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*WATER QUALITY AND ECOSYSTEM STABILITY: THEORETICAL AND PRACTICAL ASPECTS OF RESEARCH**

SUMMARY. In this paper the key concepts of water quality and ecosystem stability are defined. It is shown that without a deep study of water quality formation and stable functioning of ecosystems it is impossible to offer an appropriate system of water ecosystem monitoring and prevent the destroying impact of anthropogenic factors on the environment. It is stated that there are three ways of future interaction of the mankind and natural ecosystems: 1) we can continue destructive impact in present scale; 2) we can stop fully all the impacts and recover the natural condition; 3) we can recover main parameters and retain a stable ecosystem functioning. It is obvious that the first way is unacceptable, the second one requires considerable expenses and could be discussed for separate, specially protected water ecosystems. The third way could be chosen for the majority of water objects in the regions with anthropogenic activity.

KEY WORDS. Water quality, ecosystems, stability, monitoring.

The problem of the qualitative depletion of water resources as a result of their pollution has become urgent during the last decades. Water is among those natural components the planned transformations or incidental changes of which influence the planet to the fullest extent. The anthropogenic factor of forming waters chemical composition ranges with natural geochemical and biological processes. The exploration of mineral resources including raw hydrocarbons and the transformation of water production areas, cross-border streams, industrial and domestic effluents including unrecorded ones result in the transformation of geochemical cycles in the *water-producing area — water body* system, eutrophication, acidulation, toxic components occurrence in water environment which eventually decreases the water resource potential in the life-support system and in maintaining reproducible biological components.

In the world of science, great attention is paid to studying water quality and ecosystem stability. Modern researchers have proved that along with local pollution, global environmental transformations and cross-border pollutants have a great impact on waters quality and ecosystem transformation. Nowadays, all the water

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ecosystems, at some extent, are potentially influenced by anthropogenic factors, as a result of global processes occurring on the Earth. The climatic variations can influence water ecosystems directly, through the changes in temperature rate, or indirectly, through the changes in hydrological cycle, geochemical processes on the drainage area, toxic substances behavior, eutrophication development, acidulation, and through other anthropogenic-induced processes.

The *water quality* concept. The problem of water quality could seem a simple one, but still there is no definite opinion: what kind of water could be defined as having a good quality; and what are the objective criteria for such evaluation?

According to GOST (Russian national standard), *water quality* is "the range of consumer-oriented physical, chemical, and biological water properties". The consumers' criteria of water quality vary, depending on their purposes. These criteria differ essentially for industrial water consumption, drinking water supply, natural or artificial fish reproduction. The concept of "quality" itself has a qualitative character expressed in expert opinions, e.g. pure, polluted, highly polluted, satisfactory, non-satisfactory, etc. As water is a vital source for all living beings, including human beings, and a habitat for aquatic organisms, its quality can be evaluated only in connection with living systems. Here a logical question arises: how closely are all those qualitative and often subjective definitions of *water quality* related to the condition of living organisms consuming water or inhabiting it?

Water quality is characterized by definite properties. We should denote that the expression "biological quality of waters" is incorrect as biological systems are of the higher organizational level in comparison with chemical structures, including water as a natural component. Natural water properties are formed as a result of complex processes in the water-producing area and in the water body: 1) physico-chemical ones — chemical erosion of elements, their interaction, filtration, migration, absorption, desorption, precipitations, and surface evaporation; 2) biological ones — biochemical, microbiological, and biofiltrational processes. Relative natural stability of water properties and their seasonal variability in certain water bodies is sustained by means of the dynamic balance and cyclicity of natural processes. During life-sustaining activity, organisms using water as a source and habitat, influence its properties, and sometimes they play the key role, thus water is a nonliving body.

Aquatic organisms are more dependent on water properties as a result of their metabolism in water ecosystems in comparison with those in land ecosystems. Water is their habitat and it is characterized by definite factors. The factor, according to Yu. Odum's definition [1] is "an abiotic time-and-space dependent factor of environment which an organism responds to, depending on its strength. Vital conditions for existence and reproduction of organisms inhabiting various water bodies could differ essentially. For example, if we move typical northern species, adapted to low mineralized waters, to baseline southern lakes with certain water properties (even if we create the same temperature conditions), it is obvious that the quality of these waters will not be acceptable for these species and vice versa. There are water bodies with unique water properties (e.g. geothermal or saltish ones), where unique biocenoses are formed. The "optimal" conditions are those under which species can rise the maximum generation. This definition is in agreement with the concept proposed by Stroganov in the early 1970s: "Good water quality is such a quality in which the effectiveness of water species reproduction is the highest". But we should pay attention to the fact that pathophysiological disfunctions of living beings appear earlier than their reproductive activity decrease.

Abstracting from subjective demands of certain consumers to water quality, we find out that the most universal water quality definition can be given from the perspective of the ecological paradigm: "*Water quality is the set of water properties formed under the influence of chemical, physical, and biological processes both in the water body and in the water-producing area. The water quality in a certain water body could be called favourable if it meets the requirements of health maintenance of the most sensitive organisms and species reproduction adapted in the process of evolutionary development to living in the conditions of this water body*".

On the assumption of the definition given above, it is obvious that the evaluation of water quality (in experimental or natural conditions) is rooted in studying the impact of water properties on water ecosystems and their structural components — individual organisms, populations, or communities. As we cannot deliberately subject people to the water quality research, we assume that if water quality meets the living and reproduction requirements for the most sensitive aquatic organisms, then this water quality (except some particular cases) could be considered as meeting the requirements for human health maintenance.

The *ecosystem stability* concept. When a destructive factor, e.g. the ecosystem pollution, penetrates into the system, first of all it destroys the system stability. In specific environmental conditions with seasonable variability, which is determined by geographical location, certain ecosystems are formed. The similar values of structural and functional characteristics (taking into account the seasonable dynamics) during quite a long period of time characterize the ecosystem stability limits. The stability could be characterized as structural (the general structure maintenance with the function change) and functional (general function maintenance in the changed structure). A.A. Alimov [2],[3] defines the measurable parameters of the stability of a community or an ecosystem as variation limits of their characteristics that do not exceed the average variation level historically formed and intrinsic to this system. The stability is the function of ecosystem resistance to destabilizing factors, e.g. toxic pollution, eutrophication or other changes of the habitat.

The analysis of the published works shows the diversity of approaches and definitions of the ecosystem stability evaluation, i.e. of its ability to resist perturbing factors, including the pollution flow. Ecosystem stability could be evaluated as its ability to resist perturbations (resistant), and as its ability to revert to its initial state after the stress factor effect (elastic). The elastic stability is often referred to as the ecosystem resilience. The stability limit could be considered both as the functional one and as the structural one; in the first case the function does not change with the change of the structure, in the second case the system retains its basic species and the extinction of some species does not result in the change of principal functions [3], [4], [5], [6], [7], [8].

Yu. A. Izrael [9] formulated the concept of the ecosystem assimilation capacity characterized by its ability to utilize the pollution flow without a change in its structural and functional organization, i.e. the ability of the system to "recycle" the external pollutants. The assimilation capacity is determined, first of all, by the self-purifying processes, which in their turn depend both on hydrological and biochemical processes and on species abundance as well as functional system diversity.

A.F. Alimov [2] suggests the "tolerance" concept which means the ecosystem ability to resist the external condition changes. This concept has the same meaning both as the "assimilating capacity" concept [9], and as the generally accepted "stability" concept [2], [3], [4], [10], [11].

We also connect stability with the ecosystem structure, with biological diversity of communities, which in its turn stipulates the specific nature of thermodynamic processes of these ecosystems in their "normal" condition and under the influence of some additional perturbation factors [12], [13].

Summing up the most cited ideas of stability, we assume in general that *"the ecosystem stability is its ability to retain its structure and functions under the effect of destructive factors in the limits peculiar to the ecosystem variability, i.e. to resist perturbations or to revert to its initial state after the effect of a stress factor, e.g. toxic pollution"*.

Under the effect of some environmental factors, a certain ecosystem can stay in a stable condition while the impact of certain factors is within the limits to which the system is historically pre-adapted. If the impact is growing or the external factor properties are changing, as in the case of pollution or other anthropogenic loads, abnormal for the system, or abnormal in such amount, its structure and functions are changing and it is transforming to another state with the new values of structural and functional characteristics. In this case, it can acquire other properties and in this condition (as, actually, a new system) it will stay stable during the period of the effect of these factors.

There are three key-factors that specify water ecosystem stability under the effect of destabilizing toxic agent: 1) adaptability to high variability of environmental factors (resilience); 2) structural and functional abundance of ecosystems (tolerance); 3) self-purification ability which is mainly determined by hydrological (dilution, interfusion) and biogeochemical factors (accumulation, sorption, inactivation, sedimentation, etc.).

Energy flows play the key-role in the system stability supported both by the resistant and elastic stability. This concept is rooted in the idea that all systems tend to minimize the entropy and maximize the energy normalization [3], [4]. If the energy input is equal to the output, taking into account the dispersion, the ecosystem condition remains stable in time. If the input exceeds the output, the system adapts through the growing number of the organisms providing the ecosystem with better energy efficiency. This may look like amplification. And finally, if there is a shortage of energy input (the output exceeds the input), then the system is simplified [1], [3], [14]. During the biosphere evolution, the optimum organization determined by the peculiarities of assimilated energy efficiency on various levels of living was developed [15].

Yu. Odum formulated the "energy grant" concept, which means any source of energy increasing the part of energy which can be used for production. An energy grant, as the author believes, is a moderate flow of organic and biogenic substances to the ecosystem; however, high and irregular flows are considered as stress factors. Toxic pollution is considered as a stress factor only that results in intensive energy dissipation and the ecosystem degradation.

In a stable ecosystem with a high degree of complexity and a wide range of natural variability, all species require energy. However, species differ in consuming energy for their growth, production, and maintenance of basic metabolism. They also differ in the amount of energy stored in their tissues, depot fat, or reproductive organs. Violating the energy transmission through the trophic structure results in its unregulated dispersion. From the energy approach, the entropy of biological systems increases under a destructive (perturbing) factor, e.g. input of toxic matters, thus the mechanisms of retaining stability, as it is known, will aim to conserve and regulate energy in the ecosystem.

In nature, anthropogenic transformations develop in complicated ways with the constant interaction of opposite-oriented processes, e.g. variability and retaining stability. If energy wastes are balanced with "grants", the system will be stable in a certain condition; under the change of energy flows in one of the directions, the system will change, i.e. remain in a critical condition until it obtains a qualitatively new balanced condition [10].

The key theoretical and applied tasks. On the assumption of proposed "water quality" conception, it's obvious that the methods of its evaluation (under the experimental or natural conditions) should be based on the fundamental development in Geo- and Biosciences. Without a quite detailed study of water properties formation under current conditions of anthropogenic loads and responses of living systems (ecosystems in general) to anthropogenic pollution, it is impossible to make a case for a set of water quality evaluation and water rationing criteria; therefore, it is impossible to keep the waters of Russia pure.

The water quality monitoring system in Russia, as in a great number of other countries of the world, allows determining only an increased concentration of specific components (more often toxicants) against their limiting values, i.e. maximum allowable concentration (MAC) for the water bodies exposed generally to sewage. In Russia, from Arctic to the arid zones, the same values of MAC of toxic substances are used. MACs actually do not take into account the particularity of water quality formation, the zonality and geo-landscape features, as well as the behavior of anthropogenic foreign elements under different conditions, associated factors, and combined effects. The modern age is characterized by integrated effects, the different factors of which could be both synergetic and antagonistic. It is naturally determined that the global scientific society of this field of knowledge has focused lately on the impact study of combined effects under diverse ecological conditions in the period of climate warming.

Reasonably criticizing the system of MAC, experts in hydrochemistry propose to evaluate water quality and specify the pollution by the average background indicators of chemical water composition (including the pollution components) plus one or two quadratic deviations. We can ask the question: what will these deviations mean for the living systems? In their turn, the experts in biology propose to take into account the indicators of changes in an individual, population and community state. But it is not clear under which conditions (indicators of chemical water composition) all the registered changes in biological systems have occurred.

The methodology of ecological regulation is based on the disclosing of the cause-effect relationship which could be understood on the basis of constructing and analyzing doze-effect dependencies. The multivariable set of water quality evaluation criteria should be based on the understanding of the regularities of water ecosystem anthropogenic variability and on integral assessment of their "health";

the techniques of major negatively-influencing factor identification should be based on detailed hydro- , biogeochemical data and knowledge of behavior peculiarities and properties of toxic elements under natural conditions. In addition to the regulation of toxic flows in the ecosystem, three main blocks of tasks, revealing the necessity of quite complicated theoretical research in Geo- and Biosciences, are defined.

1. *Determination of the impact dose integrated indicator* is based on the perception of anthropogenic foreign element migration, speciation, transformation and sedimentation regularity in the system: *source → water-producing area → water body*; the interaction between the natural factors in the water-producing area and the water body. As a rule, industrial wastes and atmospheric depositions have a multi-component composition and are often followed by adverse effects. Therefore, along with the basis of chemical criteria of recording certain negative developments in aqueous media, we should find a technique to "compress" diversified information to the unified numerical value of water quality assessment adequately reflecting the impact dose on biological systems taking into account the total, synergetic or antagonistic interactions between all the components of abiotic environment.

2. *Reasoning of the criteria for the assessment of anthropogenic impact consequences* is the knot of the matter and based on the perception of regularity of biological system anthropogenic variability, stability and adaptation mechanisms; determination of "a norm and a pathology", thresholds of irreversible changes in organisms or qualitatively new conditions of communities. The most informative basis for understanding pollution effects and for reasoning criteria for their assessment is provided by the research of the integral picture of changes at all organization levels (from the molecular-cellular one to those of organisms, populations and communities). Recently, the "ecosystem health" concept has been widely used in scientific literature for integral evaluation of environmental pollution effects [16]. It is taken into account that the symptoms of physiological changes and diseased conditions of organisms, functional and structural deviations in population and community conditions reflect poor "health" of the ecosystem, therefore, a water quality problem.

The criteria of organism condition assessment (according to biochemical, physiological, clinical, and pathological-morphological symptoms of morbidity) are of importance for the assessment of the water pollution effect currently, at the level of populations (changes of growth rate, ripening period, lifespan, fertility, etc.) and communities (changes of productivity, biodiversity, trophic structure, etc.), these criteria also could be used for the integral assessment of prolonged influence consequences of low dose pollution and unsatisfactory water quality. The responses of living systems are not always direct and could show involving feedback. The secondary effects of water pollution as well as the consequences of changes in the entire trophic system can have a very significant effect.

It is easier to determine the norm and pathology at lower levels of living organization. At higher levels of ecosystem hierarchy (populations, communities), it is more difficult to specify borderline states. In reference to ecosystems, the "a norm and a pathology" concept has the meaning and subject matter only when we have specified the reference conditions and positions, in terms of which the processes moving in the ecosystem are considered.

3. *Specifying critical levels and loads* is an integration stage of the research and is based on identification of the relations in the system: volumes of pollutant release and runoffs (loads) ↔ transformations at the water-producing area and

integrated runoff ↔ water environment processes and integrated index of impact dose ↔ biological effects and their record criteria ↔ critical levels of impact ↔ loads. If the critical levels of integrated pollution are specified for the biosystems and there are bond models of emissions (inputs in the water-producing area) and of concentrations formed, then the critical loads and their excess for the specific water bodies are determined.

When forming the concept of *permissible* anthropogenic load on the specific natural objects, it is logical to set out "environmental constraints". It is out of the question that the requirements for different water bodies, for example reserved, drinking or urbanized ones, could vary significantly. Here politically correct decisions on water quality management are required.

The experience of water quality and ecosystem stability research in West Siberia. Although the majority of the regions of West Siberia are highly supplied with water sources, there could be a problem of their depletion as a result of anthropogenic loads of local and global character. Unfortunately, so far Russian economy has held a mineral-raw materials trend of which production and export of raw hydrocarbons dominate. More than 6% of the world oil production is concentrated in this region. The intensive development of oil and gas complex in West Siberia, which started in the 1970s, has led to the pollution of the water ecosystems in this region. The major pollutants of the surface waters here are oil products, phenol, ammonia, compounds of copper, zinc, manganese, and iron. The particular danger for the water bodies of the Ob-Irtysh basin is in oil products which are 80% of the total pollution. Even in those cases when there are no direct pollution of rivers and lakes, the deterioration occurs due to air pollution, spreading to the long distance. At the same time, the Ob-Irtysh basin is known in the world for its stocks of the unique valuable species of fish such as peled, Siberian whitefish, broad whitefish, and muksun.

Recently, the global scientific community has shown its great concern on the potential danger of distant pollutants transferred from the developing Asian countries such as China, Mongolia, Kazakhstan and others. According to the prognosis, the emissions of carbon dioxide and acid-forming gases, metals and other hazard substances will grow. West Siberia is located on the way of the dominant cross-border transfer of the pollutants from these countries.

In the southern regions and in the places of oil production, the situation with water quality is close to critical. We may need more detailed, systematic, and methodically grounded research, focused on the negative processes revealing and integral assessment of water resources quality condition in the West Siberian regions, especially at the production sites of raw hydrocarbons. Lots of pollutants can have toxic, carcinogenic and mutagenic effects as a result of their own properties or after the transformation.

West Siberia being a unique geographical entity is interesting for research, as it covers a great variety of natural-climatic zones (from tundra to steppe), and landscapes (arctic, marsh, forest-taiga), and therefore, of ecosystems. This provides a basis for conducting deep theoretical research and knowing the laws, controlling the anthropogenic variability of forming physicochemical water properties under current conditions, for studying ecosystem stability in regard to anthropogenic impact, for developing methods of water quality biological evaluation and creating the scientific basis for limitation of the impacts to the limits, providing the stable functioning of aquatic ecosystems.

The principal novelty of the research experience in West Siberia is the integration of the results obtained in two closely connected areas: 1) territorial large-scale research, revealing the anthropogenic variability of water quality in the context of zonal and landscape-geographical differentiation; 2) profound system research of ecosystems and their elements on experimental watershed both under natural intact conditions and according to the priority influencing factors and indicating species, providing the opportunity to reveal cause and effect relations, nature and the level of anthropogenic load on the aquatic ecosystems. In Fig.1 the block-diagram of our methodological approach is presented.

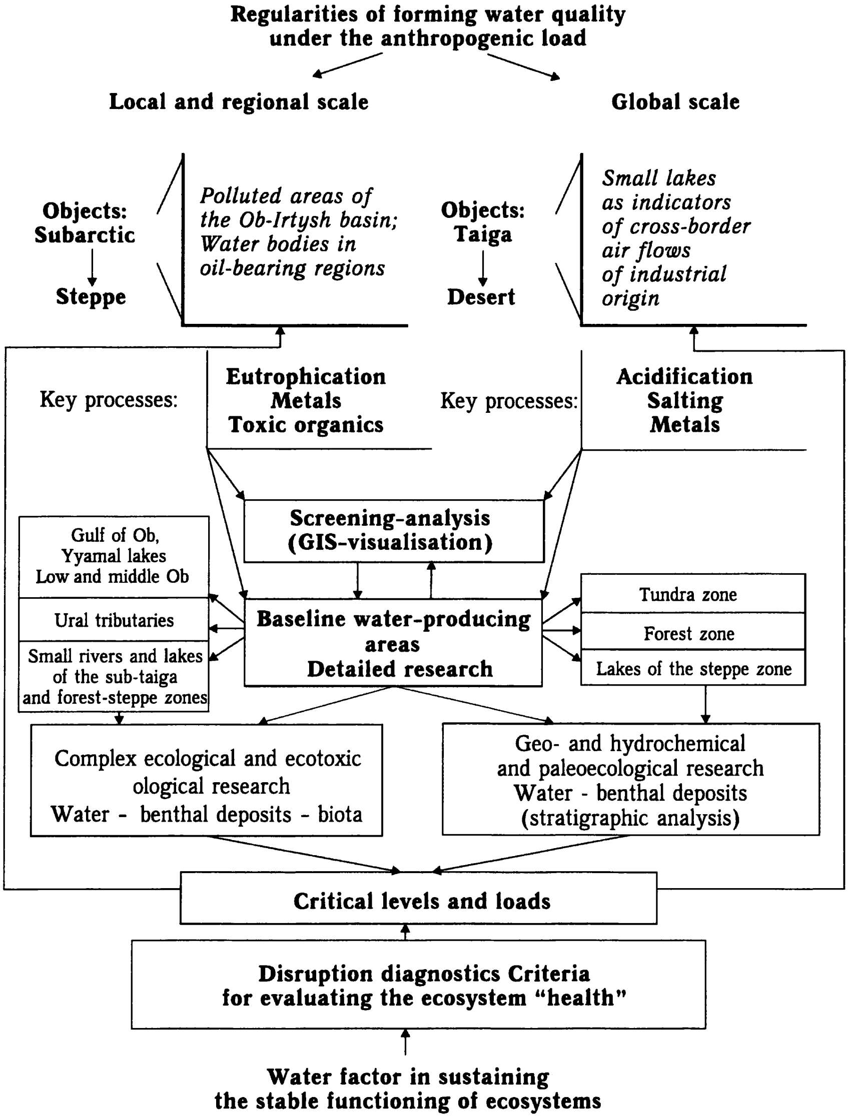

Fig. 1. Block-diagram of discipline and task integration within the project

For the last 25 years, we have been gaining experience in the West Siberian ecosystems research within experimental water-producing areas, both on the baseline territory and under the influence of an anthropogenic factor complex connected with intensive oil and gas production. It covers mainly the terrestrial plant communities, vertebrates, and invertebrates [12], [17], [18], [19], [20], [21], [22]. It helped to reveal the important laws of ecosystem functioning under the stress and distress conditions, define new ways of ecosystem adaptation to the changing conditions, assess the realization mechanisms of living organisms community stability, providing either their stability or transfer to the other stability level.

Nowadays, we are executing a large-scale project aimed at the study of water quality anthropogenic variability in the context of zonal and landscape-geographical differentiation under the influence of anthropogenic load according to the scheme below.

Thus, the ecological theory defines the key concepts of the water quality and ecosystems stability. It is impossible to provide both an appropriate monitoring system as well as prevent a destructive influence on nature without a deep study of water property forming and stable ecosystem functioning. There are three ways of future interaction of the mankind and natural ecosystems: 1) to continue destructive impact in present scale; 2) to stop fully all the impacts and recover to natural condition; 3) to recover main parameters and retain a stable ecosystem functioning. It is obvious that the first way is unacceptable, the second one requires considerable expenses and could be considered for separate, specially protected water ecosystems, such as Lake Baikal. The third way could be chosen for the majority of water objects in the regions with anthropogenic activity.

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