Evaluation of the Organization of Water Monitoring and Quality in Recreational Use Sites on River Don and Its Tributaries

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Abstract. Man-made pollution of water bodies makes the safe usage for recreational purposes impossible, in particular in areas with scarce water resources. Under such conditions, the key role in ensuring the technosphere safety is played by appropriately organized monitoring research. The analysis of the existing monitoring and forecast system for the environmental safety of water bodies was conducted for the main waterway of the Voronezh oblast, the river Don and its tributaries. The analysis of the water samples to check their sanitary, chemical, microbiological and parasitological parameters allowed to identify the priority monitoring indicators as well as the need in broadening the list of the controlled parameters, more monitoring points and higher frequency of control measures.

1. Introduction

The issues of safe drinking, household and recreational water use for the population is pertinent both for the population of the Voronezh oblast, where the river Don is the main waterway. Poorer water quality in the river Don is associated with greater man-made impact on the water environment. Local research has shown that the most damaging impact on the water quality in the river Don is exerted by the tributary, the stream "Blue Danube" that has been transformed due to human activities (cadastre name being the stream "Sandy ravine"), where the conditionally clean water was dumped from the right bank water treatment facility RVK-Voronezh, LLC that provides its services for the right-bank part of Voronezh [1, 2, 3]. The fluctuations of water quality in the river Don correspond to that in the tributary from the Voronezh water storage basin with its water quality not meeting the sanitary, chemical and microbiological requirements [4, 5, 6]. Despite significant recreational capacity of the Voronezh town agglomeration, the integral assessment of recreational sites has shown that only a few are safe for the population [7]. It has been established that water quality in the river Don does not meet the requirements for recreational water use because of the ammonium ions concentration (up to 1.2 of the maximum admissible concentration), integral indicators of biochemical oxygen demand (up to 2.21 times), chemical oxygen demand (up to 1.05 times) and a significant share of suspended...
substances (up to 75.0 mg/dm$^3$) [8, 9]. A number of researches focus on the issues of smaller rivers, or tributaries of the Upper Don: under the impact of man-made factors the water quality reduces [10, 11] which causes changes in the ichthyofauna [12, 13]. Due to environmental problems today the issues of improving the water quality monitoring system in the river Don and its tributaries as well as further assessment of the volume and quality of water resources are being addressed [14, 15].

The goal of the research is to assess the reliability of the monitoring and the results of water quality evaluation in the river Don and its tributaries from the water roster of the Voronezh oblast.

2. Methods and materials

The research uses samples from the database "Water roster of the territory of the Voronezh oblast", section "Information on the epidemiological status of water bodies used for recreational purposes". The information in the database is accumulated using the data received from laboratory analyses conducted by the Federal budgetary healthcare institution "Center for healthcare and epidemiology in the Voronezh oblast" of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being. The information analysis was conducted for 2012-2018 based on 28 control points where water samples had been collected. The water samples were analysed to establish their sanitation and chemical status (1057 samples), microbiological status (1211 samples), and parasitological (327) status under GN 2.1.5.1315-03 "Maximum admissible concentration (MAC) of chemical substances in the water of water bodies for household, drinking, recreational and everyday purposes" and Sanitary Rules and Norms 2.1.5.980-00 "Health-related requirements for surface water protection".

3. Results

The existing water quality monitoring system in the river Don and its tributaries that is implemented in the Federal State-Funded Healthcare Institution "Center for healthcare and epidemiology in the Voronezh oblast" with 28 control points in the places of recreation: 18 points on the river Don, 4 on the Devitsa river, and one on Bogucharka, Veduga, Ikorets, Osered, Tikhaya Sosna, Chernaya Kalitva. During the summer (swimming) season from June to August, samples are taken to measure 13 health-related chemical indicators (ammonium ions NH$_4^+$, oil products; nitrates NO$_3^-$, nitrites NO$_2^-$, suspended substances, chlorides, sulphates, phosphates, water hardness, mineralization, biochemical oxygen demand, chemical oxygen demand, hydrogen indicator), 5 microbiological indicators (Thermotolerant coliform bacteria CFU/100 ml; viral hepatitis antigen) and parasitological indicators (viable worm eggs: Ascarididae, Trichurus trichiura, Toxacara, Fasciolas, Taenia onchospheres and viable cysts of enteric pathogenic protozoa). All the results of the research and the data on the recreation zones are accumulated in the Water Roster of the Voronezh oblast.

The results of the analysis of the data on the water quality in 2012-2018 in the river Don and its tributaries in recreation water usage places have shown that health-care standards on health-related and chemical and microbiological indicators are not met. 59 (5.6%) out of 1057 collected samples did not meet the health-related and chemical requirements. 118 (9.7%) out of 1211 collected samples did not meet the microbiological requirements. All the 327 collected samples met the parasitological requirements (Table 1).

It has been established that 14 out of 28 control points had violated the healthcare requirements in terms of healthcare and chemical standards. The control points #27 (25.7% of the samples), a beach on the river Chernaya Kalyatva that is used by the population of the town of Rossosh and the Rossoshiansky region; #12 (25.5%), a beach on the river Don near the village of Belogorye in the Podgorensky region; #13 (21.6%), a beach on the river Don near the village of Kolodezhnoe in the Podgorensky region have violated the water quality requirements more often. These recreational sites sometimes show higher MAC of ammonium ions, nitrates, phosphates (from 1.1 to 2.5 times), same for biochemical oxygen demand indicators (up to 2.3 times) and chemical oxygen demand (up to 1.5 times). The other 11 control points (Don, Bogucharka, Tikhaya Sosna) indicate that the specific
gravity of the water samples that do not meet the healthcare requirements in terms of healthcare and chemical standards is between 2.6 and 9.4%.

Table 1. The coverage of the research and the specific gravity of the samples collected on the control points on the river Don and its tributaries near places of recreation that did not meet the standards in 2012-2018.

| Number of the point | Healthcare and chemical indicators | Microbiological indicators | Parasitological indicators |
|---------------------|------------------------------------|-----------------------------|-----------------------------|
|                     | The total number of the samples    | Violating the requirements %| The total number of the samples | Violating the requirements %| The total number of the samples | Violating the requirements %|
| 1                   | 35                                 | 2                           | 5.7                          | 47                             | 14                           | 29.8                          | 20                             | 0                             | 0                             |
| 2                   | 37                                 | 0                           | 0                            | 51                             | 3                            | 5.9                          | 13                             | 0                             | 0                             |
| 3                   | 24                                 | 0                           | 0                            | 28                             | 0                            | 0                            | 7                             | 0                             | 0                             |
| 4                   | 15                                 | 0                           | 0                            | 15                             | 0                            | 0                            | 0                             | 0                             | 0                             |
| 5                   | 22                                 | 2                           | 9.1                          | 27                             | 10                           | 37.0                         | 3                             | 0                             | 0                             |
| 6                   | 38                                 | 1                           | 2.6                          | 43                             | 5                            | 11.6                         | 15                             | 0                             | 0                             |
| 7                   | 28                                 | 1                           | 3.6                          | 24                             | 2                            | 8.3                          | 2                             | 0                             | 0                             |
| 8                   | 26                                 | 0                           | 0                            | 23                             | 2                            | 8.7                          | 2                             | 0                             | 0                             |
| 9                   | 24                                 | 0                           | 0                            | 22                             | 2                            | 9.1                          | 2                             | 0                             | 0                             |
| 10                  | 64                                 | 6                           | 9.4                          | 69                             | 4                            | 5.8                          | 17                             | 0                             | 0                             |
| 11                  | 24                                 | 0                           | 0                            | 22                             | 2                            | 9.1                          | 2                             | 0                             | 0                             |
| 12                  | 51                                 | 13                          | 25.5                         | 69                             | 8                            | 11.6                         | 19                             | 0                             | 0                             |
| 13                  | 51                                 | 11                          | 21.6                         | 71                             | 9                            | 12.7                         | 19                             | 0                             | 0                             |
| 14                  | 14                                 | 1                           | 7.1                          | 43                             | 5                            | 11.6                         | 0                             | 0                             | 0                             |
| 15                  | 66                                 | 3                           | 4.5                          | 67                             | 1                            | 1.5                          | 25                             | 0                             | 0                             |
| 16                  | 60                                 | 2                           | 3.3                          | 59                             | 4                            | 6.8                          | 22                             | 0                             | 0                             |
| 17                  | 59                                 | 2                           | 3.4                          | 59                             | 1                            | 1.7                          | 20                             | 0                             | 0                             |
| 18                  | 43                                 | 0                           | 0                            | 42                             | 4                            | 9.5                          | 14                             | 0                             | 0                             |
| 19                  | 15                                 | 0                           | 0                            | 19                             | 0                            | 0                            | 2                             | 0                             | 0                             |
| 20                  | 30                                 | 0                           | 0                            | 36                             | 4                            | 11.1                         | 6                             | 0                             | 0                             |
| 21                  | 15                                 | 0                           | 0                            | 19                             | 2                            | 10.5                         | 2                             | 0                             | 0                             |
| 22                  | 54                                 | 0                           | 0                            | 57                             | 0                            | 0                            | 24                             | 0                             | 0                             |
| 23                  | 46                                 | 0                           | 0                            | 49                             | 0                            | 0                            | 20                             | 0                             | 0                             |
| 24                  | 57                                 | 2                           | 3.5                          | 63                             | 14                           | 22.2                         | 23                             | 0                             | 0                             |
| 25                  | 48                                 | 0                           | 0                            | 48                             | 0                            | 0                            | 22                             | 0                             | 0                             |
| 26                  | 23                                 | 0                           | 0                            | 23                             | 2                            | 8.7                          | 0                             | 0                             | 0                             |
| 27                  | 35                                 | 9                           | 25.7                         | 64                             | 16                           | 25.0                         | 11                             | 0                             | 0                             |
| 28                  | 53                                 | 4                           | 7.5                          | 52                             | 4                            | 7.7                          | 15                             | 0                             | 0                             |
| Total               | 1057                               | 59                          | 5.6                          | 1211                           | 118                          | 9.7                          | 327                            | 0                             | 0                             |

The worst water quality has been registered in the water bodies in terms of microbiological standards; control points #22 and 28 show that from 1.5 to 37.0% of all the samples do not meet the established requirements (thermotolerant and total coliforms bacteria). The worst situation is on point #5, a beach on the river Don near the village of Korotyak in the Ostrogozhsky region. The microbiological standards were met in the analysed 7-year period at control points #3, a recreation site on the river Don near the town Semilyuki; #4, a beach near the village of Gremyachie in the Khokholsky region; #19, a recreation site on the river Vedyga near the town Semilyuki; #22, a recreation site on the river Devitsa near the industrial settlement Khokholsky, #23, a recreation site on the river Devitsa near the village Khokhol; #25, a beach of the Tsiurupa health resort on the river Ikorets (Liskinsky region).
As for the representativity of the monitoring data in the "Water roster of the territory of the Voronezh oblast", a number of uncertainties must be noted that are associated with the water quality assessment and monitored indicators, control frequency and monitoring sample points. The list of the control indicators must be enlarged, in particular when it comes to chemical substances.

The monitoring data is impossible to analyse during a seasonal cycle, as the water quality control is implemented only in summer, when the population come in direct contact with water in places of recreation.

It is also essential to combine the existing information on the places of recreation with the control data on water bodies with conditionally clean water from water treatment facilities and contaminated wastewater.

Due to the wide variety of employed methods of accumulating and analysing information under the water body monitoring system and to the inter-agency data accumulation, we believe that there is a possibility to address a number of organization and methodology issues by improving the monitoring through advanced research and scientific and operation cooperation of organizations and institutions under the jurisdiction of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being and higher education institutions as part of thematic Russian grants.

4. Conclusion

So, in half of the control points from 2.6 to 25.7% of the samples did not meet the healthcare standards with regards to health-related chemical indicators. The concentration of ammonium ions, nitrates, phosphates, biochemical oxygen demand indicators and chemical oxygen demand are the priority parameters out of the controlled 13. From 1.5 to 37.0% of the samples at control points #22 and #28 did not meet the existing microbiological standards (general coliform bacteria, thermotolerant coliform bacteria). All the parasitological standard requirements are met.

The existing monitoring system does not fully provide the objective information on the water quality in the river Don and its tributaries and needs to be improved, in particular its list of controlled indicators, and more frequent control, more monitoring sample collection points must be introduced.

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