Efficiency of Environmental Measures in Small Rivers' Catchment Areas Is the Basis for Their Sustainable Development

N. P. Karpenko[1][a], I. V. Glazunova[1][b] and M. A. Shiryaeva[2][c]

[1]*Federal State Budgetary Educational Institution of Higher Education "Russian State Agrarian University - Moscow Agricultural Academy named after K.A. Timiryazev, Moscow, Russian Federation*

[2]*Federal State Budgetary Scientific Institution "All-Russian Research Institute of Hydraulic Engineering and Reclamation named after A.N. Kostyakov", Moscow, Russian Federation*

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Abstract: To solve this problem, a review of the sources and causes of pollution of land and water resources, as well as modern methods of reducing pollution of the small catchment area of the Sheshma River in the Republic of Tatarstan, was conducted. Based on the results of the research, the analysis of the causes of pollution of land and water resources, as well as methods for preventing the pollution of water bodies with heavy metals and pesticides, was carried out. The main directions of reducing the anthropogenic load of catchment areas of small rivers and their sustainable development, namely: land and water resources, polluted with heavy metals and pesticides, was developed. A review and analysis of the causes and methods of pollution of water resources, as well as methods of prevention of pollution of water bodies with heavy metals and pesticides, was carried out. Based on the research results, classifications were drawn up: according to the assessment of the danger of the formation of diffused pollution for agricultural lands, according to measures of reducing the pollution of water resources by diffused flows from agricultural territories and according to methods for preventing water pollution by flows from reclaimed lands and rural areas. An expert assessment and statistical processing of the results of expert assessments on the efficiency of environmental and water protection measures were performed. An assessment of the efficiency of measures of preventing pollution of water resources was performed on the basis of water balances for the Sheshma River in the Republic of Tatarstan.

1 INTRODUCTION

Territorial inequality, large intra-annual and long-term variability of river flow become an obstacle to providing the population with water resources and developing the economy. This problem is solved by regulating the river flow. In the basins of rivers of any order, the bulk of the surface flow and its qualitative composition are formed. Anthropogenic activity, associated with any load within the catchment area basin (agriculture, reclamation, plowing and slash of the territory, etc.) leads to a significant change in the conditions for the formation of river flow. The problems of pollution are especially urgent in the catchment areas of small rivers, which, due to their natural vulnerability, primarily react to anthropogenic activity. Small rivers have the lowest self-cleaning ability and are the quickest are subject to pollution. With significant volumes of industrial and domestic wastewater discharge in rivers, the normal vital processes of organisms are stopped, most of the oxygen, dissolved in the water, is consumed and the streams turn into a sewage collector. The calculation of the water balance is carried out to assess the satisfaction of water users with their needs for water resources, assess the state of water bodies and determine the limits of their use. Water balance (WB) is a calculation of water use requirements in water resources in comparison with water resources, available for use, within the boundaries of river basins, sub-basins, water-economic areas under different water conditions (taking into account the

[a] https://orcid.org/ 0000-0001-6638-149X
[b] https://orcid.org/ 0000-0003-4931-2008
[c] https://orcid.org/ 0000-0001-8019-1203

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uneven distribution of the surface) and regional reconstruction of water flow (groundwater flow in different periods of its distribution, restoration of water resources of groundwater bodies). Water balances are drawn up for the current level of use and protection of water bodies of the river basin and the levels of development of the water-economic complex, corresponding to the stages of implementation of the scheme of the complex use of water resources. The ratios between the volumes of surface and underground flows from the catchment area change, the volumes of flows, and their qualitative composition change, both in the intra-annual context and throughout the year as a whole. Therefore, research on the sustainable development of individual catchment area basins, the preservation of the ecological state of their water resources, and the development of modern and effective methods for the restoration of water resources in river catchment areas is a relevant research (Karpenko, 2020; Karpenko, 2015).

Material and research methods. The research was carried out within the Sheshma River basin, which flows through the territory of Tatarstan and the Samara region and is the left feeder of the Kama. The river heads in the Bugulma-Belebey Upland and flows into the Kama Bay of the Kuibyshev water reservoir. The river flows through an undulating plain, dissected by a dense network of river valleys, ravines, and gullies. The width ranges from 100-300 m in the upper reaches, up to 2 km at the mouth. 69 feeders flow into the river, the main of which are: Lesnaya Sheshma, Kuvak, Talkish, Sekines, Kichuy, Tolkishka. The river is of average water content, alimentation is mainly snow (63%), as well as underground and rain, the average turbidity is 230 g/cm3, the flow velocity is 0.1-0.8 m/s (Karpenko and Glazunova, 2019).

Hydrological characteristics of the Sheshma River: the length of the river is 259 km, the coefficient of variation is Cv = 0.35; asymmetry coefficient Cs = 2; Cv = 0.7; the flow rate at the final cross-section is 724 million m3; the average slope of the river is 0.8 ‰.

Attributive characteristics of the Sheshma River catchment area basin: catchment area is 6040 km2; mark on the catchment area at the mouth is 53.1 m; the forested area is 20.3%; the area of lakes on the territory is 6.4%; the drainage density coefficient is 0.14 km/km2; the river tortuosity coefficient is 1.56; the branching coefficient is 0.2; the coefficient of development variation of the river network is 0.7 (Galyamina et al., 2016; Kireicheva et al., 2014).

The main characteristics of water use (volumes of water consumption and return water) were calculated for rural and urban households, industrial enterprises, livestock complexes, irrigated farming (Markin et al., 2016; Ratkovich et al., 2013).

The generalized characteristics of water use in the territory of the Sheshma River basin are shown in Figure 1.

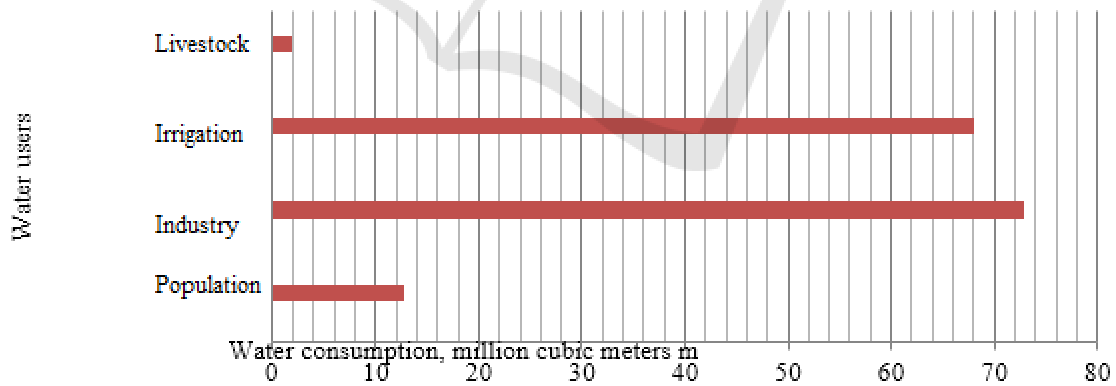

Figure 1: Volumes of water consumption in the Sheshma River basin.

The structure of the anthropogenic load, leading to the pollution of the water resources of the Sheshma River is shown in Figure 2.

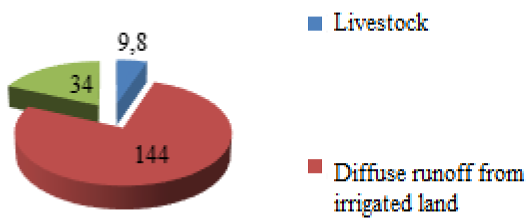

Figure 2: Structure of the polluting load on the Sheshma River.

According to the structure of the polluting load on the Sheshma River, the greatest influence is exerted by diffused flows from irrigated lands, and the smallest - by livestock business. Water withdrawal for irrigation from rivers contributes to the occurrence of irreplaceable losses and the formation of return water in improved areas. The research of diffused pollution of any water body inevitably covers a set of processes of interaction between surface and ground waters in the catchment area with the regime of anthropogenic influence. When drawing up the diagram, it was taken into account, that the treatment facilities of settlements have sufficient efficiency, they treat wastewater until the LOC of pollutants in the control cross-section is reached, and industrial enterprises have a technological cycle with a complete recycling water supply system. To restore the ecological situation and stabilize it, a complex of environmental measures was developed and proposed, taking into account their weight coefficients for land resources (Table 1) and water resources (Table 2).

Table 1: A set of measures to reduce pollution of land resources in the catchment area of the Sheshma River.

Name of the environmental measure	Dispersion of assessments σ_i^2	Variation β_i	Weight coefficients λ_i
The use of sorption materials for the immobilization of heavy metals	3.74	3.35	0.205
Vegetative reclamation. Use of tolerant plants	3.75	3.98	0.173
Establishment of the general phytotoxicity of the soil due to the action of various heavy metals	5.56	5.19	0.18
Agrochemical methods of immobilization of heavy metals in soil	5.5	5.13	0.22
Use of high-barrier plants to make environmentally friendly products	3.59	3.81	0196
Σ	–	–	1

Table 2: Results of statistical processing of expert assessments of measures of reducing pollution of water resources.

Name of the environmental measure	Dispersion of assessments σ_i^2	Variation β_i	Weight coefficients λ_i
Instalation of local drainage flow treatment facilities	3.64	0.74	0.222
Application of bioengineering facilities (BIF) for treatment and additional treatment of drainage and wastewater of irrigation systems, livestock and household wastewater	3.64	0.74	0.19
Methods and technologies for desalting and demineralization of drainage water and wastewater based on ion-exchange resins and sorption	2.86	0.58	0.23
Additional treatment of surface flow	2.17	0.44	0.09
Special tanks for the accumulation of drainage flow and rainwater	3.59	0.73	0.15
Methods to improve the self-cleaning ability of the river	2.84	0.579	0.118
Σ	–	–	1

In terms of the ecological state of water resources, it can be noted, that the following types of environmental measures have the highest weight coefficients in the expert assessment of measures of reducing pollution of river water resources:

- methods and technologies for desalting and demineralization of drainage water and wastewater based on ion-exchange resins and sorption;
- instalation of local drainage flow treatment facilities;

- application of bioengineering facilities for treatment and additional treatment of drainage and wastewater of irrigation systems, livestock and household wastewater.

According to the results of expert assessments, all the considered methods were divided into five groups, according to their efficiency and range of application. The first group included methods of increasing the efficiency of treatment and additional treatment of drainage flow and wastewater from rural settlements and livestock farms with an efficiency of up to 90%. The second group, according to the above criteria, included engineering methods for increasing the treatment of diffused flows from agricultural lands, using local facilities with an efficiency of 80%. The third group includes methods of agrotechnical and agrochemical orientation with an efficiency of 70%. The fourth group includes methods, contributing to improving the self-cleaning ability of the river with an efficiency of 60%. The fifth group included vegetative reclamation methods with an efficiency of 50%.

2 RESEARCH RESULTS AND THEIR DISCUSSION

Using the cognitive approach of expert assessment of the efficiency of environmental measures for land and water resource management to reduce pollution of small rivers, the efficiency of detoxification methods of water and land resources was assessed using the example of the Sheshma River in the Republic of Tatarstan. For this purpose, forecasts of the development of the economy were made, the parameters of water use were calculated and water balances were drawn up.

Calculations of water balances were performed according to standard formulas for years 75% - medium-low-water year and 95% - hyperarid year according to the river flow (Ratkovich, 2016; Musaev et al., 2018). When linking up the water balance (WB) in the items of the polluting load on the river, for the convenience of calculations and analysis, all methods were divided into groups of environmental measures to prevent pollution of land resources in the catchment area of the Sheshma River in accordance with the above expert assessments:

- methods of agrotechnical and agrochemical orientation;
- methods of vegetative reclamation orientation.

Methods to prevent pollution of water resources within the river basin of the Sheshma River are divided into groups:

- methods of increasing the efficiency of treatment and additional treatment of drainage flow and wastewater from rural settlements and livestock farms;
- methods for increasing the treatment of diffused flows from agricultural (reclaimed) lands;
- methods to improve the self-cleaning ability of the river.

According to experts, the most effective methods, that have a wider range of application, are methods of increasing the efficiency of treatment and additional treatment of drainage flow and wastewater from rural settlements and livestock farms, therefore, when linking up WB, the efficiency of these methods was taken into account in the first instance and amounted to 90% according to expert assessments. The next group of methods in terms of the selected criteria are methods of increasing the treatment of diffused flows from agricultural (reclaimed) lands using engineering structures, the efficiency of these methods is 80% and is taken into account in the second item of linking up the water balance. The third group of methods in terms of efficiency and range of applicability are methods of agrotechnical and agrochemical orientation with an efficiency of 70%. The fourth group in terms of the selected criteria are methods of improving the self-cleaning ability of the river with an efficiency of 60%. The fifth group included vegetative reclamation methods with an efficiency of 50%.

Calculations of water and water-economic balances allow to assess both the volume of water resources in the catchment areas and the possibility of their quantitative withdrawal for water-economic purposes and needs.

The water balance equation was composed for years of estimated frequency from known formulas. The efficiency of methods of detoxification of water and land resources was assessed by calculating the coefficients of limit pollution, which is an analog of the water pollution index for rivers according to the 5 selected groups of methods for deoxidization of land and water resources, by the formula:

$$K_{\text{пз р}} = \frac{\left(\sum W_{\text{пз}} + \sum W_{\text{вв}}\right)}{\text{ВХБ} + W_{\text{поп.}}} - 1$$

where: Wwd - the volume of water disposal; Wlp - the amount of limit pollution of wastewater; WB - water imbalance, Waug. - augmentations.

In order to improve the water quality in the Sheshma River, water-economic calculations take into account the efficiency of methods of reducing pollution of water and land resources of the river catchment area. When drawing up water balances, it is revealed, that there is no water shortage at the object under consideration, but the water quality in the river without the application of land and water resources detoxification methods is classified as "dirty". Taking into account the efficiency of the recommended groups of methods of detoxification of land and water resources, the water quality in the river goes into the class "clean", which confirms the sufficient efficiency of the recommended measures (Fig. 3).

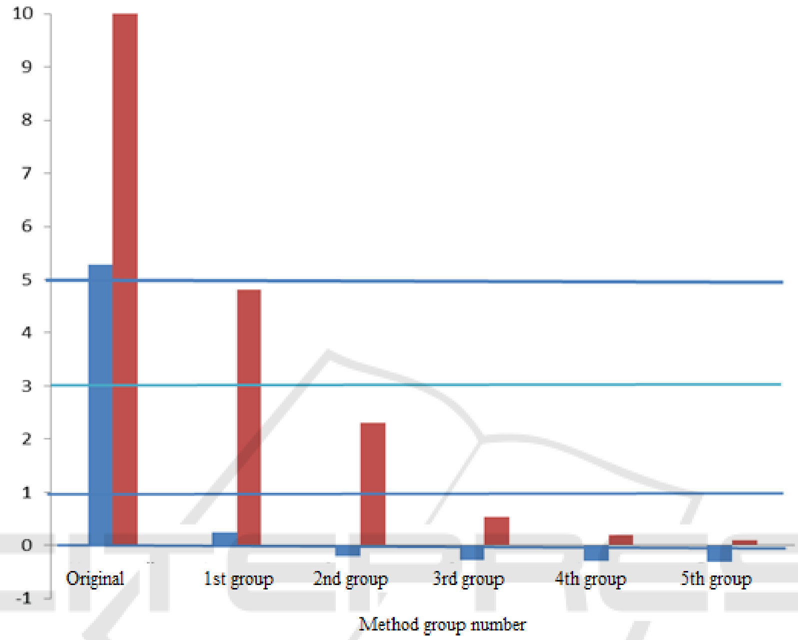

Figure 3: Diagram of the efficiency of detoxification methods of water and land resources according to the water pollution index, based on the drawing up water balances (blue - hyperarid year; red - low-water year).

As the diagram shows, drawn up based on the results of calculations of the coefficients of the limit pollution for the Sheshma River, and according to the data of water balances, the water quality in the river without the use of detoxification methods of water and land resources is classified as "dirty" and "very dirty". With the consistent application of all 5 groups of methods in accordance with the obtained expert assessments on the weight values of the methods and their efficiency, it turned out, that the compilation of the methods into 5 groups and their sequence of application has sufficient efficiency in detoxification of land and water resources since the water in the river began to be classified as "clean" in low-water years and "moderately polluted" in a hyperarid year, which is acceptable since it corresponds to the mesotrophic stage of river development.

3 CONCLUSIONS

To solve the problem posed in order to reduce pollution of the river basin under consideration, a cognitive method of expert assessment was proposed, using the gradation of the efficiency of environmental measures for managing land and water resources to reduce pollution of small rivers.

To estimate the efficiency of methods of the restoration and detoxification of water resources and the range of their applicability, an expert survey was conducted, based on the results of which, generalized tables of expert assessments of the efficiency of the methods and the recommended conditions for their use were drawn up. According to the results of expert assessments, statistical processing of the results of expert assessments was carried out in accordance with the available methods. A large group of land detoxification methods and methods of detoxification of water resources, polluted with heavy metals and pesticides, were considered. A ranked series of the efficiency of taking environmental measures was drawn up, which showed the following.

The most effective methods, which have a wide range of applications, are methods of increasing the efficiency of treatment and additional treatment of drainage flow and wastewater from rural settlements and livestock farms. The efficiency of these methods was 90%.

The next group of methods in terms of the selected criteria are methods of increasing the treatment of diffused flows from agricultural (reclaimed) lands using engineering structures, the efficiency of these methods is 80%.

The third group of methods in terms of efficiency and range of applicability included methods of agrotechnical and agrochemical orientation with an efficiency of 70%.

The fourth group in terms of the selected criteria are methods of improving the self-cleaning ability of the river with an efficiency of 60%.

Methods of vegetative reclamation orientation had an efficiency of about 50%.

Particular attention was paid to assessing the efficiency of measures to prevent water pollution, based on the drawing up water balances for the Sheshma River in the Republic of Tatarstan. Based on the results of drawing up water balances, water shortage in the Sheshma River was not established. The quality of water without detoxification methods of land and water resources corresponds to the level of "dirty".

Calculations of water balances were made from the standard formulas for years 75% - medium-low-water year and 95% - hyperarid year by river flow. When linking up the water balance in the items of the polluting load on the river, for the convenience of calculations and analysis, all methods were divided into groups of environmental measures to prevent pollution of land resources in the catchment area of the Sheshma River in accordance with the above expert assessments.

A complex of the most effective environmental measures was proposed, such as treatment and additional treatment of drainage flow and wastewater from rural settlements and animal farms, treatment of diffused flows from agricultural (reclaimed) lands using engineering structures, agrotechnical and agrochemical methods, as well as vegetative reclamation methods, the use of which will allow to improve the quality of water in the Sheshma River to the level of "clean".

REFERENCES

Galyamina I.G., Ivanova T.I., Markin V.N. et al. (2016). *Management of water systems*, 144.

Karpenko, N.P. (2020). Methodology for conducting scenario studies of land and water use in catchment areas. *Materials of the international scientific-practical conference dedicated to the 125th anniversary of the birth of V.S. Nemchinov, 3-5 December* 2019. *Reports of TSKHA: Collection of articles,* 292(2): 8-13. M.: RGAU-Moscow Agricultural Academy named after K.A. Timiryazev.

Karpenko, N.P. (2015). Assessment of the relationship between surface and groundwater rivers of the Moscow region for solving problems of ecological rehabilitation of water bodies. *Materials of the international scientific forum "Problems of water and land resources management"*, pages 3-12. Publishing house RSAU-Moscow Agricultural Academ.

Karpenko, N. P. and Glazunova, I. V. (2019). Management of land and water resources to reduce pollution based on expert assessments of the effectiveness of environmental protection measures. *Prirodoobustroystvo*, 4: 59-65.

Karpenko, N.P. and Glazunova. I.V. (2019) Sustainable development and scientific justification of the integrated use of water resources based on European experience. *Bulletin of the Scientific and Methodological Council for Nature Management and Water Use*, 14(14): 17-26. Russian State Agrarian University, Moscow Agricultural Academy K.A. Timiryazeva.

Kireicheva LV, Glazunova IV, Yashin VM. et al. (2014). Classifier of methods and technical solutions for restoring the fertility of degraded lands, *Fertility*. 6(81): 30-34.

Markin V.N., Ratkovich L.D. and Glazunova I.V. (2016). Features of the methodology of integrated water use. *Monograph*, 116.

Musaev F.A., Byshov N.V., Mustafaev M.G., Karpenko N.P., Zakharova O.A. and Ushakov R.N. (2018). Modern geoecological problems of the human environment and the role of environmental monitoring. *Monograph*, 211.

Ratkovich L.D., Markin V.N., Glazunova I.V. (2013). Issues of rational use of resources and design substantiation of VHS. *Monograph*, 256.

Ratkovich L.D., Markin V.N., Glazunova I.V. et al. (2016). Factors of influence of diffuse pollution on water bodies. *Nature management*, 3: 64-75.