On the problems of water quality in Russia and some approaches to their solution

G. M. BARENBOIM, V. I. DANILOV-DANILYAN, A. N. GELFAN & YU. G. MOTOVILOV

Water Problems Institute of Russian Academy of Sciences, 3 Gubkina Str., 119333 Moscow, Russia
hydrowpi@aqua.laser.ru

Abstract An overview of water resources in Russia is presented in terms of the problem of water scarcity. It is shown that physical water scarcity, defined as insufficient resources to satisfy demand, is a feature of water security in very few regions of Russia, whereas most regions have enough water to meet industrial, agricultural and household needs, as well as environmental constraints. Inadequate water quality creates, to a larger extent than physical availability of water, the most serious water scarcity problem in the country. A synopsis of some water quality problems in Russia is presented. As the predictable consequence of increasing anthropogenic impact, many water bodies in the industrial and urbanized regions of Russia are badly polluted. The main sources of surface water pollution, as well as changes in the relative contributions of these sources over the last two decades, are analysed. As a specific concern, the problem of drinking water supply and sanitation is presented. A rising gap between the research and engineering communities is considered as one of the reasons for the water quality problems and bridging this gap is one of the main research challenges in water quality management in Russia. Two examples of effective implementation of research findings into practice are demonstrated: (1) new modelling tools for water quality prediction, and (2) new technology for monitoring of organic xenobiotics.

Key words water quality; anthropogenic pollution; water supply and sanitation; modelling; monitoring

WATER SCARCITY IN WATER-RICH RUSSIA: TWO DIMENSIONS OF THE PROBLEM

Perceptions of water security today are influenced by ideas about water deficit. Physical scarcity of water, defined as inadequate resources to satisfy demand, is widely understood as the defining feature of water insecurity in many countries; however, *ex facte*, it is not the case for Russia. Russia is one of the water-richest countries in the world. Renewable water resources total about 4300 km^3 (second only to Brazil which has the largest share of the world's total freshwater resources), equivalent to 29 000 m^3 for every person in the country. Thus Russia has far more water than the 1700 m^3 per person minimum threshold that hydrologists treat as the amount needed to support industries and households, grow food and maintain the environment. However, there is a large mismatch between distribution of water resources and population. The majority of Russian water resources are concentrated in the great rivers of the sparsely populated Siberia and Far East, Baikal Lake (almost a quarter of the world's supply of freshwater) and mountain regions. As a result, only 8% of the renewable water is in areas with 80% of the population.

The Russian economy uses freshwater resources ineffectively. The economic productivity of water – measured as unit of GDP produced with every cubic metre of water – is around US$10, i.e. half of that in USA and three times lower than in Germany (Danilov-Danilyan, 2009). Today the Russian economy uses in total not more than 1.5% of available water resources, i.e. about 62.5 km^3; industry accounts for 58% of water consumption; 18% is used for domestic purposes and 24% for agriculture (Water Strategy of Russian Federation, 2009). Moreover, the total water withdrawal for all purposes is about 60% of that in the later Soviet time and continues to decline now, albeit slower (Fig. 1).

In spite of the uneven spatial distribution of water resources and their consumptive use, there is and will remain (at least in the near future) more than enough water in Russia for domestic purposes, for agriculture and for industry. However, water insecurity exists in the most populated regions of Russia, e.g. in the European part of the country where 80% of population is concentrated. The insecurity is caused by inadequate water quality which is, in addition to the physical availability of water, the second dimension of water scarcity and creates the most serious water-related problem in Russia.

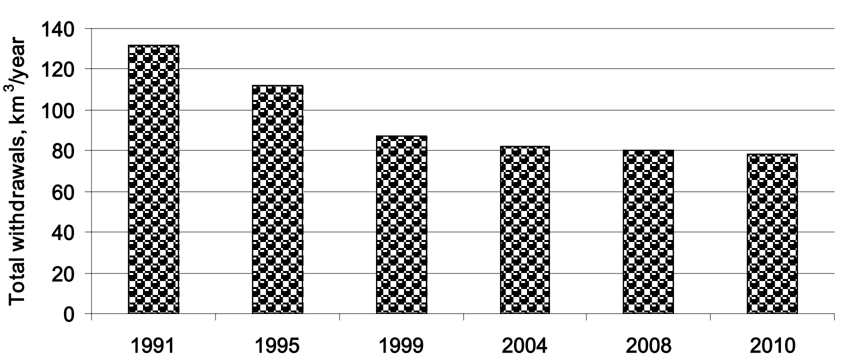


Fig. 1 Total water withdrawals in Russia from 1991 to 2010.

The first objective of this study is to provide a synopsis of specific regional water quality problems on the basis of recently published data (including the official statistics of the Russian federal agencies). The problems reviewed are broadly divided into two interrelated categories: (1) anthropogenic pollution of surface water and (2) drinking water supply and sanitation. The second objective is to present examples of the modelling tool and monitoring technology developed for mitigating some of these problems.

ANTHROPOGENIC POLLUTION OF SURFACE WATER

All major river systems and lakes in the industrial, agricultural and municipal regions of Russia are badly polluted. According to federal statistics (Water Strategy of Russian Federation, 2009), almost 52 km^3 of wastewater are discharged into water bodies. More than one third of wastewater (19 km^3) needs to be treated in order to meet Russian water quality standards. However, only 2 km^3 is treated in accordance with the established regulations, while the remainder, 17 km^3, is emitted, insufficiently treated, into water bodies. Note, that investments in water treatment in our country constitute only 0.2% of GDP (Danilov-Danilyan & Khranovich, 2010), whereas in developed countries these costs are not less than 1%. Temporal changes (for the last two decades) of the total wastewater discharge and the part of it that remains below the accepted standards of wastewater treatment are shown in Fig. 2. In Russia, these standards were established in dependence on the source of wastewater (Guidance, 2011).

The main source of water pollution is domestic sewage, providing over 60% of the total insufficiently treated wastewater emitted into water bodies, i.e. the contribution of this source to water pollution exceeds that from the industrial and agricultural pollution sources taken together. There are various reasons to explain this rather atypical interrelation between the sources of water pollution in Russia; the outdated sewerage systems (20% in a very rundown state) and huge

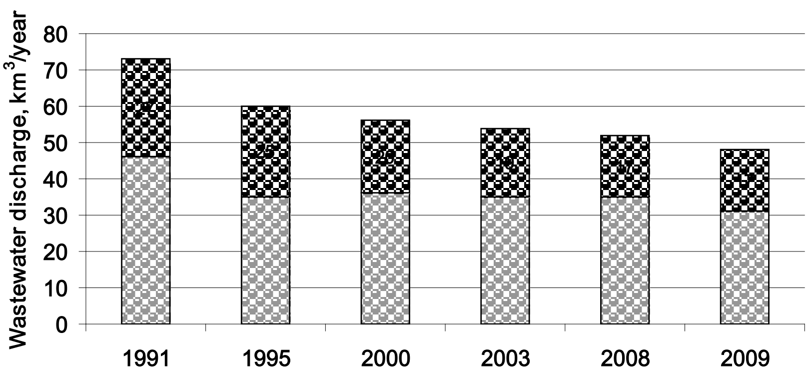


Fig. 2 Total wastewater discharge (columns) and the part of the discharge that does not conform to the accepted standards for wastewater treatment (black part of the columns) (Danilov-Danilyan & Pryazhinskaya, 2010)

irretrievable losses (almost 3.6 km^3 per year) in sewerage networks are among the main reasons. The outdated sewerage systems themselves are additional sources of pollution; that is why water chlorination is still used in the majority of the municipal treatment facilities for disinfection of water within the sewerage network.

Despite the significance of municipal wastewater, it is important not to underestimate the potential impacts of industrial pollution. Industry accounts for 25% of the total volume of untreated (or insufficiently treated) wastewater. The main sources of water pollution are pulp-and-paper mills, chemical plants, iron-and-still works, petroleum and coal industries, etc. Several studies have recorded significant industrial releases of polychlorinated biphenyls, heavy metals and radionuclides (Henry & Douhovnikoff, 2008). In some cases, emissions are detectable tens of kilometres from the source, or are so large that the affected river systems have been described as "extremely polluted".

The Volga River, the longest and one of the most polluted rivers in Europe, is a good example of the cumulative effects of overuse and poor treatment of industrial wastewater. For instance, study on water quality in the Cheboksary Reservoir (Middle Volga) has been carried out (Drinev *et al.*, 2005) and high concentrations of anthropogenic organic compounds, including drugs and hydrocarbons that are mutagenic and carcinogenic, have been detected in water and sediments.

There are tens of similar examples presented in both the state reports (e.g. Federal Center of Hygiene and Epidemiology, 2011, 2012) and scientific reviews (e.g. Danilov-Danilian, 2009). These examples include river basins located within the affected area of the Pervoural'sko-Revdinsky and Permsko-Krasnokamsk iron-and-still plants (Ural region), rivers of the Northern Dvina River basin near the Sokolsky pulp-and-paper mills, rivers of the Volga basin downstream from Samara city, the Angara River downstream from Irkutsk city, the Irtysh River between Tobolsk and Hanty-Mansiisk cities, and many others.

In the mid 1980s, agriculture was the most important source of water pollution in Russia as in most countries worldwide. Many of the pollutants of agricultural origin (nutrients, pesticides, nitrates, pathogens to name a few) can make water unsafe for human consumption and result in substantial environmental problems. Now, agriculture is the third source after domestic and industry pollution sources, providing about 11% of contaminants into water bodies. This change is caused by the degradation of irrigated agriculture over the last two decades (areas under irrigation declined from 6.2 to 4.5 million ha) accompanied by the reduction of use of chemical fertilizers (Danilov-Danilyan & Pryazhinskaya, 2010)

One of the most prevalent water quality problems resulting from the diffuse pollution by nutrients from agricultural areas is eutrophication, a result of high-nutrient loads, mainly phosphorus and nitrogen. Lakes and reservoirs are particularly susceptible to the negative impacts of eutrophication because of their complex dynamics, relatively longer water residence times and their role as an accumulating storage for pollutants from their drainage basins.

High levels of eutrophication are typical for lakes and reservoirs located in the southern agricultural regions of European Russia, e.g. Tsimlyansk Reservoir (Don River) where eutrophication is characterized by the prevalence of blue-green algae (*Cyanophyta*) having a toxic effect on the aquatic organisms (Nikanorov *et al*., 2012) is an extreme case of eutrophication.

Current levels of anthropogenic pollution in Russia are one of the main causes of degradation of river, reservoir and lake systems, accumulation of pollutants (including toxic ones) in components of the aquatic ecosystems, and the deterioration of water quality in these systems. Typical for the majority of surface waters is the increase in intensity of chemical and microbiological loads, the limited capacity of sewage treatment facilities, the virtual absence of treated wastewater, and infringements of the rules governing the use of water in water protection zones.

DRINKING WATER SUPPLY AND SANITATION

The dramatic deterioration of water quality is reflected in the current situation with the supply of clean drinking water. The official statistics (Federal Center of Hygiene and Epidemiology, 2011) demonstrate poor quality of water in the so-called "water objects of the 1st category" (sources of

Table 1 Percentage of water samples of poor quality in water bodies used for household supply.

Federal District	Percentage of water samples		
	2009	2010	2011
North-West	39.7	41.8	44.2
Ural	38.9	35.5	31.5
Volga	27.5	27.8	27.5
Central	31.9	32.9	26.0
Siberian	21.2	21.4	23.5
Far East	21.7	24.2	22.7
South	8.6	9.2	8.1
North Caucasus	-	5.5	6.7
Russian Federation	**21.9**	**23.3**	**22.2**

household water supply) in the federal districts of Russia for the period of 2009–2011 (Table 1). Here, the term "poor quality" means that at least one substance is below the quality standards permitted in Russia. As follows from Table 1, one in three samples from water bodies located in the most populated areas and used for household water supply, does not conform to the standards.

With regard to the provision of clean drinking water to settlements, the central water supply systems in Russia cover 75% of the population. In large and medium-size cities, more than 90% of population has access to a centralized water supply, while the level of access does not exceed 60% in urban type villages and rural settlements. No more than 59% of amount of water delivered to drinking water supply systems is treated; in rural settlements this amount does not exceed 20% (Water Strategy of Russian Federation, 2009). Of this amount, less than one third is treated in accordance with the established regulations, while the remainder is emitted insufficiently treated into water bodies (UN Development Programme, 2004). To a significant degree, the latter fact is a consequence of the deficiency of treatment facilities which are often outdated, underfunded and in a state of disrepair. At least a half of the wastewater treatment plants are overloaded and more than a third were constructed during the Soviet period and need reconstruction (Danilov-Danilian, 2009).

As a result, as pointed out in the Federal Act (Water Strategy of Russian Federation, 2009), one in two people in Russia drinks water that does not meet the permitted chemical and/or microbiological standards of water quality. In a number of cases a crisis situation is noted, e.g. in the Republic of Ingushetia, the Republic of Kalmykia, the Republic of Karelia, the Karachay-Cherkess Republic, the Khanty-Mansi Autonomous Area, and in cities such as Arkhangelsk, Kurgan, Saratov and Tomsk.

In many settlements, especially in rural regions, people suffer from both a lack of clean drinking water and a deficiency of sanitation facilities (Fig. 3). According to the UN Development Programme (2004), 44 towns (4%) and 582 urban settlements (27%) in Russia had no central sewerage system in 2002. Today in Russia about 30% of people do not have access to improved sanitation (UNICEF and World Health Organization, 2012).

Fig. 3 Use of sanitation facilities in Russia in 2010 (on the basis of data from UNICEF and World Health Organization, 2012).

In order to develop effective management of water quality and improve the situation described above, a detailed understanding of natural and anthropogenic factors that control water quality in water bodies is required. A necessary (but not sufficient) condition of such an understanding is the availability of reliable information on water quality characteristics at an appropriate spatial-temporal resolution. To provide this information, an improved system of water quality monitoring is required, both for water sources and at all stages of water passing from the water supply point to the consumer.

The status of surface freshwater quality monitoring in Russia was reviewed in a series of international publications (e.g. Zhulidov *et al*., 2000, 2001; Nikanorov, 2010). In the late 1990s, a critical analysis of this status was carried out by Zhulidov *et al*. (2000), and the authors demonstrated the limited ability of existing water quality monitoring to provide adequate information for decision makers in water quality management and environment protection.

During the 2000s, the status did not improve substantially. There are many reasons for that; even their cursory description will take up more space than the available here. We mention only one that is the most troubling for us: a rising gap between the research and engineering communities. In Russia, relatively few research developments have found their way into the water quality monitoring and management guidelines used by many practitioners. The problem concerns partly the scientists and scientific organizations, and partly the practitioners through their reluctance (or lack of capacity) to adopt new approaches. Bridging this gap is one of the main research challenges in water quality management in Russia. In the next two sections some examples of effective implementation of research findings into practice are demonstrated.

MODELLING THE WATER CYCLE AS A CORE COMPONENT OF WATER QUALITY MONITORING AND MANAGEMENT

Solution of the problem of water scarcity caused primarily by poor water quality is associated with implementation of an integrated water resources management (IWRM) approach. The basis of this approach is that all water should be considered as a common resource and shared among the users (industry, agriculture and domestic) and allowing for the requirements of environmental sustainability. These views are reflected in the Water Strategy of Russian Federation (2009), which defines the main lines of action to ensure the efficiency and reliability of the water supply. Therefore, IWRM can be considered as management of the whole water cycle including “blue” water in rivers and reservoirs (lakes and aquifers), “green” water absorbed by soil and providing a resource for agriculture, and “grey” wastewater (Global Water Security, 2010). As a basic tool of IWRM, modelling of the water cycle and water quality could contribute to an improved monitoring of water quality in ungauged or poorly-gauged regions, to better understanding of factors affecting water quality in water bodies, and, as a result, to delivering higher water security. Many models for simulating water quantity and quality already exist, but often need to be refined and improved for specific applications, bringing challenges for researches. It is important to note that the hydrological part of the models must take into account the specific physiographic and climatic conditions of Russia; therefore application of the widely-used models developed for other conditions is not promising. One of the modelling tools developed for Russian conditions is the model ECOMAG (ECOlogical Model for Applied Geophysics). It was developed in the late 1990s (Motovilov *et al*., 1999), and widely used during the 2000s in operational mode for water resources management in large cascades of reservoirs in Russia (Gelfan & Motovilov, 2009). As an example, some results of application of ECOMAG to reproduce water quality dynamics in river basins of the Kola Peninsula that are exposed to intensive pollution from the Pechenganickel Industrial Complex are shown briefly below. The study is presented in detail in Motovilov (2013).

The ECOMAG model consists of hydrological and water quality submodels which are operated at a daily time step. The hydrological submodel describes the main processes of the terrestrial hydrological cycle: snow accumulation and melt, soil freezing and thawing, water infiltration into unfrozen and frozen soil, evapotranspiration, the thermal and water regime of soil, lateral surface, subsurface, groundwater and channel flow. The water quality submodel describes the processes of pollutant accumulation on the surface, dissolution of pollutants by rain or snowmelt waters, penetration of soluble pollutants into soil, interaction with soil solution and soil matrix. The transfer and transformation of pollutants in the river system are described taking into account the lateral diffusive inflow of pollutants by surface, subsurface and groundwater flows, the load from point sources of pollutants discharged directly to the rivers, and the exchange of pollutants between the river water and river bed.

The model was applied within a project funded by the Kola Mining Company. The target of the project was to assess the anthropogenic contribution to the river pollution over the area of influence of the Pechenganickel Industrial Complex (PIC). The PIC includes mines, beneficiation, kiln, smelter, sulfuric acid plants and other auxiliary works. The plants consume a lot of water for technological needs. The volume of water recycled is about 80% of total water consumption. Several data sets were used for the ECOMAG calibration and validation: meteorological and hydrological data, data on emissions and discharges of pollutants into the river system, as well as data on pollution of river water at different points of the river network. The model is able to reproduce the nickel concentrations in river water quite well, and the comparison with the corresponding observed concentrations is plausible. It was concluded that the ECOMAG model could be applied for simulating the dynamics of nickel concentrations with finer space-time resolutions than possible with the existing monitoring network; the simulation results are discussed in detail in Motovilov (2013). It should be noted that the performance of the model strongly depends on the specific features of the pollutant to be simulated, and on the availability and reliability of water quality data.

Below, the response of nickel concentration to different scenarios of the PIC activity are briefly analysed on the basis of numerical experiments. Figure 4 illustrates the results. Three scenarios were simulated. The first scenario reflects the present real anthropogenic pressure on the river basin including two sources of pollution: (1) pollutants input to the catchment with precipitation (as the result of the PIC emission to the atmosphere) and absorption by soil, and (2) emission of insufficiently treated wastewater into the rivers. The second scenario includes only one source of pollution: the wastewater, whereas the effect of the polluted soil is excluded. The third scenario reflects the situation when the PIC ceases to operate (there are no emissions or wastewater), and river water pollution is caused only by subsurface inflow of water passing through the polluted soil.

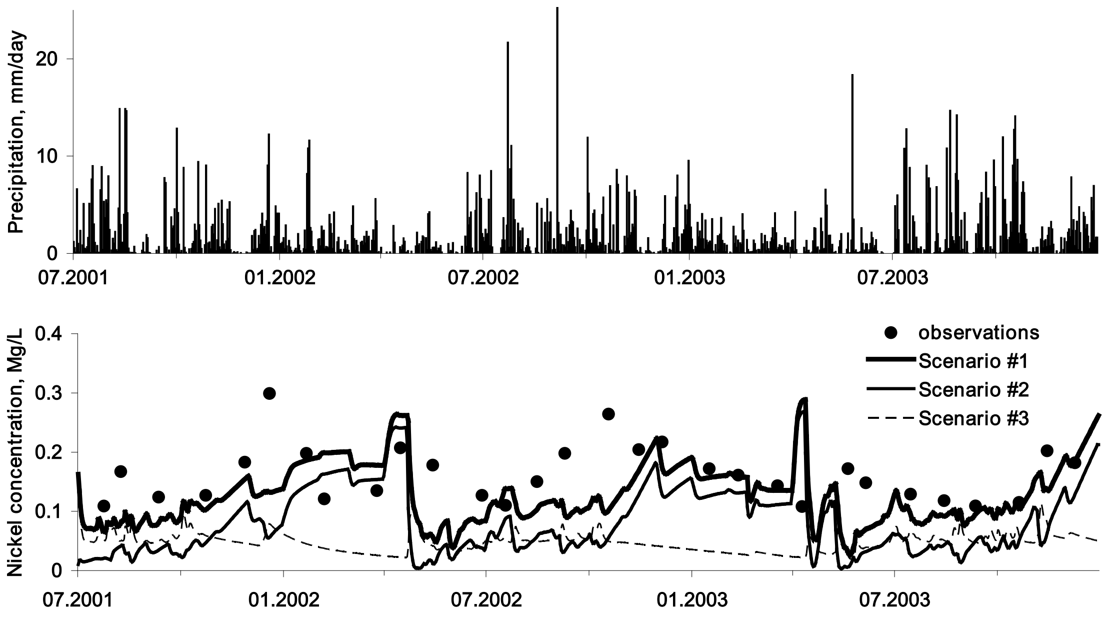


Fig. 4 Daily precipitation (top) and dynamics of nickel concentration (bottom) observed in the outlet of the Luottn-Yoki River and simulated under the three plant operation scenarios (see explanation in text).

The results of the numerical experiments for the Luottn-Yoki River basin show (Fig. 4) that the discharge of the polluted wastewater into the river network makes a significant contribution to the river water pollution. This contribution is 50–70% on average in summer and 80–90% in winter and spring. A significant contribution to the nickel pollution of the river water, especially in summer, is made by subsoil and groundwater inflow that are contaminated as a result of the considerable air emissions over the surrounding area since the plant commenced operation in 1945. Even if the PIC operation ceased, pure rainwater passing through the contaminated soils becomes polluted and flows into the river network.

NEW TECHNOLOGY FOR MONITORING OF WATER QUALITY

Monitoring of organic xenobiotics

Organic compounds of anthropogenic origin influence the quality of drinking water as well as water used in agriculture (livestock, poultry farming and irrigation), and can adversely affect the state of aquatic biota. The spectrum of such compounds is wide. Their number can be estimated from the total number of substances reported by the Chemical Abstracts Service (CAS); the number exceeded 68 million (beginning of 2013), of which at least half are organic compounds, including their complexes with different chemical elements. About 5 million compounds are used in practice, and many of them are organic (Chiganova & Barenboim, 2012). In principle, any of these compounds can appear in natural water, so the total number maybe hundreds or thousands, e.g. oil pollution of water alone leads to the appearance of at least 1000 different hydrocarbons in water. Products of physical-chemical transformations of the primary components of pollution, their metabolites generated by aquatic biota, as well as natural organic compounds increase the number.

The vast majority of the organic compounds are xenobiotics, i.e. substances, foreign to certain types of living organisms, especially to humans. Pesticides, many industrial chemicals, drugs, most of the above-mentioned petroleum hydrocarbons and other organic compounds are xenobiotics polluting water. Among the organic xenobiotics there is a large number of super toxicants, mutagens, carcinogens, etc. (see e.g. sites of the International Programme on Chemical Safety http://www.inchem.org/; the International Agency for Research on Cancer http://www.iarc.fr/). Determination of concentrations of xenobiotics in water, their type of biological activity and potential hazard to human and aquatic biota are required for effective water quality management.

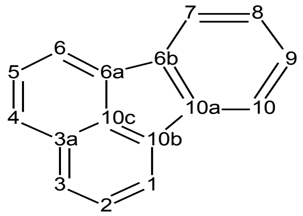
Typically, identification of xenobiotics and evaluation of their content are carried out by the standard methods of analytical chemistry, for example, by chromatographic-mass spectrometry. The evaluation of the hazard posed by xenobiotic pollution is possible, assuming that the maximum permissive concentration (MPC) is known for each of the analysed xenobiotics. Actually, this assumption is unrealistic, because: (a) the number of xenobiotics in water can be much higher than the number of those of known MPC, especially given their secondary products, and (b) the secondary products may have different structure under changing conditions and the diversity of these products is unpredictable.

For example, in four reservoirs and three rivers of the drinking water supply system of Moscow, 126 organic compounds were detected, but the MPC was known for only for 17 of them (Chiganova & Barenboim, 2012). Approximately the same ratio was observed in our studies on water quality of Cheboksary Reservoir (Middle Volga) (Barenboim *et al*., 2012a).

For solving this problem, we use the achievements of bioinformatics, namely the link between the chemical structure of a substance and its biological activity (chemioinformatics). Knowledge of such activity allows prediction of the major type of biological threat and comparison of the population diseases in the area with the biological threat. For predicting the biological activity of a substance based on its structure, different methods are used: quantum chemistry, semi-empirical equations, and methods based on the training set (see review in Barenboim & Malenkov, 1986). Our analysis has shown that the last of these methods is the most effective. Although this method was not used for the prediction of biological activity of the organic compounds, now it is being intensively developed and used in pharmacology, especially in connection with drug design.

In particular, we use the above-mentioned method, realized in the software product PASS (Prediction of Activity Spectra for Substances) (Lagunin *et al*., 2000), where the training set is represented by 260 000 compounds. Biological activity has been determined experimentally, and appropriate data were taken from different information sources. The number of types of activity determined is 4000; the theoretical basis of the approach is presented by Filimonov & Poroikov (2006); applications related to water pollution are demonstrated by Chiganova & Barenboim (2012) and Barenboim & Chiganova (2012). As an example, the results obtained for one of the detected substances are shown in Table 2.

Table 2 Example of hazardous biological activity computed on detected organic compound.

Compound	Structural formula	Prediction activities and probability of their occurrence
Fluoranthene		0.771 Carcinogenic, group 1
		0.770 Carcinogenic, group 2A
		0.704 Thrombocytopoiesis inhibitor
		0.723 Neurotoxic
		0.703 Hypercholesterolemic
		0.686 Hyperthermic
		0.674 Depression
		0.596 Carcinogenic, group 3
		0.625 Hyperglycemic
		0.548 Carcinogenic, group 2B
		0.524 Carcinogenic, mouse, male
		0.520 Carcinogenic, mouse
		0.554 Cardiotoxic
		0.532 Convulsant
		0.541 Bronchoconstrictor
		0.552 Emetic

The PASS-system is used together with the original system developed by Chiganova & Barenboim (2012), combining international and national databases on toxicity of chemicals with the database of synonyms of drugs, as well as with the database of metabolites. The developed system revealed the substances having drug activity (antibacterial, anthelmintic, antineoplastic, etc.) in the previously mentioned water bodies (Barenboim & Chiganova, 2012). The presence of organic compounds that are not defined as official drugs but have pharmacological activity, was detected. This allows prediction of the potential targets of their impact as similar to those of the drugs of the same type of action. The set of detected xenobiotics was grouped according to their predicted activity types if the probability of occurrence of this activity is greater than 0.5 (Table 3).

Table 3 Biological activity computed for several detected organic compounds.

Carcinogenic	Mutagenic	Teratogenic
Acenaphthylene	Diethylene glycol	Heneicosane
Benzanthracene	Phenanthrene	Dibutyl phthalate
Benzo(a)pyrene	Fluoranthene	Phenylacetic acid
Bis(2-ethylhexyl)phthalate	4-chloroaniline	Cholestanol
Hydroquinone	1,1,2,3-tetrachloro-1-propene	2-ethylhexyl phthalate
Embryotoxic	Neurotoxic	Nephrotoxic
Benzo(a)pyrene	Thymine	Caffeine
D-galactopyranose	1,1,2,2- tetrachloroethane	Xylitol
Dimethyl phthalate	4-chloroaniline	Ribitol
Octadecanol	9-hexadecene-1-ol	Stigmasterol
Cyclotetradecane	Methyl 3-hydroxybutanoate	Campesterol

The above-mentioned information system and, in particular, the PASS product as the main part of this system, were also successfully applied for the prediction of the biological activity (toxicity) of the individual hydrocarbons in the oil spill (Barenboim *et al*., 2012b). The necessity of such calculations is associated with the fact that the distribution of oil in water is based on the density and solubility of hydrocarbons. Therefore, different combinations of hydrocarbons occur at different water depths.

Overall, the introduction of the bioinformatics (chemioinformatics) technologies based on the fundamental link of "structure–activity" to the field of hydrochemistry and to the assessment of environmental risks related to water quality makes it possible to obtain new information essential for improving water quality monitoring and management.

Monitoring of oil spills

The major water quality problem in Russia is pollution of natural water with oil and its derivatives. For example, in late 1994, one of the largest disastrous oil spills in Russia occurred in the Komi Republic. Tens of thousands of tons of oil and the same amount of contaminated water have been emitted in the Pechora River watershed of the Barents Sea basin. It took almost eight years to eliminate the major negative effects of this accident. However, this does not account for long-term biological effects: the hydrocarbons are typical xenobiotics to humans, some of which are mutagens, carcinogens and toxicants with the long-term consequences.

Significant experience of monitoring was gained in that time (one of the authors directly supervised the task of monitoring the rivers in the Pechora River basin). This experience confirmed the need for automated monitoring systems in areas of high environmental risks related to oil spills in water bodies (in preventive, emergency and post emergency modes). The first version of this system was developed in 1998 (Barenboim *et al*., 1998), and the last one in 2012. In all versions there is simultaneous automatic registration directly in the water body of hydrocarbon concentration, radioactivity of uranium and thorium (these elements are present in the oil and produced water), conductivity of water (changing due to metals in oil and in produced water), and some other characteristics. A floating platform (buoy, container) resistant to the waves carries all these detectors and accessories. The whole measuring module of this system can operate at depths of as much as 15 m under the ice cover. The special information system for data processing, which includes the current prediction of toxicity of individual hydrocarbons, was developed in the latest version of the automated monitoring system (Barenboim *et al*., 2012a). UV-Lidar, which measures the fluorescence of oil has been also added to this version, which focuses on monitoring of oil output in the Arctic shelf or on monitoring of land water bodies in ice conditions.

CONCLUSION

A synopsis of some water quality problems in Russia, which are, to a significant degree, the outcome of the extensive use and mismanagement of water resources, is presented. Among the many reasons (political, economic, and social) for the current situation, an increasing gap between the research and engineering communities is of particular concern. We believe that bridging this gap is one of the main challenges in water quality management in Russia, as demonstrated by examples of the effective implementation of research findings into the practice.

REFERENCES

Barenboim, G.M. & Malenkov, A.G. (1986) *Biologically Active Substances. New Principles of Search*. Nauka (in Russian).

Barenboim, G.M., Avandeeva, O.P. & Stepanovskaya, I.A. (2012a) Some scientific and technological aspects of the development of systems for monitoring of natural water quality. In: *Water and Water Resources: System-function in nature and economy: a collection. scientific papers* (ed. by V.G. Pryazhinskaya), 365–375, SRSTU Press (in Russian).

Barenboim, G.M. & Chiganova, M.A. (2012) Pharmaceutical pollution of surface and waste water. *Water: Chemistry and Ecology* 10, 40–46 (in Russian).

Barenboim, G.M., Saweka, A.U., & Ryabov, V.D. (2012b) New methodological aspects of the evaluation of biological hazards of oil spills. *Water: Chemistry and Ecol.* 12, 50–60 (in Russian).

Chiganova M. A. & Barenboim G.M. (2012) Evaluation of xenobiotic profile of water bodies: problems and results. In: *Organic matter and nutrients in inland and marine waters*. Karelian Research Centre of RAS, 430–435 (in Russian).

Danilov-Danilyan, V.I. (2009) *Global water resources and the prospects of water management system of Russia*. Institute of Sustainable Development (in Russian).

Danilov-Danilyan, V.I. & Khranovich, I.L. (2010) *Water management: coordination of strategies of water consumption*. Science world (in Russian).

Danilov-Danilyan, V.I. & Pryazhinskaya, V.G. (2010) *Water resources and water quality: current state and the problems of management.* Russian Academy of Agricultutal Sciences (in Russian).

Drinev, S.E., Agishev, F.H., Andreeva, I.I., Barenboim, G.M., Venitsianov E.V. & Chernenkii, V.M. (2005) Development of system for monitoring water objects of Republic of Chuvashiya. In: *Ecological and socio-economical problems in large river basins*. 242–255. MediaPress (in Russian).

Filimonov, D.A. & Poroikov, V.V. (2006) Prediction of biological activity spectra of organic compounds. *Russian Chemical Journal*. 50(2), 66–75 (in Russian).

Gelfan, A.N. & Motovilov, Yu.G. (2009) Long-term hydrological forecasting in cold regions: retrospect, current status and prospects. *Geography Compass* 3(5), 1841–1864.

Global Water Security – An Engineering Perspective (2010) The Royal Academy of Engineering.

Henry, L.A. & Douhovnikoff, V. (2008). Environmental issues in Russia. *Ann. Rev. Environ. Resour*. 33, 437–460.

Guidance on organization and arrangement of operating monitoring of the surface water properties and pollution (2011) Published by the State Hydrochemical Institute (in Russian).

Lagunin A, Stepanchikova A, Filimonov D. & Poroikov V. (2000) PASS: prediction of activity spectra for biologically active substances. *Bioinformatics* 16(8), 747–748.

Motovilov, Yu.G. (2013) ECOMAG: distributed model of runoff formation and pollution transformation in river basins. In: *Understanding Freshwater Quality Problems in a Changing World.* Proceedings of H04, IAHS-IAPSO-IASPEI Assembly, Gothenburg, Sweden, July 2013 IAHS Publ. 361 (this issue).

Motovilov, Yu.G., Gottschalk, L., Engeland, K. &.Belokurov, A. (1999) ECOMAG – regional model of hydrological cycle. Application to the NOPEX region. *Department of Geophysics, University of Oslo, Institute Report Series no. 105.*

Nikanorov, A. M. (2010) National monitoring of land surface water pollution and perspectives of its development. *Journal Russian Meteorology and Hydrology* 35(1), 20–26.

Nikanorov, A. M., Khoruzhaya, T.A. & Martysheva, N. A. (2012) Present-day characteristics and trends of long-term changes in ecological and toxicological conditions of the Tsimlyansk Reservoir. *Journal Russian Meteorology and Hydrology* 37(4), 269–275.

Federal Center of Hygiene and Epidemiology (2011) On the sanitary-epidemiological situation in Russian Federation in 2010, *State Report* (in Russian).

Federal Center of Hygiene and Epidemiology (2012) On the conditions of sanitary-epidemiological well-being of the population in Russian Federation in 2011. *State Report* (in Russian).

UN Development Programme (2006) *Beyond Scarcity: Power, Poverty and the Global Water Crisis.* UN Human Development Report.

UNICEF and World Health Organization (2012) *Progress on Drinking Water and Sanitation: 2012 Update.*

Water Strategy of Russian Federation (2009) Government of Russian Federation Directive on 27 August, 2009 #2452-p. (in Russian).

Zhulidov, A.V., Robarts, R. & Khlobystov V.V. (2001) The need and requirements for modernizing surface water quality monitoring in the Russian Federation. *Water International* 24(4), 536–546.

Zhulidov, A.V., Khlobystov, V.V., Robarts, R.D. & Pavlov D.F. (2000) Critical analysis of water quality monitoring in the Russian Federation and former Soviet Union. *Can. J. Fish. Aquatic Sci.* 57, 1932–1939