Improving the quality of water treatment in boiler rooms through the use of natural sorbents

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Abstract. The article is devoted to the important requirements of the present time to the issues of operating reliability of heat-stressed boiler surfaces, the condition of the pipeline heat supply system and the quality of makeup water. The fight against the formation of scale and corrosion is the main task which is solved in the process of process water preparation, since significant contamination of the surfaces of heat exchange equipment with various kinds of deposits of mineral salts and the presence of corrosion products lead to a significant decrease in the efficiency of heating equipment operation, and the consequence is usually its failure. One of the essential factors in the operation of heat exchange equipment is the quality of the organization of the water-chemical regime - the determination of the necessary technological parameters, the composition of the filter load, the doses of all reagents, allowing to minimize the process of formation of mineral deposits and the area of corroded material structures. The article presents experimental data on the influence of natural sorbents on the quality of artesian water preparation for the needs of the population. The results of scientific research on the determination of composition and sorbent dose for water purification in the process of water treatment to prevent the formation of deposits and corrosion of equipment materials are presented. The assumption is confirmed that the use of natural sorbents reduces the content level of all "problematic" elements in the process of water treatment to standard values.

1. Introduction
We thank the management of the Beregovoye gas condensate field NOVATEK-Pur JSC YaNAD and personally the leading engineer for the operation of thermal equipment Mikhailov G.I. for the results of analyses of the qualitative composition of water from the underground water intake of the integrated gas treatment plant. We also express our gratitude to the reviewers for their attentive attitude to the manuscript and valuable recommendations.

The geographical and climatic location of Russia largely determines the duration of the heating season to almost 200 days in its central part and is approaching 300 days in Siberia and the Far North. In such conditions, a special role in ensuring a favorable and comfortable life for the population, as well as the normal functioning of the economy, is acquired by heat power and heat supply to rural settlements, remote settlements, and objects of extraction of various energy resources.

The main incentive for the introduction of energy and resource saving into the heat power industry was the new modern realities of the economy. This includes a sharp shortage of skilled workers, a constant increase in fuel prices, innovative development of heat supply. These conditions led to a significant tightening of the requirements for the operation reliability of heat-stressed surfaces when
heating boilers, the condition of the pipeline heat supply system and, accordingly, to makeup water. The fight against the formation of scale and corrosion is a primary task solved in the process of water treatment, since significant contamination of various surfaces of heat exchange equipment with corrosion formations and deposits of mineral salts leads to a decrease in the efficiency of equipment operation, and most often to failure.

The most important factor in the operation of heat exchange equipment is compliance with the water-chemical regime. It includes the maintenance of technological parameters, mass of reagent doses and composition of filter load. Strict compliance with the composition of the water-chemical regime allows to minimize the process and the rate of formation of mineral deposits and the corrosion area of structural materials. Improving the quality of physical and chemical parameters of feed water, which determine the possibility of its use in the heat and power system, will increase the trouble-free operation of boiler equipment.

The design standards for water treatment system in boiler houses are defined at the legislative level, in accordance with SNiP 11-35-76 (updated document SP SNiP 89.13330.2012) "Boiler units". In accordance with the norms, the operating mode of the boiler station should ensure the operation of all heating equipment and heating networks without scale deposition and corrosion on the internal working surfaces of the entire system. In addition to regulatory documents, in the process of water treatment, it is necessary to consider the recommendations of the equipment manufacturer in accordance with its technical documentation.

As practice shows, typical errors in boiler water treatment are the following: low efficiency or lack of pre-treatment, incorrect debugging of deaerators, errors in the calculation of water softening plants, incorrectly selected water-chemical regime.

In remote rural settlements, villages and temporary settlements, water from artesian springs is mainly used for the extraction of natural resources in the conditions of the Far North. Nevertheless, the quality of artesian water in natural conditions does not meet regulatory requirements by many indicators.

The purpose of the study is to conduct laboratory and production studies of the water treatment system during the operation of a boiler house in the under-populated locality of the West Siberian Artesian Basin in the conditions of the Far North.

2. Materials, Methods and Objects of research
The water from the underground water intake, which includes five artesian wells, is used for water supply of the block-modular boiler house and other facilities of the production site of the gas processing plant (GPP) of the Beregovoye gas condensate field of the Yamalo-Nenets Autonomous District. To determine the qualitative composition of water, laboratory studies of water samples taken from wells are carried out.

3. Results
Table 1 shows the composition analysis results of water from the wells of the gas processing plant (GPP) of the Beregovoye gas condensate field of the YaNAD. The analysis of the quality of artesian waters of the used aquifer is presented according to the results of laboratory analyses. Characterization of the chemical composition of artesian water was carried out in the branch of the FBHI "Center of Hygiene and Epidemiology" in the YaNAD in Purovsky, Krasnoselkup districts. Accredited testing laboratory center (certificate of accreditation No. ROSS.Yai.0001.510793).

As a result of the water chemical composition analyses, exceedances of the maximum permissible concentration of iron, manganese and organoleptic parameters are observed.

| Indicator                      | Value (min, max) | Norm | Deviation |
|-------------------------------|------------------|------|-----------|
| Dry residue, mg/dm³           | 0.15, 0.36       | 1000 |           |
Such a qualitative condition is characteristic of the groundwater of the entire West Siberian Artesian Basin [5].

It is known that the increased iron content in water contributes to the deposition of sediment in pipelines and its overgrowth. Exceeding the norm of manganese and silicon content in feed water causes scale formation on the heat exchange surfaces of screen and convective pipes and significantly reduces boiler efficiency.

To meet the strict requirements of the quality standard of purified water from artesian springs, it is necessary to use innovative technologies to ensure the high quality of the water used.

For water treatment, the equipment of the UVK-200 water treatment plant was installed in the GPP, which was supposed to provide a capacity of 200 m³/day. Commissioning work on the plant did not allow it to be brought to the declared planned design capacity of at least 200 m³/day.

The company's specialists constantly monitor the water quality at the inlet to the water treatment plant and at its outlet. According to the results of chemical analyses at the entrance to the water treatment plant (WTP), there are excesses in the presence of iron, manganese and organoleptic parameters (Figure 1) [2].
Figure 1. The content of "problematic" elements in the water before WTP.

At the WTP outlet, the concentration of organoleptic indicators is normalized to MPC. The iron - and manganese content is significantly reduced, but is not always brought into line with the MPC (Figure 2).

Figure 2. The content of "problematic" elements in the water after WTP.

The design solution according to the technological scheme and composition of the equipment of the UVK-200 water treatment plant of the Beregovoye gas condensate field, with such a composition of groundwater, did not meet the water quality requirements for the existing block-modular boiler house.
of the GPP, which threatened with sludge deposits and metal corrosion of boilers and pipelines of heating networks.

In the current UVK-200 installation, the water treatment process was carried out in several stages. The first stage of water treatment is the introduction of sodium hypochlorite reagent into the source water for the oxidation of dissolved iron, manganese, reducing oxidizability and color value, as well as water disinfection. Sodium hypochlorite, unlike other reagents (ozone, UV), has a prolonging effect and effectively suppresses pathogenic microflora in water. Further, coagulant (Aquaaurat-30) and flocculant (Praestol) are successively dosed into the water. The coagulant sorbs oxidized impurities, and the flocculant creates a sediment of a larger structure.

At the second stage, water is supplied to the clarification - de-ironing stage. Oxidized iron, manganese and organic impurities in the water form a sediment under the action of reagents and are captured by filters. The filter loading at this stage is hydro anthracite and a supporting layer of gravel.

The third stage is water purification using three sorption filters. They are used for the final removal of organic compounds that cause the oxidizability, the color value of water, as well as the residues of active chlorine after using the oxidizer. There is also an improvement in water organoleptic properties - smell and taste. Activated carbon is used as a filter loading.

At the fourth stage, the purified water is fed to the softening filter, where the hardness salts are removed.

According to the results of the analysis of the existing installation operation, it was revealed that the reason for its inefficient operation is the incorrect selection of filter elements and filtration modes. Specialists of the department of thermal equipment operation of the enterprise performed calculations of all filtration stages of the water treatment plant. The calculation results showed an insufficient number of filters in stages 2, 3 and 4. According to calculations, 7 filters are not enough in the second stage, 4 filters - in the third stage, and 7 filters - in the fourth stage. In this regard, a new technological filtration scheme was proposed [2].

In accordance with the new technological scheme, after mixing, water enters the clarification filters of the 1st stage, where hydro anthracite and gravel are replaced by a filter loading - the ODM-2F sorbent and a supporting layer of quartz sand.

When the initial composition of water moves through the ODM-2F sorbent, due to the catalytic film, particles of contaminants smaller than the channels between the particles "stick". At the 1st stage of filtration, suspensions, mechanical impurities are removed and partial purification from iron and manganese compounds occurs.

Gaize serves as raw material for the filter loading of the brand ODM-2F [4]. Gaize is a light thin-porous siliceous dense rock, consisting of silicified opal valves of diatoms and their fragments in its mass. The size of macropores is from 10-3 mm. ODM-2F is a granular terracotta-colored material with the content of the main components: SiO₂ up to 86%; Fe₂O₃ not more than 3.2%; Al₂O₃, MgO, CaO - up to 8%.

One gram of ODM-2F has a developed specific surface area - about 180 square meters. According to the mechanical strength the ODM-2F material surpasses all the most well-known domestic filter materials. Standard fractions of ODM-2F: 0.8...2.0 mm; 2.0...5.0 mm; 5.0...10.0 mm; 10.0...40.0 mm. Using the ODM-2F shows that optimal parameters for filtrate quality and operating characteristics of the filter can be achieved with a grain size of 0.8...2.0 mm. A sorbent with this grain size was used for filters loading.

Further, the clarified water enters the filters of the 2nd stage for the de-ironing process, where it is proposed to use an AC sorbent with a supporting layer of quartz sand as part of the water treatment system modernization.

AC sorbent is a natural inorganic sorbent based on opal cristobalite rocks. Chemical composition of the AC sorbent: - SiO₂ - 78%; MgO - 0.5%; Fe₂O₃ - 5%; Al₂O₃ - 7%; silicate module SiO₂/Al₂O₃ - 11.14%.

The composition of the studied material fractions is basically homogeneous and therefore there is no need to enrich it to remove the smallest and largest fractions. Table 2 presents a comparison of the
characteristics of the AC sorbent with other sorbents most used in the water treatment process [6].

The table shows that the porosity and density of the proposed sorbent is comparable to the porosity and density of traditional sorbents. Sorbents based on glauconite with a binder are characterized by higher porosity. Unfortunately, the use of a binder in the synthesis of sorbents significantly increases the cost of such sorbents.

For filter materials, the important properties are grindability, abrasion resistance and mechanical strength.

| Table 2. Mechanical properties of sorbents. |
|---------------------------------------------|
| Sorbent                                      | Density, t/m³ | Porosity, % | Grindability, % | Wearability, % | Nom. mech. strength, % |
|---------------------------------------------|---------------|-------------|-----------------|----------------|------------------------|
| Strength limits                              | –             | –           | 4               | 0.5            | 1                      |
| Opal crystobalite rock (AC sorbent)          | 0.68 - 0.72   | 46 - 52     | 0.04            | 0.06           | 0.79                   |
| Granular glauconite (binder zirconium hydroxide) | 0.8 - 0.9     | 70.3        | 0.16            | 0.2            | 1.1                    |
| Granular glauconite (binder aluminophosphates) | 0.8-0.9       | 6 8.0       | 0.02            | 0.01           | 0.72                   |
| Activated aluminosilicate adsorbent "Glint"  | 1.1-1.2       | 45 - 65     | <0.5            | <5.0           | —                      |

The AC sorbent has high mechanical strength. The mechanical properties of sorbents are much lower than the accepted strength limits. The mechanical characteristics of the AC sorbent are not inferior to similar indicators of known sorbents.

The parameters of the chemical stability of the AC sorbent are given in Table 3.

| Table 3. Chemical stability of the AC sorbent. |
|-----------------------------------------------|
| Indicator                                    | Acidic (HCl) | Alkaline (NaOH) | Neutral (NaCl) |
|                                               | Increase, mg/dm³ | Norm, mg/dm³ | Increase, mg/dm³ | Norm, mg/dm³ | Increase, mg/dm³ | Norm, mg/dm³ |
| SiO₂                                          | 27.4          | 10            | 99              | 10           | 12.5              | 10           |
| Dry residue                                   | 138           | 20            | 98              | 20           | 20.5              | 20           |
| Oxidizability                                 | 2.6           | 10            | 6.3             | 10           | 1.8               | 10           |

The AC sorbent is chemically unstable not only in acidic, but also in alkaline media. If we consider a neutral medium, then, considering measurement errors, the increase in silicic acid, dry residue and oxidizability practically corresponds to acceptable standards [1,3,4].

Any sorbent must be checked for the transfer of harmful impurities into the water during filtration process. Water after sorbent treatment is tested for total hardness, silicon, calcium, magnesium, iron by atomic absorption method and pH level. Figure 3 shows the content of these elements in water after its contact on the second stage filters with the washed AC sorbent [2].
Figure 3. The content of ingredients in water after contact with the AC sorbent.

To remove organic impurities, as well as excess reagent, water is sent to the sorption stage - filters of the third stage loaded with activated carbon.

The filters of the fourth stage are loaded with zeolite - which is a good sorbent and ion exchange loading. Ammonium salts, nitrites, nitrates, and heavy metals are removed from the water.

4. Conclusion
The analysis of the existing water treatment system operation at the enterprise showed that when the productivity is brought to the required value, the quality of water supplied to the consumer does not meet the requirements of standards for iron, manganese, ammonium ions and hardness. It is revealed that the reason for the inefficient operation is the incorrect selection of filter elements and filtration modes. A technological scheme of water purification has been developed to meet the requirements of standards and the required productivity. It includes filters with catalytic loads (AC sorbent, ODM-2F, activated carbon). The result of the use of natural sorbents is a reduction in the content of all "problematic" elements to standard values.

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