Water treatment of surface water using a ferrite reagent

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Abstract. The article presents the research results for a water treatment technology that removes chemical impurities with a ferrite reagent. The process scheme is a hydrocyclone filter for preliminary water purification from large suspensions, a vertical settler, a chamber for mixing the components of the reagent and a centrifuge for sludge dewatering, which can be used as a magnet. In the course of the experiments, the required cooling time intervals were established and the absorption effect of the ferrite reagent with respect to chemical impurities was determined. The settling was carried out at various intervals for 0.3, 1, 2 and 4 hours. It was found that the maximum permissible concentration of impurities in the test water was achieved within 2 hours of settling at a dose of 50 ml.

1. Introduction
Typically, the water provided for use cannot be used for the intended purpose without special treatment [1]. The treatment method is selected individually for each category of water, based on the composition and quality requirements of the manufacturers, as well as the constancy of these parameters [2]. The optimal solution, both from a technical point of view and in terms of economic indicators, is possible only when the water treatment scheme is modeled by the design of the equipment, types of materials and the chemical composition of the water [3–5].

The main methods of water purification applicable in practice are filtration, demanganation, neutralization, reduction of hardness, desalting, deferrization, etc [6, 7].

Sources of surface water pollution are wastewater from industrial and agricultural enterprises. If not properly treated wastewater enters natural surface waters, it leads to the ingress of chemical impurities such as zinc, copper, phenols, aluminum, ammonium nitrogen, oil products that have a cumulative effect over the years [8–11].

Most of the farms use water from surface water sources as irrigation water, while preliminary treatment is not performed. That is, the chemical impurities present get into the soil, agricultural products and, of course, into the groundwater [12–15]. The best option is preliminary treatment of surface water for irrigation of crops, which will prevent the ingress of chemically hazardous impurities into groundwater and soil [16–20].

2. Materials and methods
In this work, we propose a water treatment technology using a ferrite reagent for purifying surface water from chemical impurities exceeding the maximum permissible concentration [1, 2, 4]. Recently, the ferritization method has found practical application as a transformation of the water purification
method with the addition of reagents and flocculants using metal-containing catalysts. The ferritization method consists in the fact that the crystalline lattice is hydro-entrapped from the waste water by means of a magnetized iron-containing hydro-oxidant. The formation of ferruginous melinite, in which hydrogen is replaced with a metal-containing element, this substitution is called ferrites [16].

We propose a water treatment technology using a reagent to improve the quality of surface water. The process scheme involves a hydrocyclone filter for preliminary water purification from large suspensions, a vertical settler, a chamber for mixing the components of the reagent and a centrifuge for sludge dewatering, which can be used as a magnet (Figure 1).

Figure 1. Scheme of water treatment using a ferrite reagent: 1 - hydrocyclone, 2 - chamber for receiving primary treatment sludge, 3 - vertical settling tank; 4 - reagent chamber with a stirrer, 5 - centrifuge for sludge dewatering, 6 - gate valve.

In recent years and at present, significant work has been carried out to intensify and introduce new technological schemes for water treatment and sludge dehydration with the aim of using it as a magnet [11, 21–23].

Before settling begins, it is necessary to prepare a ferrite suspension, since a fresh solution must be prepared before each use.

To prepare the suspension, it is necessary to take a sample of ferrous sulfate FeSO₄·7H₂O, caustic soda (NaOH) and sodium nitrate (NaNO₃). We withstand the suspension for 20 minutes, to enter into the reaction of all the above chemical preparations, then add dosed to the test water, after which we carry out a photocolorimetric analysis for the content of the investigated substances and for their residual concentration.

After preparing the suspension, the test water was poured into three flasks, and then the suspension was added using a Mohr pipette in volumes of 20, 30 and 50 ml, at certain time intervals the surface
waters were taken for chemical analysis to determine the concentration of impurities. The time of contact of the suspension with the test water was 0.3, 1, 2, and 4 hours.

3. Results and discussions
The aim of the research is to treat surface waters using a ferrite reagent with further centrifugation of the sediment, which can be used as a magnet. Before settling the test water, it is necessary to conduct a chemical analysis for the content of impurities, the results of which are shown in Table 1.

| No. | Chemical substance | Initial water concentration, mg/l | Maximum permissible concentration, mg/l |
|-----|--------------------|-----------------------------------|----------------------------------------|
| 1   | Iron total         | 8.8                               | 0.3                                    |
| 2   | Zinc               | 0.3                               | 0.01                                   |
| 3   | Copper             | 0.8                               | 0.001                                  |
| 4   | Ammonium           | 2.6                               | 2                                      |
| 5   | Petroleum products | 0.56                              | 0.3                                    |

According to the results of the study, it can be seen that all substances that were identified in the source water exceed the maximum permissible concentration. After the chemical analysis, sedimentation was carried out with different time intervals and doses of the ferrite reagent to identify the optimal parameters at which the best sorption properties of the reagent with respect to chemical elements would be revealed.

| No. | Name of substance | Standing time, hour | C_{init}, mg/l | Maximum permissible concentration, mg/l |
|-----|-------------------|---------------------|----------------|----------------------------------------|
|     |                   | 0.3 hours | 1 hour | 2 hours | 4 hours |                      |
| 1   | Iron total        | 75        | 3.5    | 1.2     | 8.8     | 0.3                  |
| 2   | Zinc              | 0.25      | 0.13   | 0.09    | 0.3     | 0.01                 |
| 3   | Copper            | 0.6       | 0.48   | 0.32    | No      | 0.8                  | 0.001               |
| 4   | Ammonium          | 2.5       | 1.95   | 1.93    | sorption| 2.6                  | 2                   |
| 5   | Petroleum products| 0.53      | 0.5    | 0.49    | 0.56    | 0.3                  |

20 ml of suspension

| No. | Name of substance | Standing time, hour | C_{init}, mg/l | Maximum permissible concentration, mg/l |
|-----|-------------------|---------------------|----------------|----------------------------------------|
| 1   | Iron total        | 5.5                 | 2.36           | 8.8                                     | 0.3                  |
| 2   | Zinc              | 0.17                | 0.12           | 0.1                                      | 0.3                  | 0.01                 |
| 3   | Copper            | 0.53                | 0.32           | 0.12                                    | No                   | 0.8                  | 0.001               |
| 4   | Ammonium          | 2.4                 | 1.92           | 1.9                                      | sorption             | 1.9                  | 2                   |
| 5   | Petroleum products| 0.44                | 0.42           | 0.4                                      | 0.56                 | 0.3                  |

30 ml of suspension

| No. | Name of substance | Standing time, hour | C_{init}, mg/l | Maximum permissible concentration, mg/l |
|-----|-------------------|---------------------|----------------|----------------------------------------|
| 1   | Iron total        | 2.5                 | 0.95           | 8.8                                     | 0.3                  |
| 2   | Zinc              | 0.03                | 0.025          | 0.009                                   | 0.3                  | 0.01                 |
| 3   | Copper            | 0.01                | 0.003          | 0.001                                   | No                   | 0.8                  | 0.001               |
| 4   | Ammonium          | 2.3                 | 1.9            | 1.9                                      | sorption             | 2.6                  | 2                   |
| 5   | Petroleum products| 0.38                | 0.36           | 0.27                                     | 0.56                 | 0.3                  |

50 ml of suspension
In the course of the experiments, the ability of the ferrite reagent to precipitate ions of chemical elements at various intervals was studied. The results of the experiments carried out on sorption properties are shown in Table 3.

According to the results of photocolorimetric analysis, it can be seen that the effective removal of chemical impurities using a ferrite suspension at a dose of 50 ml is 2 hours of contact with the test water. According to these experiments, as a result of statistical processing, dependences were obtained, presented in the form of a power-law model, and characterizing the relationship between the concentration of the studied impurities and the reaction time of ferrite reagents with surface waters, Figure 2.

![Figure 2. Efficiency of zinc removal depending on the time of contact with ferrite reagents](image)

**4. Conclusion**

According to the research results, graphs were obtained that characterize the dependence of the concentration of impurities on the reaction time of ferrite reagents with the test water. Under static conditions, the optimal contact time of the ferrite suspension was determined, as well as its volume poured into the test water. The maximum absorption effect was observed within 2 hours after the addition of ferrite reagents in a volume of 50 ml, during this period of time all chemical impurities precipitated into a yellow-brown precipitate. After the lapse of time, a chemical analysis was carried out for the presence of residual concentration of heavy metals and ammonium ions, which showed the removal of these impurities by 99%.

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