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Approaches to Standardizing Environmental Quality: Legislative and Scientific Basis of Current Systems for Ecological Standardization

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Abstract—The basic systematic approaches to ecological standardization of pollutants in natural environment were described with regard to the nature conservation legislation of Russia and other countries. Some special features and shortcomings of the standards of maximum admissible concentrations (MAC) for pollutants were analyzed in comparison to the standards of admissible impacts used in Russia. The efficiency of applying standard integral indices using the values obtained in the laboratory and based on MAC was studied for their application to assessing water quality.

Keywords: standardization, legislation, Water Code of the Russian Federation, Russian Environmental Protection Law, Clean Water Act (United States), Water Framework Directive (EU), MAC problems, pollution indices, assessment of the environmental quality

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LEGISLATIVE BASIS OF ENVIRONMENTAL STANDARDIZATION OF WATER RESOURCES

Systems of Environmental Standardization in Russian Federation

Environmental standardization is one of the key problems in developing the environmental safety in Russia (Rozenberg et al., 2011). More than two decades ago, this problem was announced as one of the primary importance to define the allowable load to the environment and to restrict (standardize) the existing anthropogenic load taking into account all the negative factors and the environmental peculiarities of the ecosystems (Izrael', 1984). The environmental standardization takes into account the maximal allowable load to the ecosystem. The maximal allowable load or concentration (MAC) is the effect to the ecosystem, which causes the fluctuations from the normal state, but does not exceed the natural variability or negatively affect the living organisms and, thus, does not lead to the deterioration of the environment (Izrael', 1984).

According to the Federal Law "On the Conservation of the Environment ..." (2002) and Article 19, "... The standardization of the environment is performed by the state to regulate the effect of economic and other activities to the environment that guarantees the conservation of the environment and ensures the ecological safety. In environmental protection, standardization consists of developing of the normative standards of the quality of the environment and the standards of the allowable effects to the environment during the economical and other activities, as well as the development of other standards for environmental protection, state standards, and other normative documents about environmental safety."

Legislation prior to 2007

The standardization of water quality in water resources (WRs) and the regulation of water usage since 1974 and up to the approval of the Water Code of the Russian Federation (Water Code ..., 2006) was based on the "Rules of Protecting Surface Waters from Pollution by Sewage Waters" (Rules of Protecting Surface Waters ..., 1975, 1991) (later, Rules). Despite the Water Code of the Russian Federation (Water Code ..., 1995), the Federal Law "On Environmental Protection ..." (2002) and other legislative acts were developed, the Rules were still used.

According to the Rules, the major aim of water protection is ensuring the health of the population, the welfare of water usage, and the environmental safety of water resources. Securing water resources is aimed primarily at accommodating the economical, household, and potable needs. The standardization of water quality is mostly developing the sanitary limits of water characteristics.

The standards of the natural (including water) environment comprise several characteristics (Zykov and Chernyshov, 2008), such as the following:

(1) chemical standards, including the maximal allowable limits of the chemical compounds and radioactive elements;

(2) physical properties, including the level of radioactivity and temperature;

(3) biological characteristics, including the biodiversity of flora and fauna, the population density of the indicator species of animals and plants, and the microbiological parameters;

(4) other standards of water quality.

According to the Rules, all WRs are divided into three types, i.e., potable, household, and fishery.

However, no environmental standards were developed with regard to the agriculture objects, even after 15 years passed. The standardization of the water quality in WR and chemical compound discharge to WR with the sewage waters was based on the criteria for maintaining (restoring) these waters for potable, household, and fishery uses. These criteria are based on the laboratory testing of the MAC of contaminants in WR (the limitations of MAC are discussed in chapter 2.2).

Almost all WRs are defined as waters for fishery uses (the second category), despite the category of the WR to which it is assigned in the list.

The standards of household and fishery waters are developed for consumers, even though they may be used for the decisions of establishing fishery ponds in the body of water that are harmless to the human population, for using the WR for recreational purposes, and for the centralized support of the population by the water (Federal Law "About Sanitary and Epidemiological Security of the Population," 1999, Article 18).

If the MAC is exceeded, the economical activity and assigned water uses are prohibited by law. For example, in the case of the inconsistency of using the WR with regard to water standards, the economical activities must be terminated by the responsible controlling organizations.

The Rules take into account the local peculiarities of the environment, i.e., if the concentrations of some compounds exceed MAC, but at the same time represent the natural environment, then these concentrations are considered to be natural.

The sanitary regulations in household WR are currently represented by three major laws, i.e., Sanitary and Food Standard 2.1.5.980-00 (2001), Hygienic Standards 2.1.5.1315-03 (2003), and 2.1.5.1316-03 (2003). The water quality in fishery WR is regulated by Decree no. 20 of the Federal Agency of the Fishery of the Russian Federation (18.01.2010) and by the Guidelines of MAC Development (Guidelines ..., 1998).

The contaminant limit (CL) is the total bulk of the agent that enters the WR from stationary, movable, or other sources (in the operating regime, in accordance with the technology regulations) that do not lead to an increase in MAC in WR (according to the Guidelines of Standard Development, 2007). The water-quality standards include the overall requirements to the composition and characteristics of surface waters with regard to different purposes of water uses, as well as the list of MACs in water objects of potable and household significance and fishery uses. Unlike the maximal allowable discharge limits, CL take into account the environmental conditions "when the water quality in the water sources cannot be established due to natural factors that cannot be regulated, though the CL are established with regard to the current water quality of the background environment" (Guidelines ..., 2007, Article 1). However, the methodological approaches to establishing parameters of the background environment parameters do not yet exist.

Practically, the system of changing of maximal allowable discharge limits to the system of limits of the discharge of contaminants (CL) plays a significant role in water-security activities in Russia, but the principal weakness, relative inconsistency, and formal subjective approach do not allow one to achieve results that fit the concept of sustainable development (i.e., that minimize the negative impact and sustain the water resources under good conditions (Nosal', 2005)) or at least reach the level of water protection in the United States and European Union, even though these countries have shorter list of water parameters compared to Russia.

The Federal Law "On Environmental Protection" stipulates the definition of the standards of the allowable effect (SAEs) and standards of the anthropogenic load. Despite that the methods of the SAE calculation are ratified (Guidelines ..., 2007), they cannot be used in factories (Belyaev, 2008). Additionally, there are no methods for calculating the standards of the anthropogenic load.

Legislation in Effect since 2007

The major laws in the standardization of the environmental quality of the water resources are the Federal Law "On Environmental Protection" (2002) (FLEP) and Water Code of the Russian Federation (Water Code ..., 2006) (WCRF).

The WCRF from 2006 covers the following points, among others:

—it reallocates the responsibility for water resources from administrative to civil obligations;

—it gives a detailed definition and the role of the hydrographical and economical water classification of the territory of the Russian Federation and develops schemes for the complex use and protection of the WR;

—it gives a detailed description of the overall demands to sustainable use of the water reservoirs;

—it controls the standards of sewage waters with regard to quality control;

—it presents existing defined standards of areas of water protection around water bodies and develops regimes of the fishery and other activities;

—it provides a legislative definition of 20 watershed areas.

However, nowadays, the realization of some novelties is impeded due to the unstructured formulation of some of the statutes and the high number of reference standards, which, in turn, are not supported by legislative acts (Belyaev, 2008).

The target quality standards (TQSs) for WR were developed by the executive authorities of the Government of the Russian Federation for each river basin (or part of it) taking into account its natural environment and the purposes of use. TQSs are ratified by the legislative procedure of the Russian Federation.

With regard to WCRF, the schemes of the complex use and protection of the WR (SCUPWR) are "the basis of economical activities and the protection of the water objects located within the watershed areas" (Water Code ..., 2006, Article 33, Part 1). SCUPWR "must be followed by the government and local authorities" (Water Code ..., 2006, Article 33, Part 5). Therefore, the methodological support of SCUPWR is of primary importance for developing the procedure for implementing the Water Code.

SCUPWR includes the following:

(1) the TQS of water in water objects for the time when a TQS act is commissioned;

(2) the list of the activities in water use and protection.

In addition, Article 35 of WCRF declares the overall principles of regulating the WR status with regard to defining and following the CL and TQS of water in the WR. The standardization of the CL is developed with regard to the MAC of contaminants, radioactive elements, microbial concentrations, and other water parameters. The ratification of these limits is performed in accordance with the legislation rules of the Russian Federation. TQSs in the WR are developed by the executive authorities of the Government of the Russian Federation for each river basin or part of it taking into account its natural environment and purposes of use (WCRF, Article 35).

When describing the novelties of WCRF, we cannot miss the numerous key mechanisms of its application (including the methodological support of standardization, mostly for sewage waters) that were not developed, which has led to significant problems in the regulation of WR (Belyaev, 2008). For example, if the water object is approved for use, there are no methods for calculating the standards of TQS and CL. The key problem still requires clarification. The major reason for this is the incorrect formulation of TQS ratified by Decree no. 881 of the Government of the Russian Federation (30.12.2006, "On the Ratification of Standards of Allowable Limits of Pollution of Water Objects") as follows: "Find that the standards of the allowable limits of the load in the water objects (complex allowable effect of all the water sources located in the watershed area or its part on the water object) should be developed by the Federal Agency of the Water Resources..." (Article 1). The limitations of this act and ways to eliminate them in accordance with Federal Law no. 7-FL "On the protection of the environment" (10.01.2002) are described in the article by S.D. Belyaev (2007). An alternative method is to define the TQS for each water consumer, and the limit of the anthropogenic load (complex effect) should be classified as the necessity to take into consideration other affecting/planned local and overall sources of the load to the certain area of the water object when assessing TQS.

Another method is to define the value of the actual and allowable anthropogenic load (AAL) in a water object based on all sources of contamination, both regulated (sewages) and unregulated (discharge from the polluted areas), instead of applying TQS (Kuz'mich, 2011). These activities must be supported by calculating AAL for each parameter of pollution (chemical, physical, and biological). It is known that the influx of contaminants from the polluted area into many river basins may make up about 90% of the total actual anthropogenic load in the WR.

Meantime, the development of AAL standards as an index of the total effect of the regulated sources makes no sense, since this standard has no legislative regulation; thus, the governmental control of this standard is impossible. The discharge of certain existing factories is the object of this regulation and control; in particular, the latter must take into account the most hi-tech parameters.

The major act of the water-quality standard in WR is the FLEP (2002). FLEP contains the major definitions of the following:

—Standards of environmental quality, environmental protection, and maximal allowable limits. These standards must be met in order to support the sustainable management of the natural environment and maintain natural biodiversity.

—Standards of the environmental quality with regard to the chemical, physical, biological, and other characteristics, which must be applied in order to assess the status of the environment. These standards must be met in order to support the favorable natural environment.

—Maximal allowable limits of contaminants (also radioactive agents) and microorganisms. These standards must be met in order to prevent the pollution of the environment and the degradation of natural ecosystems;

"When ratifying the standards of the environmental quality, the natural environment (terrestrial and water objects) must be taken into account, as well as the rural environment, natural reserves and parks, and natural landscapes that have specific protection statuses" (FLEP, Article 21).

Therefore, according to FLEP, the MAC of contaminants in WR are chemical characteristics of the water quality when natural ecosystems are preserved with regard to their peculiarities and WR purpose.

One of the reasons for the ineffectiveness of water politics in the Russian Federation is the absence of long-term goals and deadlines for fulfilling the goals of improving the status of the water objects. In both the European Union and the United States, the need for deadlines and concise formulation was acknowledged long ago; in these countries, all the programs have clear step-by-step structures planned for the next 10–15 years. For example, the Clean Water Act (CWA) in the United States (1972) aspired to the following:

(1) to completely cut off the discharge of contaminants by sailing water objects before 1985;

(2) to achieve a favorable water quality for fish, crustaceans, and wild animals, as well the recreation purposes wherever possible by July 1, 1983.

Directive 2000/60/EC aims at protecting, improving, and recovering surface waters in the 15-year period following the ratification of the Directive. This document also defines the standards for the good state of the water object and the procedure for defining these standards.

Both the first and the second documents contain the circumstances that may be taken into account when shifting the deadlines for achieving goals. The analysis of the process of implementing both documents is reflected in later results compared to the planned deadlines. However, in this case, one can at least compare the detailed plan of activities and deadlines with what has been completed and focus on the most problematic issues.

Environmental Standardization Systems Overseas

In the early 1970s, worldwide activities focused on standardizing the contaminating and pollution limits were initiated (Vorobeichik et al., 1994). In particular, during this period, the most developed countries began to develop ways to manage the sustainable use of the natural environment. Water ecosystems were in the list of the primary importance, along with forest ecosystems.

The United States. The activities on the environmental protection in the United States and other countries is regulated by acts of Environmental Impact Assessment (EIA). EIA is based on MAC standards, discharge allowances for the sources of pollution, and the standards of the environmental quality (*The Air Quality* ..., 1986). The major focus of EIA is the regulation of the anthropogenic load. The economical sanctions are the most effective controls compared to administrative forcing and control (Bystrova, 1980; cited by Vorobeichik et al., 1994).

The major US federal law in the standardization of WR is the Clean Water Act (CWA, 1972). The Environmental Protection Agency (EPA) is the Federal Authority that coordinates the activities on protecting and recovering the WR, including the issues of standardization. According to the Code of Federal Regulations (2005), EPA is responsible for publishing the recommended standards and criteria for assessing water quality. The major aim of CWA ratification is to recover and sustain the chemical, physical, and biological unity of the surface waters in a state favoring the conservation and reproduction of fish, aquatic inhabitants, and wild nature, as well as recreation potential. The Water Quality Standard is a major control tool. This system includes several elements as follows:

—designated uses;

—criteria of water quality;

—antidegradation.

The designated uses support potable needs and recreation, sustain aquatic life, and meet agricultural and factory needs. The main parameters refer to the designated type of use, i.e., the physical properties of the water and MAC. The antidegradation is used for the control and excludes the possibility of deterioration in the water quality in WR that exceeds the physical and chemical features designed for each type of use.

In the United States, the standardization system was initially quite primitive and was similar to that used in the Soviet Union, but it changed dramatically in 1972.

First of all, it was ratified that the water exploitation had to take into account the "sustaining of all the kind of aquatic life" in all the water objects. Secondarily, the local peculiarities of the discharge were taken into account. Thirdly, much attention was paid to the biological indicators of the water quality, and, finally, their role was named as the decisive one when performing the integral assessment of the status of WR.

The recommended federal criteria (standards) of the water quality produced by the EPA are constantly updated and published electronically at the official governmental website (http://epa.gov/waterscience/criteria/wqcriteria.html).

All of the standards are divided into three groups as follows:

—pollutants of primary importance (120 contaminants),

—pollutants of secondary importance (47 contaminants),

—agents of organoleptic effect (23 contaminants, most of which are included into the first and second lists).

One must take into consideration the number of the physical and chemical parameters in WR ratified in the United States, which is only about 10% of the list ratified in Russia. In these three groups, the standards are subdivided into agents of long- and short-term effect. The standards of the short-term effect (criteria of maximum concentration) are the assessment of the maximal concentration in the surface waters that has no irreversible effect on the water community. The standards of the long-term effect (criterion of continuous concentration) are the maximal concentrations of the pollutants in the surface waters that have no irreversible effect on the water community for an unlimited time.

The United States is divided into 14 ecological regions in order to take into account the physical and geographical differences of each. EPA publishes the standards developed for every region, including the standards of biogenic elements (total phosphorus and total nitrogen).

The estimation of the values of the standards is performed using the statistical approach compared to the reference water ecosystems of a given region. As the reference site, they use the same type of water object (shallow or deep reservoir, river, lake, etc.) as is located under the same physical and geographical conditions and does not receiving significant anthropogenic pollution. The standard value is the upper quartile (75%) of the factor distribution at the reference site; i.e., it is assumed that only 25% of the variability is allowed for the object compared to the reference water source. If the standards of the reference site are absent, the standards refer to all the water objects of the region. The standard value comprises the lower quartile (25%) of the factor distribution at the reference site; i.e., it is assumed that at least 25% of the variability must exceed the median for all water objects included in the analysis.

European Union. Before the year 2000, the European countries used a system for calculating the critical load of the contaminants (Tankanag, 1997) that refers to the different types of designated uses. Here, as an example, consider the EU Directives on Water Quality. The first directive is titled “On Sustaining the Lives of Fish” (Council Directive 78/659/EEC). This act was applied to the WRs that were defined by the EU Council as water sources characterized by water quality that enabled the natural biodiversity of aboriginal fish species or the species that were assumed to be favorable to be sustained. The water objects were divided into two groups, i.e., favorable for salmonids and favorable for cyprinids. In turn, each standard contained an obligatory part (that could be reached before the deadline) and recommendations (absolute standards).

The second act (Council Directive 75/440/EEC) applies to the potable-water system. Three categories of the sewage disposal plants were defined as follows:

(1) A1 is simple (fast) mechanical (filter) purification and disinfection;

(2) A2 is mechanical, chemical purification and disinfection (preliminary chlorination, coagulation, flocculation, sedimentation, filtration, final chlorination);

(3) A3 is intensive mechanical and chemical purification, expanded purification, and disinfection (chlorination, coagulation, flocculation, sedimentation, filtration, absorption on coal filters, and disinfection, including final chlorination/ozonation).

This directive includes 38 parameters, 6 of which refer to the physical properties (no standards yet), while 34 are chemical parameters, and 4 refer to microbiological standards. Only 20 out of 38 are obligatory standards, but as was regulated in the Council Directive 78/659/EEC, the concentrations of the other pollutants are insignificant.

One must consider the local systems of water standardization in natural WRs that were ratified in each EU country (Kimstach, 1993; Semin, 2001). Some examples of these systems that describe the peculiarities of the standardization of the abiotic factors are discussed below.

In Belgium, each water sample is analyzed based on 40 different parameters. The most important parameters are the oxygen water regime (OWR) and concentrations of heavy metals. The OWR includes three key characteristics, i.e., oxygen saturation, BOD_5, and the concentration of nitrogen as ammonia ions. After oxygen testing has been performed, the sample is analyzed according to the expert scale (1–5) for each parameter and the total OWR is calculated as their sum.

The points are defined as follows:

—1 refers to an oxygen saturation of 91–110%, BOD5 of less than 3 mg/L, and an ammonia concentration of less than 4 mg/L;

—5 refers to an oxygen saturation of less than 30% or more than 130%, BOD_5 of more than 15 mg/L, and an ammonia concentration of more than 5 mg/L.

Therefore, the water quality is assessed ranging from “very good” (OWR = 3–4) to “very bad” (OWR = 14–15). The five-point scale for classifications with regard to the concentration of heavy metals includes the classes of variability; e.g., for cadmium they are ≤20, ≤40, ≤60, ≤80, and >80% of the annual average values.

In Denmark, groups of the water objects were classified in 1983 and included water areas with different designated uses (Table 1).

The expert criteria of water quality for all types of designated water uses were defined; these criteria must be fulfilled and are intended to achieve and conserve the water quality with regard to each type and designated use. For example, the water bodies inhabited by salmonids must fit several criteria, i.e., the water temperature must not exceed +20°C in summer and +10°C in winter (the maximal deviation during the thermal load must not exceed 1°C, dissolved oxygen—6–8 mg/L and 9–12 mg/L, for 50% of time period), pH 6–9 (maximal shift of pH for incoming

Table 1. Classification of water objects in Denmark (1983)

Running water	Lakes and coastal areas
1. Areas of specific interest 2. Areas of spawning and growth of salmonid larvae 3. Areas inhabited by salmonids 4. Areas inhabited by cyprinids 5. Running water with influx of drainage water and relatively affected by waste water 6. Running water with an influx of drainage and waste water 7. Running water affected by waste water, but not of fishery category 8. Running water that drains soils with high pyrite concentration (low pH, sedimentation of Fe oxides), where fauna is significantly depressed	1. Areas of specific interest 2. Water for bathing and drinking 3. Water characterized by natural biodiversity of flora and fauna 4. Lakes affected by waste water, exploitation of the ground water and other effects, as well as the lakes affected by harmful effect of agriculture

sewage must not exceed 0.5); the ammonia concentration must be less than 0.025 mg/L, while the concentration of chlorine must be less than 0.004 mg/L, the total zinc concentration must be less than 0.3 mg/L, particulate matter must be less than 25 mg/L, BOD_5 must be less than 3 mg/L, and the total nitrogen content must be less than 1 mg/L.

In France, an inventory of water pollution was taken in 1971 and, in 1975, they developed the scale of the quality of surface waters with regard to their hydrochemical properties. This scale comprises six classes of water quality; the first one refers to the best quality, while fourth through sixth classes represent the lowest quality (with regard to the analyzed parameter). The water is analyzed for the temperature, pH, sedimentation rate, oxygen saturation, oxygen concentration, BOD_2, BOD_5, COD, oxidation susceptibility, concentrations of particulate matter, chlorides, sulfates, ammonia-based salts, nitrates, nitrites, potassium, calcium, mercury, hydrocarbonates, phenols, phosphates, and surfactants.

In Germany (Bavarian Service of Water Use), the chemical standards are based on studies performed previously in Scotland and the United States. The applied method comprises the measurement of several chemical characteristics and combines them as one number (chemical index), which is the integral rate of the water quality, as follows:

$$CJ = \prod_{i=1}^{n} q_i W_i,$$

where n is the number of studied parameters; q_i is the subindex for the ith parameter (value of 0–100), i.e., this is the desirability function of this parameter; and W_i is the weight (impact) of the ith parameter (value of 0–1), which indicates the importance (seniority) of this parameter. When calculating CJ, eight parameters are taken into account, i.e., the concentration of dissolved oxygen, BOD_5, water temperature, ammonium-based salts, nitrates, phosphates, pH, and conductivity. The water of CJ, which is close to 100, is classified as safe, and that of CJ, which is close to 0, is classified as unsafe.

In the Netherlands, they use the OWR described earlier and analyze the total phosphorus concentration; the MAC of P_{total} is 0.2 mg/L. However, taking into account the tendency to eutrophicate, during the summer period, the concentration of P_{total} may reach 0.3 mg/L. The classification is based on the three-step scale, in which the actual concentration is compared to the MAC of this agent. In addition, the concentrations of six metals are monitored, including mercury, cadmium, copper, lead, chromium, and zinc. The standardization of the metal concentration also refers to a three-point scale, where the MAC for mercury is 0.5 μg/L, the MAC for cadmium is 2.5 μg/L, the MAC for copper is 50 μg/L, the MAC for lead is 50 μg/L, the MAC for zinc is 200 μg/L, and the MAC for chromium is 50 μg/L.

In Great Britain, the rivers are classified based on the quality criteria that refer to specific designated uses. The classification comprises four major classes that differ in the variability of the concentration of dissolved oxygen, BOD_5, and ammonia ions. The water-quality classes are as follows:

1. waters of potable importance;

2. fishery rivers, especially rivers with recreational uses and that are inhabited by commercial fish of great value;

3. rivers that may be used for potable needs after primary purification and rivers of commercial importance for fisheries of ordinary fish;

4. waters that may be used for technological needs.

The EU Frame Water Directive (Directive 2000/60/EC, FWD) was ratified on December 22, 2000. This led to even more crucial changes in the methodological and legislative bases of standardization than in the United States. The overall aim of this directive is to achieve good status of the WR in the European Union through 2015. Furthermore, this document includes the steps in achieving the goal. The key approach in the new system of standardization is the change in the reference sites when a pristine environment appeared to be the standard for water quality.

The directive aims to establish common approaches to water conservation (including surface fresh, brackish, coastal, and ground waters) that ensure the following:

—the prevention of the deterioration of the water quality and the status of water objects, as well as their protection and recovery;

—sustainable water management based on the long-term protection of water resources;

—the improvement of aquatic ecosystems by totally or gradually cutting off the discharges of the most dangerous contaminants and the agents of top priority;

—the cut-off of further contamination of ground waters;

—mitigation of draught and flood effects.

The following main parameters should be taken into account when applying FWD:

—the biological parameters include the biodiversity and abundance of aquatic plants; the biodiversity and abundance of benthic invertebrates; and the biodiversity, abundance, and age structure of ichthyofauna;

—the hydromorphological properties that are of primary importance for the living components of the ecosystem include the volume and dynamics of the runoff, connection to the ground waters, and river continuity;

—the morphological conditions include the variability of the riverbed (river width and bottom depth), structure, and grain-size properties of the river bottom, as well as the structure of coastal areas;

—the chemical and physicochemical properties that affect biological parameters: are common (temperature, COD, BOD, dissolved oxygen, mineralization, pH, micronutrients) and specific (pollution by agents of the priority importance with regulated discharge and pollution by other contaminants found in particular water body) contaminants.

The environmental-quality ratio (EQR) is applied to assess the water quality on a comparative basis. EQR is a numeric index that includes all biological parameters; a value of 1 corresponds to good environmental status and a value of 0 corresponds to a bad environmental status. The EQR scale comprises five gradations in accordance with the class of the status, i.e., perfect, good, satisfactory, unsatisfactory, and bad. FWD procedure includes the description of the reference conditions for defining the status each type and category of surface-water object. The reference conditions comprise the range of physicochemical and hydromorphological properties defined for a WR of a certain type and category that is characterized by perfect water quality. The definition of the reference condition may also be based on the spatial approach, i.e., the reference conditions may be defined as the parameters of the existing pristine environment in a WR of the same type and category located in the same ecological region. When neither of these two approaches can be applied, an expert's opinion may be obtained.

In accordance with EQR, perfect environmental conditions refer to the total absence or minor anthropogenic pollution, when the insignificant variability of the physicochemical and hydromorphological properties is allowed; however, this variability must fall in the range of conditions that are normal for a pristine environment in a WR of the same type and category. The same approach is applied for the biological characteristics of the WR.

The criteria of assessing the effect of the major pollutants include the following:

—for an artificial environment, the concentration must be close to zero or lower than the limit of the determination by the most precise methods that are currently available;

—for the natural environment, the concentration must stay within the range observed for pristine conditions (reference conditions).

Common approaches and technical recommendations are given in the WFD CIS Guidance Document (2003) for the standardization of the reference conditions, their degrees when assessing the environmental status of WR, and cross-calibration methods (unification of the monitoring methods within the particular international program). A rough scheme of cross calibration and the definition of the degrees of the reference conditions include the following:

(1) assessing the environmental status of the WR of each type and category and presented as the EQR value;

(2) performing the preliminary classification of the environmental status of the WR (perfect, good, satisfactory);

(3) choosing two or more reference sites for each type and category of WR in different countries that were previously classified as transitional between two neighboring degrees (i.e., perfect–good, good–satisfactory, etc.);

(4) comparing the reference EQR and defining the ranges for each degree of the environmental status for each country.

In addition, environmental expertise is used in many countries, including Russia, as a method of ensuring environmental security and fulfilling demands for environmental conservation activities (legislative acts) at every stage of the acceptance or rejection of decisions on start of or change in economic activities (Pavlovskii et al., 1997). In particular, environmental standard ISO 14001 (http://www.iso.org), which was developed by the International Standard Organization (ISO) and ratified in 1996, is used. The primary interest is focused on having all organizations define their environmentally unfriendly technological processes and efforts at environmental conservation. The organizations must assess the most harmful and dangerous technologies they use and what preventive activities are the most effective. In some cases, an ecological expert studies the economical inexpediency of a building or of launching a factory/agriculture project due to the extremely high costs of environmental-conservation activities.

However, in accordance with the ISO 14001 standard, quality control does not have a legislative basis for environmental characteristics (environmental metrology) (Zykov and Chernyshov, 2008). The assessment of environmental health is performed using circumstantial measurements and is based on the studies of the correlation of the environmental status of the ecosystem and some of the measured indicator properties. Furthermore, modern environmental knowledge comprises a huge dataset of scientifically proved indices of environmental health (zoological, botanical, biochemical, etc.) that may be interpreted as the categories of the norm, risk, crisis, distress, etc.

Generally, in western countries, the system of the environmental standardization fulfill two functions (Vorobeichik, 1994), i.e., (1) the preventing clearly inadmissible environmental damage and (2) stimulating the permanent cut-off of the anthropogenic pollution of the environment.

Clearly inadmissible environmental damage is usually recalculated into its economic equivalent. Failure to observe legislative standards results in economic penalties, which are more effective than administrative enforcement and control (Bystrova, 1980). Nowadays, the parameters of human quality of life (life span, morbidity rate, and mortality rate) are used more often as universal indicators of environmental quality.

SCIENTIFIC BASIS OF APPLYING EXISTING ENVIRONMENTAL STANDARDS

Standardization Based on MAC

The system of the standardizing water quality in Russia is based on a laboratory test for MAC in the WR. The MAC system approaches a toxicological control, which in turn is aimed at the short-term observation of a particular characteristic in test organisms (indicator species) that is transferred to the test water sample, or a sample diluted by a factor of *n* when the concentration of pollutants is too high. The indicator species must be represented by organisms of different taxa (Guidelines ..., 1998). The biological testing with hydrobionts may be applied to assess the toxicity of polluted natural waters; for the quality control of the sewage waters; and as an express method for the hygienic analysis of the extracts, washout, and media (Methods of Biological Testing ..., 1989).

MACs are the maximal allowable concentrations of pollutants in the water when these concentrations do not cause irreversible changes that deteriorate the hygienic and fishery value in the immediate or distant future. There is also the standard of the relative safe level of the effect (RSLE), which is temporal and is used for less than 2 years for fishery activities when new agent for this economical activity is purchased abroad or the production of this agent is launched in Russia or is already in use. Each indicator species may be used to test a number of major parameters (Guidelines ..., 1998) that are controlled by legislation. Reliable results of the toxicity test are obtained after testing the pollutant for several indicator species (Filenko and Dmitrieva, 1999).

The results of the laboratory toxicological experiments with the indicator species achieved by the integration of a sublethal concentration (the concentration causing the mortality of specific part of the tested population) allow one calculate MACs subsequently used for the environmental protection legislation. Nowadays, MAC are defined for more than 1300 of chemical compounds.

When assessing the water quality, the most popular method are calculating the integral indices based on laboratory testing of MAC and their comparison to the level of pollution in different WRs. Here, we will discuss the most applicable methods (Shitikov et al., 2003).

1. Hydrochemical index of water pollution. This index was ratified in 1986 according to “Temporal Guidelines ...” (Temporal Guidelines ..., 1986) issued by the State Agency of Hydrometeorology of the Soviet Union. The hydrochemical index of water pollution (IWP) is one of the most frequently used tools for assessing water quality. The index is a typical additive coefficient and represents the average rate of exceeding the MAC for a strictly limited number of the test agents as follows:

$$\mathrm{IWP} = \frac{1}{n}\sum_{i=1}^{n}\frac{c_i}{\mathrm{MAC}_i},$$

where c_i is the concentration of the component (in some cases, physical-chemical parameter); *n* is the number of the testing parameters (strictly the six that have the most pronounced effect of pollution); and MAC_i is the standard of MAC defined for a specific type of WR.

The IWP is calculated for strictly six parameters, i.e., oxygen concentration, BOD_5, and four others agents that have the highest concentration, regardless of whether their concentrations exceed the MAC. For the c_i/MAC_i constituents, based on ambiguous normalized components (calculated IWP), we used a number of the following conditions:

—The biological oxygen demand, BOD_5 (MAC does not exceed 3 mg O_2/dm^3 for the WR of potable value and 6 mg O_2/dm^3 for the WR of household and recreational use) has specific standards that depend on the purposes of BOD_5 measurement, i.e., if BOD_5 is less than 3 mg O_2/dm^3, the reference MAC = 3; if

BOD_5 = 3–15 mg O_2/dm^3, then MAC = 2; and, if BOD_5 is more than 15 mg O_2/dm^3, then MAC = 1.

—The concentration of dissolved oxygen (DO) is standardized in reverse proportion, i.e., its concentration must exceed 4 mg O_2/dm^3; therefore, each concentration range has its own values of c_i/MAC_i, in particular when DO is greater than or equal to 6 mg O_2/dm^3, $c_i/MAC_i = 6$. Then, when DO = 5–6 mg O_2/dm^3, $c_i/MAC_i = 12$; when DO = 4–5 mg O_2/dm^3, $c_i/MAC_i = 20$; when DO = 3–4 mg O_2/dm^3, $c_i/MAC_i = 30$; when DO = 2–3 mg O_2/dm^3, $c_i/MAC_i = 40$; when DO = 1–2 mg O_2/dm^3, $c_i/MAC_i = 50$; and, finally, when DO is less than 1 mg O_2/dm^3, $c_i/MAC_i = 60$.

—The pH standards for different types of water sources define its range as 6.5–8.5, which is why each exceeding value of the pH has its own values of c_i/MAC_i as follows:

when pH 6.0–6.5 or 8.5–9.0, $c_i/MAC_i = 2$;

when pH 5.0–6.0 or 9.0–9.5, $c_i/MAC_i = 5$;

when pH is lower than 5 or exceeds 9.5, $c_i/MAC_i = 20$.

The areas of the water objects are classified by the value of IWP as follows:

(1) the first class refers to very clean water (IPW < 0.2);

(2) the second class is clean water (IPW = 0.2–1.0);

(3) the third class is slightly polluted (IPW = 1.0–2.0);

(4) the fourth class is moderately polluted (IPW = 2.0–4.0);

(5) the fifth class is polluted (IPW = 4.0–6.0);

(6) the sixth class is very polluted (IPW = 6.0–10.0);

(7) the seventh class is extremely polluted (IPW > 10).

In accordance with the Temporal Guidelines (Temporal Guidelines ..., 1986), the pollution indices for the tested water objects must be compared with the water objects of the same type located in the same biogeochemical provinces and of the stream that are characterized by the same current taking into account the water level during the studied year.

The disadvantage of this index is that it uses six parameters as factors with equal impact, which may lead to a decrease in IPW values when the concentration of at least one parameter is significantly lower. In the other words, if the concentration of one of the agents exceeds the MAC standard, it cannot be compensated for by relatively friendly values of the other tested components.

2. Index of sum of concentration ratios (Regulation of Security ..., 1991). According to these regulations, the sum of the concentration ratios (c_1, c_2, ..., c_n) of each agent that is characterized by similar a harmful effect with regard to MAC in the studied site must not exceed 1 for all agents that refer to standardization and are used during fishery activities, and all dangerous compounds (classes I and II) used for potable, household, and recreation activities as follows:

$$\sum_{i=1}^{n} \frac{c_i}{MAC_i} \le 1,$$

where MAC_i are the fishery limits and c_i are concentration of the chemical compound in the water.

A disadvantage of this index is that the formula is only true for a specific number of components (n); meantime, the value of n has no reference. In other words, if $n = 11$ and the concentrations of all 11 agents are ten times less than MAC, we finally obtain that c_i/MAC_i exceeds 1. This index is the most rigid, and this rigidity seems to be insupportable and nearly unachievable in reality when the number of studied components n is high.

3. Index of chemical pollution of the water (ICP-10). The total index of the chemical pollution of the water is referred to as formalized one by the authors of this index (Assessment Criteria ..., 1992) and is calculated taking into account ten agents, the concentrations of which exceed MAC as follows:

$$\text{ICP-10} = \sum_{i=1}^{10} \frac{c_i}{MAC_i},$$

where MAC_i are the fishery limits and c_i is the concentration of the chemical compound in the water.

When calculating ICP-10 for the chemical compounds, the concentrations of which refer to a relatively satisfactory level of pollution, this is defined as their absence, and the rate of c_i/MAC_i is conditionally assumed to be 1.

4. Combinatory index of pollution. The method is based on the integral assessment of the water quality by measuring all pollutants and the frequency of their occurrence (Vasil'eva et al., 1998). Several parameters are defined for the index calculations as follows:

—grades of the order of MAC excess (K_i) for each component based on the data of the actual concentrations, i.e., $K_i = c_i/ MAC_i$, where MAC_i are the fishery limits and c_i is the concentration of the chemical compound in the water;

—grades of the frequency of cases when MAC was exceeded (H_i), i.e., $H_i = N_{MAC_i}/N_i$, where N_{MAC_i} is the number of cases of MAC excess based on component i and N_i is the total number of measurements of component i.

These grades then used for calculating the assessment grade $B_i = K_iH_i$. Finally, the combinatory index of water pollution is calculated as follows:

$$B = \sum_{i=1}^{n} B_i = \sum_{i=1}^{n} \left(\frac{c_i}{MAC_i} \frac{N_{MAC_i}}{N_i} \right),$$

where n is the number of compounds studied. When the number of components is true for $B_i \ge 9$, this case called the critical index of pollution (CIP). The class of water quality is defined according to Table 2.

5. Method used by Erisman Hygienic Institute. This method comprises four criteria of harmfulness (Novikov et al., 1987), and each criterion includes a specific list of compounds and water-quality indexes (Table 3).

Table 2. Classification of water quality in running water according to complex index of water pollution (Guidelines ..., 2002)

Class	Characteristics of water pollution	Complex index of water pollution					
		disregarding the number of critical pollution indices	with regard to the number of critical pollution indices				
			1	2	3	4	5
1st	Conditionally unpolluted	$1N$	$0.9N$	$0.8N$	$0.7N$	$0.6N$	$0.5N$
2nd	Slightly polluted	$(1N; 2N)$	$(0.9N; 1.8N)$	$(0.8N; 1.6N)$	$(0.7N; 1.4N)$	$(0.6N; 1.2N)$	$(0.5N; 1N)$
3rd	Polluted	$(2N; 4N)$	$(1.8N; 3.6N)$	$(1.6N; 3.2N)$	$(1.4N; 2.8N)$	$(1.2N; 2.4N)$	$(1N; 2N)$
4th	Highly polluted	$(4N; 11N)$	$(3.6N; 9.9N)$	$(3.2N; 8.8N)$	$(2.8N; 7.7N)$	$(2.4N; 6.6N)$	$(2.0N; 5.5N)$
5th	Extremely polluted	$(11N; \infty)$	$(9.9N; \infty)$	$(8.8N; \infty)$	$(7.7N; \infty)$	$(6.6N; \infty)$	$(5.5N; \infty)$

Table 3. Criteria of adverse health effect taken into account in the methods applied by Erisman Research Institute of Hygiene (Novikov et al., 1987)

Pollution criteria	Taking into account
Sanitary regulations (W_s)	Oxygen concentration, BOD_5, COD, and specific pollutants standardized by sanitary regulations
Organoleptic parameters (W_o)	Odor, particulate matter, COD, and specific pollutants standardized by organoleptic criteria
Sanitary and toxicological regulations (W_{st}) on hazard risk	COD and specific pollution standardized by sanitary and toxicological regulations
Epidemiologic regulations (W_e)	Risk of microbial hazard

The same pollutant may be included in several groups. The complex assessment is performed separately for each limiting factor of harmfulness (LFH), i.e., W_s, W_o, W_{st}, and W_e according to the formula of pseudo-compensation, as follows:

$$W = 1 + \frac{1}{n}\sum_{i=1}^{n}(\delta_i - 1),$$

where W is the complex assessment of the water pollution by specific LFH, n is the number of parameters taken into account, $\delta_i = \frac{c_i}{L_i}$ (usually, $\delta_i = \frac{c_i}{\mathrm{MAC}_i}$), and L_i is the standard for each pollutant (usually $L_i = \mathrm{MAC}_i$). If $\delta_i < 1$, i.e., the concentration is less than MAC, then $\delta_i = 1$.

Special formulas are applied for calculating the concentration of dissolved oxygen and particulate matter. The dissolved oxygen concentration is standardized according to its lower concentration, i.e., DO must exceed 4 mg/L; therefore, if $c_i < 4$, then $\delta_i = 1 + 10(L_i - c_i)/L_i$.

Special formulas also exist for the particulate matter; they take into account the demands of the regulations (Regulation of Security..., 1991).

Since the calculated indices make no sense without guidelines, they are supported by a classification table that includes the value ranges of the complex assessment index W (Table 4).

This method, like the previously described IWP method, has many limitations, since one bad factor may be compensated for by ten good factors. In other words, if only one harmful compound is taken into

Table 4. Degree of water pollution with regard to complex indices of polluton (W) calculated by limiting characteristics of adverse health effect

Degree of pollution	Pollution criteria taking into account complex assessment			
	Organoleptic (W_o)	Sanitary regulations (W_s)	Sanitary and toxicological regulations (W_{st})	Epidemiologic (W_e)
Admissible	1	1	1	1
Moderate	1–1.5	1–3	1–3	1–10
High	1.5–2	3–6	3–10	10–100
Extremely high	>2	>6	>10	>100

account, then the index is high, but if the assessment includes several other parameters that are close to MAC, then the index value decreases. This has no feasibility, since the compound with the concentration that exceeds MAC must cause the deterioration of the environment for biota.

We argue that the other formula (see below) appears to be more adequate compared to the following previously developed formula (Novikov et al., 1987): $W = 1 + \frac{1}{(n-m)}\sum_{i=1}^{n}(\delta_i - 1)$, where m is the number of the compounds the concentrations of do not exceed MAC ($\delta_i < 1$). This formula totally excludes the effect of the compounds characterized by $\delta_i < 1$ to the final result of the complex assessment.

6. Method of the water classification by V.P. Emel'yanova. This is an original approach, when the authors propose disregarding the calculations of the grade for each compound (Emel'yanova et al., 1979, 1980). The complex assessment has to include the only compounds that exceed MAC, 10 MAC, 30 MAC, etc. A significant advantage of this method is that it avoids the problems that evolve during grade assessments. However, a disadvantage of this method is that it also excludes the differences between the biological effects of each of them (Shitikov et al., 2003).

7. Ecotoxicological criterion of T.I. Moiseenko (Moiseenko, 1995). This method is based on calculating the sum of the degree of MAC that is exceeded by certain compounds (c_i) with regard to MAC (MAC_i) as follows: $X_{\mathrm{tox}} = \sum_{i=1}^{n}\frac{c_i}{\mathrm{MAC}_i}$. However, parameters such as the sulfate-ion concentration, particulate matter, and total mineralization are assessed here specifically, i.e., the grade of excess MAC refers to a pristine environment (maximal concentrations in natural environment) as follows: $X_{\mathrm{nat}} = \sum_{i=1}^{n}\left(\frac{c_i}{c_{\mathrm{nat\,max}\,i}} - 1\right)$.

A special eutrophication index is also calculated as follows: $X_{\mathrm{eut}} = \sum_{i=1}^{n}K\left(\frac{c_P}{c_{P\mathrm{nat}}} - 1\right)$, where c_P and $c_{P\mathrm{nat}}$ are the analyzed and natural concentrations of inorganic phosphorus and K is an additional coefficient that depends on the water quality ($K = 2$ for mesotrophic waters, and $K = 3$ for eutrophic waters).

The total pollution index is calculated by the formula: $X_{\mathrm{sum}} = X_{\mathrm{tox}} + X_{\mathrm{nat}} + X_{\mathrm{eutr}}$.

A common disadvantage of all indices discussed above taking into account MAC is the grade of MAC excess. This parameter considered to be equally due to the sum or product of the grade of excess $\left(\sum_{i=1}^{n}\frac{c_i}{\mathrm{MAC}_i}\right)$. This approach seems to be inappropriate because the only value that characterizes the dose–effect curve is considered, in particular the value of MAC that refers to 50% mortality of the indicator species. Moreover, it is well known that the dose–effect curve has an S shape, but the other characteristics of this curve, such as the degree of changes per time unit, e.g., if the concentration increases as much as MAC. In other words, we cannot predict in this case the consequences (mortality rate) at the concentration that exceeds MAC in n times. In addition, the mortality rate for each compound will be different at nMAC. However, if one knows the degree of changes for the dose–effect curve, then all equations include the effect (mortality rate) instead of the dose (concentration), i.e., $\frac{c_i}{\mathrm{MAC}_i} = \frac{M(c_i)}{M(\mathrm{MAC}_i)} = \frac{M(c_i)}{0.5}$, where $M(c_i)$ is the mortality rate expressed as a percentage of 1 when the concentration of the compound is c_i and $M(\mathrm{MAC}_i)$ is a mortality rate of 0.5 (50%). This replacement will help to avoid the problem of a single compound impact on the total effect (true for the formulas using MAC). However, the problem of the factor interaction will remain. When it is known that there is no combined effect, then the mortality rate serves as the integral factor as follows: $M = 1 - \prod_{i=1}^{n}M(c_i)$, where $M(c_i)$ is the mortality rate expressed as the percentage of 1 when the concentration of the compound is c_i. When the combined effect of more than one factor is observed, then the degree of changes of the dose–effect curve must be considered for the effect of one factor on another. When only two factors are involved, the 3D surface (mortality rate and two concentrations) will be a mathematical solution.

One must consider the ongoing problem of the correctly considered effect of a MAC excess, so the method of assessing the relative risk tries to couple with it.

Finally, another common disadvantage of the methods described above is interpreting them with regard to expert (subjective) degrees of water quality.

8. Method of assessing the relative risk (Novikov et al., 1999). This method was developed for assessing the quality of the atmospheric air, however, we assume that a similar approach may be applied for other tested objects. The term "relative risk" refers to the function that integrally reflects the probability and degree of consequences on biota caused by the harmful effect of the pollutant. The relative risk is calculated for each pollutant separately as follows:

$$R_i = b_i \log\frac{c_i}{\mathrm{MAC}_i},$$

where R_i is the degree of the relative risk; c_i is the concentration of compound i; MAC_i is the maximal allowable limit of compound i; b_i is the angle of slope of the concentration–relative risk curve, which integrally characterizes the danger of MAC excess by c_i for compound i. The coefficient b_i for each compound is defined in the series of laboratory experiments. The method allows one to construct integral indices of danger for multiple components with regard to the ratio of the actual concentrations to MAC for the defined risk level R.

9. Complex assessment of water pollution by G.T. Frumin and L.V. Barkan (Frumin and Barkan, 1997). This method is based on calculating the Harrington partitive function of desirability according to formula

$$d_i = e^{-e^{P_i}}.$$

The mathematical power of this function is nondimensional value P_i, which is calculated according to the equation $P_i = b_0 + b_1 c_i/\mathrm{MAC}_i$, where c_i and MAC_i are the actual concentration and maximal allowable limit of compound i, respectively, and b_0 and b_1 are the coefficients calculated with regard to the type of the compound and the class of water quality.

Problems Using MAC

Despite the great number of the methods described above that are focused on using MAC defined under laboratory conditions, one must consider some of the systematic and conceptual disadvantages that characterize these methods of standardization to be ineffective for the environmental assessments and inadequate for the main purposes of testing water quality, except the particular criticisms already given above.

1. The extrapolation of MAC to the actual biological objects cannot be considered correct, since these standards are defined under laboratory conditions during short-term (acute) experiments on isolated populations of organisms that belong to a short list of indicator species. In addition, only a few physiological and behavioral parameters are tested with regard to the effect of a particular factor without considering any possible combined effect (Abakumov and Sushchenya, 1991). The absence of the reference between the natural environment and laboratory conditions may result in increases MAC values (Zhigal'skii, 1997). The most representative example is the case of the Bol'shaya Kokshaga Nature Reserve (Mari El Republic). Despite the satisfactory results of analyzing the water resources, i.e., maintaining the water quality within MACs, the hydrobiological analysis revealed the tendency of the ecosystem degradation in the alluvial lands, which was observed for zooplankton communities (Drobot, 1997). In addition, opposite cases are known when, in 1993–1997 in the Sura River, the status of the zooplankton community was relatively satisfactory (based on the stability of the species composition), even when MACs of most of the studied parameters were excessive (Maksimov et al., 2000).

2. MACs are usually standardized when the experimental conditions are stable due to the fixed level of all other parameters compared to the concentration of the tested pollutant (Fedorov, 1974).

3. MACs are applied as unified standards for a large territory (one-sixth of the total earth's surface) (Levich et al., 2004), so they cannot consider the full variety of the functioning of different aquatic systems in various climatic zones (latitudinal and vertical variability) and biogeochemical provinces (natural geochemical anomalies with different concentrations of natural components). Therefore, the resistance to the toxic effect also differs. It is known that various biogeochemical provinces (and even water bodies) differ from each other in the natural concentration in surface waters: Pb (2000 times), Ni (1350), Zn (500), Cu (10000), and Cr (17000) (Volkov et al., 1993). Therefore, we are faced with the situation when a factory must decrease the concentration of iron in the discharge down to MAC, although the natural concentration of Fe in the water source exceeds MAC tenfold; this does not cause significant changes in the ecosystem because the biota is used to this high concentration. Unlike the concentration of chlorides, which may affect some aquatic inhabitants negatively at levels significantly lower than MAC, they are not formally the subject for legislative prosecution, nor are they required to decrease the concentration of chlorides in discharge waters. Therefore, MAC actually works as the consumer standard of the water quality. For example, excess MAC with regard to the household standard, leads to a prohibition of swimming in lakes, even though these excess concentrations are natural. Meanwhile, these MACs are used to standardize water uses and develop conservation activities. We cannot state that a regional approach to standardization is totally lacking in the existing legislative code. According to the guidelines (Guidelines ..., 1998), regional MACs for fishery activities are standardized using the indicator species that are common to this specific area (aquatic plants, protists, daphnia, chironomids, and aquarian fish) or acclimated in regional ecosystems (large fish species and mollusks). However, the development of these MACs must be performed on demand and must be paid for by the water consumer. Unfortunately, due to the high costs of these studies, the factory prefers to pay the annual fine and disregard the concentration of pollution in discharge waters.

4. The last quarter of 20th century and the first decade 21st century are characterized by the rapid increase in the number of different chemical compounds both synthesized and extracted from natural components (Barenboim, 2011). According to the Chemical Abstracts Service (CAS, the international service that registers all chemical agents) and other sources of information, in 1985, about 6 million new agents were registered; in 1990, about 10 million new agents were registered; in 2007, more than 31 million new agents were registered; and, in 2010, more than 56 million new agents were registered (Barenboim and Malenkov, 1986; History of CAS, 2011). On average, this list increases annually by 15000–50000 compounds, as was observed during last five years. Further-

more, the total number of standards for household water quality (1356) and fishery standards (1071) cannot be compared to the total number of potentially dangerous compounds that may be found now in the biosphere. Obviously, the rates of increasing the synthesis of new compounds are incommensurable to the time period necessary for their standardization. This make it nonviable to use MACs as the only reference for testing and ensuring environmental quality (Dmitriev, 1997). One must consider the number of MACs used in other countries, which is ten times less than in Russia; however, the presence of other compounds that are not yet standardized must be declared as inadmissible and nullified.

5. Existing lists of MACs do not include many of types of dangerous compounds, such as oncogenic, mutagenic, and radioactive agents, as well as compounds that deteriorate the taste and smell of water. In addition, other factors also have negative effects, i.e., thermal pollution, radioactivity, electromagnetic, and biological pollution. Although the control over nonchemical pollutants can be performed under laboratory conditions, no one studies these effects due to the high cost of these investigations.

6. The existing methodology of MAC standardization may include assessing the error of danger with regard to highly accumulative compounds because only short-term (acute) experiments have been carried out to determine mortality rates among aquatic inhabitants. In other words, the data on the toxicity index enable the discharge of pollutants in concentrations that exceed limits that are safe for humans by hundreds and thousands of times.

7. The procedure of MAC standardization does not consider the trophic status of the ecosystem or the seasonal dynamics of the factors, so they may be used as natural reference conditions in order to test the toxicity of the pollutants (Frumin, 2000). For example, the toxicity of Cd changes fivefold when the water mineralization varies from 40 to 500 mg/L. The definition of the effective dose considering only the pollutant concentration cannot adequately reflect the status of the environment during the complex effect (eutrophication, changes in major physical and chemical parameters, etc.) (Moiseenko, 1998). As was found based on the calculations carried out for Subarctic aquatic ecosystems, fish tend to degrade even when the pollutant concentration fits MAC.

8. MAC does not consider the accumulation of the pollutant in biological objects and bottom sediments, i.e., it does not consider the previous events linked to the accumulation of this agent in the aquatic environment (Frumin, 2000). It is well known that permanent pollution by insignificant doses of hardly degradable compounds leads to their accumulation and causes them to reach concentrations that are harmful for the biological communities (Sadykov, 1988, 1991). Delayed effects, such as genetic mutations (nonmortal) may accumulate and be transferred without any outspoken features. The most dangerous are the compounds of low toxicity that are standardized by organoleptic parameters, but they are especially highly mutagenic (Goryunova et al., 2003).

9. MAC does not consider the variability of the chemical forms of a compound. It is known that toxic components, such as heavy metals, may appear in different forms in water and bottom sediment. The bulk concentration of heavy metals, which is usually determined at the laboratories of the State Hydrometeorological Service, does not refer to the actual pattern of their environmental danger, since different forms of heavy metals are characterized by different toxicities (Standards and Targets ..., 1999).

10. MACs that were standardized under laboratory conditions (biological testing of certain compound) can probably be changed if they react with other chemical compounds and physical factors when they actually penetrate into the existing water object. Furthermore, chemical interactions may lead to the synthesis of new compounds that are even more toxic or, conversely, safe (Abakumov and Sushchenya, 1991).

11. Existing methods of MAC standardization consider the only maximal allowable pollution of the studied populations. Meanwhile, extremely low concentrations of some compounds may also have a negative effect, e.g., micronutrient concentrations (Bikbulatov and Stepanova, 2011; Levich et al., 2011).

12. The toxic effect of many of compounds changes significantly, along with the changes in water mineralization, pH, and temperature. These parameters are not considered in the existing guidelines.

13. The actual MAC system suffers from mixing the terms of water quality standardization and discharge standardization. For example, different MACs for fishery activities exist for silicon glass fiber (with reference to the class) and ultra-thin silicon glass fiber (both compounds are chemically the same compound, SiO_2). There is no method of distinguishing between these MACs when they are both included in the list of parameters tested for WR. Moreover, this list comprises complex mixtures and even aquatic solutions! For example, no. 286 refers to Diphezan (50% a.s.), which contains diethylamide-2-methoxy-3,6-dichlorobenzene acid (30.1% 2-methoxy-3,6-dichlorobenzene acid), diethylethanolamide-chlorsulfuron (0.2% chlorsulfuron), OP-7 (3.5%), and water up to 100%. We have no comments.

14. Less than 10% of the total number of standardized MACs are supported by the accuracy of measurements, even for MAC concentrations (Abakumov and Sushchenya, 1991). Although the list of toxic compounds that have cumulative effects already increases and comprises 48 combinations, the problem of the combined effect of three, four, five, or more agents is still important (Akimova and Khaskin, 1994). Moreover, the toxicity of the degraded compounds is also not considered (Dmitriev, 1997).

One of the theories assumes that, despite the disadvantages of the standardization system based on MACs, there is no adequate alternative method. There is only the question of improving it based on errors in MAC standardization, which will be minimized by limiting its application. For example (Patin, 2011), it is necessary to do the following:

(1) correct the existing MAC list, present the values as round numbers, ratify this as a permanent rule, and do not consider the accuracy of the method;

(2) refuse to accept the myth of reliable regional standardization of MAC when the error of MAC determination is exceeded by 10–100 times, i.e., attempts to find any regional standards will definitely fail;

(3) refuse the demand to develop a method (analytics) for every compound and pharmaceutical included in the official MAC list, since the possibilities of the Russian control services are limited to the analysis of one or two dozen compounds;

(4) the calculation methods (dilution technique, etc.) must be applied for the compounds and pharmaceuticals that are impossible to determine in natural waters (most of them fit this list), so regular control makes no sense.

These improvements do not represent the need to search for or develop methods of standardization that avoid the disadvantages of MACs. Obviously, the smallest number of these disadvantages is characteristic of methods based on analyzing environmental monitoring, which allows one to compare some of the biological characteristics of the ecosystems during a significant time period (here, we refer the reader to our next publication in the coming issue of this journal).

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