Ensuring the environmental safety of the Maliy Salgir river water ecosystem

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Abstract. In the course of human activities, most of the watercourses have turned into natural-technical systems. They must be considered as a whole and, based on this principle, environmental safety should be managed on them. Following a methodological approach based on the fact that the environmental safety level of water ecosystems is determined by their functioning which ensures the maintenance of a favorable environmental situation, technical safety of facilities hydraulically connected to the watercourse and responsible for observing the rights and interests of water users, will allow a comprehensive assessment of the actual situation on them. It is also appropriate to use it for development of a list of the best environmental and economic measures aimed at reducing the anthropogenic load on these water facilities. So, the measures proposed for the Maliy Salgir river water ecosystem (maintenance work on ponds and arrangement of centralized and decentralized water disposal systems in rural settlements Stroganovka, Denisovka, Ivanovka, Druzhnoye and Lazorevka) according to preliminary estimation will reduce the index characterizing the level of its environmental safety up to a value corresponding to the acceptable level of anthropogenic activities impact.

1. Introduction

Most watercourses, in the course of human development of the territory of their basins, have turned into natural-technical systems, the components of which are interconnected and determine the state of each other [1,2]. They need to be considered as consistent water ecosystems (WES) because only such an approach will allow a comprehensive assessment of the situation and highlight the structural elements, which require priority management decisions aimed at improving the state of the system as a whole.

These natural-technical systems are involved in almost all areas of economic activity. This fact cannot be changed because the sustainable development of society and the creation of favorable conditions for human life depend on water resources. However, the process of water use can be optimized, for this it is necessary to achieve a balance between the socio-economic needs of the population and the natural component, that is, the environmental safety of the WES functioning should be managed.

The term environmental safety (ES) was introduced into regulatory practice relatively recently, therefore, an unambiguous interpretation of this and its related concepts has its unambiguous
interpretation and related concepts have not been formed yet [3-5]. In this work, the ecological safety of the WES is understood as the state of environmental protection, of which the watercourse is a part, as well as the protection of economic, social, environmental rights and legitimate interests of water users from existing and potential harmful effects associated with the unfavorable situation on its components caused by technical accidents, man-made activities, natural disasters.

Currently, there are a number of methods used to assess the environmental sustainability of the territory [6-9], the suitability of water for various needs, the technical safety of facilities [10-16], but their application does not allow a comprehensive assessment of the environmental safety level for these systems as a whole. For this purpose, it is advisable to use the methodological approach described by the authors in [17] and based on the principle that the ES level of water ecosystems is determined by their functioning and ensuring the maintenance of a favorable environmental situation, technical safety of facilities hydraulically connected to the watercourse, and responsible for observing the rights and interests of water users. In this regard, the goal of this work was to assess the environmental safety level on the example of the Maliy Salgir river water ecosystem, using the proposed approach, and, if necessary, to develop a list of measures aimed at reducing the anthropogenic load on this system.

2. Methods and materials

The study is based on the calculation of the environmental safety index of the water ecosystem (ESI_{WES}), which was carried out in accordance with the approach described by Volkova N.E. and Zakharov R.Y. [17] by the formula:

\[
ESI_{WES} = 0.42 \cdot ESI + 0.34 \cdot ESI_{WU} + 0.24 \cdot ESI_{TF}
\]

ESI, environmental safety index; ESI_{WU}, environmental safety index of water users; ESI_{TF}, environmental safety index of technical facilities.

ES level identification was carried out according to table 1.

| The value of the integral index | Identification of the state |
|---------------------------------|----------------------------|
| watercourses on the south slope | watercourses on the north slope | watercourses of the Kerch Peninsula and the Plain Crimea |
| 0 ≤ ESI_{WES} ≤ 0.05 | 0 ≤ ESI_{WES} ≤ 0.05 | 0 ≤ ESI_{WES} ≤ 0.08 |
| 0.05 < ESI_{WES} ≤ 0.23 | 0.05 < ESI_{WES} ≤ 0.24 | 0.08 < ESI_{WES} ≤ 0.26 |
| 0.23 < ESI_{WES} ≤ 0.46 | 0.24 < ESI_{WES} ≤ 0.48 | 0.26 < ESI_{WES} ≤ 0.49 |
| ESI_{WES} > 0.46 | ESI_{WES} > 0.48 | ESI_{WES} > 0.49 |

As the initial data were used: statistical information according to statistical reporting, the results of monitoring surveys of ponds and chemical analyses of water samples taken during the field survey of the WES components of the Maliy Salgir river held in 2019.

3. Results

The Maliy Salgir river belongs to the basin of the Salgir river and is its first-order right tributary. The conditions determining the formation of the surface runoff of a watercourse are generally favorable. The average long-term value of air temperature is 10.0 °C, relative humidity - 72%, precipitation – 483 mm. The hydrographic network of the basin is moderately developed. The total length of the river network is 39.3 km.

The development of the river basin is high. Within it there is one city (Simferopol) and five rural settlements (villages - Stroganovka, Denisovka, Ivanovka, Druzhnoye and Lazorevka). 30.9% of the
Maliy Salgir river basin are urban areas. About 84.9 thousand people live in the basin. 59.3% of the river basin area are agricultural lands (plowing coefficient - 32.4%) [18].

The Maliy Salgir river basin has 37 reservoirs that accumulate surface runoff. According to the reference data [19], only 23 of them have an inventory number and are entered in the water register (figure 1). The total area of the water mirror at the normal headwater level is 32.7 ha; the filling volume is 710.7 thousand m³ [19]. The remaining water bodies are small ponds with a water mirror area from 0.02 to 0.29 ha and the total filling volume of about 19 thousand m³. At the time of the survey most ponds according to the results of the technical condition assessment performed in accordance with GOST R 22.2.09-2015 and were characterized by a high and very high level of vulnerability [20].

![Figure 1. Scheme of the Maliy Salgir WES.](image)

Water transport facilities of the Maliy Salgir WES are represented by closed pipelines. In 2019, according to statistical reporting, water losses during transportation amounted up to 8.63 thousand m³ with an intake volume of 310.44 thousand m³, i.e., in general, the efficiency of water transport systems was 97.2%, which corresponds to the normative requirements for these water facilities.

The year 2019 was characterized as a year with 60% hydrological provision according to the precipitation amount (415.4 mm at the nearest weather station in Simferopol). The formed runoff exceeded the water withdrawal from the river by more than 30 times.

According to statistical reporting 2019, wastewaters was dumped into natural water bodies of the Maliy Salgir WES from only one facility - the Taurida Thermal Power Plant. The discharge volume was 179.2 thousand m³. Preliminary treatment of this water is not performed as it meets regulatory requirements and is classified as regulatory clean.
The above mentioned information was taken into account by calculation of the environmental safety index of the Maliy Salgir river water ecosystem. The results obtained are summarized in table 2, which shows that the environmental safety level of the functioning of the Maliy Salgir river water ecosystem at the time of the survey was characterized as medium hazardous. This demonstrates the necessity to develop a list of measures aimed at reducing the anthropogenic load on this system.

The level of exposure on the Maliy Salgir river water ecosystem exceeded the acceptable level by 6 criteria characterizing the urbanization of the territory, plowing of agricultural land, the water safety for fish farming and population, the presence of unused ponds and the technical condition of water-accumulating hydraulic structures. Some of them are much easier to influence than others.

Table 2. The results of an assessment of the environmental safety level of the Maliy Salgir river water ecosystem.

| Index                                      | Designation | Number | Identification of the environmental safety level |
|--------------------------------------------|-------------|--------|--------------------------------------------------|
| Environmental safety index                | ESI         | 0.08   | medium dangerous                                 |
| Environmental safety index of water users  | ESI_{WU}    | 0.34   | dangerous                                        |
| Environmental safety index of technical    | ESI_{TF}    | 0.08   | medium dangerous                                 |
| facilities                                 |             |        |                                                   |
| Environmental safety index of the water    | ESI_{WES}   | 0.17   | medium dangerous                                 |
| ecosystem                                  |             |        |                                                   |

The negative impact of anthropogenic activities on the Maliy Salgir WES is easiest to eliminate on the basis of criteria responsible for the safe functioning of hydraulic structures. And to ensure this, you need:

- carry out the required repair work on the ponds: pans – 16p, 65p, 67p; pits – 149p, 151p, 191p, MS _1 (pond without a number on the Maliy Salgir);
- to clear the water area and coastal zone of ponds: pans – 12p, 16p, 70p, MS_9, MS_10, MS_11, MS_12;
- remove water storage facilities: 61p (a pan half filled up with earth as a result of construction); MS_4 (practically not filled with water); MS_13 (filled from the pond 61p); MS_14 (a pit filled with sub-river waters);
- remove the pond 148p from the list of water bodies (actually not visible on the ground);
- adjust the joint operation of ponds 14p and 13p including removing a levee between them.

The implementation of these measures can be carried out within a few months and does not require the investment of significant financial resources because most of them can be assigned to users who unofficially and officially use these water storage facilities. This, according to preliminary estimates, will contribute to a decrease of the environmental safety index of the Maliy Salgir WES from 0.17 to 0.15.

It is more difficult to influence the criteria responsible for the water safety for users. The main reason for the poor quality of water resources is the insufficient level of sewerage in the territory. The villages located in the Maliy Salgir river basin are mainly equipped with cesspools and drain pits. The arrangement of water disposal systems in these settlements will significantly reduce the negative impact on the water quality of the WES of the studied watercourse. According to preliminary estimates, the implementation cost of these measures will be about 70 million rubles; the execution period - at least 5 years. However, this is expected to reduce the value of the environmental safety index of the Maliy Salgir water ecosystem from 0.17 to 0.07.
According to preliminary estimates, all the measures mentioned above should be sufficient to reduce the value of the index which characterizes the environmental safety level of the Maliy Salgir WES up to 0.05 (table 3) that meets the acceptable level of exposure.

| Table 3. The results of a preliminary assessment of the impact of the proposed measures implementation on the ES level of the Maliy Salgir WES. |
|---|---|---|---|
| Index | Number | Identification of the ESL |
| | actual | projected | actual | projected |
| ESI | 0.08 | 0.08 | medium dangerous | medium dangerous |
| ESI\textsubscript{WU} | 0.34 | 0.04 | dangerous | acceptable |
| ESI\textsubscript{TF} | 0.08 | 0.00 | medium dangerous | acceptable |
| ESI\textsubscript{WES} | 0.17 | 0.05 | medium dangerous | acceptable |

4. Conclusion

According to studies, the following conclusions can be drawn:

- at present, each single watercourse should be considered as a single water ecosystem including the water body itself; catchment area; hydraulic structures hydraulically connected with it and intended for the abstraction, storage, transportation, drainage and protection of adjacent lands and buildings;
- comprehensive assessment of the anthropogenic activities impact on the Maliy Salgir river water ecosystem based on the determination of the integrated index of ESI\textsubscript{WES} showed that this water management facility is characterized by an average hazardous level of environmental safety;
- to ensure the environmentally safe functioning of the Maliy Salgir WES, it is necessary to carry out the required repair work on the ponds: 149p, 191p, 65p, 16p, 67p, 151p, MS_1; clear the water area and coastal zone of ponds 70p, 12p, 16p, MS_9, MS_10, MS_11, MS_12; remove ponds 61p, MS_13, MS_4, MS_14; remove the pond 148p from the list of water bodies because it is actually not visible on the ground; remove a levee and adjust the joint operation of the ponds 13p and 14p; to equip settlements located in the Maliy Salgir river basin with centralized and decentralized drainage systems. According to preliminary estimates, all the measures mentioned above should be sufficient to achieve the environmental safety level of the Maliy Salgir WES up to the value corresponding to the acceptable impact of anthropogenic activities.

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