Technologies for preparation of drinking water from the low power surface water source

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Abstract. The problem of providing small settlements with drinking water is important. The sources of small capacity can be used for this purpose. The quality of water in the ponds of a small capacity varies greatly during the year. The concentration of phytoplankton depends on the season of the year, and this is the main problem when using sources of small capacity. Currently, such mechanisms have not been studied properly. Water filtration is used for the preparation of drinking water from small capacity sources. The methods of water’s treatment with chlorine are also used. The use of fine filtration technologies is costly in operation. The research of phytoplankton’s detention was carried out on the floating filter. The floating filter is made of polystyrene. The study of the effectiveness of seaweed detention showed that the reduction of rising flow improves the quality of water purification. The subsequent stages of the water treatment involve the use of oxidizing agents. The technological scheme of water treatment from reservoirs of small capacity has been developed. The specifics of the technology’s functioning for water sources of low capacity has been established.

1. Introduction
One of the most important directions of use of water resources is to provide water to the population to meet the food, household and sanitary needs. Recognition of the water value is an essential part of its rational use and careful attitude to it [1,2].

The water supply to the population is one of the priority tasks of the state. The use of small water bodies as water sources is a complicated technical task due to the characteristics of water in them.

The problem of using the low power freshwater sources for household and the drinking water supply is the subject of the numerous studies by many specialists.

One of the main problems of using the small water sources is the high concentration of phytoplankton. Cyanobacteria is responsible for the specificity of the organoleptic properties of water, including the increase of the color, taste and smell.

We offered technological models, which provide the removal of algae by using a floating filter with further coagulation of the remaining suspended substances for processing of the raw water from the low power surface sources.
The application of these water pretreatment technologies from the low power sources can significantly reduce the problem of the drinking water supply to the small populated areas in different climatic conditions.

The problem of providing the drinking water to the small localities is especially acute in the areas with a shortage of fresh water. The deliveries of the tankered water to the population is an expensive way of the water supply organization. Small freshwater lakes can be used as an alternative sources. Water bodies, which were formed as a result of the regulation of small rivers, can also be used for the water supply. These solutions of water supply can be justified and appropriate in the sanitary-hygienic and the economic aspects.

At the same time, the most complicated scientific and practical tasks during the use of such water sources are as follows [3]: the selection and rationale of technological models of water treatment; the search for the necessary investments for the purchase of expensive equipment and reagents are the complicated scientific and practical task.

The ways to solve this problem are the following: to perform an analysis of the dynamic of changes in source water quality; to identify the possibility of applying the most efficient water treatment technologies for small water supply systems; to substantiate the least energy-consuming methods and water treatment facilities in the first stage of its treatment; to identify the initial data for the design of industrial water treatment plants and to perform a feasibility study on the basis of field studies.

In most cases, the small water bodies are characterized by the abundance of phytoplankton as the natural factor. The research of [4,5] are devoted to the problem of solution of phytoplankton and cyanobacteria. It shows that the amount of cyanobacteria cells in the raw water can reach 4 to 6.9x10^5 cells/l. It influences significantly on the quality of raw water and the choice of its processing technology.

It was experimentally established that before the coagulation, the colored water should be subjected to the prior oxidation. The most appropriate is the use of O3 and H2O2 or NaOCl. Al2(SO4)3·18H2O or FeCl3·6H2O can be used as the coagulating agent.

We developed technological models of the colored water treatment with the two-stage sequential filtration, the introduction of sodium hypochlorite solution and the subsequent coagulation. The proposed technological models allow carrying out the efficient pretreatment of drinking water from low power surface sources.

2. Research Site

We studied the specificity of formation of the water quality in water sources with a limited debit in the lake Staroe (the maximum length is about 2 km and the maximum depth – up to 3.5 m), located in the southern part of the West Siberian Plain and in the river Malaya Karla, located in the Republic of Kazan in Russia, which are the only local surface water source for the settlements with the population of about 8,000 and 10,000 people accordingly.

The lake water is characterized by the chromaticity of 23-115°. Turbidity in the lake, depending on the wave processes, coast erosion and depth of lake, ranges from 4 to 27.3 mg/l, and permanganate oxidizability – 7.5 to 27.9 mgO_2/l. Alkalinity of water is 7.5-8.8 mmol/l, pH ranges from 7.8 to 9.9. The quality of the source waters is formed under the influence of natural and anthropogenic factors. A large number of organic contaminants comes from: the poorly treated household wastewater; the rain and snowmelt wash off from the surface of the catchment areas of organic contaminants and biogenic substances.

It leads to the eutrophication of the surface water source accompanied by the excessive development of phytoplankton. The number of micro-algae in some periods of the year reaches 60-100 thousand cells/ml, and biomass – up to 20 mg/l. The mass development and the death of micro-algae leads to increase in the quantity of suspended matters and in chromaticity in water bodies. Thus, the concentration of organic and bacterial contamination is increased. Some actinomycetes and mold fungi serve as the basis for rotting process, and the appearance of unpleasant smells and tastes of water which can reach up to 3-4 points [6].
3. Results and Discussion

Usually, the operating water supply stations use a high chlorine pretreatment (doses up to 6-10 mg/l). Then the water is passed through the microfilters and the disc sieves, with further reagent precipitation and filtration. The pre-chlorination of water destroys the cell walls of phytoplankton and deprives it of buoyancy. Thus, the quantity of organic contaminants in water increases and its organoleptic properties deteriorate. The presence of chlororganic compounds in drinking water is strictly regulated by the sanitary standards. Further chemical treatment with using of coagulants and flocculants with higher doses leads to an over expenditure.

The application of flotation, after the coagulation, in some cases allows to improve the efficiency of the water purification from the low power surface water bodies. A large quantity of sediment forms as a result of flotation. This sediment has 99 to 99.5% humidity, which is poorly compacted and capable to decay. The dewatering and the utilization of such sediment causes some difficulties.

The application of microfilters and disc sieves requires the considerable maintenance cost to ensure a guaranteed level of the water purification from phytoplankton.

An alternative way to these methods is the detention of phytoplankton in the layers of floating bed of the prefilter, at a nonchemical filtering of water, from the bottom to the top, and for washing from the top to the bottom.

Our research of the efficiency of algae detention, which contains in the source water, at different speeds of the rising filtration through the EPS floating bed on the model of prefilter, found that the effect of removing the algae biomass can be achieved up to 45.1-48.7% at the speeds of filtration up to 40-50 m/h. The reduction of filtration rates up to 30 m/h allows to increase the effect of biomass cleaning up to 49.9-52.6% at its initial quantity in the water up to 26.2-66 mg/l and the quantity of cells up to 14-30.7 thousand cells/ml.

The majority of the detailed contaminants were taken out at the intensities of washing flow of 25 to 35 l/s.m² in the first 5-6 minutes of washing. This fact was specified by the curves of removal of the detained biomass at a filtration cycle in EPS bed of prefilter and the quantity of algae and suspended matters during the washing, which were performed with different intensities at different values of contaminant layer at the end of the filtration cycle.

The use of oxidizing agents in the technological process at a later stage of water treatment is justified by their role in ensuring the efficiency of the subsequent processes of coagulation and flocculation of contaminants in the source water. The study of these processes were carried out on the colored water of the artificially regulated area of the river Malaya Karla.

First, we studied the effect of oxidizing agents, the coagulant – aluminum oxychloride of brand ‘Aqua Aurat™’ (AOC) and flocculant – ‘Praestol 650TR’ on the stability of colloidal particles of dispersed phase of the investigated water. For this, the initial water was subjected to the treatment of water separately with ozone (O₃), hydrogen peroxide (H₂O₂), sodium hypochlorite (NaOCl), and also the combined effect of H₂O₂ and O₃. Next, the optimal dose of AOC was determined through the coagulation test of oxidized water in accordance with the standard method at the dosage range of coagulant (D_C) from 5 to 50 mg/l on Al₂O₃, and flocculant (D_F) from 0.05 to 0.5 mg/l. The kinetic stability of the particles of suspended matter in water before and after its co-processing by oxidants were evaluated by the change in the value of the ζ-potential, which was determined by amperometry by micro-electro-phoretic mobility of colloidal particles in the electric field.

The comparison of the recharging process of ζ-potentials of the colloid particles for the same colored source water, pretreated with different oxiding agents in certain combinations of doses and concentrations, and then with the solution of AOC with D_C of 5 to 50 mg/l on Al₂O₃ and flocculant with D_F=0.5 mg/l, showed the degree of influence of individual oxidizing agents on the processes of coagulation of contaminants. The most significant influence on the reduction of doses of coagulants showed the preliminary co-processing of water with ozone and hydrogen peroxide.

The obtained research results have confirmed the technological feasibility of pre-oxidation of colored natural surface waters with O₃ and H₂O₂ or NaOCl, before its coagulation.
The specificity of the physical and chemical composition of water in the water bodies with small debit calls for studying the processes of coagulation and flocculation after the application of oxidizing agents. However, their effect after the application of strong oxidizing agents (sodium hypochlorite, solution of oxidants, hydrogen peroxide, potassium permanganate, etc.) has not been studied enough.

The mode of operation of contact filters of the first stage and the rapid filters of the second stage is presented in figure 1. Flowsheet of filtration with pre-treatment background water oxidizing agents showed good results.

![Figure 1](image)

**Figure 1.** The change in turbidity and chromaticity of water in the process of treatment.

Feature of water quality, in which the processes of coagulation and flocculation were studied, is shown in table 1.

| Indicators                        | Lake Staroe | River Malaya Karla | Model solution |
|----------------------------------|-------------|--------------------|----------------|
| Smell, TON*                      | 3-4         | 2-3                | 3-4            |
| Turbidity, mg/l                  | 4-27.3      | 40-93              | 2.2-22.9       |
| Chromaticity, °                  | 23-115      | 250-320            | 26-170         |
| Permanganate oxidizability, mgO₂/l | 7.5-27.9   | 12-19.7            | 7.4-8.2        |
| Ammonia nitrogen, mg/l           | 0.4-0.7     | 2-4.8              | 1.8-2.2        |
| pH                               | 7.8-9.9     | 7.1-8.2            | 7.8-8.5        |
| Alkalinity, meq/l                | 3.9-8.0     | not measured       | 1.8-3          |
| Redox potential, mV              | 122.4       | 31                 | 244-442        |

*TON – Threshold Odor Number

We used the 4% solution of AOC as the coagulant in our study. The doses on Al₂O₃ was assigned in the ranges of 2.5, 5.0, 7.5, 10, 15 and 20 mg/l. The trial coagulation was carried out by the standard method. The results of the trial coagulation on the efficiency of sediment waters from different water sources on the turbidity, chromaticity and permanganate oxidizability showed that the range of required dosages of coagulant for these waters is in the range of 10 to 30 mg/l on Al₂O₃. The values of Redox-potential, as the measures of the ability of the chemical substance to join the electrons, and ζ-potential, determined in the range of trial doses of coagulant, reached their maximum values – +320 and +40 mV respectively.
The high molecular synthetic flocculants with molecular weight of $10^4$ to $10^7$, including ‘Praestol 650TR’ and the poly diallyl dimethyl ammonium chloride (polyDADMAC) are the most common in the practice of the purification of natural surface water.

The initial water (Table 1) was subjected to the pre-chlorination with active chlorine dose of 2.5 mg/l and coagulation of 4-5% solution of aluminum sulfate. As a result of tests, the coagulant dose was set in the range of 22 to 36 mg/l.

In addition to the coagulant, the flocculant ‘Praestol 650TR’ and organic coagulant polyDADMAC were used. Addition of 0.01% solution of polyDADMAC with the required fixed dose of 0.4 mg/l has allowed to reduce the required dose of aluminum sulfate from 36 to 22 mg/l without a substantial deterioration of water quality on permanganate oxidability while improving its chromaticity and turbidity. The loss of stability of colloidal system was determined by the change in the polarization of charges and the increase in the $\zeta$-potential. The comparison of the efficiency of polyDADMAC with the flocculant ‘Praestol 650TR’ showed that in case of its application with the coagulant dose of 22 mg/l, the effect of the subsequent sedimentation of water on the basic indicators of quality was slightly higher. However, in this case, its working dose was about 5 times higher as compared with flocculant ‘Praestol 650TR’.

Studies of water pretreatment process, before its entering to the main treatment structures, allowed to develop an improved technological model (model 1) of pretreatment of drinking water from the low power water sources [7]. It is different from the well-known technologies by using of prefilters with floating EPS bed, oxidizing agents, coagulants and flocculants in its composition, and also two-stage decoloring sorption filters (DSF) and decontamination by ultraviolet radiation with ultrasound and solution of sodium hypochlorite. Formation of the layer of combined loading in DSF was carried out by introducing the small-granule sorbent in the top layer of EPS at the last stage of washing [8].

The technological model should be supplied by the post-ozonization and the sorption under the considerable permanent anthropogenic loads on the water source (model 2). In this case, only inert loadings are used in the two-stage contact filters. Figure 2 shows one of the technological schemes of water purification.

Figure 2. Water purification scheme 1 - pump; 2 - preliminary filter; 3 - contact column; 4 - pin clarifier; 5 – filter with combined clarification and sorption loading; 6 - tank for purified water; 7 - pump; 8 – lamp for UV disinfection; 9, 10 - tanks for oxidizing solutions with dosing pumps; 11 - ozonator; 12 - tanks for coagulant solutions; 13 - tanks for flocculant solutions.

Further, we developed technological model with two-stage sequential filtration of water (model 3) and by preliminary input of sodium hypochlorite solution with active chlorine dose of 5.8 to 8.8 mg/l, by coagulation with doses of 3% AOC solution in the quantity of 10 to 15 mg/l in the primary coagulation, and in the secondary (in some filtration cycles) – 6.4 to 7 mg/l with the addition of flocculant ‘Praestol 650TR’ in a quantity of up to 0.5 mg/l. It allows to provide the deep water treatment not only on turbidity and chromaticity, but also on iron and manganese, decrease of which, as of residual aluminum, was occurred due to the presence of second stage catalyst-adsorbent of brand MC™ as a part of filter loading [9].

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Application scope of the proposed improved technologies according to the models of 1 to 3 is shown in Table 2 [7].

**Table 2. Application scope of the proposed water pretreatment technologies.**

| Indicators                        | Technological Models |
|-----------------------------------|----------------------|
|                                   | Model 1              | Model 2              | Model 3              |
| Productive capacity, thousand m³/day | 250-1000             | 1000-5000            | 250-5000             |
| Smell, TON                        | 2-3                  | 3-4                  | 2-3                  |
| Turbidity, mg/l                   | 5-30                 | 5-30                 | 50                   |
| Chromaticity, °                   | 25-150               | 25-150               | 180                  |
| Permanganate oxidizability, mgO₂/l | 10-12                | 15-20                | 12-15                |
| Iron, mg/l                        | 1-3                  | 1-2                  | 2-3                  |
| Manganese, mg/l                   | 0.1-0.2              | 0.1-0.2              | 0.5-1.0              |
| Phytoplankton, thousand cells/l   | 14-35                | 14-35                | 15-30                |

4. Conclusions
The problem of providing the population with drinking water is important. The use of water sources of low power is advisable. Now this is a complicated scientific and technical problem.
1. The study found that the use of water resources low capacity is possible provided the use of a special technology of preparation of drinking water.
2. The proposed technology of preparation of drinking water is different from the well-known technologies by using of prefilters with floating EPS bed, oxidizing agents, coagulants and flocculants in its composition, and also two-stage decoloring sorption filters and decontamination by ultraviolet radiation with ultrasound and solution of sodium hypochlorite.
3. Formation of the layer of combined loading in decoloring sorption filters was carried out by introducing the small-granule sorbent in the top layer of EPS at the last stage of washing.
4. The proposed technology of preparation of drinking water is an effective and promising.

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