Design of water reservoirs monitoring system using the example of Novosibirsk

A S Tushina¹, Y I Bik¹, E V Roshchina¹, O V Spirenkova¹, A Y Kudryashov¹, V V Gerasidi²

¹ Siberian State University of Water Transport, 33, Shchetinkina Str., Novosibirsk, 630099, Russia
² State Maritime University named after Admiral F. F. Ushakov, 93, Lenin Prospect, Novorossiysk, 353924, Russian Federation

E-mail: e.v.roschina@nsawt.ru

Abstract. The paper considers the design of a monitoring system for water reservoirs in Novosibirsk, which are the most vulnerable from the point of view of anthropogenic impact, since the self-cleaning processes are quite limited in comparison with larger water areas. At present, the observations of reservoirs are fragmentary and not regular. To obtain complete and structured data, it is necessary to clearly define the monitoring program of water reservoirs in Novosibirsk, which will serve the basis for environmental reconstruction and rehabilitation of these water bodies. The monitoring program of water reservoirs should include the systematic individual and averaged data on water quality in time and space in accordance with methodological recommendations and technical requirements. A survey point should be set up on each reservoir. The water reservoirs should have a monitoring program that includes observations of hydrological, hydrochemical and hydrobiological indicators. A well-designed monitoring program will allow implementing an integrated approach to assessing the ecological state of water reservoirs in Novosibirsk from the standpoint of environmental quality estimation. A unified database will make it possible to assess changes in the degree of technological impact in order to develop recommendations for the rational use of water reservoirs.

1. Introduction
Continuous growth of industrial and agricultural production inevitably leads to a constant and intensive increase in the rate of water consumption, depletion of water reservoirs, their clogging and increased pollution. As a result, natural aquatic ecosystems are degraded and water resources are depleted. Urban small water reservoirs are the most vulnerable to anthropogenic impacts, as their self-cleaning processes are quite limited compared to larger water reservoirs [1–4]. The lack of flowage in a large city causes their shallowing, an increase in the mass of bottom sediments, garbage and intensive overgrowing with cane and algae. As a rule, large city require the purification of dozens of closed water reservoirs.

There are about 60 small reservoirs (ponds, floodplain lakes, watered quarries) on the territory of the city of Novosibirsk, which belong to the state water fund objects of Novosibirsk Region. The City Hall of Novosibirsk conducts regular work aimed at improving the state of water reservoirs, which includes clearing river channels, strengthening the banks, eliminating unauthorized landfills in water.
protection zones, stopping the discharge of untreated effluents, regularly removing snow, arranging recreational zones in the territories adjacent to rivers [5]. Besides, state monitoring of surface water reservoirs is carried out on the territory of Novosibirsk Region within the framework of the state network of stations and posts of the Federal Service for Hydrometeorology and Environmental Monitoring, observations of Rosvodresurs and water users, in particular, water quality control of the Novosibirsk reservoir, sanitary control in places of drinking and household water use.

However, all the above measures mainly concern watercourses, large and small rivers, and almost no attention is paid to water reservoirs located within the city boundaries. Therefore, in order to obtain complete and structured data, it is necessary to clearly define the monitoring program of small reservoirs in Novosibirsk, which will serve as the basis for environmental reconstruction and rehabilitation of these water bodies. In Novosibirsk, where urban development often turns into infill construction, landscape and park zones with ponds could serve as the “oases” of health and aesthetics in the metropolis, become a resting place for citizens and a development opportunity for small businesses [6].

2. Monitoring system procedure
The monitoring of surface waters is designed to solve the following problems: to obtain selected and averaged data on water quality in time and space; to provide industries with regular and urgent information and forecasts of hydrological regime and water quality of water reservoirs [7].

To design the monitoring system, it is necessary to organize a sufficiently representative network of observations, correctly prioritize (determine which natural components and sources of pollution will be monitored, and what indicators will be recorded during observations). With regard to environmental interventions priority is given to those factors that cause the most persistent and long-term negative environmental changes.

The source data for the monitoring project include data on the sources of pollutants entering the environment in a given territory: location and volumes of emissions (discharges) of industrial enterprises, landfills, solid domestic waste warehouses, agricultural fertilizers; information about the existing man-made accidents and disasters; data on the status of anthropogenic emission sources: location of emission sources, emission power and periodicity, natural and climatic conditions in which each specific emission source is located; data on the transfer of pollutants outside the territory, as well as data on the migration of pollutants in the air basin of the region, by river and lake network, soil horizons and groundwater [8, 9].

3. Research results and the project of water reservoirs monitoring system
The studies of water quality, the state of snow cover, hydrological and hydrobiological studies of reservoirs located within the city of Novosibirsk were carried out in 2011-2020. The locations of the reservoirs are shown in Figure 1.

The study revealed that many reservoirs are subjected to the strongest anthropogenic impact, their water areas and feeding watercourses are often littered with garbage, unauthorized drains are possible, water is susceptible to flowering, has high turbidity, a putrefactive smell. Water reservoirs and their surrounding areas have an extremely non-aesthetic appearance. The analysis of the ingredient composition of water showed that in all reservoirs there is the MPC excess of a particular pollutant. To assess water pollution in the Rosgidromet system and other services, a specific combinatorial water pollution index (SCWPI) was widely used.

The index is a complex relative indicator of the degree of contamination of surface waters. It conditionally estimates the share of the polluting effect introduced on average by one of the indicators of water quality in the total pollution of water due to the presence of a number of pollutants. This method of integrated assessment makes it possible to unequivocally assess water pollution simultaneously according to a wide list of ingredients and indicators of water quality, to classify water according to the degree of pollution. Only normalized ingredients and water composition and properties of water body are used in SCWPI calculation. As a standard, MPC of harmful substances
for fisheries, as well as water reservoirs of drinking and cultural and domestic water use are used. According to the specific combinatorial index of water pollution, most reservoirs belong to class 4 and 5 (dirty, extremely dirty) [6].

Figure 1. Water reservoirs on the territory of Novosibirsk

The pollution of snow cover from the watershed area of water reservoirs was estimated by the concentration of pollutants in snow water and the total indicator of snow pollution by heavy metals. For all the considered indicators the snow condition may be estimated as average, however, the considered water reservoirs are characterized by an excess of certain compounds in comparison with the background values of such indicators: suspended substances, copper, aluminum, zinc, manganese and iron [10].

The hydrobiological study showed that the taxonomic composition of benthic, planktonic organisms, macrophytes, algophlora and ichthyofauna turned out to be quite typical for the water
reservoirs of Western Siberia, however, it is most seriously affected by the anthropogenic impact. According to the Mayer index, water reservoirs are classified as “dirty” and “moderately polluted”.

The results provide an opportunity to assess the ecological state and the degree of anthropogenic impact on water reservoirs, but they do not reflect the dynamics of the state of the studied water reservoirs, which require long-term and systematic observations. This task requires monitoring observations and an observation point on each reservoir. Given the small size of these water reservoirs and the absence of organized wastewater discharge, it is possible to carry out observations based on hydrometeorological and morphometric features “along the entire reservoir” with the installation of three section lines, if possible evenly distributed in the water area, for the same reasons one vertical may be installed in each line.

The number of horizons on the vertical should be determined depending on the depth of the reservoir at the point of measurement: at a depth of up to 5 m – one horizon; from 5 to 10 m – two horizons; at a depth of more than 10 m – three horizons (Table 1). Sampling frequency: in summer – before rains, in winter – at the lowest levels during ice breaking. There is a need for the monitoring program at water reservoirs, which includes observations of hydrological, hydrochemical and hydrobiological indicators, with the simultaneous application of various methods – aerospace survey, ground visual and instrumental examination, biotesting and calculation methods. When planning routine observations, it is necessary to assign pollutants specific to the point that are above the normal content in water. It is also important to identify the key problems (salinization, organic pollution, contamination with hazardous substances, eutrophication) and problem areas of water reservoirs by analyzing changes and deviations from natural processes.

| Depth, m       | Number of section lines | Number of verticals | Number of horizons at depth | Type of study               |
|---------------|-------------------------|---------------------|-----------------------------|----------------------------|
| up to 5 m     | 3                       | 1                   | 1                           | at the surface             |
| from 5 to 10 m| 3                       | 1                   | 2                           | at the surface; at the bottom|
| more than 10 m| 3                       | 1                   | 3                           | 0.5 h; at the bottom       |
|               |                         |                     |                             | hydrological               |
|               |                         |                     |                             | hydrochemical              |
|               |                         |                     |                             | hydrobiological            |

4. Conclusion

A well-designed monitoring program will allow implementing an integrated approach to assessing the ecological state of water reservoirs in Novosibirsk from the standpoint of environmental quality estimation. A unified database will make it possible to assess changes in the degree of technological impact in order to develop recommendations for the rational use of water reservoirs. The most important step towards solving this problem is the creation of a geo-information environment for water reservoir monitoring [11–15].

GIS will make it possible to solve such problems as the assessment of water quality in a multi-year section; analysis of activities of water users; systematization of water users according to the degree of impact; normalization of the environmental impact on the reservoir. Such an information environment in the future will allow presenting a set of data that qualitatively and quantitatively characterizes the ecological state of the reservoirs in Novosibirsk.

References

[1] Bogdanovskaya-Gienef I D 1945 Waterlogging of reservoirs by accretion Scientific Bulletin of LSU 2 37-47

[2] Korneev O Yu, Ribalko A E, Fedorova N K 2000 Geo-environmental monitoring of coastal areas is the basis of rational use of nature in urbanized areas (Saint Petersburg: state scientific production enterprise “Sevmorgeo”)
[3] Kochish I I, Kalyuzhny N S, Volchkova L A, Nesterov V V 2008 Zoohygiene (Saint Petersburg: LAN)

[4] R Vollenweider 1968 The scientific basis of lake and stream eutrophication, with particular reference to phosphorus and nitrogen as eutrophication factors (Tech. Rep. OECD, DAS (DSZ))

[5] 2020 Review of the state of the environment in Novosibirsk for 2019 (Novosibirsk: Novosibirsk City Committee for Environmental Protection and Natural Resources)

[6] Buchelnikov M A, Perfiliev A A, Sedykh B A, Spirenkova O V, Tushina A C 2014 Hydroecological problems of reservoirs of the city of Novosibirsk (Novosibirsk: NGAVT)

[7] Afanasyev Yu A, Fomin S A, Menshikov V V 2001 Monitoring and methods of environmental control (Moscow: MNEPU)

[8] Gerasimova M I, Stragonova M N, Mozharova N V, Prokofieva T V 2003 Anthropogenic soils: genesis, geography, recultivation (Smolensk: Oikumena)

[9] Golunkov Yu V, Saltykov A V, Bogdanova R A 2007 Problems of small water reservoirs in urbanized territories (on the example of the Sviyaga River within the city of Ulyanovsk) Problems of regional ecology 5 18-22

[10] Sedykh V A, Spirenkova O V, Tushina A S 2017 Study of snow cover from catchment areas of a number of small reservoirs in Novosibirsk, In the collection: Water and environmental problems of Siberia and Central Asia. Proceedings of the III All-Russian Scientific Conference with International participation

[11] Belenko V V 2012 Development of a methodology for creating a GIS cartographic database for geoeocological assessment of built-up areas: candidate dissertation abstract (Moscow)

[12] Vlasova A G 2011 Development of a specialized database for geoinformation modeling of the natural resource potential of intensively developing territories: candidate dissertation abstract (Moscow)

[13] Makarov V Z, Novakovsky B A, Chumachenko A N 2002 Ecological and geographical mapping of cities (Moscow)

[14] Mironova M O 2012 Geocological assessment of the natural environment of the uranium-ore regions using geoinformation technologies (on the example of the Elkonsky uranium-ore region): candidate dissertation abstract (Moscow)

[15] Polivanov V S, Polyakov M M, Vorobyova T A 2000 Municipal GIS: ensuring the solution of environmental problems (Vologda: Vologda Scientific Coordination Center of CEMI RAS)