Improvement of design parameters of geotextile containers made of polypropylene for removal of silt layers and industrial waste

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Abstract. The article deals with the issues of improving the design parameters of geotextile containers made of polypropylene for the removal of silt layers and industrial waste as exemplified by the Krasnodar reservoir. The article presents statistics of waste accumulation in the Russian Federation in recent years. A new technology for transportation and disposal of liquid waste is proposed. The calculation of the parameters of geotextile containers made of high-strength fabric materials based on polypropylene has been developed. The development of chemical industry has allowed us to offer a new cost-effective innovative technology of dewatering and waste disposal based on the use of geotextile containers made of high-strength fabric material. In the Russian Federation, more than 3.5 billion tons of waste are accumulated annually, the amount of which increases with the growth of economic activity. Of the waste produced in 2020, 47% was placed at the enterprises' own facilities, and 19% was buried. In order to improve the state of the environment, it is necessary to improve waste storage and disposal technologies. The use of geotextile containers made of high-strength fabric materials for dewatering and waste disposal is the most environmentally and cost-effective technology that has no restrictions and contraindications for technical equipment and has all the necessary indicators of strength, rigidity and reliability for effective use.

1. Introduction

In the early 70s, new technologies of processing, storing and disposing of waste, including industrial and household waste, were widely developed and introduced in Europe. The law of the Russian Federation "On waste production and consumption" was first adopted in 1998. Much earlier, similar laws were issued in the United States, Germany, France, and other countries [1].

In the State Report for 2009 [2] it is noted that at the beginning of 2009, the Russian Federation accumulated 30.591 billion tons of waste (218.5 tons/person) and (according to Rosttechnadzor) 3.505 billion tons / year (25.6 tons/person) were produced.

The constant increase in the volume and diversity of waste requires an immediate integrated approach to the development of technologies of its processing, dewatering and disposal, because waste is often a direct factor of negative impact on the environment. In 2019, according to the State Report of the Ministry of Natural Resources of the Russian Federation, 3747.5 million tons of production and
consumption waste were formed on the territory of the Russian Federation, which is 232.4 million tons more than in 2018 [3].

At the beginning of 2019, 30165.4 million tons of waste were accumulated, i.e. 8.1 times more than was produced during the year. The largest amount of waste in 2020 was produced in the extraction of coal, brown coal and peat - 2200.6 million tons; in the extraction of metal ores - 832.2 million tons; in the extraction of other minerals - 298.1 million tons [4].

Fresh water is a limited and vulnerable resource. Access to clean and safe water is a basic and universal human need. According to some estimates, 1 million people in developing countries do not have access to clean water. Currently, in the Gulf Emirates, the exchange of a liter of crude oil for a liter of drinking water is considered a good deal [5].

It is known that 20% of the world's population is experiencing a shortage of clean drinking water. Water scarcity occurs when it is not possible to meet all existing needs and the exploitation of limited water resources becomes competitive.

Water is an irreplaceable vital resource. This means that the current generation of people on the planet should use not only water, but also all natural resources in such a way that the next generations of people can also live in a favorable environment [6].

Water, like no other natural resource, is subject to numerous types of pollution. It is advisable to distinguish between physical, chemical and biological pollution of drains and reservoirs. Physical contamination corresponds to the case of artificial changes in river flows, volume of lakes, concentration of suspended particles, decrease or increase of sediment runoff, violations of the thermal state and hydraulic regime of water bodies. Chemical pollution of water bodies is characteristic of almost all types of nature management. Biological pollution is characterized by artificial increase in the content of biological substances in water. It occurs as a result of the entry into water bodies of bacteria dangerous to public health, microbes in the composition of wastewater. The degree of pollution can be characterized by water quality, which is a measure of the consumer properties of water resources, reflecting the possibility of their use in the interests of the population and economy. At the same time, it characterizes the conditions of existence of aquatic ecosystems [7].

Ensuring the reliability of water supply in settlements currently is the main problem for employees of environmental safety services. Quite often, crisis situations with the water supply of settlements occur below the sections of the pipeline crossing over the rivers. Pipelines cross water bodies in a surface or underwater position, at a greater or lesser depth below the surface of river sediments. In conditions of non-stationary water, riverbed and thermal conditions, they are not guaranteed against dangerous hydrological influences, during which the destruction of product pipelines is possible. The probability of such an event, given the statistics of accidents at pipeline crossings across Russian rivers, is low. More often, accidents are associated with a violation of the integrity of pipelines due to the use of defective structural materials.

Accidents are accompanied by the entry of various types of chemicals into drinking water sources. It is accompanied by a sharp deterioration in water quality. Once in rivers or reservoirs, pollutants begin to move downstream from the pipeline where the leak occurred. The change in water quality will depend on the duration of the accident, the volume and concentration of pollutants, as well as on the factors of a particular emergency. An important characteristic of the dependence or independence of the reliability of water supply systems from accidental releases of pollutants into rivers is the distance from the place of their entry to the water intake line. An accident at the crossing closest to the water intake is the most dangerous. This is due to the lack of time to choose management decisions aimed at meeting water needs in conditions of critical changes in water quality [8].

When analyzing the distribution of waste over the past decade, there is a trend of their exponential accumulation. Despite the fact that production volumes in Russia have significantly decreased, the amount of waste increases from year to year, this is due to an increase in the variety and mass of substances involved in economic turnover.

When cleaning channels of reservoirs and small rivers from sediments, as well as during mining, a large volume of liquid waste is formed. This waste is removed in the form of pulp in the settling tanks.
The use of various types of resources is accompanied by a violation of the background conditions for the entry of water, chemical impurities, solids and sediments into small rivers, and the conditions of transit, mixing, dilution and self-purification of water flows are also changing [9].

The development of chemical industry has allowed us to offer a new cost-effective innovative technology of dewatering and disposal of waste. For this purpose, we offer geotextile containers made of high-strength fabric material, which allows water to pass through and retains solid particles. Over time, the water from the container goes away, the solid fractions remain. Dewatered containers made of high-strength material are convenient for loading, transportation and storage, including disposal. From the working experience with a pulp volume of 500 thousand m$^3$, 120 – 130 containers are sufficient.

Geotextile materials are widely used in domestic and foreign water management construction, in the constructions of anti-filtration lining of channels, coatings of reservoirs, as well as in drainage and shore protection devices [10].

When designing geotextile containers, it is very important to choose the perimeter of the geotextile container and the permissible length, so that the annular and longitudinal stresses in polypropylene do not exceed the permissible lengths both at the time of filling with sediments and during dewatering. When pumping the pulp into the container, the strength conditions must be met both across and along the container and especially along the seam.

2. Results

One of the options of waste disposal is their use in construction industry as raw materials for the production of building materials. However, the volume of their use is small, since waste still cannot compete with natural raw materials.

It is possible to use waste in the arrangement of degraded landscapes, backfilling of used up quarries.

When cleaning channels, reservoirs and small rivers from sediments, a large volume of liquid waste is formed. This waste is removed in the form of pulp in the settling tanks. After the hydraulic dump is reclaimed, the external slopes of the embankment dams are reclaimed, greening them, thereby preventing harmful effects on the environment [11].

The use of various types of resources is accompanied by a violation of the background conditions for the entry of water, chemical impurities, solids and sediments into small rivers, and the conditions for transit, mixing, dilution and self-purification of water flows are also changing. The activities of such sectors of the economy as forestry, industrial and agricultural production, water management and urban planning, the recreational complex leads to physical, chemical and bacterial pollution of small rivers, the consequences of which are catastrophic. The properties of water resources and water quality have changed, and as a result, the probability of the population diseases increases, ecosystems are degrading, fish-carrying capacity of rivers is decreasing, the cost of water purification and use is rising, production efficiency is decreasing [12].

Since the second half of the 20th century, in the European part of the Russian Federation, there has been a degradation of small rivers due to intensive economic activity. Based on the report of the Chairman of the Committee of Environmental Protection, Grigory Skripka, the disappointing ecological state of water resources of the region are largely determined by the state of small rivers. There are 165 small rivers in the Rostov region with a total length of more than 9.5 thousand km. Taking into account streams and gullies, the number of watercourses reaches 4.5 thousand.

Meanwhile, increasing economic use of small rivers and their catchment areas, withdrawal of significant part of discharge water, inlet of runoff waters into rivers lead to their contamination and siltation of riverbeds [13].

A particularly dangerous cause of degradation is the pollution of the river bottom with various household waste, garbage, which, getting into the water, settles to the bottom, where the rotting processes soon begin, so small rivers and reservoirs need systematic cleaning and pumping of silt. The technologies used for cleaning small rivers are not effective enough, and after 5 to 10 years, their next
siltation occurs [14].

The development of chemical industry has allowed us to offer a new cost-effective innovative technology of dewatering and disposal of waste. For this purpose, geotextile containers are offered made of a high-strength fabric material that allows water to pass through and retains solid particles.

Geotextile materials have become widely used in domestic and foreign water management construction [15], in the construction of anti-filtration linings of channels, coatings of reservoirs, as well as in drainage and riverside protection devices.

Geotextile materials can be divided into the following types:

waterproof (anti-filtration) -- geomembranes designed to provide waterproofing basements, tunnels, used as anti-filtration elements in linings of channels and water bodies, as the material there were used PE, PVC, butyl rubber;

water-permeable (filtering) [16] -- geotextiles, geocomposites are used in the construction of drainage devices, for fixing soils and in anti-filtration linings of channels and reservoirs as protective gaskets.

Geotextile can be woven from polypropylene, thickness 0.7-3.0 mm, tensile force 110-1100 kN/m, surface density 340-2110 g/m² and non-woven made of needle-punched polypropylene, thickness 2.0-5.0 mm, tensile force 6-28 kN/m, penetration resistance 500-2500 N, surface density 400-1000 g/m².

The possibility of multi-purpose use of geotextile containers made of fabric material in the purification of water bodies from bottom sediments, pollution products and integrated environmentally safe amelioration and recultivation solves the following tasks [17]:

− localization of water body pollution;
− cleaning of water bodies from bottom sediments;
− processing and disposal of bottom sediments of water bodies;
− determination of rational parameters of fabric structures intended for utilization of bottom sediments.

For the manufacture of geotextile containers, the following types of polymers are most often used: thermoplastics; crystal thermoplastics; elastomers; thermoplastic elastomers [18, 19].

Geotextile container made of high-strength fabric materials is a container made of filtering fabric geotextile in an unfilled state is presented in the form of a shell, equipped with a pump for water suspension supply (pulp from sediments, silt, sludge, soil) into the container (Figure 1).

![Figure 1](image_url)

**Figure 1.** Scheme of basic structures: A-system of surface floats; B-system of bottom anchors; 1-load-bearing panel of fabric structure; 2-flexible connection fixing the crest of the structure; 3-anchor bolt.
The main task of using geotextile containers made of high-strength fabric materials is the technology of dehydration of suspensions of various origin. Using in practice the excellent filtration characteristics of the applied geotextile material, geotextile containers fully cope with the task [20, 21].

The main principle of operation of geotextile containers intended for the disposal of bottom sediments is to fill containers with a necessary volume of sludge from sediment, silt, sludge, soil, filtration of liquid through the holes of geotextile, remove filtered liquid, dispose of geotextile containers filled with waste and solid particles shrunken for convenient loading, transportation and storage.

Currently, research is underway to determine the rational parameters of geotextile containers intended for the disposal of bottom sediments.

However, methods for calculating such geotextile containers made of high-strength fabric materials are not sufficiently developed.

The material of geotextile containers is destroyed at forces of 80 kN/m – 100 kN/m with a thickness of 3 mm to 4 mm. The yield strength is 44 kN/m – 67 kN/m, respectively. The elastic relative deformations are 12 %. The weight of a geotextile container made of high-strength fabric materials with a thickness of 4.0 mm, height of 3.0 m and width of 20.0 m is less than 250 kg [22].

At this stage of the research conducted in the development of effective and reliable geotextile containers made of high-strength woven material, it is possible to judge the effectiveness and reliability of the developed structures by the service life of the geotextile. In this case, the service life of a particular type of geotextile is predicted based on the physical and mechanical characteristics of materials that make up the coating, the absence or presence of protective layers in the coating and the scope of application of the coating.

3. Conclusion

Currently, the technologies of transportation and disposal of liquid waste in the Russian Federation are very outdated (they have been used without modernization since 1970) compared to the technologies used in Europe and the United States. The development of the chemical industry has allowed us to offer a new cost-effective innovative technology of dewatering and disposal of waste, based on the use of geotextile containers made of high-strength fabric material. In the Russian Federation, more than 3.5 billion tons of waste are accumulated annually (2019), the amount of which increases with the growth of economic activity. From the generated waste in 2019, 47% are located at the enterprises' own facilities, 19% are buried. In order to improve the environmental state, it is necessary to improve waste storage and disposal technologies.

The use of geotextile containers made of high-strength fabric materials of dewatering and waste disposal is the most environmentally and cost-effective technology that has no restrictions and contraindications in theoretical and technical equipment and has all the necessary indicators of strength, rigidity and reliability for effective use.

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