

# Increasing the water yielding capacity of natural water sediments

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**Abstract.** When carrying out water treatment processes, a significant amount of hydroxide sediments is formed, which have a low water-yielding capacity. In the paper, the sediment of sewage treatment facilities of water pipes, which is formed in the conditions of low turbidity and medium color of water in a water source, was investigated. The effect of seasonal variations in turbidity, color and temperature of the treated water on the specific resistance of sediment filtration is shown. The features of sediment formation in sedimentation tanks of various types are considered. It is shown that the conditions for the formation of sediment affect its properties. It is established that the return of washing water, realized on one of the blocks of main water treatment facilities, increases the turbidity of the water to be purified and leads to the formation of sediments that are easier to be conditioned. At the same time, the sediment, formed in two-tier sedimentation tanks, when they are conditioned, require large doses of reagents. To intensify the dewatering of sewage treatment facilities, reagent methods were investigated using lime and filler materials. The mechanism of lime action on hydroxide sediments is shown.

## 1. Introduction

Due to changes in climatic conditions, which have an increasingly significant impact on the redistribution of water resources, the increasing attention is paid to the problem of their condition and rational use. Water resources, especially such a resource as fresh water, are one of the basic and dynamic elements of natural wealth in the world. An important direction in increasing the efficiency of water sector enterprises is to maximize the use of secondary resources, including the resulting sediment [1-2]. According to the averaged data, the amount of sediment formed can reach from 1% to 5% of the total volume of water to be purified. The sediment is a high-moisture mass (up to 99.9%) of organomineral substances of various degrees of dispersion, combined with the help of hydroxide bonds into a single spatial structure possessing colloidal properties.

As it is known, the composition and properties of sediment are directly dependent on the technological process of water treatment and water quality in the source, which is very diverse. At present, there are no ready-made standard solutions for the processing of water-based sludge in domestic practice, at the same time, in connection with the increase in requirements for environmental protection, municipal enterprises face the task of transitioning to intensive methods of processing sediment in order to reduce their volumes, prevent environmental pollution, obtaining secondary products suitable for utilization [3-6].



## 2. Main part

Dewatering of the sediments of natural waters is technically difficult due to the seasonal variability of their initial quality (composition, structure and properties), the stability of the structure and, as a result, the low water-yielding capacity, characterized by the specific resistance of filtration. The main task is to select the optimal method for conditioning precipitation for the possibility of further dehydration. For mechanical dewatering, sediments with a specific resistance of filtration no more than  $500 \cdot 10^{10}$  m/kg are recommended [7-8].

To improve the water-yield of sediments, it is necessary to change their structure. One of the methods used to change the structure of sediments is preliminary reagent treatment, for example, with lime. Studies have shown that lime when introduced into the sediment has a dual function: as a chemical agent, partially dissolving gel-like aluminum hydroxide, and as a filler material that reduces the value of the compressibility index. This combination of actions leads to improved filtration properties of the sediment, and, in addition, lime has a disinfecting effect [3].

In the laboratory conditions, studies were carried out to investigate the effectiveness of methods for reagent treatment of sediments in sewage treatment plants in the city of Chelyabinsk. The total amount of sediment formed at the water treatment facilities of the city of Chelyabinsk is about 2 million cubic meters per year. Currently, sediment is formed on three blocks of a sewage treatment plant, the first stage of clarification in which there are sedimentation tanks of various designs: bunk and horizontal. In addition, one of the blocks organizes the return of the washing water of the fast filters to the head of the main water treatment facilities [4].

Studies were conducted in different periods of the year from November 2016 to October 2017. The average values of temperature, chromaticity, turbidity and content of plankton in the initial water in the periods preceding the collection of sediment are presented in the table. The averaging was carried out according to the data a month before the sampling of the sediment. It is not possible to determine more accurately the period of sediment formation.

**Table** Average values of the source water quality indicators in the periods prior to sediment collection.

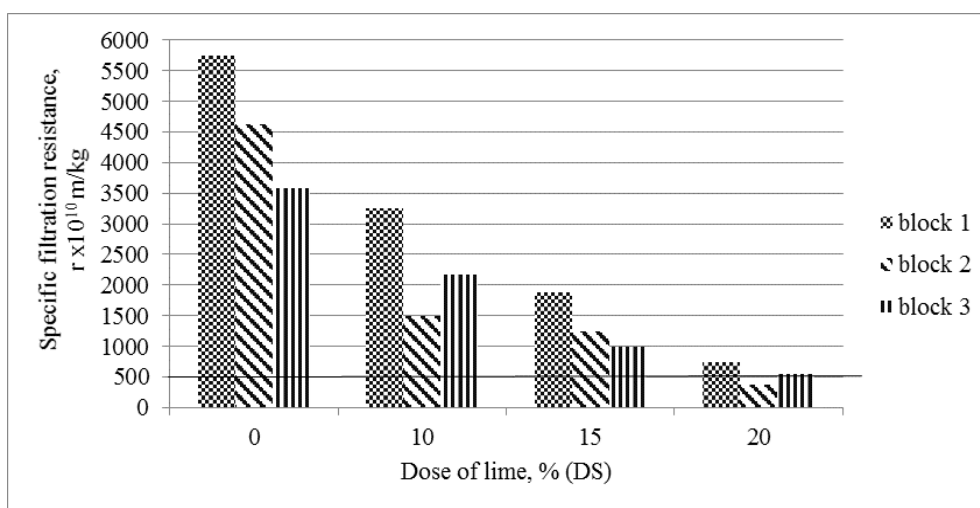
Period cells/ algae	Turbidity mg/l	Color deg.	Temperature °C	Phytoplankton, million	
				Total	Blue-green
October, 2016	3,9	14,2	10,2	21,1	17,4
February, 2017	2,9	12,9	0,5	2,6	2,4
May, 2017	6,7	14,5	12,2	123,2	97,6
September, 2017	4,0	13,6	14,2	62,2	60,0

The analysis of the obtained data shows that the turbidity and color of water in the reservoir vary slightly over the periods of the year in which the sediment was taken. Significant changes are observed in the water temperature and in the content of plankton cells. The temperature factor significantly affects both the process of sediment formation and the intensity of its dewatering, since with increasing temperature the dynamic viscosity of water decreases significantly. Blue-green algae prevail throughout the plankton all year round. During the winter sedimentation (selection - March 2017), the content of plankton is minimal and 93% of it is made up of blue-green algae. The minimum content of organic component in the sediments should be expected. In summer (selection - June 2017), massive reproduction of blue-green algae is observed. In sediments, a high content of organic matter should be expected. Finally, in the autumn period the amount of plankton decreases, but the blue-green algae continued to dominate.

The change in the water-yielding capacity of the sediments was investigated from the value of its filter resistivity, which was determined by the three-dimensional method proposed by P. Coakley and V. Johnson [9-11]. The method consists in filtering under vacuum (500 mm Hg) a certain amount of sediment and measuring the volume of the filtrate formed. According to the results of the study, the specific resistance of filtration of the initial sediment for different periods of the year varied from

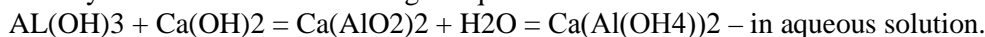
$1470 \cdot 10^{10}$  to  $5750 \cdot 10^{10}$  m/kg. The humidity of the sediment was  $\sim 96\%$ , the solids content in the sediment varied from 13.6 to 35 g/l. The values of the specific resistance of sediment filtration of all three blocks show its low water-yielding capacity and classify them as difficult-to-filter, requiring preliminary treatment of sediments. A small amount of mineral impurities in the water, the presence of colloids of organic origin and plankton lead to the formation of loose sediments with a gel-like structure containing structurally trapped water that is difficult to release under mechanical methods of action [12-14].

To reduce the water-yielding capacities of sediments two kinds of treatment were used: treatment of sediment with lime and combined treatment with lime and filler material - opoka. The reagent doses were calculated as a percentage by weight of the dry substance of the sediment. Lime milk with a concentration of 139...146 mg/ml (by CaO) was used for sediment conditioning. Treatment was carried out with different doses of lime milk from 10 to 20% of the dry matter of the sediment. The results of lime conditioning of sediments are shown in figures 1 ... 3.



**Figure 1.** Reduction of the specific resistance of filtration depending on the dose of lime – Autumn 2016.

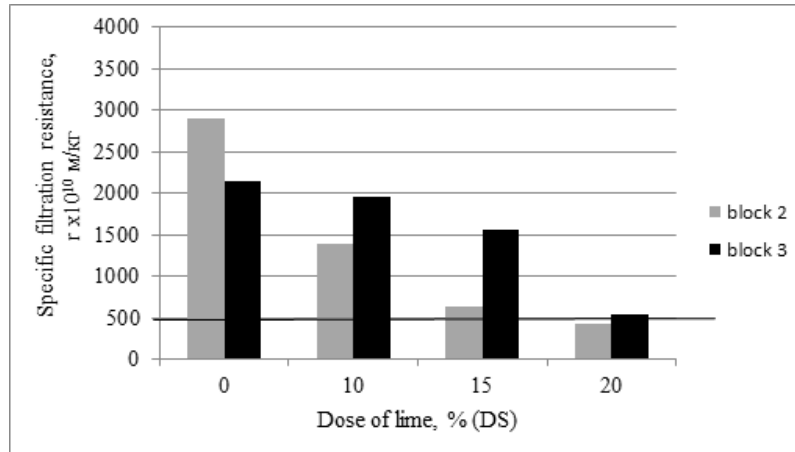
As a result of the treatment with lime milk, the release of free water from the sediment is visually evident. As a chemical reagent lime partially dissolves the gel-like aluminum hydroxide, and also partially works as a filler material, which reduces the value of the compressibility index [15-17]. Theoretically, this combination of actions leads to an improvement in the filtration properties of the sediment. When lime milk is introduced into the sediment, a part of aluminum hydroxide is converted into calcium aluminate, but their existence is short-lived, and they pass into the solution in the form of calcium hydroxoaluminates according to equation:



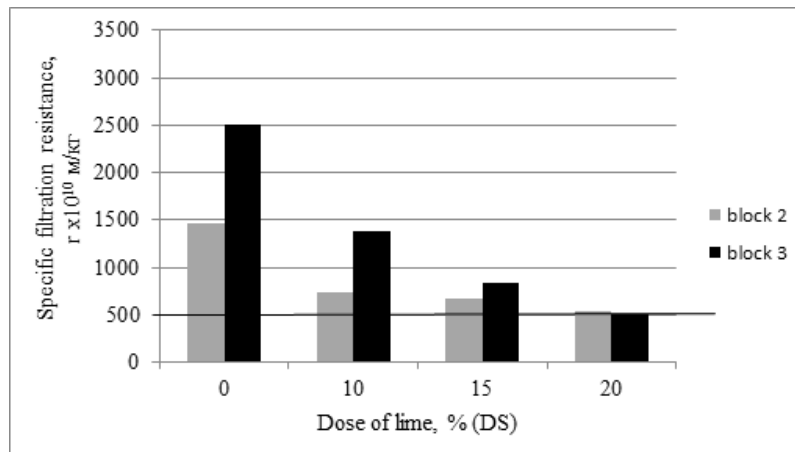
According to this reaction, it can be seen that there must be a disturbance in the structure of the sediment with the release of pore water.

The results of the conducted studies of the changes in the specific resistivity of filtration of sediment formed within the same site of water treatment facilities, but under different conditions, show that the most effective dose (by CaO) is 20% of the dry solid in the sediment for all blocks for all periods studied. Under these processing conditions, the specific resistance of the sediment filtering of block 2 has decreased to a level below  $500 \times 10^{10}$  m/kg, the conditioned sediment is classified as being highly filterable and can be sent for further treatment. At the block 3, the washing water of the fast filters is returned, and an additional quantity of colloidal particles containing aluminum hydroxide enters it, which complicates the treatment. It should also be noted that in order to effectively reduce the specific resistance of filtration at block 1, an increase in the lime dose is required. Probably staying

in a two-tier sump creates conditions for additional structuring of the sediment and increasing the strength of water connection in it [12,16,18,19].



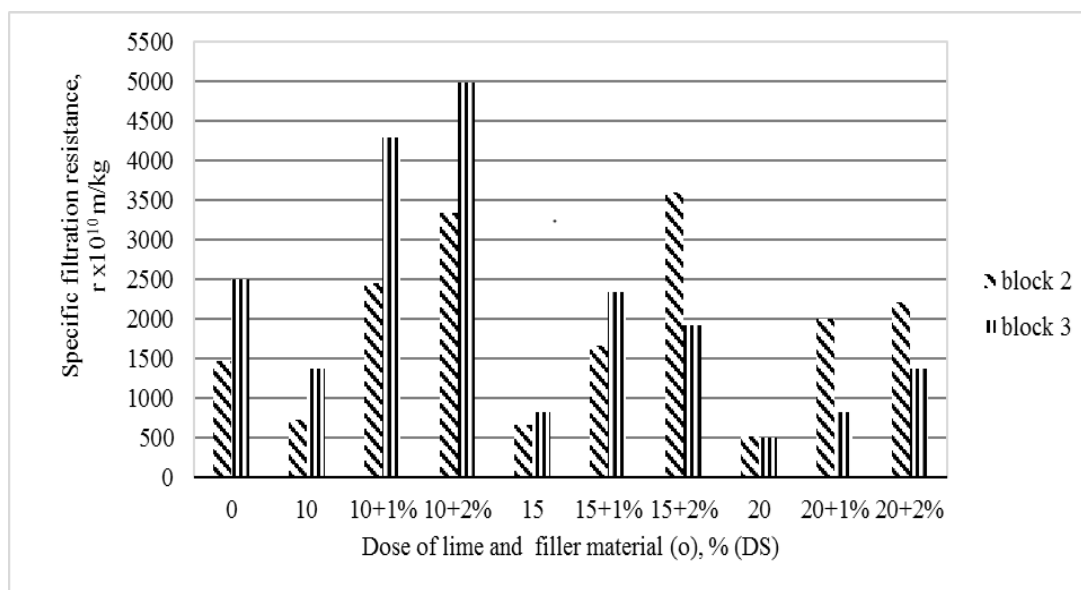
**Figure 2.** Reduction of the specific resistance of filtration depending on the dose of lime – Spring 2017.



**Figure 3.** Reduction of the specific resistance of filtration depending on the dose of lime – Summer 2017

In order to reduce the consumption of lime, studies were carried out on the processing of sediments with lime together with a filler material - opoka. Opokas belong to clay materials and have a large volume of sorption space, high specific surface (100 ... 130 m<sup>2</sup>/g) and porosity (43 ... 38%), are characterized as high-quality sorption materials with a high content of amorphous silica.

According to the data of the studies [15], it is advisable to use clay as an additive to improve the water-yielding capacity of hydroxide sediments is confirmed by the dual mechanism of its effect on the sediment: first, clay weighted light flakes of hydroxides, promotes their aggregation, accelerates sedimentation and, thus, sediments to humidity 90 ... 94%; secondly, clay minerals of a complex structure, for example kaolinite, with increasing temperature under conditions of constant loading, tend to orient the basal planes of the particles perpendicularly to the applied load, which leads to a change in the structure of clay suspensions, the most dense packing of the particles, intensive compacting of the solid phase, and isolation a significant amount of water previously in a related form. However, the results of the studies presented in Figure 4 indicate the opposite.



**Figure 4.** Reduction of the specific resistance of filtration during conditioning of the sediment with lime together with filler material.

By results of researches it is possible to draw a conclusion about inexpediency of use of a flask as a filler material for water sediments of these treatment facilities. The joint use of lime with filler material converts the sediment into a category not filterable at any doses of lime. Apparently, the fine fraction of the filler material in the vacuum filtration is rapidly deposited on the filter surface, reducing the pore space of the filter cloth, which leads to a sharp increase in the resistivity of the filtration. With an increase in the dose of filler material, the specific resistance of filtration increases in comparison with the sediments treated only with lime.

### 3. Conclusion

Thus, the sediment formed during the water treatment of surface waters is classified as difficult to filter with high specific resistance of filtration. By the value of the resistivity of the filtration of the initial sediment, it can be concluded that the highest values are achieved in the autumn period, and the lowest values are reached in summer. Such differences complicate the process of conditioning the sediment. An effective lime dose for further mechanical dewatering of sediments is 20% of the dry matter mass of the sediments. The use of such filler material as a flask (opoka) has not shown its effectiveness and has not given a reduction in the lime dose. The water-release capacity of sediments is influenced by the conditions of their formation and creates additional difficulties in their treatment. The sediment formed in the two-tier sedimentation tanks is more difficult to conditioning and requires higher reagent costs. Also, the results of studies showed that in order to minimize reagent costs, it is possible to separate sediments formed in conditions of increased turbidity of the source water for a separate treatment, since the return of wash water contributes to better water -yield of sediments.

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