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DEVELOPMENT OF SUSTAINABLE WATER TREATMENT TECHNOLOGY USING SCIENTIFICALLY BASED CALCULATED INDEXES OF SOURCE WATER QUALITY INDICATORS

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The article describes selection process of sustainable technological process flow chart for water treatment procedure developed on scientifically based calculated indexes of quality indicators for water supplied to water treatment facilities. In accordance with the previously calculated values of the indicators of the source water quality, the main purification facilities are selected. A more sustainable flow chart for the modern water quality of the Seversky Donets-Donbass channel is a two-stage filtering with contact prefilters and high-rate filters. The article proposes a set of measures to reduce such an indicator of water quality as permanganate oxidation. The most suitable for these purposes is sorption purification using granular activated carbon for water filtering. The increased water hardness is also quite topical. The method of ion exchange on sodium cation filters was chosen to reduce the water hardness. We also evaluated the reagents for decontamination of water. As a result, sodium hypochlorite is selected for treatment of water, which has several advantages over chlorine and retains the necessary aftereffect, unlike ozone. A technological flow chart with two-stage purification on contact prefilters and two-layer high-rate filters (granular activated carbon - quartz sand) with disinfection of sodium hypochlorite and softening of a part of water on sodium-cation exchangers filters is proposed. This technological flow chart of purification with any fluctuations in the quality of the source water is able to provide purified water that meets the requirements of the current sanitary-hygienic standards. In accordance with the developed flow chart, guidelines and activities for the reconstruction of the existing Makeevka Filtering Station were identified. The recommended flow chart uses more compact and less costly facilities, as well as additional measures to reduce those water quality indicators, the values of which previously were in compliance to the quality of the water supply standards.

Key words: water quality indicators, water treatment technology, water purification plant, sustainable technological flow chart, reconstruction of water treatment plants

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Introduction. Providing consumers with quality tap water is one of the main functions of any state. The existing water treatment facilities (WTF) do not always correspond to the modern quality of source water. The rated composition of water in the source of water supply has a determining influence on the structure of water treatment facilities. Water quality indicators in surface sources usually demonstrate significant fluctuations in the seasons of the year and in the years of observation. Normative documents [2, 7] require determining the structure of water treatment plants for the maximum values of indicators for all years of observation, but not less than three years. In some cases, this requirement leads to a significant increase in the cost of water treatment plants during their construction and operation. In Ukraine, the issue of determining the calculated indicators that are used to select a technological flow chart for water purification for drinking purposes was not considered in detail. In Russia, this issue is being investigated by Zh. M. Govorov and A.O. Rodina. Zh.M. Govorova has developed a new method for a new technique for assessing the quality of source water based on the relationship between the index of the water quality parameters and the health risks of the population from the short-term excess of the residual concentrations of the limited ingredients in purified water over their MPC and the potential capabilities of the designated water treatment flow chart [1]. A.O. Rodina has developed a methodology for justification of calculated surface water quality indicators in the selection of water treatment technologies using the risk of chemical water contamination [5].

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Articulation of issue. The Makeevka Filtering Station (MFS) facilities are not relevant for the present water quality in the Seversky Donets-Donbass Canal. Thus, there was a need to develop the most sustainable technological flow chart of water purification.

Research methodology. To carry out this task we have used statistical, computational and analytical research methods, as well as comparison of obtained results with results of similar projects and researches and we also have studied the works of scientists and specialists working in the field of water supply.

Results and discussion. Based on the study of the hydrochemical regime of the Seversky Donets-Donbass channel [6] and the mathematical and statistical data on long-term observations of the water quality of the channel, we have suggested the methods for selecting the calculated values of water quality indicators for choosing a sustainable technological water purification flow chart [3]. In order to increase the reliability of water treatment structures, it is suggested to choose the following values with security of 1 %:

- suspended materials concentration – 16 mg/l;
- colour – 26 deg;
- hardness – 8.8 mEq/l;
- permanganate oxidation – 9.0 mg/l;
- TMC – 1890;
- coli-index – 4200.

The main facilities of the MFS are horizontal sedimentation tanks and high-rate filters. Due to the reduction in water consumption the operational performance of the MSF is 160000 m³/d, and designed is 260000 m³/d.

In accordance with recommendations [2, 7], a preliminary selection of the main facilities, which are most sustainable ones, is carried out:

– contact pre-filter – high-rate filters (suspended materials concentration up to 300 mg/l, colour up to 120 deg);

– contact clarifier (suspended materials concentration up to 70 mg/l, colour up to 70 deg).

Both versions of the technological process flow diagrams are more sustainable for a given quality of the source water than the existing flow sheet. The horizontal settling tanks are necessary to use when the water in the source is sufficiently turbid (up to 1500 mg/l), which in this case does not correspond to the proposed calculated values. Contact clarifiers are more compact in comparison with horizontal settling tanks, their installation process is less expensive but in case of single-stage flow chart, it is very difficult to provide a stable water purity (according to suspended materials concentration) in accordance with regulatory requirements.

Since the permanganate oxidation index exceeds the MPC, and due to water decontamination, the toxic organochlorine substances are formed, it is necessary to provide measures to remove organic substances from the water. For these purposes (as an option) it can be recommended to use biological pre-cleaning of water entering treatment facilities. Biological purification of natural waters uses controlled biocenoses, the principle of which is based on the absorption and mineralization of suspended substances by hydrobionts. With the help of biological treatment, flavors, odors, organic substances (phenols, petroleum products), ammonium compounds, iron, manganese, water-dissolved gases can be removed from the water [10]. But this method has a significant drawback - the processes of biological purification will proceed normally at a water temperature not less than 10 °C. That is why the water treatment is efficient in warm seasons. However, the water of the Seversky Donets-Donbass canal is characterized by an increased content of organic substances during the spring flood, when the water temperature is still below 10 °C.

Thus, in order to reduce the permanganate oxidation index, it is more appropriate to use activated carbon for sorption water purification [13, 15]. This reagent is the most common and effective adsorbent in water treatment practice. It helps to remove from the water organic substances of both natural and anthropogenic origin, as well as organochlorine compounds. When designing new

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treatment plants, a more effective method of sorption purification will be the usage of carbon filters as the last stage of purification before secondary disinfection. But since in the developed flow chart the fast sand filters are applied, it is proposed to treat the water by filtration through a two-layer filter, where the first layer is granulated activated carbon, and the second one is quartz sand. However, it is necessary to take into account that activated carbon eventually exhausts its sorption ability and effective purification requires regular replacement of filters.

The calculated value of rigidity exceeds the MPC, therefore, it is necessary to consider the measures for softening water at the WPP. Softening of water is understood as a decrease in the content of calcium and magnesium salts in the incoming water. The choice of a specific method of softening depends on the quality of the initial water, the required degree of softening and technical and economic factors.

The most common softening methods are ion exchange and reagent methods. The reagent method cannot be used for treatment of drinking water. Lime or lime-soda methods cannot be used because of the high pH value of softened water, since this is not permissible. The remaining reagents used in the practice of water softening are either costly or toxic. Therefore, in this case, the most suitable for softening drinking water is the ion exchange method, based on the ability of some materials to exchange the cations (which they have as pre-charged) with the cations contained in water that determine its hardness [9, 13].

In the developed flow chart to reduce the overall hardness of water, it is recommended to use sodium cation-exchange filters. Since the hardness of drinking water should not be more than 7 mEq/l, and with this method, softening at the end of the process provides s a hardness of up to 0.1 mEq/l, it is suggested not to process the entire volume of water purified at the station, but only a part of it, and then mix the softened water in the total volume.

The last and most important task is to choose the safest and most effective reagent for water disinfection. In the framework of this work, a quantitative assessment of the risk to human health caused by impurities in drinking water was also calculated and the we obtained the results according to which chlorine and its compounds are a major threat to the health of the population [8]. Unfortunately, chlorine is still the most effective disinfectant reagent, which does not require significant capital investments, so there is no special alternative to its use, but it is possible to use safer reagents than the currently used liquid chlorine.

The strongest oxidant is ozone, it destroys enzymes of bacteria almost 20 times faster than chlorine. Ozonation [14] has a broad spectrum of action and is used as a complex method of water treatment process. Nevertheless, treatment with chlorine-containing disinfectants is still applied in technological flow charts used for ozone disinfection, since only chlorine has the required aftereffect.

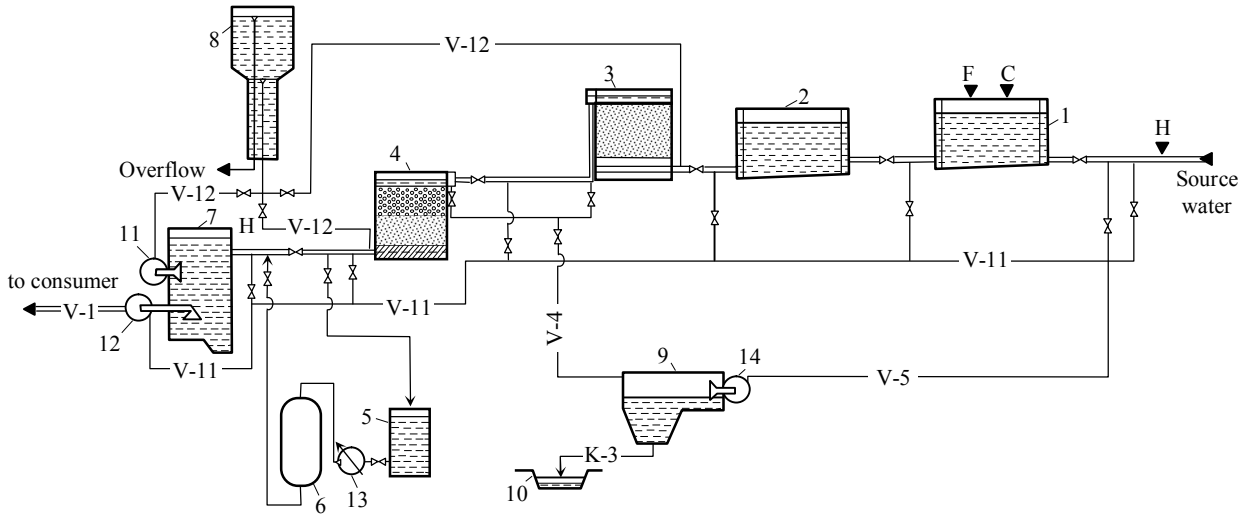
Having considered various disinfection methods, it is recommended to use sodium hypochlorite for water treatment [11, 12]. This method is not expensive, and simple and safe to use during treatment with sodium hypochlorite water containing organic substances, and a smaller amount of disinfection by-products is formed. The removal of secondary disinfection products can be solved by sorption cleaning.

As a result, we have developed a technological flow chart of two-stage purification with contact prefilters and double-layer high-rate filters (granulated activated carbon - quartz sand) and disinfection with sodium hypochlorite, softening of a part of the water using sodium cation-exchange filters.

This technological flow chart of water treatment is the most sustainable for the quality of the water of the Seversky Donets-Donbass canal and, under any fluctuations in the quality of the source water, is able to produce purified water that meets the requirements of the existing sanitary and hygienic standards.

Currently, the MFS performance is below the projected 40%, this trend has been observed over the past 15 years. In case of reconstruction of this station with two-stage filtration, some of the high-rate filters can be converted to contact prefilters, and the rest of contact prefilters

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Sustainable technological flow chart of water treatment facilities

1 – baffled mixing basin, 2 – contact chamber, 3 – contact pre-filters, 4 – two-layered high-rate filters, 5 – tank for softened water, 6 – sodium cation-exchange filter, 7 – pure water tank, 8 – wash tower, 9 – equalization tank, 10 – sludge tank, 11 – washing water supply pump, 12 – second pumping station, 13 – pump providing water for softening, 14 – pump for return of washing water; H – supply of sodium hypochlorite, C – coagulate supply, F – flocculant supply; V-1 – drinking and household pipeline, V-4 – process return water supply pipeline, V-5 – return pipeline for process return water, V-11 – emergency pipeline, V-12 – washing water supply pipeline, K-3 – sewage water pipeline

should be built on the basis of existing horizontal sedimentation tanks. It should be noted that two-stage filtration is guaranteed to reduce the suspended materials concentration of water to the normative sanitary requirements.

Re-construction of high-rate filters into contact clarifiers does not cause any difficulties and requires comparatively small changes in individual units; the horizontal settling tanks are re-equipped by dividing them into separate cells of contact clarifiers and does not encounter any fundamental difficulties, but requires significant construction work. The re-equipment of all operating facilities in contact clarifiers, including the sediment tanks, will make it possible to intensify the work of existing water treatment facilities to greater extent [4].

To solve the issue of the increased content of organic substances in MFS, it is recommended to apply sorption cleaning with two-layer high-rate filters (the first layer is granulated activated carbon, the second – quartz sand). The two-layer filter unit consists of acting high-rate filters with additional layer of activated carbon. For normal operation of the filters, it is necessary to replace the activated carbon at least once a year.

In order to reduce the overall water hardness in the technological flow chart of water purification at the MFS, it is recommended to introduce the ion exchange method with sodium cation-exchange filters. In this case not all amount of treated water will be processed but only a part of it. Taking into account that the calculated capacity of MFS is 160000 m³/d, hardness of source water is 8.94 mEq/l, hardness of purified water os 7 mEq/l, calculated consumption of softened water is 35000 m³/d. Then water with lowered hardness will be added to the rest amount of water. Thus, the hardness of the purified water will meet the requirements of current regulation standards.

MFS does not have a system for sediment treatment and usage of washing water from filters, due to this fact during re-equipment process we have to consider it and design such a system. During two-stage treatment process the washing water from filters go through sand-slit collector and flow into equalization tank and is directed to the starting section of the water treatment technological process flow chart. The sedimentation of washing water can be done in equalization tanks as well. The sediment formed in tanks is directed into thickeners, then to the dewatering units and sludge tanks.

Conclusion. As a result of the conducted research it can be concluded that the technological flow chart obtained using scientifically valid calculated values of water quality indicators is more sustainable in comparison to existing technological processes flow chart used at

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Makeevskaya filtering station. The suggested flow chart uses more compact and less expensive units, as well as additional activities for reducing the water quality indexes that previously were in compliance with water quality standards. For disinfection, it is recommended to use sodium hypochlorite, which has some advantages over the liquid chlorine that is being used at the moment. In the new flow chart, it is necessary to provide a system for treating the sludge and washing water from the filters.

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