Innovative unit for water treatment

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Abstract. The main pollutants of groundwater sources are compounds of iron, manganese and dissolved gases (carbon dioxide, hydrogen sulphide). Requirements to small capacity groundwater treatment units specified by a group of consumers were reviewed in this work. Various aeration units are used at the first stage as a part of simplified aeration method in deferrization process flow chart. There is offered an innovative unit which combines several processes, such as aeration, degassing, filtering through the layer of expandable polystyrene foam. The unit allows excluding additional aeration units, washing pumps and flush water storage tanks, as well as to intensify the aeration-degassing process, increase treatment efficiency and provide specified requirements. The article contains data on modular units with capacity up to 1 m³/h, their operating principle and the laboratory equipment used, as well as the aeration and degassing processes analysis results. When the level of dissolved oxygen in groundwater reaches 1.24-1.64 mg/l and free carbon dioxide - 46.8-50 mg/l outbound of the aeration units dissolved gases are blown out (up to 36%), the concentration of oxygen increases up to 7 mg/l, which is enough for an effective water deferrization process. At the same time, this process takes less time up to 2.7) in the aeration unit rather than in the aeration column.

1. Introduction
Consumers of groundwater sources for household and drinking purposes are not only large cities and towns, but small residential areas, new neighborhoods with local heat distribution and metering stations that include one or several groundwater wells. It is important to mention similar facilities in the railway industry, which use decentralized system of water supply from groundwater sources [1].

When justifying existing technologies and developing new ones and taking into consideration their rational fields of application, it is necessary to pay attention to some peculiarities, such as small size of water treatment units and equipment, limited height and space of water treatment facilities, operational independence, absence of maintenance stuff, etc.

Underground water sources used for household and drinking purposes in various groups of consumers is characterized by diverse physicochemical composition. Increased concentrations of iron, manganese, hardness salts, organic compound and dissolved gases (carbon dioxide, hydrogen sulphide) could be found in water [2-4]. Hydrogen pH varies in wide ranges from 6.6 to 8.04.

Groundwaters, unlike natural surface waters of rivers, lakes, reservoirs are more protected from the influence of anthropogenic and industrial load, they are less exposed to bacterial contamination. In
most cases, the TBC (Total Bacterial Count) value in water won't exceed standards, and TC (Total Coliforms) and TCB (Thermotolerant Coliform bacteria) are absent.

Taking into account the abovementioned data groundwater treatment technology should include degassing, clarification, deferrization and disinfection [2-9]. In this case, reagentless methods of deferrization are preferred [2-4]. In each particular case exploratory studies of groundwater samples and initial testing of the technology on active water supply intakes is required.

One of the most common methods of deferrization, which has a rational field of application, is the method of simplified aeration followed by filtering through nonreactive loads. Aerator-degasser, aeration column, air-and-water ejector, installed on the intake pipeline, compressor have found application as aeration units in single-stage technological scheme [3]; bioreactor with jet vacuum ejection - in two-stage schemes. High-rate filters with different types of loads are used as filtering facilities [10]. According to data [11-19] the processes of both physicochemical and biological deferrization can take place simultaneously in the layer of filter loads with different level of efficiency. The high efficiency of the process of aeration and degassing of groundwater significantly influences its deferrization. In this regard, the aim of the work was to study the process of aeration and degassing at an innovative unit and its analog.

2. Materials and methods

Object of the study is the current groundwater.

Water quality analysis was conducted on the certified laboratory equipment and in compliance with standard procedures. While conducting an express water quality analysis colorimetric kits and comparators were used to determine the presence of ferrous iron HACH 1467-01 and manganese HACH 1467-00. ProfiLineOxi 3205 by WTW portable oxygen meter with a case, and oxygen sensor CellOx 325 and accessories, as well as the AMT03 Series pH / ORP / TDS / analyzer were used to determine the concentration of oxygen.

Various aeration units (Figure 1) were used to conduct experiments focused on studying the aeration-degassing process: device (aeration unit) as part of groundwater treatment unit; single aeration column.

Figure 1. General view of groundwater treatment unit.

The general view of the groundwater treatment unit is shown on Figure 1a.

The unit consists of vertical cylindrical body with a diameter of 200 mm and a height of 2100 mm, divided by a horizontal grid into aeration and filtering zones [20-21]. The aeration zone with 500 mm of height is located in the upper part of the unit and supplied with dissolved gases retractor assembly. The filtering zone is situated in the lower part of the unit. The body of the unit is equipped with the mixing chamber with a diameter of 50 mm.
Technical characteristics and operation parameters are given in Table 1.

### Table 1. Technical characteristics and parameters of operation of the unit and air-stripping tower.

| Parameter                               | Value                  |
|-----------------------------------------|------------------------|
| Capacity, m³/h                          | 0.13-0.66              |
| Diameter of the ejector's nozzle, mm    | 2.1-4.0                |
| Filtering rate, m/h                     | 4-20                   |
| Contact time, min                       | 5.25-1.0               |
| Filter load                             | Expanded polystyrene   |
| Load granules size, mm                  | 1.0-2.5                |
| Thickness of the layer, m               | 1.0                    |
| Aeration column                         | 0.13-0.66              |
|                                        | 2.1-4.0                |
|                                        | 4-20                   |
|                                        | 14.4-2.74              |

Operational principle of the unit is: groundwater is supplied into the mixing chamber through an air inflow providing ejector, installed on the source water pipeline [20].

The lower end of the supply pipeline is equipped with a nozzle, which provides a tangential supply of water-air mixture and twisting of the flow, as well as a radial exit of water into the aeration zone, and as a result, intensive aeration of water by air. Simultaneously with the process of aeration the process of degassing of dissolved water gases (free carbon dioxide and hydrogen sulfide) which are removed from the aeration zone through the dissolved gases removal unit assembly is carried out. Pre-aerated water from the aeration zone enters the filtering zone with a downward flow in a layer of floating granular polystyrene foam load with an evolved specific surface on which the iron-depositing bacteria are fixed and held. As the water is filtered at a variable gradually decreasing rate, the processes of biological deferrization are carried out in the layer of load and treated water is supplied into the water storage system outside of the unit.

Flushing of filter load is processed with source water with intensity of 12-14 l/s m² for 4-6 minutes. The aeration column has a body made of composite material with 200 mm of diameter and 960 mm of height, the general view of which is shown on Figure 2b. The column is provided with an air valve installed in the body neck, equipped with source water, aerated water and excess air pipelines, control and safety valves, instrumentation and control equipment and samplers.

Water for analysis is supplied into the air-stripping tower by a pump from the pipeline which combines a group of wells. The ejector, is installed on the inlet water pipeline and serves as an air inflow device. Water-air mixture is supplied into the tower by the pipeline. The intake of mixed with air water is carried out by another pipeline, the lower end of which is located from the bottom of the column at a height of no more than 0.15 m. An air "plug" is formed in the upper part of the column. Excess air is removed by the pipe connected to the air valve.

Parameters of the aeration column operation are shown in Table 1.

WILO WJ-202EM/C (Qₘₐₓ = 4.5 m³/h, Nₘₐₓ = 34 m, 230 V, 50 Hz) pump (Figure 2c), unit's modes of operation control devices, such as: water meter VSKM 90-20; pressure gauge by Watts with a range of pressure measurement from 0 to 6 atm; household gas meter DTSG-1.6 with a range of air flow measurement from 0.04 to 1.6 m³/h were used to conduct the experiments.

## 3. Results

During the period of the experiments, the experimental units were supplied with underground water from a group of wells with following parameters are shown in Table 2. The concentration of dissolved oxygen - 1.24-1.64 mg/l. The redox potential changed widely - from 44 to -70 mV, water temperature did not exceed 10.8-11.6 °C. The content of dissolved carbon dioxide was determined by the precision chart. Its concentration in the source groundwater did not exceed 46.8-50 mg/l.
Table 2. Quality of groundwater.

| Indicator                        | Groundwater treatment unit capacity |
|----------------------------------|-------------------------------------|
| pH                               | 7.12-7.24                           |
| Odor, point                      | 2-3 (sulph.)                        |
| Taste, point                     | 1-2                                 |
| Turbidity, FTU                   | 0.67-14.4                           |
| TDS, mg/l                        | 578-810                             |
| Chromaticity, degrees            | 13.5-14.8                           |
| Permanganate oxidizability, mgO2/l | 2.1-3.1                             |
| Iron, mg/l                       | 5.95-7.29                           |
| Manganese, mg/l                  | 0.13-0.45                           |
| Ammonium ion, mg/l               | 0.67-1.4                            |
| Alkalinity mmol/l                | 5-6.5                               |

Specifically selected ejectors with the active nozzle diameter of 2.1-4.0 mm were installed on the source water inlet pipelines for air inflow supply purposes.

Water consumption in the aeration zone built into the body of the unit and in the aeration column varied from 0.13 to 0.66 m³/h with filtering rate (4-20 m/h) through the layer of expandable polystyrene foam load, located in the filtering zone of the unit. Inlet water pressure varied from 1.9 to 2.5 atm.

Water barbotage time in the aeration zone of the unit was from 5.2 to 1.0 minutes, including time, spent in the mixing chamber - from 45 to 9 seconds. Water barbotage time in the air stripping tower varied in the range of 14.4 to 2.9 minutes, which was 2.74 times more that in the unit itself.

As the result of the experiment it was found that the carbon dioxide removal effect varied from 24 to 36% in average (Figure 2). The longer the water was aerated, the more gas was removed.

![Figure 2. Dependence dioxide removal effect of barbotage time.](image)

As it can be seen from Figure 3 as the pH level increased due to carbon dioxide stripping, the Eh was increased and the process shifted in the area of biochemical activity thanks to iron-depositing bacteria [11, 18].

Comparative studies of the aeration-degassing process in various aeration units showed that the saturation of water with air oxygen up to 6.6-7 mg/l from the initial concentration of 1.24-1.64 mg/l is achieved in the aeration zone of the unit at a barbotage time approximately 2.7 times less than in the aeration column.
Figure 3. Dependence of Eh and pH in aeration-degassing process.

A distinctive feature of this unit is running the process of aeration, degassing and filtering in one stage in a single housing. Our newly developed unit will allow us to exclude additional aeration column, pumps, washing pumps, flush water storage tanks, intensify the process of aeration-degassing, increase the efficiency of treatment and provide the abovementioned specific requirements.

4. Conclusions
The assessment of source groundwater quality has been made, main pollutants have been identified, and the requirements to small-capacity water treatment units have been studied.

The new unit in a single body of which the simultaneous intensification of the aeration process is achieved and rapid oxidation of iron compounds is realized, which does not require prior and prolonged contact between water and air oxygen, which is typical for biological deferrization has been developed.

Experimental studies have been carried out to understand the process of aeration-degassing in various aeration devices. It was found that the effect of carbon dioxide removal is 24-36%, water is saturated with oxygen from the initial 4.5-5.5 times.

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