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PRINCIPLE OF THE NORMALITY IN THE ENVIRONMENTAL GEOCHEMISTRY

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ABSTRACT

The propounded by the author (2002) principle of the normality is a new specific paradigm of the environmental geochemistry. It reads: The optimum living conditions of the environment are determined by the normal values of its geochemical characteristics – elements content level, physical-chemical and thermodynamic parameters. There are six aspects and consequences of the principle: (1) the clarke contents of the elements serve as an ecological-geochemical standard of the conditions for living organisms habitat, incl. man, in the biosphere; (2) an important goal of the environmental geochemistry is the determination of minimum and maximum threshold values of the variation intervals of the normal (clarke or background) element contents; (3) all the chemical elements are indispensable for the normal existence of the living organisms, incl. man – there are not "useful" and "injurious" or "useless" elements; (4) the background content of the elements is a cardinal geochemical standard for the quality of the environment; (5) the complex assessment of the state of the environment includes the investigation also of its physical-chemical and thermodynamic parameters; (6) the geochemical approach gains an advantage over the ecotoxicological one at the assessment of the quality of the environment components and of the degree of pollution.

Key words: environmental geochemistry, principle of the normality, clarke contents, geochemical background, geochemical standards.

INTRODUCTION

A new interdiscipline science – *the environmental geochemistry* was born in the 70ties of the 20th century in reply to the high sharpening of the problems connected with the contamination of the nature. It develops in the field of interface of the geochemistry with a number of other natural sciences, first of all – ecology, geology, physical geography, chemistry, mineralogy, soil science, hygiene (geohygiene), etc. At the present time the environment geochemistry has its clearly defined philosophy and object of investigation. As a separate branch of the geochemistry it studies the regularities of the distribution and the migration of the chemical elements and their anthropogenic transformations in the man's natural environment. The latter includes the part of the Earth exospheres (the anthroposphere), which is being inhabited or visited by man: the land surface, the low part of the atmosphere, the hydrosphere and the upper part of the lithosphere. The distinctive feature of the environmental geochemistry is the investigation of the interaction between the substances of the "technogenesis" (Ферсман, 1955 – p. 704) and of the natural geochemical systems, and the reply of the latter ones in the case they undergo an anthropogenic impact. Its strategic object – "geochemical ideal", in accordance with the term of L. G. Bondarev (Бондарев, 1976 – p. 48) – is the preservation of optimum natural living conditions for the man and the other organisms on Earth. As far as the anthropogenic pollutions of the environment are presented by different kinds of substances, the studies for their identification and their effects on the nature systems turns the environmental geochemistry into a fundamental and immutable element of the struggle for the survival of the human society, for balanced ("sustainable") relations between it and the environment. Thus it strengthens its position as a science of the 21st century – one of the most modish and priority directions of the investigations in the Earth sciences.

A brief analysis of the development of the environmental geochemistry and its theoretical bases is done in previous publications of the author (Kuikin, 2002; Куйкин, 2002). The aim of this article is to present more fully the principle of the normality, which has been developed further after the two above cited works.

REASONS FOR THE FORMULATION OF THE PRINCIPLE OF THE NORMALITY

As J. Fortescue (Фортескью, 1985 – p. 308, 309) notices, during the 60 – 70ties of 20th century, when the geochemistry as a scientific discipline proved not to be ready to face the problems on the contamination of the environment, research workers without any geological education and knowledge of the principles of the geochemistry began studying the behavior of the elements (mostly of the toxic substances) in the environment. This contradiction caused an evident confusion, and in particular – spending of great funds for investigation without using the available information and knowledge (Such a process happened later on in Bulgaria during the 90ties – see: Куйкин, 2002). A gradual return to the holistic approach in the environmental geochemistry was observed in the advances countries toward the end of the 70ties and a contribution of importance for this have the works of E. Kothny (1973), J. Fortescue (1980 – Фортескью, 1985) and others. It was clarified that a good knowledge of the state and the processes within the nature geochemical systems and their transformations under an anthropogenic influence is necessary for the preservation, and according to some authors – for "the creating" (Перельман, 1973; Бондарев, 1976), of optimum living conditions on Earth. A proper choice of a complex of nature protective measures is possible only under such circumstances. Regardless of this, the cases of substantial misunderstandings are still not rare in the practice of this field. They are manifested in relation to such matters as: lack of

understanding of the importance of the geochemical background; not giving an account or underestimation of "the weak" geochemical anomalies; neglecting of the physical-chemical and the thermodynamic parameters of the environment; formalistic attitude to the hygiene norms – maximum allowable concentrations (MAC), etc.; overestimation of the results of the laboratory ecotoxicological examinations irrespective of their relation to the geochemical characteristics of the nature environment; giving absolute meaning of the terms "toxicity" of some elements (e. g. arsenic, cadmium, mercury, selenium, etc.) and the "usefulness" of other ones (e. g. the "nutrients" nitrogen, phosphorus, etc.). The clash with such ones and similar to them misunderstandings brought about the author to the idea of the necessity of the formulation of a new paradigm of the environmental geochemistry, that would reveal the essence of such basic terms as: optimum living environment, pollution of the environment, geochemical standards and so on. The term ***"paradigm"*** (from Greek ***"paradeigma"*** – pattern, example) is introduced in the Wissenshaftslehre by T. Kuhn and means a generally acknowledged scientific achievement (a law, a theory, an application, instruments), which gives models of problems and of their solutions to a practising scientific community for a space ot time (Кун, 1996 – p. 12). The paradigm determines the way of thinking (the ideology) and the directions of the studies in a given scientific field.

The environmental geochemistry builds up its theoretical concepts upon the *fundamental paradigms of the general ("classic") geochemistry* (Kuikin, 2002; Куйкин, 2002) and three specific new paradigms: (1) principle of the normality; (2) ecological geochemistry (or "ecological approach"), and (3) landscape geochemistry (or "landscape-geochemical approach"). The second and the third of the specific paradigms are considered as such ones by J. Fortescue (Фортескью, 1985). The principle of the normality is formulated for the first time by the author in 2000 (I. Atanassov, S. Kuikin *et al*.: "Investigation and elaboration of precautionary values for heavy metals and metalloids in soils", Sofia, 2000, MEW – report № 874-2324) and is presented publicly in 2002 (Kuikin, 2002). The concrete motives to that are the coming across in the practice mistakes of deriving as hygiene norms (thresholds) for increased contents of injurious substances in the environment components – maximum acceptable/permitable concentrations (MAC or MPC, etc.). For example, values for maximum acceptable risk levels (MAR) and negligible risk levels (NRL) of heavy metal concentrations in soil, equal and even lower than their referent background values were derived through laboratory ecotoxicological investigations in the Netherlands (Meent, Aldenberg, *et al*., 1990). Such results are unacceptable for a geochemist. A doubt arises that "something is wrong" – the researchers' "paradigm" is wrong (after T. Kuhn – Кун, 1996)? According to the paradigms of the geochemistry, such thresholds should be above the upper variation limits of the normal ("background") contents of the polluting substances. Moreover, obviously it hasn't been given an account of the fact, that the substances in the nature are usually met in "inert" (immobile) forms, and only a part of them – in "mobile" (soluble) forms, easily consumable by the living organisms (the concept of the total and partial element contents). The authors of the cited study themselves, notwithstanding the derived values, recommend the background contents to be accepted as "desirable levels" for the naturally occurring substances.

FORMULATION OF THE PRINCIPLE OF THE NORMALITY; ARGUMENTATION

The propounded principle, with slight modification of the formulation in Kuikin (2002), could be defined in the next way: ***The optimum living conditions of the environment are determined by the normal values of its geochemical characteristics – elements content level, physical-chemical and thermodynamic parameters***. This principle as a paradigm is closely connected with the other two "specific" paradigms – the ecological and the landscape-geochemical (the three ones are parts of a whole and they function together), but its separate formulation ensure a more clear and deeper vision (outlook) on the essence of the nature phenomena and a model of solving of the problems connected with the environment quality.

The principle of the normality is a manifestation of two fundamental theses: (1) the V. I. Vernadskiy's (Вернадский, 1954) law of the ubiquitous distribution and the uniform dispersion of the elements, and (2) the unity of the inorganic and the animate nature. Life on Earth has originated and evolved in the course of several milliards of years under the conditions, determined by the presence of all the chemical elements and the respective physical-chemical and thermodynamic parameters of the outer spheres of the earth crust. The living organisms build their bodies from the substances of their habitat, and these substances, due to their ubiquitous distribution, enter into the organisms' composition and, in accordance to their different properties and abundance, exercise their specific functions in the structure of their tissues and in the exchange processes of matter, energy and information. On the other hand, under the influence of the living organisms, the Earth exospheres change their composition too – the biosphere is formed. A dynamic equilibrium is established between its components, which is kept through the biogeochemical circle of the elements. The present-day biogeocoenoses and ecosystems are formed in the course of hundred thousands to millions of years (the Quaternary period). The adaptation of the organisms to the geochemical conditions has a global nature, owing to that the normal, wide-spread characteristics of the environment are optimum for them.

SOME ASPECTS AND CONSEQUENCES OF THE PRINCIPLE OF THE NORMALITY

Being aware of the difficulties to put all aspects and consequences of the considered principle in a nutshell, we will dwell on six statements of paramount importance.

First*:* ***The clarke contents*** of the chemical elements serve as an ecological-geochemical standard of the conditions for living organisms habitat, incl. man, in the biosphere. YU. E. Saet, B. A. Revich et all. (Сает, Ревич *и др*., 1990 – p. 58) formulate this maxim particularly about man, but it has obviously a wider ecological significance. The clarkes, calculated as mean element contents totally for the earth crust, for its individual layers and environment components, are objective reference values – geochemical standards for the element concentrations, in which presence the life on Earth exists. At

the regional assessments, the element contents are being categorized as normal (nearly equal to their clarkes), deficit or insufficient (bellow the clarkes) and surplus or excessive (above the clarkes). The ecological effects (endemic diseases of plants, animals and man) within the regions of deficit or surplus concentrations of some elements – "the biogeochemical zones and provinces" (Ковальский, 1974) – are an object of study for the geoepidemiology.

Second: An important goal of the environmental geochemistry is the determination of ***minimum and maximum threshold values*** of the variation intervals of the normal (clarke or background) element contents in the environment components, that limit the conditions of an optimum development of the organisms (Ковальский, 1974; Сает, Ревич *и др.*, 1990; Алексеенко, 2000). So far the accent in the geochemistry was put mainly on the mean values, or only on the upper thresholds of the normal contents with a view of the geochemical typification of the objects of study or the identification of the ore-genic anomalies and the anthropogenic pollutions.

By the adoption of the new rule, the principle of the normality proves to be in accordance with the two known fundamental laws of the ecology: (1) the law of the tolerance: each one of the living organisms has its determinate, evolutionary inherited upper and low limit of tolerance to every ecological factor; the going out of the factor level even beyond one of those limits is adequate to an incompatibility of the surroundings with the life, i.e. leads to death; (2) the law of the limiting factor: each one of the living organisms has such limits of stability (endurance, tolerance) to whichever of the ecological factors, at the going out beyond that this factor causes reversible and irreversible functional aberrations (disturbances) both of some organs and of some physiological processes, without leading directly to a lethal exit (Стадницкий, 2002). The considered principle deals namely with the geochemical factors of the environment. A. I. Perelman (Перельман, 1975 – p. 131) proposes the notion of an optimum content of the chemical elements in the environment – such a content of theirs in the foodstuffs, water and air, which supplies the man's needs in the best way. He pleads for a creating of optimum geochemical conditions in the different landscape zones (Перельман, 1973).

Third*: **All the chemical elements are indispensable*** for the normal existence of the living organisms, incl. man – there are not "useful" and "injurious" or "useless" elements. "A question could stand only about their necessary and injurious concentrations" (Алексеенко, 2000 – p. 162 and 525). The compounds of all chemical elements could be both useful and toxic for the man (Бъчварова и Петров, 1977 – p. 12). From this follows the notion of the conventionality of such terms as "nutrient" and "toxic" elements. In this respect we find a forerunner of our paradigm in the maxims of the Swish physician and naturalist from the 16th century Paracelz (Philip Theofrast Bombast von Hohencheim, 1493 – 1541): "Everything is poison and anything is not devoid of poisonousness" and "The dose makes the poison". The concentration is the thing that specifies a particular substance as a medicine or a poison. At that not the quantities only, but the forms of state of the elements are of importance as well.

It is not difficult to illustrate the thesis that even "the most toxic" elements in low concentrations are a necessary food for the organisms, and "the most nutritious" elements in high concentrations become a poison for them. Arsenic occupies the position of "a king of the poisons" and selenium – of "a cardinal of the poisons" on the top of "the poisonous hierarchy of the chemical elements and their compounds" (Бъчварова и Петров, 1997 – scheme 1). However their compounds are being used as medicines as well. The optimum concentrations of selenium compounds in the human organism are necessary for the realization of the functions of some organs (the retina of the eyes, the skeleton muscles, the heart, the liver, etc.). In the regions of selenium insufficiency it is provided to the organisms in the forms of food supplements or medicines. On the other hand, the "nutritious" elements ("the nutrients") carbon and nitrogen, together with hydrogen and oxygen, are constructive components of the toxins – ones of the most dangerous poisons, many times stronger than the classic poisons of the arsenic and cyanic compounds. Or another example – with the vital necessary for the man oxygen: both the oxygen hunger (the suffocation) and the oxygen satiating (the oxygen overdose) are varieties of a poisoning (Бъчварова и Петров, 1997 – p. 18 – 23). A man needs (his organism is adapted to) an optimum oxygen concentration. The rule of "the golden mean" is active in the cases considered.

Fourth*: **The background content*** of the elements is a cardinal geochemical standard for the quality of the environment at the ecological-geochemical assessments. The regional geochemical background is a basis for the elaboration of hygiene norms for quality of the environment components, and the local geochemical background – for the assessment of the concrete geochemical anomalies (natural or anthropogenic ones). The level of concentrations and the forms of element state, generally speaking, are determined by the geological history, the geological structure and the climatic, or in a broader sense – by the physical-geographical conditions (by "the geological past" and "the climatic present" – Ферсман, 1954, p. 555) of the individual regions or "biospheric structures"(Алексеенко, 2000 – p. 527). In the stage of "the noosphere" an increase of the geochemical background for the components of the Earth exospheres (soil, water, air, etc.) is observed in some regions, as a result of the ubiquitous regional diffuse dispersion and input of substances from anthropogenic sources (Terytze, 2001 – p. 76; Kuikin, Atanassov *et al.*, 2001 – p. 129).

Fifth: The complex assessment of the state of the environment includes the study also of its ***physical-chemical and thermodynamic parameters*** – power of hydrogen (pH), oxidation-reduction potential (Eh), temperature (T), pressure (P), humidity, etc. They are factors for the forms of the element state, the migration or the accumulation of the natural and the anthropogenic substances, and at the same time they are a part of the direct ecological factors. As it is well-known, each one of the ecological factors is dynamic and changeable in the time and in the space. That's why the contemporary environmental-geochemical investigations must be carried out on a landscape-geochemical basis, with giving an account of the development history of the landscapes.

Sixth: ***The geochemical approach*** gains an advantage over the ***ecotoxicological one*** at the assessment of the quality of the environment components, in particular – at the assessment of the degree of pollution. Many critical notes are given in the literature about the developed in the recent decades hygiene norms for the maximum acceptable or permissible levels (MAC or MPC, etc.) of increased concentrations of the pollutants

(Сает, Ревич *и др*., 1990; Алексеенко, 2000, *and others*). It is concluded that MAC should be applied in the practice only as previous indicators–reference points, necessary probably in the countries of low ecological culture and during the initial stages of investigations in new regions (Алексеенко, 2000 – p. 521). The quality norms/standards must give an account of the geochemical characteristics of the concrete biosphere (or landscape-geochemical) structures.

"The weak pollutions" also must be controlled carefully – a thing that is already brought as obligatory into action by means of the soil protection legislation in some countries, for instance The Netherlands (Swartjes, 1999) and Germany (Teritze, 2001). The adoption in the Germany's legislation of differentiated precautionary soil values – indicators of the arising of a hazardous soil change is indicative in this respect. It is required the ecotoxicologically founded effect thresholds to be checked against the actual soil background values (Terytze, 2001 – p. 74 and 76). Incompetent are the expert's interpretations, often coming across in the reports about the assessment of the influence on the environment – AIE (Bulg. "OBOC"), that the values below MAC are an indicator of an absence of pollution, without juxtaposing the date to the upper background thresholds. "Weak" pollutions are possible to be available in such cases, which could be a cause to find out the sources and the mechanisms of the anthropogenic pollution in order of its further elimination or restriction. At the same time, we must have in mind that the prolonged influence of the "weak" pollutions also leads to negative ecological effects, similar to that ones of the short-term "intensive" pollutions.

CONCLUSION

The considerable experience from the practical activities and the theoretical developments in the course of more than three decades created favourable prerequisites for the formulation of the principle of the normality as an important specific new paradigm of the environmental geochemistry, an essential component of its philosophy. The literary quotations in connection with the considered six aspects and consequences of the principle show that recently the last ones have been realized and traced out to a great extent by the leading specialists in this scientific discipline. Their systematization within the scope of a general paradigm and the formulation of the principle of the normality is expected, on the other part, to stimulate the progress in the further solution of the problems in the environmental geochemistry, for the preservation of optimum natural conditions for the life and the activity of the human society on Earth.

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