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WATER RESOURCES DEVELOPMENT: ECONOMIC AND LEGAL ASPECTS

Water-Management and Environmental Problems of the Lower Volga and Ways to Their Solution

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Abstract—The key water-management and environmental problems of the Lower Volga are considered. The items discussed include the characteristics of intake and utilization of water resources and wastewater discharges in Lower Volga Region from 1990 to 2013. The current state of the key participants of water management complex is analyzed. The quality of Lower Volga water and ecosystems is shown, and the problems of maintaining the biodiversity are discussed. The key regional programs pertaining to the rational use and protection of water resources, as well as the development of water-management complex are considered.

Keywords: Lower Volga, water-management and ecological problems, water-management complex, water quality, ecosystems, regional programs

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INTRODUCTION

Water-management and ecological problems of the Lower Volga are determined by both the natural conditions of the region and the practice of the economic entities, which does not meet the environmental requirements during the multipurpose development of water resources. The most important current water-management and ecological problems of the region are

dependable supply of high-quality water resources to the population and economic objects;

improvement of the environmental quality, including water; the preservation of the unique ecological system and biodiversity of the Volga–Akhtuba floodplain and the Volga delta; improvement of environmental safety;

protection of the population and economy objects against emergencies of natural origin (floods, underflooding, etc.);

stable functioning of the region in different spheres, including agrarian sector, fishery, transport, power engineering, recreation, and extension of the competitive advantages of the region through solving the problems of dependable water supply and rational use of water resources.

The main problems of the further development of Lower Volga Water-Management System include

the implementation of an integrated approach to Volga water resources use, involving the development of management methods for a complex water-resources system of the entire basin, taking into account the contradicting requirements of economic branches and constituent entities of the federation, the priority of problems of environmental preservation, and the considerable uncertainty in the forecasts of resources condition, and the depletion of bioresources;

elimination of local water deficiencies through constructing and modernizing water supply ducts, creating additional control structures, clearing and dredging water intakes and supply channels, and wider use of subsurface sources;

prevention of the water-induced adverse effects and reduction of the damage caused by floods through regulating the regimes of use of flood-hazard areas, constructing systems of engineering protection of populated localities, and ensuring appropriate safety levels for hydroengineering structures;

preservation and recovery of water bodies by dredging, channel clearing, removing excessive aquatic vegetation, as well as through ecological rehabilitation of water objects and reduction of anthropogenic load onto them;

making water resources development more rational by reducing water losses during its transportation from the sources to the consumers and decreasing specific water consumption and introducing water-saving technologies;

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Table 1. Dynamics of withdrawal and use of water resources in regions of Lower Volga Basin over 1990–2013, million m^3

Constituent entity of the Federation	Freshwater withdrawn				Freshwater used			
	1990	2000	2010	2013	1990	2000	2010	2013
Astrakhan oblast	3495.7	1756.6	1122.3	852.4	2335.0	1322.0	771.9	800.3
Volgograd oblast	1728.6	1161.4	1005.8	834.2	1134.9	827.0	611.0	514.1

Table 2. Dynamics of wastewater discharge into surface water bodies and consumptive water use in RF constituent entities in the Lower Volga Basin over 1990–2011, million m^3

Constituent entity of the Federation	Discharged wastewater, mine water, and collector-drainage water				Consumptive water use and losses			
	1990	2000	2010	2013	1990	2000	2010	2013
Astrakhan oblast	1079.1	593.7	281.4	144.5	2416.6	1162.9	840.9	708.0
Volgograd oblast	232.2	225.9	173.5	142.3	1496.4	935.4	832.3	691.9

engineering-exploratory and design studies for fishery-oriented amelioration, fishery-amelioration works in spawning areas and fish-pass channels;

improvement of the governmental management system based on basin management principle in the sphere of water relationships;

development of monitoring systems for water bodies by extending and upgrading observation networks, automation of the processes of data collection, processing, and transfer;

development of legal, engineering, technological, and information support of water economy;

education and training of the population in the sphere of the use and protection of water bodies in the Lower Volga.

The solving of these problems is complicated by the background variations of Caspian Sea level, leading to surge intensification and shore transformation, as well as unsatisfactory conditions of hydroengineering structures and other engineering protection elements, considerable channel deformation, shore transformation, and hydrographic network degradation.

ANALYSIS OF THE CURRENT STATE OF LOWER VOLGA WATER MANAGEMENT SYSTEM

According to data in [2, 3, 10], the anthropogenic load on Lower Volga water resources has dropped in the two recent decades more significantly than it did in other Volga regions. Freshwater intake volume from water bodies in Astrakhan oblast decreased from 3.50 in 1990 to 0.85 km^3 in 2013 (4.1 times) (Table 1). The analogous decrease in the Volgograd oblast, which belongs to the Lower Volga Basin, was 2.1 times. In the Upper Volga and the Kama Basin, water consumption in this period dropped 1.4–1.6 times.

The mean annual Volga runoff downstream of the Volgograd Hydropower Structure varied in recent decades from 177 (1996) to 337 km^3 (1994), thus demonstrating a high potential for meeting the needs of consumers.

The abrupt drop in water consumption in the Lower Volga Basin is mostly due to the crisis in the agrarian sector of the economy along with a considerable decrease in irrigated land areas. The decrease rates of the discharge volumes of waste, mine, and collector-drainage waters into water bodies were in general agreement with the rates of water consumption decrease (Table 2).

The decrease in water disposal volume in this period was largest in Astrakhan oblast (7.5 times). This is mostly due to the abrupt decrease in collector-drainage discharges from irrigated lands because of the shrinkage of the actually irrigated fields and the introduction of water-saving irrigation technologies.

The regions of the Lower Volga Basin show the largest decrease in consumptive water use because of the high proportion of agriculture in water consumption structure. Thus, over 23 years, the volume of consumptive water use and water losses decreased 3.4 times in the Astrakhan and 2.2 times in the Volgograd oblast. In the same period, the consumptive water use in the Upper Volga basin decreased 1.2 times and that in the Kama basin, 1.7 times.

Under current conditions, the shares of industry, municipal economy, and irrigation in water use in the Lower Volga are similar.

Utility and Drinking Water Supply

The situation in the sphere of drinking water supply in the Lower Volga is alarming. Nowadays, many people have to drink water not meeting hygienic requirements and use decentralized water supply sources without appropriate water treatment. The population

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in some region suffer deficiency of drinking water and use imported water [9].

Astrakhan oblast is far below the mean Russian level of high-quality water supply to the population. Groundwater sources account for as little as 0.5% of consumed water in the structure of utility and drinking water supply. Surface water sources in this oblast are rivers with numerous branches, ilmens, etc. The southwestern part of the region contains many fresh- and salt-water lakes. They receive artificial water supply through ducts with a chain of pumping stations (mostly used for amelioration), which are now partially not in use because of the lack of financing.

In some regions in this oblast, the problem of drinking water supply is critical because of the deficiency of water resources and the anthropogenic pollution of drinking water supply sources. The main problems in water supply to Astrakhan oblast population are due to the following circumstances:

considerable heterogeneity of surface and subsurface water sources in terms of water availability and quality;

bacterial pollution of surface water sources, whose water quality fails to meet sanitary–hygienic standards;

periodic inundation and underflooding of populated territories, sump-type sewer systems, and the lack of treatment facilities;

in rural settlements, the same water distribution network is often used for both industrial and drinking water supply.

Water supply problems are especially acute in Narimanovskii, Ikryanskii, Chernoyarskii, and Enotaevskii districts of the oblast with a population of about 150 thousand [15]. Up to 50% of the rural population uses untreated water; more than 50% of settlements have no centralized treated-water supply, and ~10% among them use imported water. Astrakhan and district centers have no drinking-water reserves for the case of emergency. The authors' calculations showed that the share of water losses because of the poor condition of the worn distribution network increased from 17 to 35% over period 2000–2012 [8].

Water quality in the Volga and its numerous branches within oblast territory forms under the effect of upstream reservoirs, industrial and urban household waste discharges, drainage discharges from irrigated lands, wastewaters of fishery and river navigation. The operation of treatment facilities is sometimes inefficient.

The share of samples substandard in terms of sanitary-chemical characteristics in first-category water bodies was not found to decrease. The situation is especially alarming in what regards the availability of safe drinking water in rural areas. In 2012, only 54.3% of the rural population had good and conventionally good drinking water.

The development of water supply and disposal in the region is a part of the "Clear Water" program in Astrakhan oblast for 2010–2014 with a perspective up to 2017 [13]. The analysis of the current state of criteria and target characteristics of domestic-drinking water supply shows that some important criteria are not met. Thus, the share of leaks and unaccounted water losses increases rather than decreases, the rates of decrease of specific water consumption are far below the assumed values, etc.

In Volgograd oblast, the share of groundwater in the balance of domestic-drinking water supply is as low as 18%, and the groundwater intake for these needs is steadily decreasing [12]. Water supply to Volgograd C. is based exclusively on the Volga water. Groundwater reserves for the domestic-drinking water supply in the region have been explored very poorly.

In some cities and district centers, the wear rate of water supply structures is 40–60%. The wear of distribution networks is growing; the technologies of water treatment and conditioning in use are out of date and inefficient; the commissioning terms of water supply and disposal facilities will not be fulfilled. The result is the deterioration of the quality of consumed water.

The wear rate of urban water distribution system on the average for the oblast increased from 37% in 2006 to 50% in 2012, reaching 70–80% in some districts. In the oblast, 68% of the dwelling space in rural areas is not covered by centralized water supply, making the population to use water from springs, dug wells, and bore holes for domestic needs and drinking. In 2012, only 59.3% of the rural population had good and conventionally good drinking water.

Agricultural Water Supply

The amelioration fund in Astrakhan oblast amounts to 211 thous. ha; however, only one third of lands with an irrigation network can be used, while other areas are out of operation (salinization, waterlogging, failure of pumping stations and sprinkler systems) and require capital repair (Table 3).

The majority of irrigation systems had been constructed before 1980. In the post-Soviet time, water consumption in the irrigated farming and the area of actually irrigated lands in Astrakhan oblast decreased three times. The irrigation systems include 360 pumping stations, 10.5 thousand km irrigation channels, 9 thousand km collector-drainage and discharge network, and 94 thousand hydroengineering structures in agricultural use.

Water losses in the irrigation network amount to 40–60% of water intake volume. The amelioration condition is poor for one-third of the area and good for a quarter of it. Only 30% of irrigated lands are provided with drainage systems. Less than 50% of sprinkling systems are operable. Urgent works are required

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Table 3. Major characteristics of irrigated farming in Lower Volga regions

Characteristics	1990	1995	2000	2005	2008	2010	2011	2012
Water used for irrigation, million m^3								
Volgograd oblast	770	747	449	313	300	173	227	148
Astrakhan oblast	1605	1315	817	480	454	408	763	515
Irrigated land area, thousand ha								
Volgograd oblast	352.8	305.1	256.0	221.9	180.9	180.9	180.9	180.9
Astrakhan oblast	238.5	213.3	192.7	219.1	213.2	211.2	211.0	211.0
Actually irrigated land area, thousand ha								
Volgograd oblast	341.4	295.4	121.2	152.6	143.1	121.9	125.0	–
Astrakhan oblast	210.4	205.8	62.7	86.9	77.8	69.3	75.3	–

for the reconstruction and repair of irrigated lands in an area of 125 thousand ha.

As of January 1, 2013, the area of lands with regular irrigation in Volgograd oblast is 180.9 thousand ha. Irrigation systems operate 14.9 thousand hydroengineering structures and 588 electric pumping stations. The main factors that hamper the irrigation of crops are the worn-out state of amelioration funds (including sprinkling machines), insufficient financing of amelioration, and the high energy charges, which increased 12 times in 2003–2009. The wearing rate of pumping and power equipment is 84% and that of farm irrigation network is in excess of 80%; only 70–80% of the available irrigation lands are actually watered.

Drip irrigation has gained popularity in recent years, resulting in saving considerable amounts of water and fertilizers with an abrupt increase in productivity. The area of fields under drip irrigation increased from a few ha of crops in 2000 to 930 ha in 2004 and 2.8 thousand ha in 2007. The area of such fields in the late 2010 was 11.4 thousand and in 2011 and 2012, it was 14 and 20 thousand ha, respectively.

In Volgograd oblast, it is mostly used in vegetable production and, at a small scale, for production of fruits and berries. The areas under drip irrigation increased from as little as 160 ha in 2004 to 2.9 thousand in 2007 and 6.9 thousand ha in 2010.

Program documents on the development of agroindustrial complex and land amelioration were accepted in regions. In Astrakhan oblast, the implementation of programs by 2020 will result in introducing ~34.8 thousand ha of ameliorated lands; an increase in the area of irrigated lands with the use of high-tech energy- and water-saving irrigation technologies from 38 to 57 thousand ha; and the protection of agricultural lands against water erosion, inundation, and underflooding on an area of 18.9 thousand ha; etc.

In Volgograd oblast, the area of lands with regular irrigation will reach 300 thousand ha by 2020 (including 160 thousand ha in state-owned irrigation systems and 140 thousand ha on local runoff); the lands of basin irrigation will be reconstructed in areas of 18.4 thousand ha. Innovation irrigation methods, advanced resource-saving technologies and engineering irrigation techniques will save up to 25% of water resources.

Industrial Water Use

In the context of economic crisis, industrial water consumption in Volgograd oblast decreased more than 2.5 times in the Volgograd oblast and 1.9 times in the Astrakhan oblast from 1990 to 2011. The volume of recirculated and re-used water also dropped considerably. The introduction rates of new capacities of recirculated water supply have also decreased several times. Nevertheless, the water rotation coefficient in the Volgograd oblast was high to have increased to 0.925 by 2011. In the Astrakhan oblast, it appreciably dropped during the crisis, but increased again to 0.71–0.74 by 2009–2011. The difference between water rotation coefficients in these regions is due primarily to the specific structure of their industrial production.

Fishery Complex

The natural complexes of the Lower Volga (Volga–Akhtuba floodplain, Volga Delta) have no analogs in both Russia and Europe. The natural poloi-ilmen lowland areas 525 thousand ha in square are annually inundated during Volga spring flood (April–June) and serve as a mass spawning site of commercial fish species: zander, carp, bream, roach, pike, catfish, etc. Volga main channel in the segment from the lower pool of the Volgograd Hydropower Structure to Zam'yany Settl. in Astrakhan oblast is the only spawning enclave on the European continent where sturgeon fish reproduction is taking place under natural conditions.

Currently, most fish species are in a depression state in terms of abundance and require a careful approach to their withdrawal volumes and ensuring normal conditions for their natural reproduction.

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The main causes of the currently low abundance of commercial fish species in the Volga–Caspian area arranged in the size of their adverse effect form the following series:

Volga runoff regulation and poor water support of fish spawning cycle during spring flood (conventionally, the II quarter of each year);

large-scale poaching capture in both the river and sea, unaccounted for fish withdrawal in fishery areas, undermining fish reserves and not entering the official catch statistics;

insufficient volume of amelioration works at both spawning areas and in the Volga mouth area aimed to reduce the adverse effect of anthropogenic factors and improve the environmental conditions for favorable spawning cycle of fish.

The limiting factors of the preservation and recovery of the population of anadromous and semi-anadromous fish are the unfavorable hydroecological conditions of fish reproduction in the Lower Volga. The problem of integrated use of Volga water resources can be solved by introducing many-year regulation and use of water resources in the entire Volga–Kama system, better runoff forecast accuracy, amelioration on spawning massifs, etc.

A bifurcation gate was constructed in 1976 in Volga delta head 22 km downstream of the source of the Buzan branch with the aim to form temporary backwater in the delta head and to create conditions corresponding to the optimal watering regime of spawning grounds in the eastern part of the delta and the lower Volga–Akhtuba floodplain. The flow is regulated with the use of a reinforce-concrete dam 1200 m in length. The weir front of the dam consists of 33 regulation passages, each 20 m in width, and two navigation passages, 110 m each. The main part of the structure also includes a two-line fish-passing facility and a navigable diversion system—a single-lift dock lock. After its construction, the bifurcation gate was in operation several times, commonly, within 15–20 days during spring flood recession, except for 1986, when it was operated in autumn. Presently, the use of this structure is limited by its wear; the sluice channel is not used for its intended purpose.

A special economic cluster, based on aquaculture, is created in Astrakhan oblast. In the recent 6–7 years, the catch of pond fish in the region was doubled to reach more than 17 thousand t, accounting for one tenth of its production in Russia. The main task of the creation and development of the aquaculture cluster will be the intensification of pond fishery technology, the construction of processing and canning shops, the creation of bases of summer fish keeping, development of own grain production and pond-based sturgeon production. The overall implementation of these plans will increase the volume of produced commercial fish in the nearest future to 30–45 thousand t [5].

Water Transport and Navigation Problems in the Lower Volga

The Astrakhan water transport complex includes two ports: consolidated Astrakhan port, the development of which is limited by the city, and Olya commercial seaport in the Volga–Caspian Channel (VCC). The number of ships visiting the Astrakhan and Olya seaports every year is about 12000.

The construction of the Olya port started as long ago as the 1990s; however, it became more active only in the recent years. This construction is a part of the development of a large transport center in the Southern Russia as a component of international transport corridor (ITC) "North–South." The ITC is intended to deliver cargo from India, Pakistan, and Gulf countries in Russia via Iran territory and farther transit into the countries of Northern, Eastern, and Central Europe. Cargo transshipment volumes in the Olya port are anticipated to increase to 30 million t.

A conceptual program of the integrated development of the Astrakhan Water-Transport Center up to 2020 has been developed [14]. The objective of this program is to increase cargo transshipment for the participants of foreign economic activities and transportation of Astrakhan oblast population by passenger river transport.

ITC is the main navigation path connecting the Caspian Sea with the Volga and, further, with other seas of Russia and Europe. The anticipated increase in traffic, as well as changes in ship draft and dimensions, stricter requirements to navigation safety and environmental protection require new reconstruction of the channel to improve its state and navigation conditions.

The most recent reconstruction of the channel was made in the 1960s. Until the 1990s, the traffic in the channel reached six thousand large-capacity ships. The main cargo was oil products (up to 20 million t). In the recent years, the total cargo turnover in the channel is ~5 million t.

The anticipated volume of hydrocarbon production in the northern Caspian Sea and the development of transit freight traffic of the "North–South" ITC will lead to a considerable increase in navigation in the VCC. This process will be accompanied by the involvement of ships with larger dimensions. The increase in the traffic and the availability of ships with larger dimensions will require another reconstruction of the channel. The channel is to have at least the depth of 6–6.5 m and the width of 130 m, compared with the present-day 100 m. Channel reconstruction will be accompanied by an increase in the volumes of dredging operations.

Hydropower Use of Water Resources

Eleven large hydroengineering structures are now in operation in the Volga Basin (the Ivankovo, Uglich, Rybinsk, Nishegorodskii, Cheboksary, Kuibushev,

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Saratov, and Volgograd hydrostructures on the Volga R. and the Kama, Votkinsk, and Nizhnekamskii hydrostructures on the Kama R.). The active storage capacity of the reservoirs of the Volga–Kama HPP system is 78.0 km^3, and such capacity of the three Lower Volga reservoirs is 49.3 km^3, or 56.3% of the total [1].

Water in the Volga Basin is mostly used to produce electric energy at the Volga–Kama HPP system. The functioning regime of this system largely determines WMC functioning in the Lower Volga. The most acute is water resources deficiency in the Lower Volga in the spring and summer of dry years. To ensure the reliable functioning of Lower Volga WMC under such conditions, it was proposed to pass to a variable mark of reservoir drawdown before spring flood with the use of preliminary hydrological forecast of water inflow in the second quarter.

It is necessary to assess the possibility to implement ecologically favorable spring water releases from reservoirs into the Lower Volga with coordination of the current and anticipated water use conditions in the basin upstream of the Volgograd hydroengineering structure. To meet the conditions of increasing water release from the system in the second quarter under the existing water-management system, when the reservoirs are not full, a variant is considered in which the scheme of runoff regulation is changed by passing to variable drawdown mark of the reservoirs, depending on the forecasts of water inflow into the reservoirs of the system, their lead time, and accuracy. In this case, the additional drawdown of the reservoirs in the period between the forecast becomes available and the spring flood begins will be made if high inflow is anticipated in the second quarter, while, in the case of forecasted small inflow, water discharge into the lower pools of reservoirs will be reduced, thus allowing the system to increase the drawdown level of reservoirs before spring flood and to create a reserve which can be used to increase water volume discharged into the lower pool of the Volgograd Hydroengineering Structure.

A scheme was proposed for water resources management in the reservoirs of the system in the period before spring flood. The passage to the variable drawdown of reservoirs before spring flood is proposed to implement at the Rybinsk, Kama, Votkinsk, Kuibyshev, and Volgograd reservoirs [1].

Systems of Engineering Protection against the Adverse Effect of Water

The basin of the Lower Volga shows a wide occurrence of hazardous geological processes induced by water factor, including marginal erosion, underflooding, and accompanying land-slide formation. The largest urban territories are the cities of Volgograd, Astrakhan, and Volzhskii, which suffer some direct or indirect, permanent or temporary effects of groundwater.

Underflooding processes are most pronounced in Astrakhan City. In the developed part of the city, the underflooding is governed by technogenic factors: the lack of storm drainage, the technogenic type of relief, water leaks from water-bearing network, the deterioration of the carrying capacity of municipal watercourses. Currently, underflooding affects 90% of urban territory of Astrakhan C., of which 81% shows high underflooding hazard. Of primary importance in solving the underflooding problem are the organization and equipment of monitoring well network, the implementation of groundwater monitoring, and the construction of storm drainage systems.

The shore protection activity in the populated localities in Astrakhan oblast and the engineering protection of their territories against the adverse effect of water in the period up to 2020 will be supported by 4.9 billion rubles. The length of the new and reconstructed engineering protection structures and shore protection will increase from 2.2 to 28.2 km, and the share of population in the territories that suffer the adverse water effect and will be protected as the result of these measures will increase from 33 to 63% of its total population [11].

The plans for Volgograd oblast envisage the construction of engineering protection and shore protection structures with a total length of 7.7 km, as well as clearing river beds to improve their channel capacities. As the result, the share of the population in analogous territories will increase to 42% [4].

Water Recreation and Tourism

Recreation on water objects, an important component of recreation industry, includes bathing, oaring, boating, sun and air bathing. Water recreation resources include all water objects that can be used for recreation, sport, and tourism. In Astrakhan oblast, 123 travel companies are in operation now, of which 63 are in Astrakhan C. and more than 20, in Kamyzyak district; the number of such companies is minimal in Akhtubinskii and Ikryaninskii districts.

Fishing and hunting tourism is the basis of Astrakhan regional tourist product, providing stable tourist flow. It features pronounced seasonal variations governed by climate factors.

The unique natural conditions and the wide choice of conditions for fishing and hunting tours to Astrakhan oblast result in that the tourist allocation facilities are 100% occupied during the high season. In the low season (December–early March and summer months), the mean occupation percent of tourist camps is 40%.

One of the most promising lines in the tourist activity in the region is eco-tourism. Current ecotouristic programs include visits and excursions into

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reserves, i.e., Astrakhan State Biosphere and Bogdinsko-Baskunchakskii reserves, as well as trips to lotus fields. Astrakhan is often visited by passenger cruise ships. However, in recent years, the region has become much less attractive for tourists because of the high prices of the cruises. Other constraining factors are the lack of developed beaches and places for rest.

PRESENT-DAY WATER QUALITY AND THE STATE OF ECOSYSTEMS IN THE LOWER VOLGA. BIODIVERSITY CONSERVATION PROBLEMS

The major sources of pollutants into surface water bodies in the area under consideration are municipal objects and various production facilities at industrial centers; surface runoff from populated areas and agricultural fields; animal production units; water transport; and polluted waters entering from upstream areas. Some estimates show the quality of Volga water to vary mostly under the effect of diffuse pollutant sources (developed and ploughed areas, motor roads and railroads, landfills and municipal solid waste dumps, etc.). Point pollution sources (water discharges from industrial and agricultural enterprises, as well as enterprises of municipal economy, power engineering, and transport) have much lesser effect.

Based on the results of hydrochemical studies of Lower Volga water, carried out by the Laboratory of Surface Water Pollution Monitoring, Astrakhan CHMS, in recent years, water quality of the rivers Volga and Akhtuba and the branches Buzan, Krivaya Bolda, and Kamyzyak was referred to the fourth class of pollution, i.e., was classified as *dirty* [6, 7]. A combinatory index of water pollution and a specific combinatory index of water pollution were calculated by 18 components (dissolved oxygen, chlorides, sulfates, chemical oxygen demand (COD), biochemical oxygen demand (BOD), ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, phenols, oil products, synthetic surfactants, sulfides, Fe^{2+}, Fe^{3+}, Cu^{2+}, Zn^{2+}, Hg^{2+}, Mn^{2+}, Ni^{2+}).

Values in excess of the MAC were recorded for COD, BOD_5, Fe^{2+}, Fe^{3+}, Cu^{2+}, Zn^{2+}, Ni^{2+}, Hg^{2+}, Mn^{2+}, phenols, oil products, nitrites, Mo, H_2S, and sulfides. In terms of the majority of the characteristics listed above, the pollution is classified as *characteristic* or *stable.*

The contribution to pollution is largest for Cu^{2+}, Zn^{2+}, Hg^{2+}. The concentration of Cu^{2+} in Volga water averages 4 μg/L (4 MAC). The concentration of Zn^{2+} compounds in water averages ~2 MAC. Water pollution by sulfides and compounds of Fe^{2+}, Fe^{3+} in the main Volga channel in recent years was about 2–3 MAC. The number of cases of high Hg^{2+} pollution increased from 4 in 2012 to 30 in 2013. The background concentration of Hg^{2+} compounds increased by 0.5 MAC. Water pollution by oil products commonly is not greater than 2 MAC, and their concentrations gradually decrease from the beginning to the end of a year.

Compounds of Cu^{2+} (their mean annual concentration is 3–4 MAC) and Zn^{2+} contribute most to Akhtuba water pollution. In 2014, the concentration of Zn^{2+} in Akhtuba water varied within 3–99.8 μg/L (0.3–10 MAC) at a mean concentration of 24.4 μg/L (2.4 MAC).

The major pollutants of the Buzan branch are compounds of Cu^{2+} and Zn^{2+}. The pollution by Cu^{2+} compounds averages 4–4.5 MAC. The mean annual concentration of Zn^{2+} compounds is 15–20 μg/L (1.5–2 MAC). The maximal contribution to the overall pollution of the Krivaya Bolda branch is due to Cu^{2+} compounds. Their concentrations average 4–5 MAC. Phenol concentration averaged about 2 MAC. The mean annual concentration of Zn^{2+} compounds in recent years is 1.5–2.5 MAC.

The state of Lower Volga ecosystems is determined by natural and anthropogenic factors. In the period of Volga runoff regulation (since 1961), considerable changes took place in some characteristics of river runoff regime that have an effect on the state of ecosystems:

the volume of spring flood runoff (April–June) decreased by 30%, the runoff volume over December–March increased more than twice, and that for August–November increased by 14%;

the date of spring flood start remaining nearly the same, its duration at Volgograd gage decreased, on the average, by a month (from 95 days under natural runoff regime to 64 days under runoff regulation);

flood peak now appears 20 days earlier, resulting in the earlier silting of floodplain areas;

the duration of the phase of spring flood rise decreased by half, resulting in an abrupt increase in the rate of water level rise and a decrease in water temperature at flood peak at Volgograd gage by 6°C;

the duration of the period of inundation and high water in Lower Volga floodplain decreased considerably.

Volga runoff regulation caused changes in the structure and diversity of vegetation. The northern and middle parts of Lower Volga basin show xerophytization of meadows, deterioration of the state of forests and their disappearance from the original natural habitats. Subsoil water and soil move deeper and salinize. Winter water releases inundate near-river forests to a depth of 0.5–1.0 m.

Fauna biodiversity in the region decreases. The prolonged and high winter floods increase the death rates of young animals in the majority of mammal species. The rapid growth of recreation and the construction of recreation centers reduce the animal habitats and the populations of mammals.

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The winter silting and spring water releases from the Volga HPP are the main causes of biodiversity depletion of bird fauna in wetlands of the floodplain and delta of the Volga. The effect of transport, construction, agriculture, fires, and poaching on the bird fauna contributes to a decrease in bird populations and species diversity.

The allocation system of specially protected natural territories (SPNT) in the Lower Volga basin is extremely uneven. The protected areas include only the extreme north of the Volga–Akhtuba floodplain, a small fragment of the floodplain in Kalmykia, and areas in the Volga northern delta and delta front. SPNTs are vital for the vast wetlands in the central, western, and southern parts of the Lower Volga, as the existing SPNTs cannot ensure the preservation of the entire biodiversity in the region.

To improve the unfavorable situation and to prevent the effects of climate changes require a system of measures, primarily involving the control of the volume and regime of water releases into the lower pool of the Volgograd Hydropower Structure. In the assessment of water needs and water regime for the control of water releases, natural ecosystems are to be assigned the status of full-fledged water users in the water-management system of the Lower Volga. The criterion to underlay the ecological water releases with nature-protection purposes is to be the preservation characteristic of the integrity and diversity of territory landscape organization. The volume of flood water inflow into the northern and southern parts of the Volga–Akhtuba floodplain is to be increased at least twice compared with its present value.

The optimal functioning of meadow ecosystems, which are of critical importance for regional economy, will require spring water releases, mostly in April–early May, 25–30 days in duration, with a volume of 110–120 km^3; under such conditions, these ecosystems will preserve both their high yield and diversity. In favor of forest ecosystems, winter floods are to be ceased as well as special forestry measures, including forest replantation.

A single interdepartmental multi-region environmental monitoring system is to be created in the Lower Volga floodplain, for which an integrated research system is to be developed for the entire Lower Volga territory based on the up-to-date scientific methods, including the use of GIS-technologies, space images, monitoring ecosystem functioning and the key factors of ecosystem existence, i.e., soils, floodplain extent, alluvial processes, and subsoil water mineralization and depth to its table.

CONCLUSIONS

A considerable portion of Lower Volga population has to use drinking water, which fails to meet hygienic requirements, and non-centralized water supply sources, which have no appropriate water treatment. The volume of groundwater used for this purpose is very small. The population of some regions suffer drinking water deficiency and uses imported water.

The majority of irrigation systems have been constructed before 1980. A considerable area of irrigated lands was abandoned. Water losses in the irrigation network amount to 40–60% of water intake volume. Only 30% of irrigated lands have drainage. At the same time, drip irrigation systems and other energy- and water-saving technologies are being introduced.

Insufficient water abundance for fish spawning cycle during spring flood, widespread poaching, poor amelioration works have an adverse effect on the populations of commercial fish species. However, an economic cluster, which is being developed in the region based on aquaculture, will considerably increase the volume of commercial fish production.

The Astrakhan Water-Transport System is being developed as a large transport center in Southern Russia as a component of the international transport corridor (ITC) "North–South." The anticipated production of hydrocarbons in the Northern Caspian Sea, the development of transit cargo traffic via "North–South" ITC will considerably increase the navigation through the Volga–Caspian Channel, which will require its modernization.

In the recent years, Volga and Akhtuba water referred to the IV pollution class and was classified as *dirty*. The major pollutants are Cu^{2+}, Zn^{2+}, and Hg^{2+} compounds.

In the period after the start of Volga runoff regulation (since 1961), considerable changes took place in the characteristics of river runoff regime, which have their effect on the state of ecosystems; the result was changes in the structure and diversity of vegetation, deterioration of forests and their disappearance. In the floodplain, the depth to groundwater table increases and the subsoil water and the soils become saline. The diversity of fauna in the region decreases. The long and high winter floods, the intense recreation, and increasing development of the territory cause a decrease in animal habitats and the populations of mammals and bird fauna.

Several important programs were adopted in recent years in the Astrakhan and Volgograd oblasts with the aim to supply high-quality water resources to the population and industry, to improve the environmental quality, to preserve the unique ecological system of the Volga–Akhtuba Floodplain and Volga Delta, and to protect the population and enterprises against natural hazards.

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