State of the small rivers of the Volga basin within the lower Volga

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Abstract. Nowadays the water management measures are ineffective. The field trips of 2017-2018 are carried out. The Lower Volga is drained by 37 watercourses, 34 of them belong to small rivers. The right bank tributaries of the Volga are short and flow in deep channels - 76% of all tributaries of its lower reaches. Left bank waterways are long, flowing in shallow channels - 24%. This is due to the location of the right bank of the Volga within the Volga Upland with a developed ravine-net system and a zone of dry steppes. The left bank of the lower reaches of the Volga River lies in the semi-desert zone, where the ravine-gully network is poorly developed. Factors affecting the state of these rivers: the flow of wastewater from industrial enterprises; pollution by fertilizers, pesticides; flow regulation; irrevocable withdrawal of river runoff for household, industrial, agricultural needs. Measures to address these problems: the transition to modern water-saving technologies; cleaning of domestic, agricultural and industrial waste; toughening control over compliance with the norms of discharge of pollutants into rivers; the establishment of water protection and sanitary zones for all reservoirs; clearing channels, coasts and floodplains from debris; tight control over livestock grazing in floodplains; planting forest belts along the river channels.

1. Introduction.
With the development of economic activity, the natural regime of river systems in the territory of the lower reaches of the Volga River has undergone significant changes, and the water management measures that are carried out make significant changes in the landscape of catchment areas and the hydrological regime of the rivers themselves create prerequisites for changing the entire natural complex of the territory under study. Due to the constantly increasing anthropogenic pressures on the basins and channels of small rivers, there are imbalances in the equilibrium of the ecological-hydrological systems of small rivers, which leads to their gradual degradation [1, 2].

Small rivers and their basins should be preserved not just as separate geographical elements of the earth's surface, but as integral ecological-hydrological systems of the region [3, 4]. It is difficult to overestimate the significance of small rivers, especially in the dry steppe zone, where the functioning of medium and large rivers in the region depends on their condition.
Despite the large number of works devoted to the study of watercourses of the lower reaches of the river, Volga, the question remains insufficiently illuminated in the scientific literature due to the constantly changing geo-ecological situation in the region and requires more detailed research.

Among modern researchers studying aquatic objects and the anthropogenic impact of their state, the following fundamental works should be noted: “Use and protection of water resources, hydrology of regions” (Musaelyan, Loboyko, 2002); “Surface water resources of the Volgograd region” (Musaelyan, Loboyko, Petrov, 2003); “Volga-Akhtuba floodplain: features of hydrography and water regime” (Goryainov, Filippov, Plyakin, Zolotarev, 2004); “Springs and rivers of the Volgograd region” (Brylev, Samus, Slavgorodskaya, 2007); “Volgograd reservoir. Water and environmental problems and their solutions” (Musaelyan, 2009); “Small rivers and springs of the Volgograd agglomeration” (edited by Prof. Brylev VA, 2014); “Small rivers of the Volgograd region” (Ovchinnikov, Loboyko, Ovcharova, Kosenkova, Agisheva, 2018), etc.

2. Materials and methods
The paper conducted a detailed analysis of stock data and scientific sources, made requests to the Administration of municipal districts and the Committee of Natural Resources, Forestry and Ecology of the Volgograd Region, which were analyzed, which allowed creating a summary table of morphometric indicators of small rivers of the study area as of 2018. Field trips in the spring and summer of 2017-2018 with the aim of assessing the physical parameters of water in some of the Lower Volga watercourses were organized. The information obtained from the Committee of Natural Resources, Forestry and Ecology of the Volgograd Region on the quantitative indicators of the main pollutants of the small rivers of the Volga basin, which made it possible to identify the factors of anthropogenic impact on them within the Lower Volga, was studied.

3. Morphometric characteristics of small rivers of the Lower Volga.
The Volgograd reservoir with a length of 540 km (Saratov and Volgograd regions) and about 400 km on the Volga proper (Volgograd and Astrakhan regions and the Republic of Kalmykia) fall to the Lower Volga.

The valley of the Lower Volga is asymmetric and is the natural boundary between the high right bank of the Volga Upland and the low Trans-Volga of the vast Caspian lowland. Its right slope is sublime and considerably cut by a ravine net, while the Volga region is dining plain lowland, almost devoid of ravines and girders.

Near the city of Volgograd, the flow of the Volga River before the construction of the Volga Hydroelectric Station was the maximum according to long-term data averaged 8450 m³/s, but in different years it could fluctuate between 6000 and 11500 m³/s. Water flow during low-flow periods (in summer and early autumn) was located at around 3000–4000 m³/s [5-7].

From 1958 to 1961 north of the city of Volgograd, work was carried out on the construction of the Volga dam. The Volga was blocked by it, and as a result, the upper (Volgograd reservoir) and lower (Volga-Akhtuba floodplain) pool were formed. The construction of the Volga hydroelectric station caused a change in the hydrological regime. Prior to the construction of a hydroelectric power station, the flow rate of the Volga during the low water period could reach 0.8-1.0 m/s, and during periods of high water at high water - 2 m/s [8-10].

Hydroelectric station is below the Volga. The Volga remains in its natural state, but the water regime, solid runoff, and on this site are significantly transformed. The flooding of the Volga-Akhtuba floodplain, located in the downstream of the Volga hydroelectric station, especially during the spring flood, halved, while during the winter low water period it increased by an average of 2 times [8, 11].

The Lower Volga is fed by about 37 watercourses of a different order; most of them belong to small rivers - 34. Small rivers include watercourses, the length of which does not exceed 100 km, and the catchment is not more than 2000 km² [12, 13]. The largest tributaries of the river are as follows: Yeruslan, Turgun and Akhtuba sleeves, originating in the Caspian lowland. They refer not to small, but
to medium rivers. Consider in detail some morphometric characteristics of the Volga tributaries in its lower course.

Small rivers of the lower are reaches of the river. Volga lengths up to 10 km make up 11% of their total, with a total length of 24 km (1.6%). The largest number of watercourses falls on rivers with a length of 10 to 25 km – 69.4% of the total, which is 24% of their total length. Unfortunately, the length and area of the catchment basins of the small rivers of the Lower Volga cannot be determined either. This fact is due to the fact that the study area is located in the zone of dry steppes and semi-deserts, the beds of some watercourses are filled every few years during the period of high spring floods [11].

Among the shortest watercourses, we note the Belokonevaja beam – 5 km, the Elshanka River – 5.2 km and the Kuporosny Stream – 5.8 km (Table 1). All of them belong to the right-bank tributaries of the Volga. The left bank watercourses here are significantly less - 9, of which 3 are medium level rivers (Akhtuba, Eruslan and Torgun). This is due to their location in the semi-desert zone and the poorly developed gully-ravine network of the Caspian lowland.

As mentioned above, one of the longest tributaries of the Lower Volga are the rivers Eruslan and Torgun. Their total length is 423 km, which is 27.5% of the total length of the rivers represented (Table 1). The area of their catchment basins is 5570 km² and 3550 km², respectively (Table 2). That is, the total area of the drainage basins of these rivers can be compared with some states. For example, Luxembourg - 2600 km², Comoros - 2200 km², Samoa - 2700 km², and many others.

Table 1. Number and length of the Volga basin watercourses in the lower reaches (compiled by the authors)

| Gradation of watercourses in length, km | Total number of streams | The percentage of the total number of streams, % | Their total length, km | The percentage of the total length of watercourses, % |
|----------------------------------------|-------------------------|-----------------------------------------------|------------------------|---------------------------------------------------|
| До 10                                  | 4                       | 11                                            | 24                     | 1.6                                               |
| 10 – 25                                | 25                      | 69.4                                          | 370.6                  | 24                                                |
| 26 – 50                                | 2                       | 5.6                                           | 67                     | 4.4                                               |
| 51 – 100                               | 2                       | 5.6                                           | 114                    | 7.4                                               |
| Over 100                               | 3                       | 8.4                                           | 960                    | 62.6                                              |
| TOTAL                                  | 36                      | 100                                           | 1535.6                 | 100                                               |

The Akhtuba branch is the longest river belonging to the basin under consideration - 537 km (Table 2). Over the long time of Akhtuba’s existence, its course has changed many times; the peoples living here, cities and villages were built and destroyed on its shores, at the time of the Golden Horde of hands. Akhtuba was called the Sara River or the Sarai River along the capital, which lies on its banks. Only since the 17th century, the hydronym - Akhtuba [11] finally became fixed to the watercourse.

4. Analysis of the status of small rivers of the Lower Volga

Currently, the state of small rivers, as a result of a high anthropogenic load, is estimated as catastrophic. Their runoff are significantly reduced, a large number of rivers that disappeared or are on the verge of extinction.

The river is closely connected with the surrounding landscape. Each change in the natural-territorial complex of its catchment is reflected in its water regime. At the same time, small rivers are more vulnerable than medium and large ones. For example, deforestation and plowing of soil for 20% of the catchment area can significantly affect the water regime of a river with a catchment area less than 2000 km². The main reason for this is the uneven hydrological regime of small rivers caused by the simultaneous flow of melt and rainwater over the entire catchment area, the rapid flow of floods, low underground feeding of rivers in the steppe and semi-desert zone [11, 14].
Table 2. List and main hydrological characteristics of the small rivers of the Lower Volga (compiled by the authors according to the Administrations of municipal districts and the Committee of Natural Resources, Forestry and Ecology of the Volgograd Region)

| No. | Name of the water body       | Where it flows                           | Length of the watercourse, km | Catchment area of the river, km² | Distance from the mouth, km |
|-----|------------------------------|-----------------------------------------|-------------------------------|----------------------------------|----------------------------|
| 1.  | Danilovsky Ravine           | The right tributary of the Volgograd reservoir | 16                            | 110                              | 836                        |
| 2.  | The Wet Galka River         | The right tributary of the Volgograd reservoir | 10                            | 70.8                             | 804                        |
| 3.  | The Eruslan River           | The left tributary of the Volgograd reservoir | 278                           | 5570                             | 802                        |
| 4.  | The Salt Cuba River         | The left tributary of the Eruslan River   | 81                            | 1190                             | 6,4                        |
| 5.  | The Otrozhina River         | The left tributary of the Salt Cuba River | 25                            | 233                              | 32                         |
| 6.  | The Gorkaya River           | The right tributary of the Salt Cuba River | 13                            | 56.9                             | 19                         |
| 7.  | The Salt Cuba River         | The right tributary of the Volgograd reservoir | 37                            | 682                              | 43                         |
| 8.  | The Yama River              | The left tributary of the Cuba River      | 19                            | 328                              | 9.4                        |
| 9.  | The Torgun river            | The left tributary of the Volgograd reservoir | 145                           | 3550                             | 30                         |
| 10. | The Vodyanka River          | The right tributary of the Torguna River  | 30                            | 540                              | 118                        |
| 11. | The Bulinka River           | The right tributary of the Torguna River  | 11                            | 216                              | 77                         |
| 12. | The Staraya Balka River     | The left tributary of the Torguna River   | 12                            | 114                              | 55                         |
| 13. | The Solyanka River          | The left tributary of the Torguna River   | 19                            | 234                              | 0.7                        |
| 14. | The Solyanka River          | The left tributary of the Volgograd reservoir | 15                            | 505                              | 4.2                        |
| 15. | The Fish Solyanka River     | The right tributary of the Volga River    | 11                            | 170                              | 1.4                        |
| 16. | The Market Solyanka River   | The left tributary of the Solyanka River  | 15                            | 40.6                             | 1.4                        |
| 17. | The Dry Talovka River       | The left tributary of the Volgograd reservoir | 12                            | 92.3                             | 25                         |
| 18. | The Linden Ravine River     | The right tributary of the Volgograd reservoir | 11                            | 86.6                             | 795                        |
| 19. | The Popov Ravine River      | The right tributary of the Volgograd reservoir | 14                            | 74.8                             | 784                        |
| 20. | The Kamyshtinka River       | The right tributary of the Volgograd reservoir | 10                            | 102                              | 761                        |
| 21. | The Elshanka River          | The right tributary of the Volga River    | 8                             | 20.3                             | 7                          |
Table 2. Continuation

| No. | River Name         | Right Tributary of | Length (km) | Discharge (m³/s) | Water Quality |
|-----|--------------------|---------------------|-------------|------------------|---------------|
| 22. | The Balykleika     | Volgograd reservoir | 52          | 408              | 694           |
| 23. | The Naked River    | Volgograd reservoir | 24          | 240              | 12            |
| 24. | The Single River   | Volga River         | 14          | 122              | 1.6           |
| 25. | The Deer River     | Volgograd reservoir | 14          | 110              | 649           |
| 26. | The Pichuga River  | Volgograd reservoir | 10          | 79.1             | 621           |
| 27. | The Pichuga River  | Volgograd reservoir | 10          | 94.5             | 615           |
| 28. | The Belokoneva River | Pichuga River    | 5           | -                | 7             |
| 29. | The Dry Mechetka   | Volga River         | 21.1        | 86.3             | 604           |
| 30. | The Wet Mechetka   | Volga River         | 19          | 182              | 602           |
| 31. | The Queen River    | Volga River         | 19.8        | 110              | 586           |
| 32. | The Gratifying River | Volga River       | 11.7        | 30.2             | 574           |
| 33. | The Akhtuba River  | Volga River         | 537         | -                | 67            |
| 34. | The Kucherda River | Chervlennaya River | -           | 33.6             | -             |
| 35. | The Vitiolic Creek | Volga River         | 5.8         | -                | -             |
| 36. | The Elshanka River | Volga River         | 5.2         | 20.4             | -             |
| 37. | The Scherbakovka River | Volgograd reservoir | 14          | 42               | -             |

Anthropogenic factors altering the chemical and biological composition of water and the hydrological regime of small rivers are numerous. From the most essential it is necessary to select and analyze the following:
- flow of sewage into the rivers from industrial enterprises.
- pollution of water bodies by fertilizers and pesticides coming from agricultural land, by storm and melt waters of urbanized territories;
- regulation of the flow of small rivers;
- withdrawal of river flow for household needs.

The monitoring of surface water quality, carried out by territorial subdivisions of Federal Service for Hydrometeorology and Environmental Monitoring of Russia in the Volgograd Region on more than 80 physical and chemical indicators, indicates that it has not improved over the past decade and does not correspond to standard indicators at most sites. This is evidenced by the diagrams below, reflecting the change in water quality, in Figures 1 and 2, both within the upper and lower pools. Most of the water samples taken from tributaries and sleeves of the lower reaches of the river, Volga, showed that the quality of water belongs mainly to the 3rd class – “dirty” [11].
Figure 1. Dynamics of change in water quality in the Volga river from 2012 to 2016 (UKIZV) (compiled by the authors according to the Committee of Natural Resources, Forestry and Ecology of the Volgograd Region).

The most common pollutants were hydrocarbons, phenols, organic substances, various compounds of copper, iron, zinc, nickel, ammonium and nitrite nitrogen, formaldehyde, etc. All these substances and compounds have a very negative impact on the aquatic systems of the Lower Volga. Water pollution is manifested in changes in their physical and organoleptic properties [11].

According to Federal Service for Hydrometeorology and Environmental Monitoring of Russia of the Volgograd region, currently the bulk of pollutants enter the rivers from industrial and domestic sources. For large cities with a population of over 1 million inhabitants, which is Volgograd in the Lower Volga region, the flow of pollutants with surface runoff is up to 50% of the total amount of pollution. Among the causes of water pollution should be highlighted: the massive development of water protection zones and coastal areas, non-compliance with the mode of economic activity in sanitary protection zones, reduced effectiveness of environmental protection activities, and sometimes its absence, and much more [11].

The diagram in Figure 3 demonstrates the discharge of storm, collector-drainage and wastewater into rivers for 2015-2016 within the Volgograd region. Normatively clean wastewater discharges do not exceed 10% of the total discharged water. While insufficiently treated wastewater accounts for more than 90 million m³ of discharges into the surface waters of the Lower Volga, which is about 80% of all discharges (Figure 3). Huge damage to small rivers is caused by industrial effluents: discharge of untreated sewage into water bodies; washing away toxic chemicals with heavy rainfall; gas and smoke emissions; oil and oil products leakage, etc.
A significant problem is the pollution of water bodies with agricultural waste, namely: carrying out work without complying with the requirements of geo-environmental safety for the application of mineral and organic fertilizers and toxic chemicals; widespread violation of the rules of storage of fertilizers; the discharge of wastewater from livestock farms in the absence or inefficient operation of sewage treatment plants; accommodation in water protection zones of livestock farms, warehouses of fuel and lubricants; discharges of waste processing agricultural complexes and much more.

The problem of dumping household and industrial waste into small rivers is no less. It decomposes, releases substances that adversely affect the ecological situation in general. For example, in 2015, about 62.55 thousand tons of pollutants in the form of wastewater were discharged into the waters of the lower Volga and in 2016 - 49.47 thousand tons. Unauthorized dumping of household and construction debris is commonly observed throughout the entire Volga small hydro network and is the scourge of modern cities, especially million-plus cities [11].

Siltation of small rivers leads to a rise in the level of groundwater and waterlogging, eutrophication and siltation of floodplain areas, which become unsuitable for any use. Separately, it is worth noting the silting processes leading to an increase in the probability of flooding in the period of the flood or flood of villages, villages, cities and arable lands.

Another significant problem is the overregulation of river flow by a multitude of ponds, reservoirs, dams, as a result of which, when floods pass, water flows out of the channels into their floodplains and floods coastal lands. While on the low ground, on the contrary, there is not enough water and the rivers dry up.

The diagrams in fig. 4 and 5 show changes in the water flow in the Volga in natural and regulated conditions by quarters. Obviously, with the commissioning of the Volgograd reservoir, significant changes occurred in the regime of the river. Water consumption in the second quarter (spring flood) decreased significantly, but at the same time increased in I and IV (winter low water).

Figure 3. Dynamics of discharge of storm, collector-drainage and waste waters into reservoirs in 2015 and 2016 on the territory of the Volgograd region (compiled by the authors according to the Committee of Natural Resources, Forestry and Ecology of the Volgograd Region).

Figure 4. Average quarterly volumes of runoff of the Volga River under natural conditions, compiled according to S Yakovlev and V I Kazakevich.
Figure 5. Average quarterly flow volumes of the Volga River after regulation, compiled according to S Yakovlev and V I Kazakevich.

The rationalization of water use, especially in small rivers, has received very little attention. New technologies that take into account the natural environment and scientifically-based methodological approaches to optimizing water use are poorly introduced, many laws and regulations are not implemented.

The system of financing water protection activities does not provide for a «basin approach», but is based on the territorial principle, which does not take into account the geoeconomic aspects of the functioning of river systems. The functions of the register of water bodies are performed by the State Water Cadastre, in which there is no delimitation of water basins by type of property. The civil code and land legislation do not fully coincide with the Water Code of the Russian Federation [11].

The following measures should be the main measures to solve the geoeconomic problems of water bodies in the lower reaches of the Volga: transition to modern water-saving technologies; cleaning of domestic, agricultural and industrial waste; toughening control over compliance with environmental standards and regulations for the discharge of pollutants into small rivers; the establishment of water protection and sanitary zones for reservoirs of various categories; limiting discharges of agricultural production wastes and industrial waters to various water bodies; clearing the channels, coasts and floodplains of rivers and lakes from debris; use of modern approaches and technologies for waste processing; the implementation of strict control over the grazing of the cattle lakes of the rivers and lakes; planting forest belts and zones along the river beds and adjacent ravine valleys.

5. Conclusion

The Lower Volga is fed by 37 watercourses of various orders, the dominant part of which belongs to the small rivers - 34. The right-bank Volga tributaries are short and flow in relatively deep channels. They constitute about 76% of all tributaries of the lower reaches of the Volga. The left-bank water-toclyblins, flowing in relatively shallow channels, they account for 24%, of which three are medium-sized rivers (Akhtuba, Eruslan and Torgun). This pattern is associated with their location of the right bank of the Volga within the Volga Upland with a highly developed ravine-gully network, as well as the zone of dry steppes. In turn, the left bank of the Volga River flows in the semi-desert zone and the poorly developed ravine-ravine network of the Caspian lowland.

The main factors affecting the state of the small hydraulic network in the lower Volga: the flow of sewage into rivers from industrial enterprises; pollution with fertilizers and toxic chemicals; regulation of small rivers; withdrawal of river flow for household, industrial and agricultural needs.

Monitoring the quality of surface water suggests that over the past decade it has not changed and at most of the river sections water belongs to the 3rd class – «dirty». Discharges of regulatory clean wastewater do not exceed 10% of the total amount of discharged water, insufficiently treated wastewater, which is 80% of all discharges. In recent years, there has been a positive trend to reduce discharges of pollutants into the small rivers of the Lower Volga in the form of wastewater from 62.55 thousand tons to 49.47 thousand tons. The most common pollutants include hydrocarbons, iron, zinc, nickel, nitrogen, formaldehyde.

The main measures are proposed to address the environmental problems of the small hydro network of the Lower Volga: the transition to modern water-saving technologies; cleaning of domestic,
agricultural and industrial waste; toughening control over compliance with environmental standards and regulations for the discharge of pollutants into small rivers; the establishment of water protection and sanitary zones for reservoirs of various categories; limiting discharges of agricultural production wastes and industrial waters to various water bodies; clearing the channels, coasts and floodplains of rivers and lakes from debris; use of modern approaches and technologies for waste processing; strict control over livestock grazing in the floodplains of rivers and lakes; planting forest belts and zones along the river beds and adjacent ravine valleys.

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