Compact groundwater treatment units

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Abstract. This thesis is dedicated to a systematic approach when choosing appropriate groundwater treatment technologies with regard to specific water consumers’ requirements. The groundwater analysis indicated that iron compounds were the main pollutants which could be found in biominerals, manganese, solution gases etc. This study represents the research results of compact groundwater treatment units which use nonchemical biological deferization methods and applied ozone treatment technologies. As the result, it was demonstrated that the source water with hydrogen-sulfide odor, 6.8 mg/l of iron content, 46 degrees of chromaticity and pH up to 7.6 was successfully treated in compliance with the statutory requirements. The authors also study wash water sediment structure and composition.

1. Introduction

Provision of water to consumers living in residential areas and to some industrial facilities is subject to severe public health, and environmental requirements. From this perspective it is important to follow a systematic approach when choosing existing and developing technologies with regard to diversity of physicochemical composition of natural water.

In reality there are some peculiarities and issues to encounter, such as abnormal irregularity and low water consumption which lead to underperformance of water treatment units; limited size of facilities intended for use of the treatment equipment; self-contained operation of certain elements or the whole unit itself. In compliance with the above mentioned peculiarities, specific requirements are imposed on the technology and compact water treatment units. The requirements are following: small size and low power consumption, avoidance of reagents usage, avoidance or low wash water waste and reliability of all engineering elements of the unit [1].

The choice of water treatment technology applied on large-scale water treatment plants as well as on small water treatment units should be determined by [2-4]:

- systematically collected natural water quality data for the last five years of monitoring;
- the detailed data analysis and determination of the top-priority pollutants (both natural and anthropogenic) and the range of their concentration;
- analysis of existing water treatment technologies and their fields of application or test results of new or modified technologies, that are in compliance with regulatory requirements to drinking quality water;
• choice of several alternative technologies based on former suggested classification of water sources and technological water treatment plans classifiers;
• techno economic comparison of several alternative technological plans in relation to a certain object

The water quality analysis of a number of groundwater sources located in different regions of Russia showed its diverse physicochemical composition. For example, groundwater is characterized by the presence of solution gases (O₂, H₂S and CO₂), iron content is up to 7 mg/dm³, manganese - up to 0.35 mg/dm³. Chlorides content is less that 74 mg/dm³, sulphates vary from 2.5 to 415 mg/dm³, dry residue varies from 160.8 to 756.6 mg/dm³, pH - from 6.8 to 7.53. Underground water from some sources is characterized by high hardness salts and ammonium ions (up to 2.5 mg/dm³). In certain cases organoleptic indicators exceed the maximum residue limit of turbidity 20 times and chromaticity - 3 times. Moreover, sometimes, water can have odor up to 3 points of intensity. There are organic substances in underground water which can be identified by chromaticity indicators (51.6-60 degrees) and oxidation characteristic (up to 4.5 mgO/dm³). In most cases underground water is bacteria-free.

Based on the given data, the technology of groundwater treatment should involve a combined treatment, including clearing, deferrization, odor-control, purification with the use of reagentless methods [4-7].

Over the last years biological deferrization and demanganation of groundwater was preferably used [7-17]. Physicochemical and biological deferrization processes run simultaneously, but with a different level of efficiency. In a number of situations, for example when the presence of some inhibitors can slow the oxidation process down, biological deferrization and demanganation can prevail. Biological methods can be used in conditions, where physicochemical methods cannot always be applied: dissolved oxygen concentration is 0.2-0.5 mg/dm³; pH - 7.2; oxidation-reduction potential Eh = 100-200 mV. Biological deferrization and demanganation are based on the ability of bacteria to oxidize bivalent ferrous iron and manganese by various enzymes and biopolymers. Oxidation processes may vary.

In cases when water is characterized by high chromaticity and ferrous iron in a form of organo-mineral complex it is reasonable to enhance the technology by using ozone treatment [18-19], or purify water using filtering apparatus with ozone pre-treatment [20].

2. Research Site
Object of the study is the current groundwater. Researched compact groundwater treatment units (capacity of production from 1 to 25 m³/h) are represented on the Figure 1.

The unit with the capacity of less than 1 m³/h consisted of a built-in mixing chamber, aeration zone and filter zone filled with expandable polystyrene. It was also equipped with an ejector, adjustable gas-trap, industrial pipelines, lock valves, control equipment [21]. The water filtration rate was 5-20 m/h, the contact time – 5-12 min. Filter media flushing was planned to be performed once every 2-3 days.

Units with capacity over 1 m³ were equipped with the ozone generator, filtering apparatus, ejectors, controller with sensors, residual ozone decomposer, electrical motor operated valves etc. [20,22]. The process of groundwater treatment was initially implemented by delivering water through the ejector to filtering apparatus. The ozonizer produced ozonized air mixture, which was delivered to the ejector under the influence of negative pressure where it mixed with the source water. Ozone was generated from the undrained atmosphere. Ozone dose varied from 1.3 to 1.6 mg/dm³, contact time - 10-12 minutes. The unit provided oxidation of ferrous iron compounds from Fe²⁺ to Fe³⁺ as well as oxidation of hydrogen sulphide and organic compounds. At the same time the process of water disinfection was being implemented. Oxidation products were captured by the resign charge, located in the filtering apparatus. Filtering speed varied from 6.4 to 7.8 m/h. Treated water was collected in a treated water tank. Air washing was required as sediment deposited. Filter media was flushed by treated water.
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. The following equipment was used for water treatment unit wash water sediment research: vacuum filter unit with a water stop – «Vladipor» type MFAS-OS-3 designed by the Water Supply and Sewerage department of the Moscow State (National Research) University of Civil Engineering, «Binder» drying chamber, and scanning electron microscope Quanta (Figure 2).

3. Results and discussion
Physicochemical composition of groundwater treated in the units is represented in Table 1.
The analysis of research results demonstrated compliance of treated water quality with SanPiN 2.1.4.10.74-01 regulatory requirements (Table 2).

Wash water sediment structure and composition research, demonstrated the prevailed presence of oxygen (40,4…57,1 %), ferrous iron (14,4…34,8 %), and carbon (9,5…10,7 %), in a less degree – nitrogen (1,3…2,8 %) and phosphorus (3,9…5,7%).

The result of microscopic analysis of the researched sediment samples determined the presence of myxobacteria covered with ferric hydroxide. These microorganisms belong to the group of thread bacteria *Leptothrix* and stalked bacteria *Galionella* (Figure 3).

**Table 1.** Quality of groundwater treated in the units.

| Indicator               | Groundwater treatment unit capacity |
|------------------------|-------------------------------------|
|                        | 4-8 m³/h                            | up to 25 m³/h                      |
| pH                     | 6.6…7.5                             | 6.9…7.9                            |
| Odor, point            | 2 (sulph.)                          | 2 (sulph.)                         |
| Turbidity, FTU         | 4.7…37                              | 7.2                                |
| Chromaticity, degrees  | 2…46                                | 4-25                               |
| Permanganate           | 1.0…1.7                             | 1.2                                |
| Oxidizability, mgO₂/dm³| 0.38…6.9                            | 0.72…1.3                          |
| Iron, mg / l           | 0.02…0.03                           | 0.03                               |

**Table 2.** Groundwater quality indicators.

| Indicator               | Groundwater treatment unit capacity | SanPiN 2.1.41074-01 [23] |
|------------------------|-------------------------------------|--------------------------|
|                        | 4-8 m³/h                            | up to 25 m³/h                      |
| pH                     | 6.6…8.1                             | 8.2                        | 6…9                      |
| Odor, point            | 0                                    | 0                          | 2                        |
| Turbidity, FTU         | 1.0…2.2                             | 1.2                        | 2.6                      |
| Chromaticity, degrees  | 2…8                                 | 2                          | 20                       |
| Iron, mg / l           | 0.07…0.17                           | 0.1                        | 0.3                      |
| Manganese, mg / l      | 0.005…0.02                          | 0.02                       | 0.1                      |

**Figure 3.** Microphotography of the sediment units.
4. Conclusions
The choice and rationalization of treatment technology, as well as the conditions of practical application of groundwater treatment units should be based on a systematic approach and depend on the qualitative composition of groundwater, required capacity and specific standards set by a certain group of consumers.

The analysis of research results showed that the tested groundwater treatment units with capacity up to 25 m³/h are in compliance with the requirements and able to produce drinking quality water.

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