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Purifying Water from the Om River Using Ferrate-Containing Reagent

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Abstract

Basing on the results obtained in comparative studies on the purification efficiency of water from the Om River using a coagulation method with alumina, ferric chloride, and the reagent containing sodium-potassium ferrate (VI) (FSR) and ferric chloride as a coagulating agent, possibility has been demonstrated for obtaining potable water with required quality, making no considerable change in the process flowsheet of water treatment plant at the Kormilovka settlement.

Key words: water purification using coagulants, sodium ferrate (VI), ferrate (VI)-containing reagent

INTRODUCTION

Nowadays the Om River is a unique source of the organized water supply for three districts of the Omsk Region such as the Kormilovka, the Kalachinsk and the Nizne-Omsk Districts due to the absence of a group water pipeline therein. Water drain from the Om River is enough to provide these areas with potable water. However, the water in the Om River according to a number of parameters does not meet the requirements for water supply sources. For example, the turbidity level of water can reach 20 mg/L; the chromaticity level can amount to 400 degrees, the content of iron being equal to 3 mg/L, with the oxidability level (COD) of 30 mg O₂/L, which is greater to a considerable extent than the MPC values for these parameters. As the analysis of the literature data concerning water purification from suspended and tinted impurities has demonstrated [1–3], the coagulation method is most frequently used for these purposes. In order to decrease the content of iron in natural water

one carry out the preliminary oxidation of iron up to the oxidation level +3 *via* the aeration of water by air and treatment by oxidizers (ozone, chlorine, sodium hypochlorite) with the further iron precipitation as iron (III) hydroxide.

Using water treatment by oxidizers (sodium hypochlorite, potassium permanganate, ozone) and the subsequent use of coagulants one could succeed in obtaining a required level of water chromaticity, too.

In order to acceleration of the precipitation of sediments formed by coagulants one always uses adding flocculation agents.

CHARACTERISTICS OF THE OBJECT UNDER STUDY

The process flowsheet at the water treatment plant in the Kormilovka settlement includes the following stages. The water supplied to the plant is fed to a vortex mixer, where to also sodium hypochlorite and coagulant alumina are fed, whereas a VPK-402 flocculating agent is fed at the output from a pocket of the

TABLE 1

Parameters of water from the Om River according to the results of analyses

Parameters	MPC [8]	21.03.2009.	22.04.2009.	21.05.2009	07.06.2009
Smell, points	2.00	3.00/2.00	3.00/2.00	3.00/2.00	3.50/2.50
Flavour, points	2.00	3.00/2.00	3.00/2.00	3.00/2.00	3.50/2.50
Turbidity, mg/L	2.60	1.75/0.25	11.00/0.75	7.50/2.25	10.00/2.25
Chromaticity, deg	20.00	75.00/50.00	50.00/20.00	95.00/90.00	130.00/110.00
Total iron, mg /L	0.30	1.30/0.80	1.15/0.40	0.90/0.68	1.70/1.10
Hardness, mg/L	7.00	8.95/8.60	5.65/5.55	2.30/2.15	2.77/2.62
Oxidability, mg/L	5.00	22.40/7.2.0	10.4/3.20	20.00/10.40	24.80/10.40
Residual					
aluminium, mg/L	0.5	0.00/0.19	0.16/0.51	0.01/0.45	0.10/0.40
C_{sac} , mg/L	0.5	0.01/0.02	0.01/0.01	0.01/0.01	0.03/0.01
Solid residue, mg/L	1000.0	315/290	345.0/305.0	345.0/305.0	310.0/295.0
pH	6.0–9.0	7.00/6.00	7.80/7.49	7.81/7.56	7.95/7.65

Note. The first value is obtained before water passing through the water treatment plant; the second value being obtained after the passing.

mixer. From the mixer, water is fed into clarification tanks with a fluidized bed layer of precipitate, wherefrom it further is passed to fast filters. After filtering, water goes through a modular pipeline into the tanks of pure water; the input of sodium hypochlorite for disinfection is made into the same pipeline.

The scheme of water conditioning is classical, however, as the results of analyses demonstrate, the water, both before and after passing through a water treatment plant demonstrate, not always meets quality requirements [4].

As an example, Table 1 demonstrates the results of analysis for water obtained at the laboratory of water treatment plant in the springtime of 2009. According to the requirements for the technological schedule such analysis is carried out every day.

One can see that on such water parameters as chromaticity, the total content of iron and oxidability, the water does not meet the requirements of the sanitary standards and regulations (the SanPiN) both before and after the treatment procedure [4]. Moreover, there is a sufficient amount of aluminium in water after water conditioning. Before purifying, aluminium is almost absent in the river water, whereas after water treatment its content increases almost up to the MPC level. To all appearance, it could be connected with the use of alumina

as a coagulant whose source is presented by aluminium sulphate.

Since the technical condition of the equipment is maintained at a good level and the production schedules are kept, one could assume that insufficiently efficient operation of water treatment plant is connected with bad quality coagulant used.

The purpose of the present work consists in finding a coagulant whose application would allow to purify the river water to obtain the standard quality and would not require for any essential change in the operating process flow-sheet for the water treatment plant at the Kormilovka settlement.

In order to attain the objective, it was necessary to accomplish the following tasks:

1. Basing on the literature data, choosing coagulants those could be used to replace alumina.

2. Taking into account the requirements of the sanitary standards and regulations (the SNiP) [5], performing comparative studies under laboratory conditions concerning the efficiency of water conditioning taken from the Om River using the technology close to that practiced at the Kormilovka settlement, with the use of alumina and chosen coagulants.

3. Developing recommendations concerning the improvement of water treatment plant operation at the Kormilovka settlement.

EXPERIMENTAL

For determining physicochemical parameters of water (pH, chromaticity, turbidity, smell, flavour) and other controlled impurities (total iron, iron (III), permanganate oxidability) we used standard methods [6–8].

According to the requirements [5, 9], the studies on the efficiency of coagulants were carried out according to the following scheme. Into six graduated cylinders 0.5 L in capacity was poured the river water under investigation, then was added a required amount of a coagulant solution therein. The content of all the cylinders was mixed *via* fast rotation of a glass stick during 15–20 s. Further, into the cylinders was added different amount of a flocculating agent solution, and then during 3–5 min the samples were slowly stirred and left for precipitation. After the precipitation water was supplied to a laboratory setup for fast filtering.

When studying the influence of acidity upon the efficiency of water purification, adjusting the pH value of water was carried out before adding the reagents. The analysis of water for the content of controlled impurities was carried out at all the stages including prior to starting the procedure of purification.

The following reagents were studied in this work as coagulants:

1) alumina being nowadays in use at the Kormilovka water treatment plant;

2) iron chloride (III), recommended by the SNiP [5];

3) sodium ferrate (VI) (for the last ten years this substance is studied with the purpose of its use as a coagulant).

Alkali metal ferrates (VI) are water-soluble to a significant extent; these compounds belong to the strongest oxidizers (conceding only to ozone). The reduction of ferrates (VI) results in the formation of iron (III) hydroxide. Thus, alkali metal ferrates (VI) represent oxidizers capable of destroying organic impurities and oxidizing iron up to the oxidation level equal to +3. Formed thus iron (III) hydroxide can operate as a coagulant. No toxic products are formed during the decay of the reagent.

Unfortunately, there is no commercial production of the mentioned reagent in Russia. For the last two years (Ecros Co., St. Petersburg)

periodically releases experimental batches of sodium ferrate (VI) named “Ferroxine”. In the present work, sodium ferrates (VI) were obtained via the oxidation of sodium ferrite by sodium hypochlorite solution [10].

The ratio between reagents was chosen to be such that there was no iron (III) complete oxidation into iron (VI). Such a mixed reagent containing iron with the oxidation level +6 in the amount about 10 mass %, we have named a ferrate(VI)-containing reagent (FCR). We expected that this reagent would provide an increased efficiency of water treatment as a mixed coagulant [11, 12].

RESULTS AND DISCUSSION

The results of analyses have demonstrated that for first two hours of precipitating after the addition of aluminium sulphate as a coagulant the quality of water becomes worse. An improvement of the quality parameters is re-

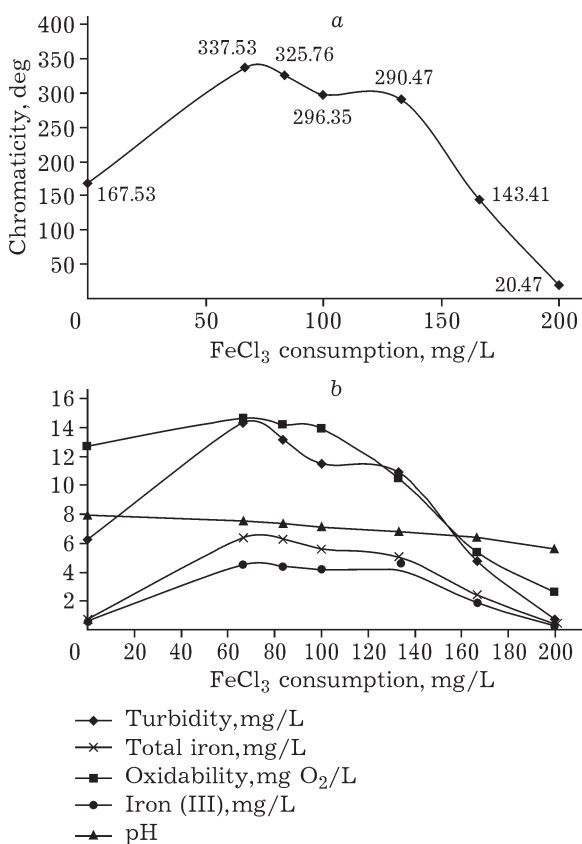


Fig. 1. Changing the controlled parameters depending on the iron (III) chloride consumption: a – chromaticity, b – turbidity, oxidability, pH, total iron and iron (III).

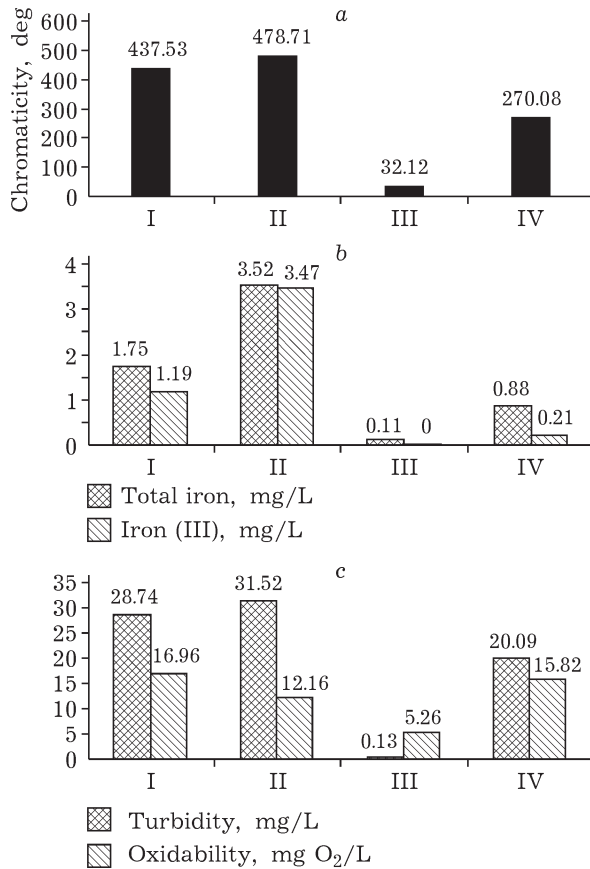


Fig. 2. Changing the controlled parameters according to purification steps (FCR concentration amounting to 1.18 mg/L, VPK-402 concentration being equal to 0.5 mg/L): *a* – chromaticity, *b* – concentration of total iron and iron (III), *c* – turbidity and oxidability; I – initial water, II – water after precipitation with adding the reagents, III – the same after filtering, IV – the same without adding the reagents.

sulted from precipitating the water within a day: the parameters such as turbidity, oxidability and pH are at the MPC level, however the chromaticity and the content of iron in water do not meet the requirements of MPC. In this case the use of aluminium sulphate results in additional water contamination with aluminium.

Using iron (III) chloride, one could reach good level of water treatment; however the efficiency of using the mentioned coagulant leaves much to be desired. The controlled parameters of water quality depending on iron (III) chloride consumption are presented in Fig. 1. To all appearance, the required quality of water could be reached obtained only at a high consumption level of the reagent (up to 200 mg/L). A high consumption level of the coagu-

lant is not favourable both from the economic standpoint, and because of a short filtering cycle of filtering installations.

The results of estimating the efficiency of the Om River water treatment from with the application of ferrate(VI)-containing reagent are presented in Fig. 2.

In order to purify the same volume of water, the ferrate(VI) -containing reagent is required by 2–3 times less than iron (III) chloride. However, the time of water processing is rather long, amounting to 1 day. For intensifying the process of water treatment we used a VPK-402 flocculating agent which is used at the water treatment plant. The application of this flocculating agent allows reducing the duration of water processing from 24 to 1.5–2 h. After 1.5–2 h, water becomes transparent, large flakes of iron (III) hydroxide precipitate onto the bottom of a sediment bowl, whereas a great amount of fine flakes are suspended due a high alkalinity level and cannot precipitate even in a day. Therefore, high turbidity and chromaticity level values are observed for the solution.

The removal of fine-dispersed suspension from water was made via filtering through the layer of quartz sand with the particle size of 0.7–1.1 mm. After the filtration, the purified water meets all the requirements of the San-PiN [4], except for slightly exceeding the MPC in the chromaticity level, connected with a high chromaticity level of the initial water.

CONCLUSION

The comparative analysis of river water purifying efficiency with the use of various coagulants has demonstrated that aluminium sulphate does not provide a required purification level for the Om River water, the iron chloride, though providing a good purifying level is inexpedient in use because of a high consumption of this coagulant. In order to purify the Om River water it is much more appropriate to use ferrate(VI)-containing reagent which provides a much more profound water treatment, being at the same time economic and environmentally safe. Moreover, the mentioned coagulant exerts a good disinfecting effect, which would provide reducing the volume of

sodium hypochlorite used in a purification process flowsheet as an antiseptic agent.

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