data on the origin of the province (sources and processes of concentration, reason of deficiency or redundancy of elements in the environment;
- health and hygienic parameters and general evaluation of an ecological condition;
- data on the cartography of the provinces (as regard the level of elements or compounds and the manifestation of biological reactions);
- possible models and forecasting estimation of a condition of BGC provinces.

The methodology of a geochemical ecology includes the specified above methods of approach and comparative during the study of BGC provinces. Thus, the complex of microbiological, soil, geochemical, geobotanical, zoological, biochemical, medical and other methods is used within the framework of concrete researches.

RESULTS AND DISCUTION

Biogeochemical principles of V.I. Vernadsky

The understanding of a number of the biosphere functions of the Earth as a region of inhabiting and vital activity of organisms transforming the earth's crust, has become possible due to works of Vernadsky V.I. (Vernadsky, 1926, 1940, 1960). His ideas about a geochemical role of the living matter, formation of a medium of life, unity of life and geochemical environment have resulted in creation of the new issue of a natural science

- biogeochemistry studying life in aspect of migration of atoms and transformation of the energy. These ideas of the scientist alongside with the concept or the technogenesis of the biosphere and concept of the noosphere make up the base of present biosphere researches.

We owe the development of biosphere ideas in Russia, as well as biogeochemistry all over the world, to the brilliant Russian scientist, Academician of the Russian Academy of Sciences Vladimir Ivanovich Vernadsky. His ideas about the unity of organisms and the environment, about the geological role of man in the transformation of the biosphere are fundamental (Vernadsky, 1940).

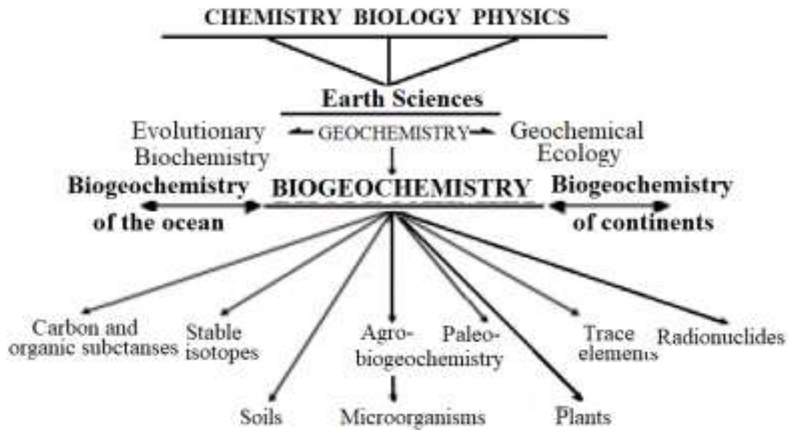
In ecology-biogeochemical views of Vernadsky V.I. generated under the influence of ideas of Dokuchaev V.V. (Dokuchaev, 1899), it is ought to allocate the following: global interaction in processes of transformation of matter, interrelation of the phenomena, ecological orientation of BGC principles, technogenic estimation of the evolution of the biosphere and concept of a noosphere as spheres of judicious transformation of the biosphere.

Vernadsky V.I., forming the theory of the biosphere, examines it as an active mobile film of living matter bearing all marks of processes and phenomenon occurring on the planet and in the cosmic surrounding. The role of the living matter having concrete chemical structure and specific functions, in dispersion and concentration of chemical elements and their compounds in the biosphere is reflected in concepts of biogenic migration and geochemical (BGC) energy of organisms (Vernadsky, 1940,1960).

The intensive development of a biogeochemistry in Russia and the former USSR was the result of differentiation of this science and origin in Russia such information trends as a carbon biogeochemistry and other macroelements, biogeochemistry of isotopes, biogeochemical prospect of the mineral deposits, paleobiogeochemistry, radiobiogeochemistry, soil biogeochemistry, plants, ocean biogeochemistry, agrobiogeochemistry etc. (fig. 1) (Ermakov, 2018).

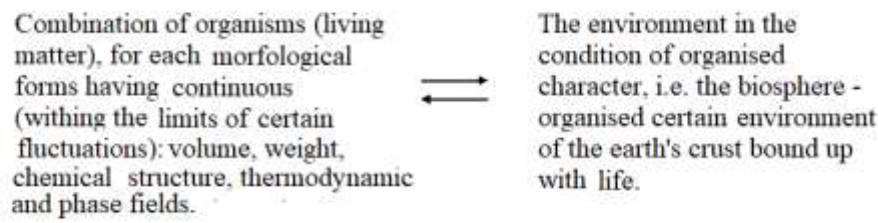
The ecological aspects of a biogeochemistry have found the most complete reflection in the concept of biogeochemical (BGC) provinces and geochemical ecology (Ermakov, 1995). Generalisation of researches in this area of knowledge and history of development of a biogeochemistry in the USSR until 1983 are reflected in the work «60 years of a biogeochemistry in the USSR» by Kovalsky V.V. (Kovalsky, 1985) and until 2019 in other publication (Ermakov, Kovalsky, 2016).

Figure 1. The main directions of biogeochemistry



The scientist considers extremely important the meaning of interaction of a heterogeneous living matter, capable to reproduction, regulation, preservation of the information and transformation of energy, and the biosphere as environment of organisms (planetary ecosystem). The circuit which is given below testifies (Fig. 2) (Vernadsky, 1980):

Figure 2. Scheme of the interaction of environment: organism



Source: Vernadsky (1940)

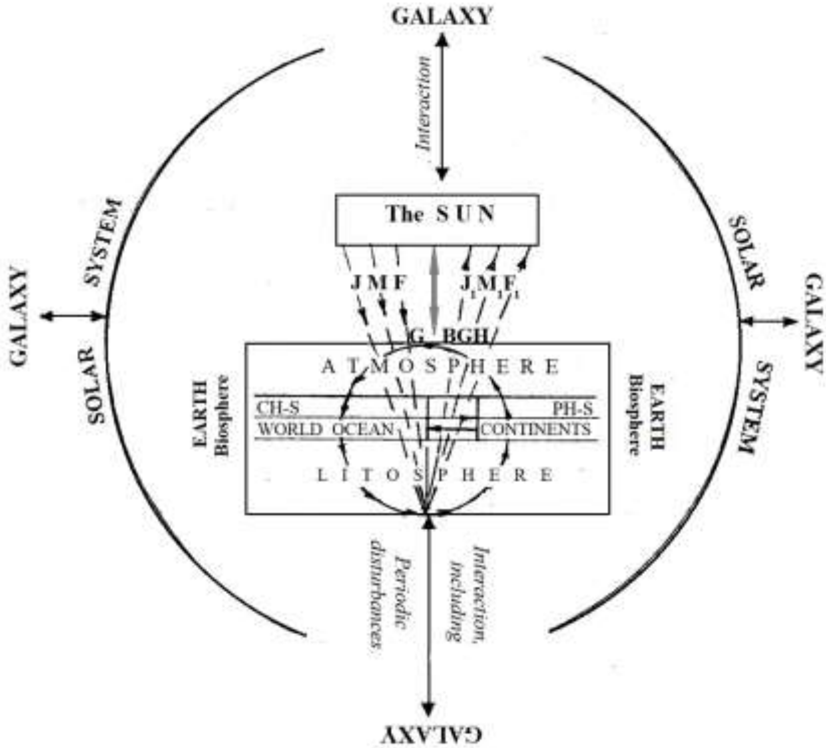
The interaction is carried out through the biogenic migration of chemical elements (BGC cycles), transformation of matter and energy. During these processes the living matter of the Earth is physic-chemical indivisible: "Every living thing arises from living matter in the biosphere, in which the complex of the physic-chemical phenomena is precisely limited and determined" (Vernadsky, 1980, p.279), and "the biogenic migration of chemical elements in the biosphere aspires to the maximal display" (1-st BGC principle) (Vernadsky, 1960, p.244). Further Vernadsky V.I. approves: "the evolution of kinds resulting in creation of the life forms, steady in the biosphere, should go in a trend, of increasing display of biogenic migration of atoms in the biosphere" (2-nd BGC principle) (Vernadsky, 1980, p.247); "the living matter is in a continuous chemical exchange with the cosmic medium, which environmental it ,..., the living matter forms and encourages on our planet by the space energy of the Sun " (3-rd BGC principle) (Vernadsky, 1980, p.260). This concept has received later the name of law of unity of organism - environment: "the life develops as a consequence of uninterrupted exchange by matter and information on the basis of energy flow in cumulative unity of environment and organisms, occupying it" (Reimers, 1994). In this unity the principle of ecological conformity works: the form of an organism existence (including its genetic features) always corresponds with the conditions of life.

On the basis of a BGC principles (Vernadsky, 1940, 1980) and works of the later period (Budyko and co-authors, 1985; Bashkin and Howarth, 2014) it is possible to allocate the following basic functions of the biosphere:

- power, bound up with accumulation and transformation of energy by autotrophic and
- heterotrophic organisms (photo and hemosynthesis, nutrition);
- biochemical, consisting in synthesis of organic matters with involving macro- and microelements (ME), their accumulation and dispersion;
- transformation, which essence consists of a mineralizing of organic matter and transformations of organic and inorganic compounds;
- transport, bound up with a mass transfer of matter and biogenic migration of chemical elements;
- forming environment and homeostatic, consisting in formation of geochemical properties of environment and in maintenance of a relative constancy of internal organism medium and of a environment;
- ecological, which essence consists of interaction of various groups of organisms and components of environment inside the ecosystems;
- informative, ensuring a regulation of development of organisms and environment;
- space, causing periodicity of migratory and biological rhythms, reactions of organisms.

The specified functions of the biosphere are displayed in the unity in a local, regional and global BGC cycles of chemical elements composing geological cycles. Taking into account a place of the biosphere of the Earth in Solar system and Galaxy, it is necessary to examine all scale biospheric changes bound up with its energy, mass-exchange of substance and productivity, in interrelation with global planetary processes and separate blocks of the higher order, and interaction of local and global processes in the biosphere as in ecosystem - within the frame of the three system levels: static (informative), geodynamic and systemic-prognostic (Fig. 3).

Figure 3. Scheme of the basic bonds in the global eco-system: the biosphere of the Earth - Earth - Sun - Solar system - Galaxy. J – flows of energy, M - total mass of sub-stance, F – magnetic flow, G - BGC - geological and biogeochemical global cycles of chemical elements. CH-S, PH-S – chemo- and photosynthesis.



Such a systematic multifactorial method of approach is also one of the necessary conditions in modelling processes in the biosphere and forecasting assessment of an ecological condition of ecosystems.

The biogeochemistry as a systematic science about geochemical processes with participation of organisms, their interaction with geochemical environment and geochemical functions of the biosphere has a number of attributes, identical with general ecology, both on essence of a subject, and on considered objects and soluble tasks. That is the interaction of organisms with geochemical environment, dependence their chemical composition from the structure of environment, which gives to biogeochemistry an ecological orientation and pull it together with general ecology.

Especially it concerns of biogeochemical cycles considered by general ecology (Ermakov, Jovanovic, 2010). All the same, it is impossible to identify a biogeochemistry with ecology, as they differ by a subject, objects of researches, general methodology and investigated processes.

Man-made transformation of the biosphere

The technogenesis and man-made evolution of the biosphere is the important moment in development of the doctrine of the biosphere. The essence of the technogenic biogeochemistry and genesis of the noosphere are also incorporated in work of Vernadsky V.I. (Vernadsky, 1940). So, he marks in one of works: "it is not also casual that during long million years in chemistry of an earth's crust, in a history of chemical elements the evolution of the organic world was not reflected by an appreciable mode, and only now, in our geological epoch we see sharp change in this respect, bound up with occurrence of a new organism – human being created by a long way of evolution and who has appeared to be the geological factor, unknown earlier in a history of the planet. The origin of cultural mankind on the Earth, which has taken possession of the basic substratum of an animate matter - green plant substance due to an agriculture, begins to change chemical face of our planet, and we do not know the end, sizes and meaning of that" (Vernadsky, 1940, 1980). In the article "Problems of a biogeochemistry" the scientist regards activity of the human being as the powerful biogeochemical factor, and "the force of civilised mankind estimates a genesis of new geological Psychozoic epoch" (Vernadsky, 1980).

The term "technogenesis" was offered by Fersman A.E. in 1924 (Fersman, 1934). Both scientists emphasised its amplifying range, compared to natural geological processes. Nowadays anthropogenic factors are so immense and instant in time, that they put an essential task of a local and global estimation of passing technogenic processes and protection of organisms from their injurious effect. Problems of a planet development, adequacy of energetic and source of raw materials, quality of food products and of environment of organisms as a whole - are factors, estimating it. (Fedotov, 1994; Ermakov, 2004).

The zone of the technogenesis is briefly characterised as follows. Radius of width reaches 7,5 km. Migration and redeposition of comparatively dead rocks in the top part of a hydrolitosphere in 8,1 times exceeds intensity of Phanerozoic sedimentation - 2,3 mlrds T/Years. The receipt of industrial and agricultural manufacture wastes, including fertilisers and pesticides, surpasses intensity of Phanerozoic sedimentation in 3,2 times (Tyutyunova et al., 2006). The territorial distribution of huge weights of organic matter of a planet is not appreciated yet, but, undoubtedly, it enters to the limited areas of a land and reservoirs extremely non-uniformly, causing local pollution.

Annually it is suit about 20 tons of minerals per each person of a planet, and the human being uses more than 10% of a total river flowing. About 11% of land territory accustoms to agriculture on the Earth as a whole (Kovda, 1985). There are sites of the maximal congestion of the population (large cities) and powerful industrial and power objects within the limits of land tenure. Volume of industrial throwing-out of inorganic and organic compounds is rather significant. So, in 80's the total throwing- out of fluorine as a highly toxic fluorohydrogen averaged 8 million tons per year, and fluororganic substances - 1 million tons per year. Total carrying-out of fluorine with pasture, meadow and agricultural plants is estimated as 20 million tons per year (Tyutyunova, 1987). Thus, it is necessary to have in mind a locality of falling-out of man-made fluorine flows. Some pesticides, chlorcontaining dioxins, fluorated and chlorited naphthalenes, components of mineral fertilizers, radionuclides, some toxic chemical elements and their compounds (As, Ba, Be, Cd, Hg, Pb, Tl etc.) have the greatest importance among matters of anthropogenic character negatively influencing the organisms. Many from them are carcinogenic and have mutagenous action. Thus, the technogenic blowout of chemical elements on a surface of fodder and food plants is more dangerous in a number of cases, than cumulation of them by plants from the soils (Ermakov, 2003).

The given materials reflect technogenic development of the biosphere as one of stages of its natural evolution. Usage of huge masses of chemical elements caused by a technogenesis, has no an effect yet on global cycles of chemical elements, which support the indivisibility of the biosphere. But in the future a number of technogenic processes can render appreciable influence on migration of elements in the biosphere (blocking of atmospheric nitrogen, sulphur and carbon oxidation, increase of an acidity of natural waters), promoting formation of man-made anomalies as a consequence of changes of BGC cycles of chemical elements.

Biogeochemical provinces

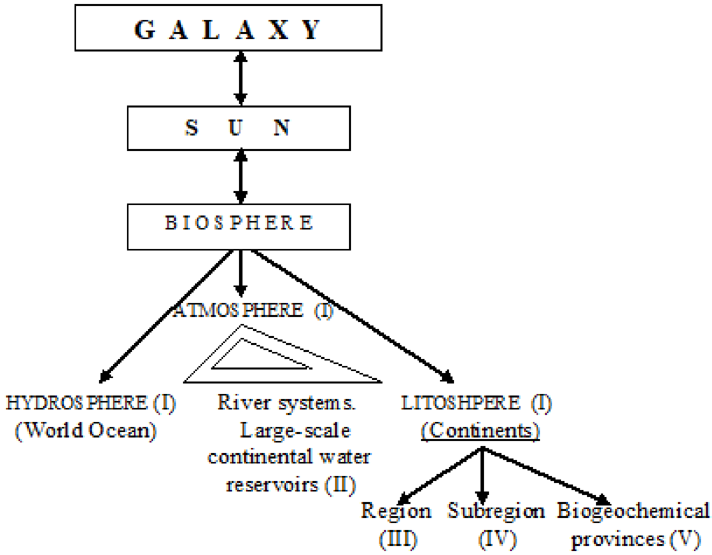
A.P.Vinogradov (1938) has introduced a concept “biogeochemical provinces” in the 30-s of the previous century. In his opinion, the latter ones represent “areas on the Earth differing from neighboring areas for their chemical element content levels and thereof triggering various biological reactions of local flora & fauna”. In extreme cases there emerge biogeochemical endemics, i.e. diseases affecting plants and/or animals within the boundaries of a certain biogeochemical province due to some element(s) critical deficiency or redundancy. The scientist emphasized that there is a close relation of biogeochemical provinces to geochemical factors, and a diversity of the areas in the levels of several chemical elements present in the environment (i.e., in soil, water or air), while the flora & the fauna reactions were considered as characteristic.

Thus, each site of the environment having a specific structure and chemical composition is characterized by its peculiar flora & fauna natural complex. When classifying biological reactions into groups and separate chemical elements (like the alkaline earth ones, alkalines, metalloids or heavy metals), A.P. Vinogradov (1960) emphasized: "Biological reaction of the flora and the faunae of a given area which grew being affected by some chemical element(s) redundancy/deficiency, serves as the most significant and principal sign of a biogeochemical province".

Summarizing of results obtained for biogeochemical provinces and taxons in a large number of researches enabled V.V. Kovalsky (1977) to suggest a diagram of ecological & biogeochemical demarcation of the former USSR territory which is quite informative today, for it includes extensive data covering both biogeochemistry results and those obtained for differentiated analyses of organism pathological conditions.

Nowadays BGC provinces examine as taxon of the biosphere of the 5-th order, sites of the biosphere characterised by certain levels and balance of chemical elements and specific reactions of organisms (Fig.4). The biosphere is initial as an ecosystem, and corresponds with zero level. It is divided into three main taxons of the 1-st level: hydrosphere, atmosphere, lithosphere (continents) co-operating through global biogeochemical cycles as a consequence of a photo- and a hemosynthesis, transformation and mass-transfer of matter. Thus, the balance between sizes of ocean and continents is the estimating factor reflecting power engineering of the biosphere and an orientation of global biogeochemical cycles, in particular of carbon, oxygen and nitrogen. The river systems and large continental reservoirs as transfers or accumulators of matter are accordingly referred to taxon of the biosphere of the 2-nd order. In limits of continents the taxon of 3-rd (regions) and 4-th order are allocated (Ermakov, 2003).

Figure 4. Basic biogeochemical taxons of the biosphere. 0-V - taxons of the 0-Vth order



In view of formation of some geochemical fields and dynamic characteristics (i.e., chemical element flows), biogeochemical provinces are regarded as specific ecosystems resulted from an integrated interaction of chemical element geochemical fields exhibiting well pronounced organismic reactions, including pathological manifestations, specific types of metabolic processes and adaptation to redundancy/deficiency of the respective compounds. Geographically, the biogeochemical endemic area should fit zones of a specific superposition for one or several geochemical fields within the boundaries of which the thresholds of the biological regulation providing normal functioning of the population are exceeded. With this approach, the mapping of the fields enables determination of highest ecological risk zones, and biogeochemical demarcation can be carried out in the form of a territory zoning for the character of a biological response to a developing geochemical situation (Korobova et al., 2019).

Thus, a biogeochemical province can be regarded as a part of a special natural zone within the structure of a single physiographic region, as a unit of physiographic demarcation for its biogeochemical parameters, and/or morphostructural specificities of its relief and climatic factors.

The environmental disasters at nuclear power plants (Chernobyl, Fukushima) activated the assessment of the migration of radionuclides in the environment, the creation of special GIS, tracking and monitoring systems, as well as the creation of a theory of the behavior of radionuclides (the concept of patterns) (Linnik, 2018).

Now biogeochemical provinces are classified from their genesis patterns (e.g., natural, natural & technogenic or technogenic), space scope (regional, subregional, zonal or azonal), their evolutionary processes, biological reactions or ecological status. The origin of technogenic biogeochemical provinces is closely connected with formation of steady associations of chemical elements in areas of large industrial enterprises, power centers, cities, airports or agrolandscapes. In contrast to natural biogeochemical provinces, the technogenic ones are formed just instantly in geological terms, the process biological consequences being still unpredictable in some cases (Ermakov, 2017).

Biogeochemical abnormalities, being a part of a biospheric taxon showing content indices for a single (or a group of) chemical element(s) and/or their compounds in organisms and the environment that differ from the background ones, serve as precursors of biogeochemical provinces. A term “biogeochemical aureole” often used in biogeochemical research practice is close to “biogeochemical abnormalities”. We can distinguish positive (redundancy) and negative (deficiency) biogeochemical anomalies. Unlike biogeochemical provinces, for biogeochemical abnormalities the biological responses (like growth/metabolic disorders, morphological changes or diseases) are not inevitably inherent. Besides, in biogeochemical abnormalities the distinctions between a concentration factor and the background can occur not in every link of biogeochemical food chain (Ermakov, 2015).

A concept “lineaments” is also worth mentioning here. Discrimination of global (i.e., intercontinental) biogeochemical provinces (lineaments) was suggested by A.L. Kovalevsky (1999). They are regulated by a geological structure of the respective areas and cover large parts of continents. As an example, there are selenium- and iodine-deficient biogeochemical provinces that are irregular in shape, and lineaments that are extended linear structures. Territories characterized by redundancies for chemical elements cover smaller areas in the biosphere as compared to those with the element(s) deficiency (for example, there are global mercury-redundant lineaments related to some known mercury belts of the Earth).

Besides, a concept of anthropobiogeochemical provinces and zones is being established now. It has been introduced T.M. Beljakova, T.M. Dianova and T.M. Kramkova (2003) at estimation of an ecological status of mainly residential areas with differentiated analysis of pathologies among their populations: “Human health status really reflects the ecosystem status in general. Therefore, a disease incidence rate among the population can be accepted as an integrated parameter of the inhabitancy influence upon human health (in view of social and economic living conditions), whereas a certain disorder caused by some chemical element (substance) redundancy in landscape components (primarily, ground air inhaled by humans, potable water, etc.) can serve as an index or, sometimes, a degree of environmental technogenic pollutions, as well as a criterion for demarcation of anthropobiogeochemical provinces and zones".

The ecological analysis of some biogeochemical provinces regarding an impact factor, its level, duration and prevalence area suggests that the following azonal and subregional provinces are ecologically most affected: polymetallic provinces with dominating associations like Cu-Zn, Cu-Ni, Pb-Zn, Cu-Ni-Co (the Southern Ural Mountains, Bashkortostan, Chara, Norilsk and Mednogorsk); nickel provinces (Norilsk, Monchegorsk, Nickel, Polarny, Zapolarie and Tuva); lead (Altai, Caucasus and Transbaikalia); mercury (Altai, Sakha and the Kemerovo region); fluorine-redundant (Kirovsk, East Transbaikalia, Krasnoyarsk, Bratsk and Shelekhov); subregional provinces with higher boron and beryllium content. Among them there are areas that are exclusively high-affected in ecological terms while covering smaller areas and being just local sites of the biosphere (Ermakov, Tyutikov, 2008).

Biogeochemical provinces, as well as some other natural and technogenic complexes, are dynamic systems. Exogenous and endogenous flows of the material which migrate into and off the system and are determined with the atmosphere, the hydrosphere and the lithosphere interactions, are common both for background areas and biogeochemical provinces. Nevertheless, in the latter case the flows of substances that are in demand can be reduced or, on the contrary, amplified from some sources.

Thus, the principal causes of the evolution of biogeochemical provinces are: change in the scopes and technologies of ore extraction/process sing; morphological & environmental changes in the structure and/or composition of provinces (including natural accidents like mud flows, floods, volcanism, etc.); transformations of provinces as a result of some technogenic processes and using respective technologies and materials (i.e., pollutions or alterations in environmental and organismic composition); effects of energy factors (fuel burning and coal, oil or gas extraction); a heavy use of mineral fertilizers and pesticides; extensive land tenure; wars and military accidents (Ermakov, 2012).

Biogeochemical endemics

Let's briefly consider biogeochemical provinces coupled with world-wide emerging of some endemics. The term “endemic” is derived from a Greek word *endemos*, i.e. “area” or “locality” meaning a persistent presence of some disorder among humans within a particular biospheric taxon, the disorder being caused by some specific social and environmental conditions. A biogeochemical endemic implies here a local disease caused by some macro- or microelement(s) deficiency or redundancy in the environment and/or food chain.

As a rule, biogeochemical endemics emerge in certain biogeochemical provinces, with fluorosis, adenoma of thyroid or selenium deficiency-associated pathologies being the examples of such global (i.e., widespread) endemics.

Fluorosis

Fluorosis is one of the most widespread endemic diseases in the world; its emergence and development are connected with fluorine redundant content in natural waters, foodstuffs and forages. Endemic fluorosis is a disease affecting both humans and animals, changes in hard tooth tissues being its initial and sometimes single symptom. Externally, these changes are manifested as tooth enamel discoloration and, in heavy cases, damage. Depending on the disorder severity, enamel coloration changes from hardly visible matte-white spots to spots brown or dark brown in color; furthermore, erosion of enamel and change of the hard tissue mechanical properties like fragility/friability or raised dental abrasion are also possible (Roholm, 1937; Ermakov, 2004).

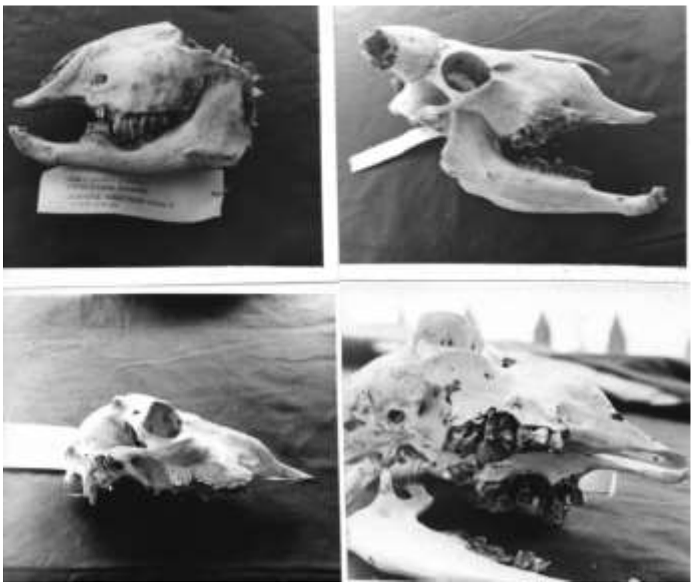
The disease is most often found in some volcanic areas (in Mexico, countries of Latin America, some regions of Africa, and Italy) or drainless arid regions (deserts of China, Mongolia, Kazakhstan, Australia, Africa, Arab Peninsula and India), see Fig. 4.

The linkage of endemic fluorosis incidence levels to one of hydro-chemical parameters, i.e. fluorine redundant content in natural waters is not accidental, clearly reflecting biogeochemical patterns, i.e. fluorine high concentrations in natural waters are primarily found where geological materials are rich in this element (e.g., granite intrusions to which fluorite deposits are often associated, minefields of natural phosphate or fluorite sedimentary deposits which also contain large amounts of disseminated fluorine-containing minerals, and areas of past or current volcanic activity).

Besides, today phosphorites applied as fertilizers, and aluminium enterprises are also a source of fluorine.

Dental and/or osteal fluorosis is the most important manifestation hyperfluorosis. In volcanic areas, a number of arid regions of the world and in zones of phosphorites or apatites extraction/processing endemic and technogenic fluorosis are often observed among human population and livestock, primarily affecting teeth and skeleton. Here a problem of dairy cattle reproduction and maintenance sprang up. When taken in toxic quantities, fluorides disturb calcium metabolism and osteal collagen synthesis due to raising bone accretion rate (i.e. osteal growth or incrementation), and also raise osteal resorption rate and calcium general turnover in organism (Fig. 5) (Safonov et al., 2022).

Figure 5. Fluorosis of farm animals (2-year-old sheep). The third stage of the lesion (changes in the configuration of the skull and dental arcade). Dzhambul region, Kazakhstan



Source: Ermakov et al. (1998)

Adenoma of thyroid (endemic goiter)

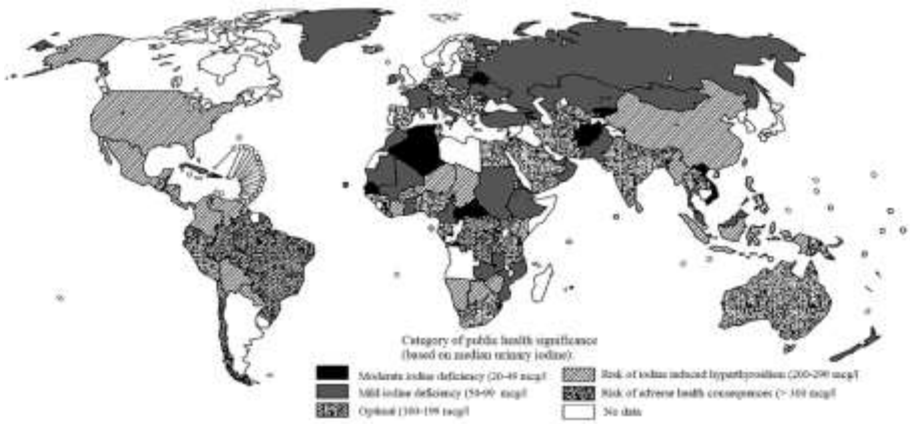
The history of iodine deficiency in animals & humans began together with development of animal life and is traced back deep into antiquity. Thus, a Chinese Code of 1567 B.C. is known, which recommends using seaweeds to treat thyroid adenoma. The link between thyroid adenoma manifestations and iodine content levels in water, soil and food in France was established by a Frenchman A. Chatin in 1854. Though the French Academy of Science did not recognize these data as a discovery, half a century later German researchers E. Bauman and A. Oswald succeeded to prove the etiological significance of iodine in thyroid adenoma pathogenesis (Anke, 2004).

The etiological significance of iodine deficiency for thyroid adenoma and cretinism development is supported by data on thyroid adenoma prevalence in iodine-deficient areas, efficacy of iodine prophylaxis and some determined metabolic features in patients with thyroid adenoma. At iodine deficiency the element concentrations in blood and tissues decrease, thyroid gland functioning is disturbed, and the gland increases in size. In a mammal organism iodine principally provides synthesis of thyroid gland hormones (3, 5, 3'- triiodothyronine, 3, 3 '- diiodothyronine and also thyroxin and hormone tissue derivatives like diiodtyroacetic & monoiodtyroacetic acids, etc.). Cobalt is one of regulators of iodine metabolism and hormone synthesis, apparently forming in thyroid gland a cobalt enzyme regulatory system regulating iodination reactions. Presumably, manganese and copper are also significant in iodine metabolism regulation (Ermakov and Tyutikov, 2008).

The average content of iodine in the Earth's crust is $5x10^{-5}$% (i.e., 0.5 mg/kg). In ground plants iodine presence is estimated on the average at 0.42 mg/kg of dry matter, and in organs & tissues of terrestrial animals it is about 0.16-0.43 mg/kg, while in seaweeds and marine wildlife its content levels are 30 to 1500 and 1 to 150 mg/kg, respectively (Ermakov et al., 2018). Coastal areas of sea and ocean reservoirs are considered to be most positive in terms of their ecological status for iodine, while mountain regions and continental inner parts are, as a rule, deficient for iodine in waters, soils and plants. The ecological status for iodine depends in many respects on a global process of aerosol transfer from the World Ocean to continents and on some specificities of this cycle.

According to WHO data, as many as 12 countries (comprising a half of European countries surveyed) make a group in which thyroid adenoma remains to be a serious problem. There are more than 200 million thyroid adenoma-affected patients worldwide (Li and Eastman, 2012). In separate regions of the world some 0.4 up to 90% of the population are affected by thyroid adenoma. Endemic goiter is found both in mountain areas (like the Alps, the Altai, the Himalayas, the Caucasus, the Carpathians, the Cordilleras, the Pamir and the Tien Shan) and in flat ones (Tropical Africa, South America). In the CIS countries thyroid adenoma is observed in the central areas of Russia, in the Western Ukraine, Belarus, Transcaucasia, Central Asia, some areas of Transbaikalia and the Far East, and also in lower reaches of Siberian rivers. Prevalence of thyroid adenoma is shown in Fig. 5. A district is considered endemic for the disease if 10% of its population exhibits the disorder signs. Iodine-deficient condition may be corrected through iodinated kitchen salt intake and/or special drugs administration.

Figure 6. Assessment of the prevalence of iodine deficiency in the countries of the world based on the measurement of renal iodine excretion (WHO data 1993-2006)



Source: De Benoist et al. (2008)

There are some goitrogenic factors that enhance goiter development. Thus, some points of thyroid adenoma prevalence are known to be located in a number of seaside areas that have sufficient iodine content indices. Here some inadequate and unbalanced nutrition patterns, particularly due to protein/vitamin deficiency, were found to have the negative effect. In polluted potable water some toxic substances like urea serve as a source of formation of strumogens, i.e. thiourea, thiouracil or urochrom. Also, insufficient intake of bromine, zinc, cobalt, copper, or molybdenum into organism or unbalanced microelement ratios (i.e., calcium, fluorine, manganese or chrome redundancy) are shown to promote goiter endemic development. Furthermore, some food products, for example, those originating from representatives of *Cruciferae* family belonging to *Brassica* genus, contain compounds that provide the goitrogenic effect, like thiocyanates or perchlorates, or those blocking iodides entry into the gland; besides, thiourea and thiouracil & its derivatives hamper iodide transformation into organic iodine, and reduce hormone synthesis. Strumogenous substances are contained in turnip, swede, string bean, cauliflower, carrots, radish, spinach, peanut, mango, soya, etc. (Platonova, 2015; Ermakov et al., 2018; Alferova et al., 2019).

Selenium deficiency

The contemporary period in estimation of selenium as a vital microelement is characterized by mastering a profound knowledge of biological functions of selenium compounds. Selenium was found to be genetically important as a synthesis of selenium-containing enzymes, regulated by certain genes, depends on biologically tolerant selenium forms content levels. Selenium-containing proteins and peptides regulate peroxidate levels, nucleic acid synthesis, lipidic metabolism, spermatogenetic processes, visual acuity and attention in human and animal organism. They prevent development of endemic chondrodystrophy, prostatitis and pancreatitis, and possess carcinostatic and radioprotective properties. Selenium deficiency is associated with pathologies like cardiovascular and tumoral diseases (e.g., Keshan disease of humans, pancreatitis, prostatitis, white muscle disease of animals, avian exudative diathesis, porcine liver toxic dystrophy and some others) (Ermakov, Kovalsky, 1974; Maksimović et al., 1991; Djenbaev et al., 2004; Ermakov, 2007; Ermakov, Jovanović, 2010a; Safonov, 2022).

Selenium distribution in the biosphere is non-uniform. In Fig. 6 some basic continental localities of selenium deficiency of the Russia regions are shown. Besides, there are the territories of Se-deficience including a number of areas of the USA and Canada, Australia, New Zealand, Serbia, the Baltics, Belarus, Norway and Finland. Some localities Se-enrichment a number of areas with an excess of selenium are available in other countries (USA, Mongolia, Russia, Kazakhstan and China). But such territories are rare. (Ermakov, Kovalsky, 1974; Ermakov, Jovanovic, 2010b).

The selenium deficiency correction is carried out through microfertilizers and special agrotechnologies, as well as using Se-preparations and food additives, and nutrition control. Wheat growth with optimal selenium content, developed by Professor Ivana Djujić, proved to be quite a successful approach (Djujić, 1995). Besides, a new nontoxic preparation "Selecor" (dimethyl (3,4)-dipyrazolyl selenide), developed by a scientific & innovation firm "AREAL", is of undoubted interest (Safonov, 2022). Finland represents a good example of selenium deficiency prophylaxis at a governmental level. As a result of the measures as taken against selenium deficiency in this country, an optimal status of selenium in food products was achieved, which called for a decrease in most widespread human diseases (Alfthan, 1988; Golubkina et al., 2017).

Figure 6. Selenium Status of the regions of Russian Federation

Source: Ermakov et al. (2018)

Currently, the problem of selenium deficiency in humans and animals remains very actual, since selenium compounds as antioxidants are involved in the fight against viral pathologies, in particular COVID 19 (Iovanovich, Ermakov, 2020; Zhang et al., 2020; Ermakov, Jovanovic, 2022). Nevertheless, it is necessary to take into account the biological rhythms and features of the biogeochemical cycles of seleniu

CONCLUSION

The article focused on vital aspects of biogeochemistry: the influence of the chemical composition of the habitat on human and animal health, on the optimal relationship between man and nature as a whole.

Over the century long period of its development, biogeochemistry has become a popular science covering the problems of the genesis of life, the relationship of organisms and their communities with the environment, the planetary role of living matter, including man-made human activity and its consequences. Biogeochemistry makes a significant contribution to the approximation to the goals of sustainable use of natural resources, to the goals of preventing global changes. Biogeochemistry also plays an important role in the development of the green economy when evaluating green products and plant cultivation media.

Now it is possible to consider realised the geochemical approaches to an evaluation of an ecological condition of territories. If we have data about biota and the environment, the creation of appropriate geoinformation systems (GIS) and also application of BGC modelling of processes taking place in natural-man-made complexes is real. However, the responses of organisms on the extreme geochemical factors are investigated obviously insufficiently. At differentiated analysis of man pathology specific diagnostics of microelementhoses until now predominates common mortality and in very rare cases the specific diagnostic of microelementhoses. As if to responses of other organisms, behind some elimination of rather agricultural and home animals, they are poorly investigated. And in this respect, it is necessary many more to make. And the same time alongside with existing criteria of an assessment of the condition of health of man, animal and various organisms – inhabitants of ecosystems, the development of integrated methods of an evaluation is necessary Zakharov et al., 2000).

If to count biovariety as a measure of sustainable and optimum existence of mankind, in this respect we are able to note the state of society as critical, constantly worsening the future. The modern person is conservative, and this quality in many respects worsens of prognostication evaluation of development of society and the biosphere as a whole. In this connection it’s appropriate to underline, that the future of the person in many respects depends on its interaction with other organisms. And the prognostication evaluation should advance "conservatism" intrinsic *Homo sapiens*. And in this respect modelling of natural-technogenic processes based on deep knowledge of biospheric processes and the ecological laws, becomes an invaluable "saving" means of man of the future creating the noosphere.

Thus, biogeochemistry becomes not only the theoretical basis of the doctrine of the biosphere, but also the foundation for the development of modern technologies in overcoming the ecological crisis, including the development of a green economy and environmental protection.

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