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The introduction of resource-saving technology in water treatment plants

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Abstract. The purpose of a technological research is the development of a technology that would allow eliminating the discharge of untreated washing water from a water station in Omsk into the Irtysh, with their repeated use. The paper presents the results of a technological research, which made it possible to determine the optimal technology option for reuse of wash water filters. The studies were carried out by the trial coagulation method, introducing a different amount of contaminated wash water from 10 to 30% into the initial river water and the reagents used in the waterworks. When the combined purification of river and untreated washing water, the turbidity in the settling process decreases to 4.35 mg / l. The efficiency of purification increases with an increase in the amount of raw washing water also increases up to 30%. The technological solutions adopted on the basis of the conducted studies formed the basis for the design documentation for the facilities aimed at developing the re-use of wash water from the Omsk waterworks. The facilities have been built and are being successfully operated now. The proposed solutions made it possible to reduce the intake of water from the source by 10-16.5% and to eliminate the discharge of the contaminated wastewater from the station into the river of Irtysh up to a volume of 51 thousand m^3/day.

1 Introduction

The paper presents the main stages of an integrated approach for solving the problem of pollution of a water supply source with the discharge waters coming from a waterworks station. Despite the design standards, the availability of solutions for the treatment of washing water in standard and individual projects and their use are carried out only at a few waterworks in Russia. At the remaining stations, these facilities are either not available or not in operation. The most relevant solution for waterworks is in large cities, especially when washing and slurry waters are diverted to a water body [1]. This situation creates a significant negative impact on surface water sources due to the introduction of anthropogenic pollution [2, 3]. For small and medium-sized stations (deironing stations, for example) there are good solutions [4]. At large waterworks using water from surface water sources, the volumes of washing water and precipitation reach tens of thousands of cubic

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meters per day. At some stations, the problem is solved by cleaning the washing water to the quality of drinking water [5, 6].

A number of studies on introducing the technology and facilities for the cleaning and re-use of wash water from early filters at different times were carried out by specialists from the Research Institute of Municipal Water Supply and Water Purification and the Moscow State University of Civil Engineering at waterworks in Kaluga, Yaroslavl, Izhevsk, Omsk, Arkhangelsk, Kirov, Syktyvkar, and others [2, 8]. Similar studies were carried out by other specialists at various waterworks [9, 10, 11].

A completed version of the problem solution was carried out by us at a water station in Omsk. The Irtysh river serves as a source of water. Water purification is carried out at water treatment facilities with a design capacity of 610 thousand m^3/day. Currently, there are two units for the purification of river water (2nd and 3rd).

At the time of starting the technological research, the washing water filters (WWF) were taken to a small reservoir-averager and then pumped into the mixer of the third block. A part of the WWF was discharged into the river Irtysh without cleaning. To eliminate the discharge of unclean WWF into the water source, the JSC OmskVodokanal decided to develop a process for their reuse at the waterworks, with the subsequent design and construction of a reuse unit for washing water.

2 Materials and Methods

The studies were carried out on the basis of water treatment facilities in Omsk in two directions of possible use of washing water: reagent-free and reagent cleaning and optimization of the process of joint treatment of river water and washing water from filters at the waterworks of the station.

An analysis was carried out of the station's existing data on the operation of its facilities, including the quality of initial water, marks and doses of reagents, the quality of water purification by steps and individual blocks.

For conducting laboratory studies, raw river water and WWF were used. The studies were carried out using the trial coagulation method [8], adding to the initial river water a different amount of WWP, up to 30% by volume. Water samples were treated with reagent doses being applied at the waterworks, or even smaller.

Studies to determine the effectiveness of reagent-free clarification of WWF were carried out in all periods of the year. The selected samples of WWF were allowed to stand for 1 hour, the turbidity of the water was determined by the photometric method according to a standard procedure. Studies on the effect of quality and quantity of WWFs when they were combined with river water on the process of water treatment were carried out under the same conditions as in the purification of river water. Water was added to the river water as a preliminarily clarified WWF (standing for 1 hour) and as an unlighted one. For a number of samples, extended monitoring of water quality indicators was carried out, including microbiological indicators for compliance with the requirements of the standard "Drinking Water: Hygienic Requirements for Water Quality of Centralized Drinking Water Supply Systems – Quality Control" (SanPiN 2.1.4-1074).

3 Results

Analysis of water quality indicators of the Irtysh river allows us to characterize the water source as being a little polluted, with pronounced seasonal changes in the values of the main indicators. The maximum values of turbidity are reached in the flood period in the range of 52-72 mg/l. The lowest value is observed in the winter peropd, 2,3-3,9 mg/l. In the summer period, the turbidity of water varies over a wide range of 8 to 34 mg/l. Throughout the year, the color of the river water is 20-27 degrees. Permanganate oxidation is at the level of permissible concentrations (5.0 mg O2 / L).

In terms of bacteriological contamination, the river water can also be classified as a low-polluted water.

Water purification at the station is carried out using coagulants of aluminum oxychloride (OXA) and a flocculant, an organic coagulant such as PolyDADMAC (FL-4540). Doses of reagents depend on the quality of the initial water, and mainly on the value of the turbidity index. According to several years of work of the station, during the year they significantly change: the dose of coagulant from 0.1 mg / l with periodic administration, up to 2.3 mg / l - during the flood period. The dose of FL-4540 is from 0.05 mg / l in winter to 0.11 mg / l during the flood period. Disinfection of water is carried out in two stages. The total dose of chlorine does not exceed 2.6 mg / l. The quality of purified drinking water meets the requirements of SanPiN 2.1.4.1074-01.

An important technological parameter characterizing the operation of treatment facilities is the turbidity of the standing water, which depends not only on the efficiency of the settling tanks, but also on the coagulation process [12]. The average annual turbidity of standing water at the facilities is 3.03-4.7 mg/l; it increases during the flood to 5.6-7.8 mg/l. The minimum turbidity of the clarified water is noted in the summer. The average efficiency of clarification of water in sedimentation tanks is 60-74%, the minimum is 11% in cold periods of the year with a small turbidity of the initial water, and the maximum is 82% in flood and summer.

The washing water from the filters, which is formed when using the FLA-4540 coagulant OXA and flocculant for the purification of river water, was characterized by high clarification efficiency in settling (Table 1), which was 78-98%.

Table 1. Turbidity of wash water from filters.

Indicators	Unit of measurement	Summer	Autumn	Winter	Spring (flood)
Turbidity of the initial PVP	mg / l	63-78	13,1-16,7	4,8-5,1	46,6-51,4
Turbidity of a stationary PVP	mg / l	1,2-1,8	2,9-3,19	0,78	4,68
Efficiency of clarification (1 hour)	%	98	78	84	90
Efficiency of clarification (30 min)	%	93	70	80	87
Filtrate turbidity	mg / l	0,58	0,67	0,35	0,58

This is due to the fact that the doses of reagents are correctly set at the station, the coagulation process is complete, and the flakes formed have a dense, strong structure and quickly settle. The use of reagents to clarify this washing water is practically not required. In one of the experiments, it was found that the turbidity in settling the wash water without reagents decreases on average from 13.5 to 2.56 mg/l. With reagents, however, the turbidity decreases to 1.44 mg/l.

Studies were conducted on the effect of WWF on the main process of water purification when they were returned to the mixer. The results obtained show that when the pre-fixed WWF is added in the amount of 0 to 30% of the total volume of the treated water, the efficiency of the clarification process increases. The Figure 1 shows the values of the clarity index of clarified water obtained after the joint treatment of river water and a permanent WWF.

Other results were obtained during the joint purification of river and untreated WWF (Figure 2).

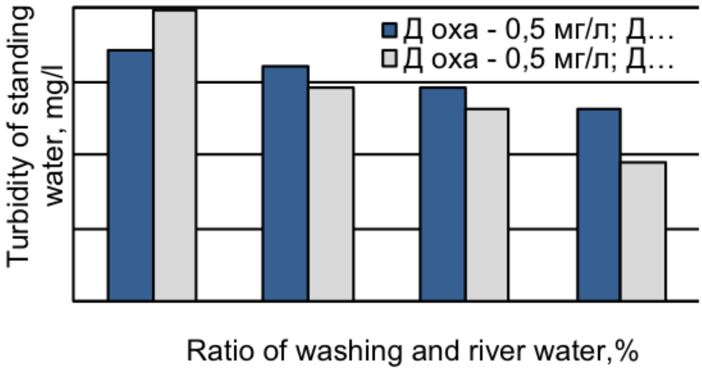

Fig. 1. The effect of the addition of purified WWLs on joint purification with river water.

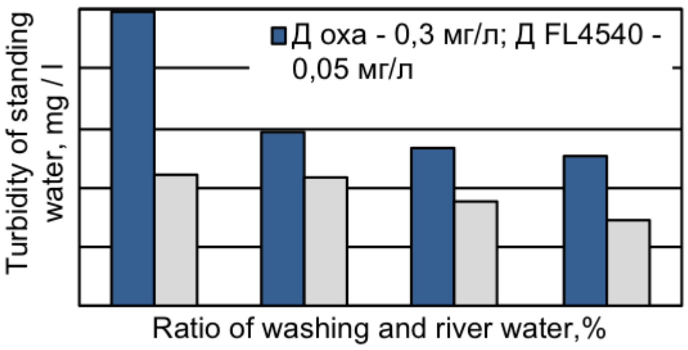

Fig. 2. The effect of the addition of untreated PVPs on combined treatment with river water.

With scarce doses of reagents (OXA, 0.3 mg/l and FL-4540, 0.05 mg/l), the turbidity of river water after sedimentation decreases only to 9.85 mg/l, and the efficiency of purification of the river water being mixed with the WWF reaches 47% and little depends on the share of WWF.

At sufficient doses of reagents (OXA, 0.50 mg/l and FL-4540, 0.150 mg/l), the turbidity of the river water after the settling tanks is reduced to 4.35 mg/l, and cleaning efficiency is increased to 33% with an increase in the amount of raw washing water added. In winter, the doses of reagents for water treatment were significantly lower than in other periods, but the tendency to improve the quality of treated water in the joint treatment of river and rinse water was maintained.

The quality of the filtrate is improved when the amount of the untreated WWL is added. With the combined treatment of river and wash water in certain periods of the year, it is possible to reduce the dose of reagents somewhat. At the station, -0. 15-0.16 mg/l of OXA and -0,09 mg/l of FL-4540 were applied, while adding the untreated WWL in the amount of 20-30% of the dose of reagents, according to studies, can be reduced to 0.1 mg/l and 0.07 mg/l, respectively.

Table 2 presents the characteristic results of experiments on the joint treatment of river and wash water from filters, when washing water is supplied to the head of the structures without preliminary cleaning in the most difficult, high water period of the year. The turbidity of the river water was 45-55 mg/l, the turbidity of the non-clarified water was 44.5-46.4 mg/l, and the turbidity of the wash water after preliminary settling was 3.6 mg/l.

Table 2. The values of the turbidity index of the purified water in the joint treatment of WWL and river water in the flood period.

No. experi-ment	Dose of reagent, mg / l		Ratio of WWL and river water, %			
	OXA	FL-4540	0/100	10/90	20/80	30/70
when mixed with a crude PVP						
18	1,0	0,1	5,8/0,58*)	4,06/0,58	3,19/0,29	2,95/0,29
16	1,2	0,1	3,15/0,29	2,32/0	1,9/0	2,03/0
12	1,2	0,13	2,47/0,58	2,32/0,16	2,15/0	2,15/0
when mixed with a fixed PVP						
21	1,0	0,1	4,7/0,63	3,62/0,29	2,86/0,29	2,73/0,16

* Eurbidity of standing water /turbidity of filtrate, mg/l.

4 Discussion

The pre-project technological studies carried out showed that the washing water from the filters at the water treatment plant, which is characterized by high clarification efficiency at sedimentation, the turbidity of the standing water is 3.02-4.68 mg/l. The return and reuse of WWL in an amount of 10 to 30% into the “head” of structures and their combined treatment with the original river water improves the purification process. So, the turbidity of the clarified water after settling tanks decreases in 1.5-2 times, and the filtered and disinfected water meets all requirements of SanPiN 2.1.4.1074-01. The results of the studies made it possible to recommend the use of wash water from these filters without purification for these water treatment plants. However, this cannot be a universal recommendation and wound require appropriate research for each source and station, as evidenced by the works [13, 14, 15].

Based on our technological research and proposed technological solutions, the design organization SibAkvaStroy LLC, with the participation of the RVC-Consulting LLC, completed a project for the construction of facilities for the re-use of washing water from a water supply station in Omsk. The facilities were built and put into operation in February 2015.

According to the data for 2015-2017, the volume of the returned WWL was in the range of 10-16.5%. Doses of reagents depended to a greater extent on the quality of the initial water and practically did not change with the launch of the WWL reuse structures.

The Figure 3 shows the monthly mean values of the turbidity of water being clarified in the sedimentation tanks of the second block of structures operating only on river water and the third block of structures operating on a mixture of river and the returning WWL . The commissioning of the WWL reuse facilities at the waterworks did not affect the quality of the treated drinking water. According to the data of 2017, the average monthly water turbidity indices supplied to the city were in the range 0.061-0.125 mg/l, and the chromaticity being within 1-4 degrees. The results of the microbiological analysis showed that the purified drinking water corresponded to the established requirements during the whole period of operation.

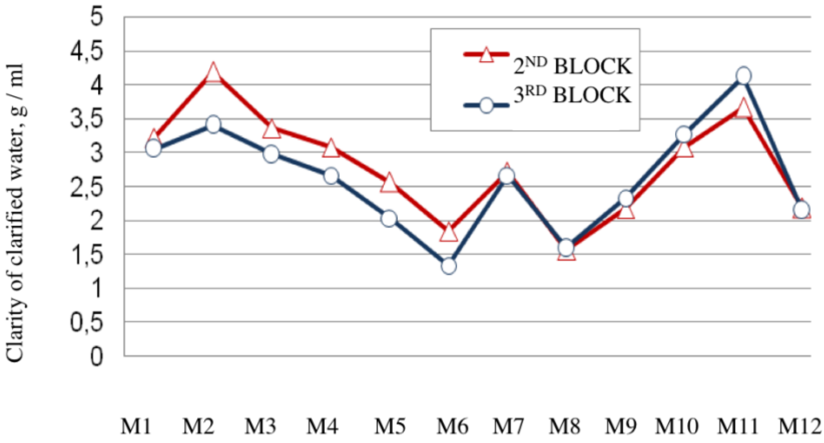

Fig. 3. Mean values of clarity of the clarified water (mg / l) after sedimentation tanks of the 2nd and 3rd blocks of treatment facilities, 2017.

5 Conclusion

Our studies at a water station in Omsk show that it is expedient to aerate the wastewater and return to the "head" of the drinking water treatment facilities, in the amount up to 30% of the total flow of river water processed at the facilities. At the same time, the efficiency of water purification in sediment tanks is increased, and the quality of the purified drinking water in all indices, including microbiological ones, meets the requirements of SanPin.

Based on the research, a technological scheme was developed and a design of facilities for re-use of WWL was implemented. In 2015, a unit for the reuse of WWL was built and put into operation, so the main goal was achieved: the discharge of the contaminated wash water in the river of Irtysh was eliminated in the amount of 36 ... 51 thousand m^3/day and for this same volume the intake of river water decreased. Successful operation of the unit for 3 years has confirmed the main results of the research and the correctness of the developed technological and design solutions.

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