Experience of reconstructing deferrization station

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Abstract. We conducted analysis of the currently functioning deferrization station. We demonstrate that in some cases stations built in 1950-60-s became obsolete, and technology based on simplified aeration followed by filtration does not ensure required quality of purified water at all times. Moreover, this article provides an example which justifies the development of tech solutions for the reconstruction of the deferrization station. We propose an introduction of new technology with bioreactors and filters with a floating load, use of technological pipelines from non-laminated polyvinyl chloride and energy-saving fittings. Results show that concentration of iron in purified water after the reconstruction does not exceed 0.075-0.084, manganese - 0.025-0.028 mg/l, turbidity is less than 1 FTU, chromaticity is less than 2.8 degrees. Total energy consumption comprises 0.96 kW per hour.

1. Introduction
Domestic water supply in both large cities and small settlements is typically provided by surface or ground water sources. Surface water sources, as opposed to ground ones, are characterized by higher bacterial contamination and pronounced seasonal fluctuations of quality of water.

The main constituents of artesian groundwater lying at depth of 60-150 m are dissolved gases (carbon dioxide, hydrogen sulfide, methane), iron and manganese compounds, hardness salts, biogenic and organic substances. The amount of dissolved forms of compounds of iron and manganese in groundwater is directly dependent on the presence of oxygen, carbon dioxide and carbonates. At the same time, there are microorganisms in the groundwater, however they do not threat human health, at least directly [1-3].

Diversity of groundwater composition emerges various technologies and methods. In general, methods of deferrization are divided into reagent-free and reagent [1-8]. Non-reagent methods of water deferrization are the most common ones. They involve aeration of water using various aeration devices and filtering through inert or active loads.

The majority of deferrization stations in Russia utilize the method of simplified aeration via venting into pocket filters or by supplying compressed air to the source water with a compressor. Those stations were built around 1950-60s according to drafts. Examination of the technical condition of such stations demonstrated that the depreciation of the main equipment is more than 60-70%; the premises of the stations are oversaturated with numerous tie-ins of supply and discharge water- and air pipelines; pressure filters, steel piping and valves and fittings are subject to corrosion (Figure 1).
Current technology is simply not able to continuously provide SanPiN’s 2.1.4.1074-01 [9] quality standards of drinking water for iron, manganese, hydrogen sulfide (odor and taste) and hardness salts. Moreover, this technology is energy-intensive due to use of powerful pumps for washing heavy filtering loads, compressors and receivers, and it requires additional amount of water storage in a clean water tank held for flushing. Lack of facilities for processing and reuse of wash-water leads to unsustainable use of water resources and, consequently, an increase in water consumption for the station’s own needs.

Thus, the need to ensure modern sanitary and hygienic standards for the quality of purified water, to reduce energy intensity, to increase the level of maintenance seems to be a priority. It requires the replacement or improvement of outdated water processing technology, modernization or reconstruction of technical means and fixing of deferrization stations in general.

2. Research Site
Object of the study is the current deferrization station. The station with a capacity of 10000 m$^3$ per day is located in the Moscow Region and has been in operation for 60 years.

Water supply to the deferrization station is carried out with the help of a group of wells. The physico-chemical composition of groundwater is presented in Table 1. Groundwater is characterized by high iron content up to 9.79 mg/l, manganese to 0.45 mg/l, and has an unpleasant hydrogen sulfide odor, the pH varies from 6.88 to 7.66.

Analysis of the stability and corrosivity of groundwater showed that it is low-corrosive and aggressive [2, 10]. As observed in the Table. 2 the maximum value of the Langelier index was (-0.41), the Riezer index - (+7.96).

Water quality indicators were determined by standard methods and with certified equipment of the laboratory. Express analysis of water quality in terms of pH, Eh, oxygen, total iron and manganese concentrations was conducted via the HI98128 tester, pHep 5 waterproof pH / C / F meter tester, Ecotest-120-pHH-M analyzer, ProfiLine Oxi 3205 oxygen meter, colorimetric kits and comparators for the determination of iron HACH 1467-01 and manganese HACH 1467-00.

At the deferrization station groundwater was pre-supplied with compressed air to oxidize Fe$^{2+}$ to Fe$^{3+}$. Then the water entered eight pressure filters of the FOV-2.6-6.0 brand with a diameter of 2.6 meters each and height of 3.74 meters, in which the flocculent sediment of iron hydroxide was retained. Filters were arranged in two parallel lines. Quartz sand with a fraction of 0.7–1.2 mm was used as a filtering charge. Disinfection of purified water was carried out via UV lamps UDV-7F-10-200.

The equipment was strapped using steel pipes. The equipment was obsolete and worn out. There were no facilities for cleaning and reuse of wash water filters at the station. Current deferrization station did not process water up to regulatory requirements and, thus, required reconstruction.

We proposed to engage a promising technology based on biological oxidation of iron and manganese by a group of iron bacteria [11-19]. First stage of the technology implies application of bioreactors with jet vacuum ejection and contact loading, second stage - filters with floating polystyrene foam FPZ-1 [18-19].
Technical solutions for reconstruction of deferrization station were based on the results of previous research of water purification technologies, i.e. [20-21].

### Table 1. Groundwater quality.

| Indicator          | № 4   | № 5   | № 6   |
|--------------------|-------|-------|-------|
| Odor, point        | 2-3   | 1-2   | 1-2   |
| Taste, point       | 1-2   | 1-2   | 1-2   |
| Turbidity, FTU     | 2.01-14.4 | 1.34-5.7 | 0.67-0.84 |
| Chromaticity, degrees | 16.6-50.6 | 10-29.4 | 10.1-16.6 |
| pH                 | 6.88-7.54 | 7.25-7.66 | 6.9-7.54 |
| TDS, mg/l          | 705-810 | 578-773 | 616-778 |
| Ammonium ion, mg/l | 0.012-0.003 | 0.003  | 0.003  |
| Nitrates, mg/l     | 0.14-0.57 | 0.13  | 0.13-0.17 |
| Iron mg/l          | 2.28-4.2 | 1.07-3.36 | 3.74-9.79 |
| Manganese, mg/l    | 0.18-0.45 | 0.09-0.21 | 0.12-0.38 |

### Table 2. Groundwater quality indicators

| Well | Ca, mg/l | Alkalinity mmol/l | pH | pHs | Langelier index \(I_L\) | Riezer index \(I_R\) |
|------|----------|-------------------|----|-----|-------------------------|---------------------|
| № 4  | 137.7    | 4                 | 7,13 | 7,52 | -0,39                   | 7.91                |
| № 5  | 124.6    | 4                 | 7,35 | 7,52 | -0,17                   | 7.69                |
| № 6  | 150      | 4.2               | 7,14 | 7,55 | -0,41                   | 7.96                |

3. Results and Discussion

Reconstruction of the deferrization station included the following types of work:

- inclusion of two bioreactors with jet vacuum ejection with a diameter of 3.0 and a height of 8.1 m in the technological scheme;
- installation of energy-saving valves with electric drives to control the process of filtering and flushing the load;
- replacement of steel pipelines with pipelines of non-plasticized polyvinyl chloride (PVC-U), which is chemically resistant, has a low roughness, self-cleaning ability, and is not subject to corrosion. (Table 2);
- conversion of FOV-2.6-6.0 filters to FPZ-1 filters with the replacement of sand filter loading by floating polystyrene foam with an advanced specific surface and the installation of drainage of low resistance;
- dismantling compressors and wash pumps for heavy-duty filters.

Reconstruction of the station was carried out in stages without shutdown. Figure 2 shows a general view of the deferrization station after reconstruction, and Table 3 shows data on the quality of purified water in the deferrization station which has been operating for four years.
Figure 2. Deferrization station after reconstruction (piping from PVC-free pipes).

Table 3. Quality of drinking water.

| Indicator                  | Drinking water | SanPiN 2.1.4.1074-01 |
|----------------------------|----------------|-----------------------|
| Smell, point               | 0              | 2                     |
| Taste, point               | 0              | 2                     |
| Turbidity, FTU             | < 1            | 2,6                   |
| Chromaticity, degrees      | 2.56-2.83      | 20                    |
| pH                         | 6.98-7.0       | 6-9                   |
| TDS, mg / l                | 675-682        | 1000                  |
| Ammonium ion, mg / l       | 0.36-0.4       | 2.6                   |
| Nitrites, mg / l           | 0.0036-0.0045  | 3                     |
| Nitrates, mg / l           | 1.36-1.48      | 45                    |
| Iron mg / l                | 0.075-0.084    | 0.3                   |
| Manganese, mg / l          | 0.025-0.028    | 0.1                   |

Application of new technology in the process of reconstruction, modernization of the deferrization station and, as a result, exclusion of pumping and compressor equipment from the technological scheme, as well as replacing old electrified valves with energy-saving valves, significantly reduced the station's power consumption (Table 4).

Table 4. Energy consumption of deferrization station.

| Power consumer                  | Energy consumed, kW per h |
|---------------------------------|---------------------------|
|                                 | Before reconstruction | After reconstruction|
| Total, including:               | 87.8                      | 0.96                   |
| Electric drives of bioreactors  | -                         | 0.18                   |
| Electric drives for filter gate | 38.6                      | 0.78                   |
| Compressor                      | 15.0                      | -                      |
| Wash pump                        | 34.2                      | -                      |

4. Conclusions
Analysis of the currently existing deferrization station demonstrated that the technology based on the use of simplified aeration followed by filtration does not provide sufficient drinking water quality. Technical depreciation of equipment, pipelines and fittings require reconstruction and modernization.

We introduced a new technology utilizing bioreactors and filters with a floating load, based on the biological oxidation of iron and manganese at the station with a capacity of 10.0 thousand m³ / day. This technology allowed to significantly reduce station’s energy consumption.

Evaluation of the groundwater processing station of four years in work allows us to believe in bright future in terms of further application of the new technology at the water supply and sewerage facilities.
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