ISSN 1070-3632, Russian Journal of General Chemistry, 2014, Vol. 84, No. 13, pp. 2588–2591. © Pleiades Publishing, Ltd., 2014.
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# Research of Demanganation Process of Artesian Well Water

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Received April 11, 2014

**Abstract—**In article we present the experimental results on demanganation of well water where the manganese concentration exceeds 5 mg/L and iron concentration 20 mg/L. The developed technology for demanganation is described. The results of experiments at water treatment plant of Komsomolsk-on-Amur are presented.

**Keywords:** iron, manganese, manganese removal, water purification

**DOI:** 10.1134/S1070363214130155

## INTRODUCTION

Manganese is presented in the earth's crust in large quantities and is usually found together with iron. With manganese content exceeding 0.1 mg/L water is unfit for drinking, industrial and commercial purposes, there are stains on the plumbing fixtures, as well as undesirable taste of water [1]. On the inner walls of pipelines it forms a precipitate which peels off in the form of brown-black film. In most cases, this precipitate contains a considerable amount of iron substances.

Divalent manganese contained in groundwater, is very slowly oxidized to three and tetravalent forms by oxygen dissolved in the water or other oxidants.

According to chemical study content of manganese in water from artesian wells in Komsomolsk-on-Amur is 2.5–7.4 mg/L, which is significantly higher than the common values. To date, in the water treated at the water treatment plant in Komsomolsk-on-Amur, the concentration of dissolved manganese can reach 0.7–0.9 mg/L, that 7–9 times exceeds the official norms (according to SanPiN 2.1.4.1074-01) [2]. Also water contains black suspended particles, from film of oxidized manganese formed on load in high-rate filters (Fig. 1).

The purpose of this study was to develop technologies of demanganation of well water supplied to the minicipal network of Komsomolsk-on-Amur, to achieve water parameters meeting SanPiN 2.1.4.1074-01 requirements and provide end users with quality drinking water.

## EXPERIMENTAL

The technology comprises the steps of sequential dosing in treated water alkaline agent (NaOH), an oxidant ($KMnO_4$) and coagulant (aluminum polyoxychloride) followed by filtration the precipitate formed on the catalytic load (MFO-47), and fine post-treatment through granular sorbent (Filter-AG). The concentrations of the reagents were: NaOH solution

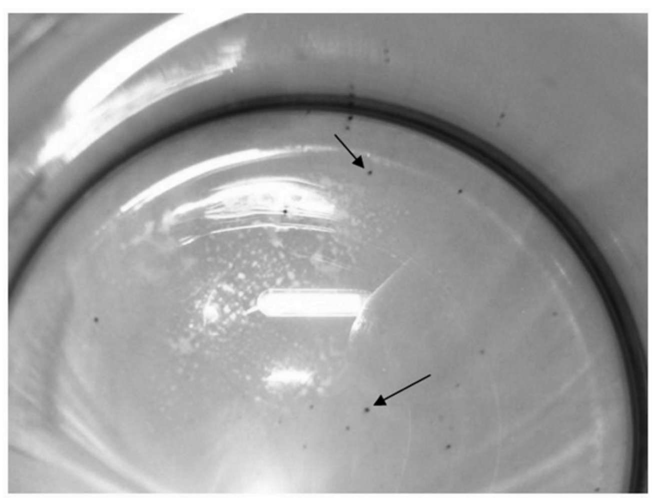

**Fig. 1.** Particles of oxidized manganese film in the network water.

**Table 1.** Technical specifications of WTU

| Parameter | Value |
|---|---|
| Performance, $m^3$/h | 2.1 |
| Pressure in the hydraulic path, MPa (set by the pressure switch) | 0.2–0.3 |
| Compressor performance, $m^3$/h | 2.5 |
| Compressor discharge pressure, MPa | 0.7 |
| Maximum consumption of dosing reagents, L/h | up to 2.4 |
| Weight without water, kg | ~175 |
| Total weight when full, kg | ~350 |
| Overall dimensions (without filters), m | 0.6 × 0.85 × 1.81 |
| Power supply, V | 220 |
| Power consumption, kW | 1.5 |

**Table 2.** Purification of network water

| Mode no. | Water consumption, L/min | Initial manganese concentration, mg/L | Residual manganese concentration, mg/L |
|---|---|---|---|
| 3a | 5 | 0.186 | 0.068 |
| | 10 | | 0.066 |
| | 15 | | 0.048 |
| 3b | 5 | 0.186 | 0.091 |
| | 10 | | 0.083 |
| | 15 | | 0.089 |
| 3c | 5 | 0.186 | 0.014 |
| | 10 | | 0.014 |

20 g/L, $KMnO_4$ solution 5 g/L, aluminum polyoxychloride solution 3 g/L.

For research on well water demanganation a pilot experimental water treatment unit (WTU) was designed and built (Fig. 2).

WTU is a mobile water treatment plant that provides clean water to standards not below the requirements of SanPiN 2.1.4.1074-01. Realized water treatment technology allows to clean water from the coarse, colloidal and dissolved solids. WTU can purify water, obtained from artesian wells and water from

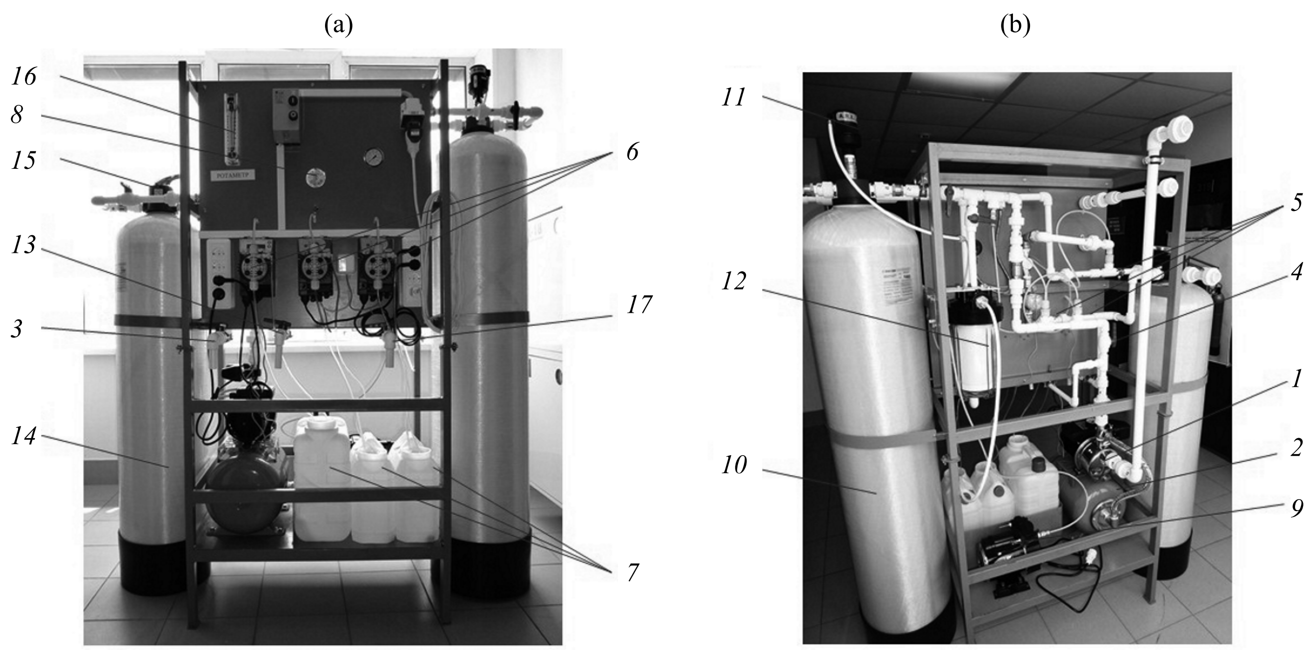


**Fig. 2.** General view of the experimental WTU: (a) from the dashboard; (b) from the aggregates. (*1*) Charge pump; (*2*) accumulator; (*3*) water feed; (*4*) control valve; (*5*) injector; (*6*) dosing pumps (*7*) container with the reagent solutions; (*8*) impeller flowmeter; (*9*) compressor; (*10*) aeration column; (*11*) vent valve; (*12*) residual ozone post-combustion filter; (*13*) collection of water samples after aeration column; (*14*) mechanical filter; (*15*) hand tip; (*16*) flowmeter; and (*17*) collection of water samples after filtering.

**Table 3.** The results of pilot tests

| Mode no. | Type of water | Water consumption, L/min | pH of raw water | Initial water temperature, °C | Initial manganese concentration, mg/L | Residual manganese concentration, mg/L | Initial iron concentration, mg/L | Residual iron concentration, mg/L |
|---|---|---|---|---|---|---|---|---|
| 1 | Water from vortex aerator | 5 | 6.36 | 8.1 | 5.120 | 0.774 | 20.050 | Not detected |
| 2 | Water after clarifiers | 15 | 6.54 | 8.8 | 4.284 | 0.020 | 0.564 | Not detected |
| 3 | Network water | 10 | 6.54 | 8.8 | 0.186 | 0.014 | 0.032 | Not detected |

surface water sources intended for technological and drinking purposes. Installation is not intended for wastewater with high levels of color and turbidity.

Table 1 contains technical characteristics of pilot WTU.

Water for treatment in the experimental unit was collected from the three main technological stages of water treatment plant: from vortex aerator, from the surface of high-rate filters and water mains.

Performance of the experimental unit was varied from 5 to 25 L/min. If the installation achieved limits on manganese content already on the previous level of performance, subsequent level was not set up.

Manganese and iron content were determined by atomic-absorption method on a SHIMADZU AA-6200 instrument.

## RESULTS AND DISCUSSION

The principle of operation is based on the following water treatment technologies:

– Corrective treatment of raw water (alkalinization, acidification, etc.) for correction of the characteristics of media in order to optimize water treatment processes and improve the final parameters of treated water achieved by feeding of chemicals into a stream of water with reagent dosing pumps;

– Oxidation of dissolved impurities in the source water with gaseous or liquid oxidizer in order to convert them into a colloidal form, by mixing water with air, ozone, chlorine, potassium permanganate or other specially chosen oxidant;

– Direct-flow coagulation based on the pretreatment of water with reagents (coagulants and flocculants), performed by entering the desired quantity of reagents in the cleaning water with feeder pumps;

– Clarification of the water by filtration through mechanical filters of vessel type with specially selected load;

– further water purification from difficult to remove impurities on connected sorbtion filters.

**Study of water demanganation modes on an experimental WTU.** *Mode 1. Cleaning water from vortex aerator.* Here, the term "water from the vortex aerator" means water, raised from the wells, that passes the first stage of processing-aeration in a vortex aerator on water treatment plant in Komsomolsk-on-Amur.

From the pipeline intake unit, water was supplied to the experimental WTU, where it was added to an alkaline solution, in order to increase the pH to shift redox potential towards oxidation, $KMnO_4$ as an oxidant and coagulant-aluminum polyoxychloride. Water treated with reagents entered the aeration column, which acted as reaction vessel, and was vigorously stirred by bubbling air and after 15-min stay feeded in the filter column. In filtration columns water was sequentially filtered through MFO-47, and then, through Filter-AG loads.

A special feature of work in this mode was a high dirt load on the installation. The high content of iron and manganese leads to increased consumption of reagents, which together with the coagulant provides a significant amount of precipitate. This precipitate almost immediately clogs the filter of the first stage (based on MFO-47), and then second stage filter (based on Filter-AG).

In the current technological scheme used in water treatment facilities after aeration and adding of ozone water is fed to the horizontal tanks. Thus, the load on the high-rate filters for iron hydroxide is significantly reduced-filters only reduce the residual content of iron in the water. In experimental setup the whole mass of oxidated and hydrolyzed iron is sent for high-rate pressure filtration, the filter works with a large load of dirt. Situation is worsened with significant doses of an alkaline agent in order to achieve high pH levels, with the possible stabilization of charging iron hydroxides microsols and/or premature hydrolysis of coagulant salt without its effect on the suspension.

Additional portions of an oxidative solution ($KMnO_4$) makes this system even more difficult to find the ways to reduce manganese content in the water.

*Mode 2. Water cleaning after clarifiers.* Here, the term “water after clarifiers” means water that is in the process of water treatment passed the aerator (ozonation) and clarifiers stages and is fed into the upper volume of high-rate filters for further treatment.

After clarifiers water is free of hydrogen sulfide, carbon dioxide, virtually free from dissolved iron and partly from manganese.

Water treatment mode is similar to mode 1.

Potable water can be obtained directly from the technical on spot using units identical to the experimental.

*Mode 3. Cleaning of network water.* Here, the term “network water” means water that is fed into the municipal water supply network for end consumers.

We investigated three modes of water purification: two-stage filtration through a bed load (MFI-47, Filter-AG) (mode 3a); coagulation, followed by a two-stage filtration (mode 3b); complete chemical treatment followed by a two-stage filtration (mode 3c, similar to mode 1).

Table 2 shows the results of purification of the network water in different modes.

As it can be seen from Table 2, all three modes of filtration reduce manganese concentration to values below SanPiN 2.1.4.1074-01.

Higher concentrations of manganese (mode 3b) are due to the slightly acidic reaction of coagulant, which reduces the pH of the water and reduces the efficiency of the catalyst loading MFI-47. This mode, despite providing manganese content below SanPin standards is impractical due to irrational use of coagulant.

Achieved parameters of network water and its high organoleptic properties convincingly argue that one of the ways to supply high quality drinking water to end consumers-installing on the spot of small mobile units of required performance, similar to experimental WTU.

The results of pilot tests are given in Table 3.

## CONCLUSIONS

Positive results obtained in the course of work, have shown that the developed technology can be used to purify drinking water and process water for industrial purposes. The most effective use of its on small treatment plants and drinking water purification installed on food enterprises, small enterprises making products using high-purity water, in small businesses to provide services in the field of drinking water supply, enterprises and organizations of all other activities with increased requirements to the quality of water used.

## ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Education and Science of the Russian Federation, by order of P 218, the contract no. 02.G25.31.0035-225 dated 12 February, 2013 between Open Joint Stock Company “Far East Plant “Zvezda” and the Ministry of Education and Science of the Russian Federation.”

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