Application of geotextile containers for removal of silt layers of the Krasnodar reservoir

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Abstract. The article deals with the issues of improving the methods of removing silt layers of the Krasnodar reservoir using geotextile containers. The new technology exceeds all the characteristics of the dewatering facilities available in Russia. The necessary stage of preparation of wastes for disposal is dewatering to a humidity of 50-60%, which allows you to reduce their volume tenfold and improve the structure of raw materials. For these purposes, Russia has quite a lot of different structures and a large number of sludge dewatering methods. For the construction of sludge dewatering facilities and various types of precipitation of sewage, much less time and economic costs are required than for the construction of mechanical cleaning facilities. Also, new technologies occupy quite a little free land area compared to silt sites and they do not depend on climatic factors because atmospheric precipitation falling on the container drains from its surface. The impact of negative temperatures provides the deep moisture drainage after thawing of organogenic silt and hydroxide slimes. Also, new technologies occupy. Geotextile container technology is ideal for silt maps cleaning, sludge storage facilities and reservoirs, for temporary storage of dewatered sludge on a site, and, most importantly, for disposal of wastes directly at the dewatering site in the form of a highly loaded landfill that is resistant to wind and water erosion. When reducing the area of silt maps, the containers can be used as an emergency reserve, since their guaranteed storage period is 25 years. The main principle of the technology is to provide the sludge into the container through a pulp pipeline and then wait for the free water to drain. When dewatering granular suspensions (from sand to dense slimes), the container is filled with natural pulp. When fine silts and hydroxide slimes are dewatered, a flocculant is added to the pulp. After the initial filling of the container with pulp, its subsequent pumping is carried out from 1 to 5 times, after which the process of consolidation of the dehydrated material to the limit of free water release occurs, the duration of which depends on the properties of the solid phase. The main thing is that waiting does not consume any resources, except for the area provided for containers. After consolidation, a loose or refractory material is formed, the size of which depends on the size of the geotextile container used.

1. Introduction
The preparation of water for use in thermal power plants is accompanied by the formation of large volumes of waste. The main indicators of wastewater discharged from industrial enterprises are largely
determined by the production technology and the water supply and drainage system. In the processes of mechanical, biological, and physico-chemical wastewater cleaning at sewage treatment plants, various types of sediments containing organic and mineral components are formed. Depending on the conditions of formation and the characteristics of the separation, primary and secondary sediments are distinguished [1].

Gray sediment refers to primary precipitation and is lingered by primary sedimentation tanks. In domestic sewage, these sediments are a gelatinous, viscous suspension with a sour smell. Organic substances make up 75-80% in them and quickly rot, giving off an unpleasant smell. The moisture content of the sediment during spontaneous removal after 2-hour of settling is assumed to be 95 %, and when removed from the sedimentation tank by plunger pumps - 93-94 %. The mechanical composition of sediments from primary sedimentation tanks is highly heterogeneous. The size of individual particles ranges from 10 mm or more to particles of colloidal and molecular dispersion [2].

Secondary sediments include [3] active silt retained by secondary sedimentation tanks after aeration tanks, it represents the biocenosis of microorganisms and protozoa, and has the property of flocculation. The structure of the active silt is a flake-like mass of brown color. In fresh form, an active silt has almost no smell or smells of soil, but when rotting, it emits a specific putrid smell. According to the mechanical composition, active silt refers to thin suspensions consisting of 98% by weight of particles smaller than 1 mm [4]. The active silt of aeration tanks is characterized by high humidity - 99.2-99.7 %. The biofilm separated in secondary sedimentation tanks after biofilters is less watered; its humidity is on average 96 %.

The largest-tonnage waste generated in the process of water softening is water treatment sludge [5]. The composition of sludge and sediments includes mineral particles, compounds of silicon, aluminum, iron, calcium, magnesium, and some organic impurities. All this allows us to consider the above-mentioned waste as raw materials for the production of building materials and wastewater cleaning reagents. A promising direction of utilization is the use of them as recultivated materials and substitutes of natural soils. However, the high humidity of slimes and sewage sludge in the range of 99.0-99.5 % limits the possibility of their further use [6].

The necessary stage of preparation of waste for disposal is dewatering to a humidity of 50-60 %, which allows you to reduce their volume tenfold and improve the structure of raw materials. For these purposes, Russia has quite a lot of different structures and a large number of methods for sludge dewatering [7].

Silt platforms are one of these constructions. They are designed for the natural dewatering of sediments formed at biological wastewater treatment plants. The attractiveness of these structures is explained by the simplicity of construction and ease of operation. But the main disadvantages of silt platforms are their complete dependence on climatic factors, if there are no additional buildings of canopies made of transparent material and the need to use large free land areas for their construction.

2. Materials and methods

Methods of dewatering on centrifuges, filter presses and a number of other mechanical devices are widely used, but these methods are distinguished by the need to build capital buildings with energy-consuming equipment. Therefore, the main way to dispose of sludge is to place it in storage tanks. Storage tanks simultaneously perform the functions of both waste disposal facilities and hydraulic structures. The latter require expensive measures to ensure industrial safety.

To solve such problems, a modern technology comes to the rescue, new for Russia, but already proven in practice in Europe and the United States [8], this is the technology of dewatering suspensions in geotextile containers.

The manufacturer of geotextile containers is the company TenCate (Holland), which has 100 years of experience in manufacturing industrial fabrics. The use of containers on the site is carried out with mandatory technological support by an authorized company specializing in the technology of geotextile products.

In Russia, the authorized representative is the company «Admir Eurasia LLC», a subsidiary of the
Israeli holding «Admir Technologies Ltd» with 15 years of experience in the use of geosynthetic materials in the field of environmental protection and construction services [9].

The new technology exceeds all the characteristics of the dewatering facilities available in Russia. For the construction of facilities of sludge dewatering and various types of sewage sludge, much less time and economic costs are required than for the construction of mechanical cleaning facilities. Also, new technologies occupy quite a little free land area compared to silt sites and they do not depend on climatic factors because atmospheric precipitation falling on the container drains from its surface. The impact of negative temperatures provides the deep moisture drainage after thawing of organogenic silts and hydroxide slimes.

The technology of geotextile containers is ideal for cleaning of silt maps, sludge storage facilities and reservoirs, for temporary storage of dewatered sediments at the site and, most importantly, for disposal of waste directly at the dewatering site in the form of a highly loaded landfill that is resistant to wind and water erosion [10]. When reducing the area of silt maps, containers can be used as an emergency reserve, since their guaranteed storage period is 25 years.

Geotextile container is a product of woven geotextile made as a flat buffed sleeve, length from 5 to 100 r.m in increments of 5 r.m. An empty container, laid on a drainage area may have a width from 5 to 14 meters depending on the perimeter of his sleeve. The wider the sleeve, the higher the specific capacity of the container (Figure 1).

![Figure 1](image)

**Figure 1.** A design scheme of geotextile container: \(K(\theta) F(\theta)\) – complete elliptic integrals of the first and second kind; \(\theta\) - module elliptic integrals; \(N\) – calculated measurement connected to the height of the container; \(H_{11}\) – height of the geotextile container.

The main principle of the technology is to feed the sludge into the container through a pulp pipeline and then wait for the free water to drain. When dewatering granular suspensions (from sand to dense slimes), the container is filled by the natural pulp. When thin silts and hydroxide slimes are dewatered, a flocculant is added into the pulp [11].

After the initial filling of the container with the pulp, its subsequent pumping is carried out from 1 to 5 times, after which the process of consolidation of the dehydrated material to the limit of free water release occurs, the duration of which depends on the properties of the solid phase. The main thing is that waiting does not require the consumption of any resources, except for the area given for containers. After consolidation, a loose or refractory material is formed, the size of which depends on the size of the geotextile container used [12].

When filling the container with the pulp through the supply hoses, the sludge particles are deposited on the inner surface of the container, forming an alluvial filter layer, which ensures a high
efficiency of solid phase retention (99-99.8 %). With a geotextile pore diameter of 0.375 mm, particles smaller than 0.1 mm are retained in the container.

The container can be filled with pulp either by gravity under a hydrostatic pressure of 4±1 m of water flow, or in the pressure mode [13]. The internal pressure is controlled by the permissible lifting height of the arch, which ranges from 1.8 m to 2.4 m. When the nominal height is reached, the pulp supply to the container is suspended, but the process of its dewatering remains continuous: the flow is switched to nearby containers [14].

The sludge body packed in a geotextile container is constantly in a state of water output to the outside using all climatic factors, while atmospheric moisture is excluded from entering the container until fracturing occurs in the overdried sludge body. This factor favorably distinguishes the technology of geotextile containers from traditional hardware processes, in which the force applied to the sludge works only at the time of its stay in the device. Further, the dehydrated cake is subject to export and storage on the site open to rain and snow, where the sludge is moistened and, as a result, its volume increases [15].

The dewatering process in the container is completed by the moment of its opening, by cutting the geotextile. The dehydrated material is shipped or stored locally [16].

Table 1 shows the values of complete elliptic integrals of the first and second kind calculated from the expressions [17] through complete elliptic integrals and taken from tables [18] through logarithmic functions. The discrepancy between the calculated values of the full elliptic integrals in terms of expressions is less than 1%, which allows us to recommend the following dependencies for engineering calculations for a certain perimeter and cross-sectional area of a geotextile container.

| Module of elliptic integrals (θ) | Complete elliptic integral K(θ) calculated through complete elliptic integrals | Error, % |
|---------------------------------|---------------------------------------------------------------------------------|---------|
| 85°                             | 3.8560                                                                          | 0.65    |
| 80°                             | 3.1841                                                                          | 0.97    |
| 70°                             | 2.5273                                                                          | 0.86    |
| 60°                             | 2.1699                                                                          | 0.35    |
| 50°                             | 1.9422                                                                          | 0.68    |
| 45°                             | 1.8590                                                                          | 0.26    |
| 40°                             | 1.7891                                                                          | 0.53    |
| 35°                             | 1.7324                                                                          | 0.69    |
| 30°                             | 1.6860                                                                          | 0.76    |
| 20°                             | 1.6194                                                                          | 0.57    |
| 10°                             | 1.5821                                                                          | 0.39    |
| 5°                              | 1.5730                                                                          | 0.29    |
| 0                               | 1.5700                                                                          | 0.23    |

Depending on the application, whether it is the disposal of sludge and various types of sediments, cleaning of small rivers or any other work related to the dewatering of suspensions, it is necessary to calculate and adopt certain parameters of geotextile containers. Also, the parameters of these
containers depend on the type and composition of the products subjected to dehydration. One of the most important parameters of geotextile containers is the force value per width unit. Table 2 shows the values of complete elliptic integrals of the first and second kind calculated from the expressions [19] through complete elliptic integrals and taken from the tables [20] through logarithmic functions. The discrepancy between the calculated values of the full elliptic integrals in terms of expressions is less than 1%, which allows us to recommend the following dependencies for engineering calculations for a certain perimeter and cross-sectional area of a geotextile container.

Table 2. Assignment of a complete elliptic integral of the first kind \( E(\theta) \)

| Module of elliptic integrals (\( \theta \)) | Complete elliptic integral \( K(\theta) \) calculated according to expressions through complete elliptic integrals | Complete elliptic integral \( K(\theta) \) calculated according to Tables through logarithmic functions | Error, % |
|------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------|
| 85°                                      | 1.0080                                          | 1.0126                                          | 0.46    |
| 80°                                      | 1.0311                                          | 1.0401                                          | 0.86    |
| 70°                                      | 1.1113                                          | 1.1184                                          | 0.89    |
| 60°                                      | 1.2136                                          | 1.2111                                          | 0.73    |
| 50°                                      | 1.3158                                          | 1.3055                                          | 0.82    |
| 45°                                      | 1.3628                                          | 1.3506                                          | 0.90    |
| 40°                                      | 1.4057                                          | 1.3931                                          | 0.91    |
| 30°                                      | 1.4775                                          | 1.4675                                          | 0.93    |
| 20°                                      | 1.5293                                          | 1.5238                                          | 0.87    |
| 15°                                      | 1.5475                                          | 1.5442                                          | 0.79    |
| 10°                                      | 1.5675                                          | 1.5589                                          | 0.74    |
| 5°                                       | 1.5682                                          | 1.5678                                          | 0.42    |
| 0                                        | 1.5708                                          | 1.5704                                          | 0.03    |

The calculation of the force is very important when designing containers made of high-strength fabric. Based on what types of work are planned to be carried out and the amount of waste that needs to be recycled, engineers calculate the effort that the loaded geotextile fabric will experience. Depending on the calculated forces, the composition of the material from which the geotextile container will be made is selected and its sizes are calculated. Therefore, the use of containers at the facility is carried out with the mandatory technological support of specialists in the new developments [21, 22]. No less important parameters of geotextile containers are perimeter, cross-sectional area and height. By their values, we can determine the volume of waste processing and the required amount of geotextile for the production of the container.

3. Conclusion

Currently, the problem of disposal of silt layers of the Krasnodar reservoir requires special attention. With the growth of economic activity, the amount of wastewater discharged from industrial enterprises increases, which adversely affects the environment. The previous treatment facilities no longer meet the current requirements of waste treatment. The use of new cleaning technologies in geotextile containers in domestic environmental projects to clean water bodies and prevent their silting leads to...
the development of water management in Russia. Despite the simplicity of geotextile containers’ design, the calculation of their parameters is crucial.

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