

Ecological Aspects of Condition of Ground Deposits in Shershnevsky Reservoir

I A Arkanova, S E Denisov, D Yu Knutarev

Department Town Planning, Engineering Networks and Systems, South Ural State University (National Research University), 76, Lenina ave., Chelyabinsk 454080, Russia

E-mail: denisovse@susu.ru

Abstract. The article considers the aspects of the condition of ground deposits influencing the operating conditions of the water intake facilities in the Shershnevsky reservoir being the only source of the utility and drinking water supply in Chelyabinsk. The object of the research is a section near the Sosnovskie intake stations of the Shershnevsky reservoir. Based on the hydrometric surveys of the studied section and using the Kriging method and the Surfer suite, we calculated the volume of ground deposits. As a result of the analyses, the authors have proved that ground deposits in the studied section have a technology-related nature which is connected with the annual growth of the volume of ground deposits which is inadmissible in the operating conditions of the pump stations of water intake facilities whereas ground deposits will fully block the intake windows of pump stations. In case the bed area of the Shershnevsky reservoir is not timely treated, the ground deposits here will complicate the operation of the pump stations which will result in a technological problem of the treatment facilities operation up to a transfer of the pump station premises to other territories less exposed to the deposits. The treatment of the Shershnevsky reservoir from the ground deposits accumulated in the course of time will help to considerably increase its actual capacity, which will allow one to increase water circulation paths and to improve the water quality indices. In its turn, the water quality improvement will decrease the supply of suspended solids into the water intake facilities and cut the reagent costs in the course of the treatment water works operation.

1. Introduction

The Shershnevsky reservoir was created in 1969 in the Miass river, it is located on the territory of Chelyabinsk and Sosnovsky district of Chelyabinsk region between villages Poletaev and Shershni.

The reservoir belongs to channel water bodies. It has 3 reaches – a reach located near the dam, a middle and a river reach. The Shershnevsky waterworks facility is meant for the creation of a reservoir to ensure the industrial, utility and drinking water supply of Chelyabinsk by the first water intake category. Besides, the reservoir is used to cut the spring flood peaks and to accumulate summer and autumn floods.

The major part of the spring runoff volume in the dam site of the Shershnevsky reservoir is mainly formed by the runoff in the upper, deepest part of the water catchment area of the Miass river over-regulated by the Argazi reservoir. The spring runoff volume from a private water catchment area of the Shershnevsky reservoir comprises 20-30% of the total runoff supplied therein.



The catchment area in the dam site comprises 5360km². The average annual flow of the 95% occurrence from the private water catchment area of the reservoir comprises 1,04 m³/s. Basic parameters of the Shershnevsky reservoir are presented in table 1.

Table 1. Basic parameters of the Shershnevsky reservoir.

Level, m	Volume, mln.m ³	Area, km ²	Length, km	Width, m max./av.	Depth, m max./av.
FSL*=225,0	176,0	39,1	17,5	4,0/1,6	14,0/4,0
AL**=224,5	157,0	36,2	16,2	3,7/1,5	13,6/4,3
DSL***=222,0	82,0	25,4	11,0	2,4/1,0	11,0/3,2

* – full supply level;

** (affluent level) – summer-autumn operating level, in accordance with the reservoir operating procedures ensuring the transformation of rain flows;

*** – dead storage level (upon an agreement with the administration of Chelyabinsk region adopted from 1984 to ensure a safe operation of the Sosnovsky water intake facility).

The length of the shoreline at FSL=225,0 comprises 85km, the area of the shallow water regions with the depth of up to 2,0m – 9,0 km².

According to the operating procedures, an obligatory drawdown to the level of 223,0 is performed before the spring flood. During the spring flood, the reservoir is filled to the level of FSL=225,0 m. After completion of the flood, to accumulate rainfall floods during the entire summer and autumn season, the water level in the reservoir is maintained at the mark of 224,5 m.

The thickness of ground deposits is uneven: within the dam, the layer thickness comprises 0,1-0,15 m, in the tail part of the reservoir it is 0,5-0,8 m, within the Sosnovsky water intake - 1,0-1,5m, within separate sections it reaches up to 2,0 meter and higher.

A peculiar feature of the water body is its eutrophication – an abundance of flora and plankton. This results in an abundant development of weed and water “blooming”. Over such periods, there is not enough oxygen in the water body, fish and fauna representatives die. The eutrophication of the reservoir is strengthened by phosphorus and nitrogen. They appear in the water mainly as a result of the waste discharge from cattle farms. The second reason is washing out of fertilizers from fields into the ground water getting into the catchment area.[1-2]

The water quality corresponds to class 2, which is “clear, insignificantly polluted”. However, the water body is characterized by an outburst of water blooming in June and mid-August. This results in a sharp worsening of the quality of the water used for municipal water supply. The development of blue-green algae, which contain toxic cyanic compounds, is very hazardous for the shallow Shershnevsky reservoir. According to scientific studies, 60% of cyanic compounds of the Shershnevsky reservoir are highly toxic by the classification of the World Health Organization. [3-4]

The water pollution is caused by the pollution of the reservoir itself. The natural water body is a balanced ecological system subject to self-purification and self-recovery.[4-6]

The reservoir’s condition is violated as a result of the accumulation of natural organics of bed-silt in the water: foliage, branches, dead water plants, fish and birds, as well as different waste, storm sewage, insufficiently treated industrial effluents. These matters are accumulated on the reservoir bottom and form ground deposits subject to the decomposition by putrefactive bacteria and fungi. At the putrefaction of organic compounds, the dissolved oxygen is removed from the water, and decay products escape into the water. It leads to the reservoir “blooming” and bogging.[7-12] The signs of a strong contamination of the reservoir are a high level of the bottom slimy precipitate, high water turbidity particularly during the warm season, foul smell, active gas production, active development of hazardous microorganisms. To recover the reservoir cleanness the water must be treated from the putrifying organics and ground deposits.[14-18]

2. Research Object, Materials and Methods

The research object is a section within the water intake facilities of the Shershnevsky reservoir. The results of the hydrometric surveys (depth measurements) cover the territory considering the influence of the operation of pump stations # 12 and # 13 and the necessity to take top-priority measures to clean the reservoir bed in their region. The scheme of the hydrometric survey sites is shown in figure 1.

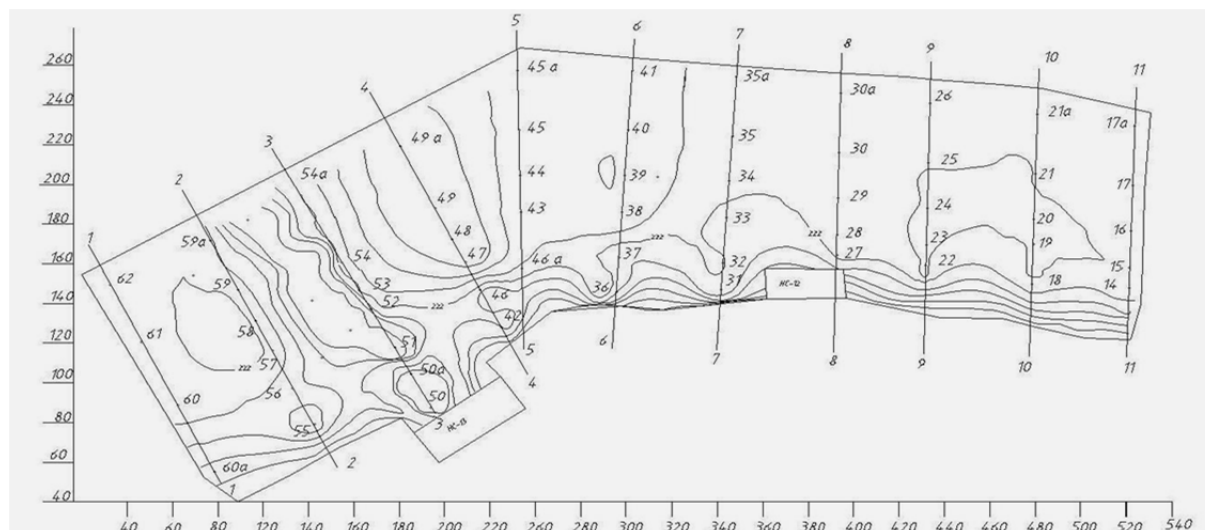


Figure 1. Scheme of the hydrometric survey sites.

The relief of the bed of the studied reservoir's section has a technogenic nature connected with the flooding by the dike, grooves and other territory developments.

Maximum depths to the reservoir beds within the section reach 5-8 m and are located in the northern half of the section (within pump station No12).

Minimum depths are located in the sections of the flooded dikes and dumps and comprise about 2 m. In the southern part of the section (within pump station No13) the average depths to the bed comprise 4,5-6 m.

The engineering-geological structure of the surveyed section is represented by the alluvial and alluvial-diluvial soils of the reservoir bed lying on rocks and ground deposits (silts) accumulated in depth shapes of the bottom.

The alluvial and alluvial-diluvial soils of the reservoir bed are represented by clay loams, clays, sands of different fineness and gravel-cobble soils. Their base bedding rocks are represented by granodiorites and granites wind-blown to the condition of loamy and medium gravel-cobble soils.

Ground deposits are represented by silts (biogenous soils), which are loamy, black, more seldom brown-grey, of a fluid-elastic (suspended sludge) in the upper parts to a high-plastic texture, with an admixture of organics and thin sandy layers in the bottom parts of the section.

The thickness of fluid-plastic silts (suspended sludge) based on the hydrographic surveys of all the years does not exceed 0,4 m, these petro types are widespread in the upper part of the ground deposits along the entire section territory.

The thickness of high-plastic silts depends on the bed relief and varies from 0 to 3 m.

Due to the technical difficulties at the collection, storage and transportation of monolith samples of the described soils, their physical and mechanical properties are studied only in single points, and the indices of physical and mechanical properties are apparently overstated, whereas monoliths are most often collected from high-plastic but not fluid petro types. [19]

The definable parameters (volumes of ground deposits) were calculated by a computer, using the Kriging method and a Surfer suite.

As a result of the calculations, we defined the following volume parameters within the section under study:

- total volume of the considered water area section with regard to mark 224,5 m - 337055 m³,
- water volume -167840 m³;
- volume of ground deposits -169215 m³ (including suspended silt-22452 m³).

The silt getting into the reservoir is distributed along its bottom and forms a ground complex of deposits. The composition and the arrangement of reservoir ground deposits can vary and depend on the drawdown value and the degree of the reservoir flowage, flow and wave climate, amount and thickness of silt; these factors are greatly influenced by the geographical position of the reservoir, its size and morphology. In each certain water body, the determining factors include the nature and the amount of the ground-forming material and the hydrodynamic activity of water masses.

In 2017, the authors collected samples of ground deposits with the attraction of divers from Ostra LLC. The samples of ground deposits were collected without violation of their structure, using a GR-69 bottom probe. GR-69 bottom probe is meant for the collection of ground deposit samples in rivers, lakes and reservoirs with a silty, sandy, gravel or fine pebble bottom.

The collected samples were further examined in FSBE Chelyabinsk Interregional Veterinary Laboratory. The deposits were tested for the content of chlororganic compounds, such as hexachlorbenzene, hexachlorocyclohexane (α,β,γ -isomers), dichlordiphenyl trichlormethyl methane and its metabolites; toxic elements: cadmium, copper, nickel, lead, zinc; the content of benz(a)pyrene and the mass fraction of oil products.

Document [20] was used as the basis to evaluate the degree of the ground deposits pollution.

This document covers the pollution norms and criteria of the ground deposits extracted from water bodies in the course of bottom dredging, as well as the solution of problems of their further use (alluviation of territories, discharge into water bodies, storage in specially equipped dumps using a complex of protective measures).

This regulatory document offers a classification of the extracted ground deposits, a subdivision into deposits pollution classes and pollution degree evaluation levels. Ground deposits of the Shershnevsky reservoir were compared with the standard target pollution level. The results and norms of the ground deposits pollution are shown in table 2.

Table 2. Results and norms of the ground deposits pollution.

No of item	Index name	Unit of measure ment	Test results	Standard target pollution level Mg/kg	Regulatory document for the test method
1	Hexachlorbenzene	mg/kg	less than 0,005	0,0025	MU-1766-77
2	Hexachlorocyclohexane (α,β,γ -isomers)	mg/kg	less than 0,005	0,0025	MU-1766-77
3	DDT and its metabolites	mg/kg	less than 0,005	0,0025	MU-1766-77
4	Cadmium (Cd)	mln ⁻¹	less than 1	1,2	RD- 52.18.191-89
5	Copper (Cu)	mln ⁻¹	less than 20	46,6	RD- 52.18.191-89
6	Nickel (Ni)	mln ⁻¹	less than 20	35	RD- 52.18.191-89
7	Lead (Pb)	mln ⁻¹	less than 20	105	RD- 52.18.191-89
8	Zinc (Zn)	mln ⁻¹	less than 20	170	RD- 52.18.191-89
9	Benz(a)pyrene	mg/kg	less than 0,005	1	PNDF16.1:2.2.2:2.3:3.39 -2003
10	Oil products	mg/kg	6±3	180	PND F16.1:2.21-98

According to the data in table 2, we can conclude that the content of heavy metals, such as cadmium, copper, nickel, lead, zinc, chlororganic compounds, such as hexachlorobenzene, hexachlorocyclohexane (α, β, γ -isomers), dichlordiphenyl trichlormethyl methane and its metabolites, as well as benz(a)pyrene and oil products in the ground deposits of the Shershnevsky reservoir is within the standard target pollution level, i.e. the deposits are not polluted and belong to class 0 (clean deposits).

At an analysis of the existing national and foreign technologies, it is necessary to choose a method of treatment and dewatering of ground deposits to obtain recoverable resources.

Whereas the deposits belong to class 0 (clean deposits), dewatered ground deposits can be used to plan the territories of new building estates under construction, arrange dikes for reservoirs, reclaim disturbed lands, build roads, backfill hollows and landscape blanks, for the needs of the park and garden economy.

3. Conclusion

Upon commissioning of the Shershnevsky reservoir, the hydrological regime and the environmental condition of the Miass river have greatly changed. The channel flow was lost, the abrasion processes were activated, the dynamic balance of the ecosystems was disturbed.

The basis for the reservoir's ground complex formation is filling, and the source material is the soil cover of the territory occupied by the water body. Under the influence of physical and biochemical processes, ground deposits causing silting of the reservoir are formed from primary soils and ground-forming materials (flooded soils and vegetation, alluvial sludge, bank and bed erosion products, waste products and remains of animals and plant bodies inhabiting the water layer) getting into the water body and forming therein.

Silting processes worsening the carrying capacity and decreasing the available capacity of the water body are particularly hazardous for the Shershnevsky reservoir. Over the existence period, a considerable amount of secondary deposits was accumulated in the reservoir bed, which resulted in a decrease of its volume, formation of vast shallow water regions and active colonization by higher aquatic vegetation.

The treatment of the Shershnevsky reservoir from the ground deposits accumulated in the course of time will help to considerably increase its actual capacity, which will allow to increase water circulation paths and to improve the water quality indices. In its turn, the water quality improvement will decrease the supply of suspended solids into the water intake facilities and cut the reagent costs in the course of the treatment water works operation.

References

- [1] Khodorovskaya N I, Eremkina T V and Antipova V A 2011 Present Condition of the Shershnevsky Reservoir in the Conditions of the Anthropogenic Eutrophication *Anthropogenic Influence on Water Organisms and Ecosystems: proc of the IV All-Russian Conf of Water Ecotoxicology* **2** pp 177–181
- [2] Khodorovskaya N I, Speranskiy V S, Tseizer N M, Tryapitsyna S V and Chernov K S 2008 Inventory Auditing and Ranging of the Pollution Sources of the Shershnevsky Reservoir *Bulletin of Chelyabinsk State University* **4(105)** pp 126–128
- [3] Deryabina L V, Safonova E V and Pryakhin E A 2008 *Biological Evaluation of the Condition of the Shershnevsky Reservoir in 2007 Bulletin of Chelyabinsk State University* **4(105)** pp 128–131
- [4] Nokhrin D Yu, Gribovskiy Yu G, Davydova N A and Arsentieva N Yu 2010 Chemical Composition and Water Quality of the Shershnevsky Reservoir in 2001-2009 *Bulletin of Chelyabinsk State University* **8(189)** pp 67–71
- [5] 2005 Safety Declaration for Hydraulic Structures of the Shershnevsky Waterworks Facility at the Miass River. Federal State Agency for the Operation of Reservoirs of Chelyabinsk Region

- [6] Zhurba M G, Sokolov L I and Govorova Zh M 2010 *Design Engineering of Structural Systems: VI. Water Supply Systems – Water Intake Facilities* (Moscow: ACB)
- [7] Edelshtein K K 2014 *Hydrology of Lakes and Reservoirs* (Moscow: Pero) p 399
- [8] Shtanko A S and Shepelev A E 2013 *Ameliorative Reservoir Operating Procedures* (Novocherkassk: Federal State Funded Scientific Establishment Russian Research Institute of Melioration Problems) p 32
- [9] Yuldasheva K A 2011 *Experience of Sediment Control in Reservoirs* (Tashkent: Scientific-Information Center of the Interstate Coordination Water Commission) p 70
- [10] Smetanin V I 2003 *Recovery and Treatment of Water Bodies* (Moscow: KolosS) p 157
- [11] Stroganov N S 1976 Toxic Pollution of Water Bodies and Degradation of Water Systems *Results of Science and Technology. General Ecology. Biocenology. Hydrobiology* vol 3 (Moscow: VINITI) pp 5–47
- [12] Naumenko M A 2007 *Eutrophication of Lakes and Reservoirs* (Moscow: Russian State Hydrometeorological University) p 100
- [13] Khabidov A Sh, Leontiev I O, Marusin K V, Shlychkov V A, Savkin V M and Kuskovskiy V S 2009 *Control of the Reservoir Shorelines* (Novosibirsk: Siberian Branch of the Russian Academy of Sciences) p 239
- [14] Iliash D V 2012 Ground Deposits of the Voronezh Reservoir as a Source of Secondary Pollution of Surface and Ground Waters *Proceedings of the youth innovative project School of Environmental Initiatives* (Voronezh) pp 123–127
- [15] Zhukov S A and Starodubtsev V S 2009 Sedimentogenesis Process of Ground Deposits in the Natural-Technical Ground Water Intake System *Scientific and Practical Conference Modern Environmental Problems* (Tula: Tula Regional Public Organization D.I. Mendelev's Chemical Society) pp 39–42
- [16] Prytkova M Ya 2011 *Hydrological Regime and Sedimentation of Small Diverse Water Bodies of the North-West* (St.-Petersburg) p 200
- [17] Prytkova M Ya 2007 Strategy of the Recovery (Enhancement) of the Affected Water Ecosystems *Theory and Practice of the Inland Water Bodies Recovery* (St.-Petersburg) pp 270–279
- [18] Subetto D A and Prytkova M Ya 2016 *Ground Deposits of Diverse Water Bodies. Methods of Studying* (Petrozavodsk: Karelia Scientific Center of the Russian Academy of Sciences)
- [19] 1993 *Report on: "Surveys for the Development of Basic Provisions of the Scheme of Chelyabinsk Engineering Protection from Hazardous Geological Processes"* (YuzhUralTIZIs) p 111
- [20] 1996 *Norms and Criteria for the Evaluation of Ground Deposit Pollution in St. Petersburg Water Bodies Regional standard developed within the framework of the Russian-Dutch Cooperation on PSO 95/RF/3/1 Program* (St.-Petersburg) p 20