Wastewater preparation for irrigation based on the sorption filtering technology

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Abstract. The article presents the results of scientific research in the field of wastewater purification from heavy metals using natural sorbents as a filter load for a sorption filter. Based on the obtained experimental data, the particle size distribution of the natural sorbent is correctly selected, which in turn directly affects the quality of wastewater purification from various harmful impurities. During the experiments, the required filtering time intervals were established and the absorption effect of the sorbent in relation to heavy metals and ammonium was determined. Filtering was carried out at various intervals for 0.2, 1, 12, and 24 hours. It was found that the achievement of the maximum permissible concentration of impurities in wastewater was reached in 24 hours of filtration. The conducted studies will allow one to make the more reliable calculations and choose the optimal filter load for wastewater purification from heavy metals in the sorption filter, which in turn will allow for the further use of treated wastewater in irrigation systems and increase the economic effect when irrigating crops.

1. Introduction
The quality of irrigation water plays an exceptional role in obtaining the required yields of agricultural products [1–3]. One of the priority areas for growing agricultural products is wastewater irrigation [4, 5]. That is why it is necessary to carry out the preparation and treatment of effluents [6, 7]. The cleaning technology itself is quite complex and requires the necessary knowledge, and the complexity is associated with the presence of all kinds of impurities in the effluents, which vary in their quantitative and qualitative composition. Nowadays, various methods and techniques are used for wastewater purification, but it is necessary to develop and implement advanced technologies in the enterprises of the agro-industrial complex [8, 9]. We propose a new solution in the preparation and purification of effluents as a result of the use of a natural sorbent [10, 11], which has a high degree of absorption capacity [12–16]. This is characterized by volumetric capacity, which is determined by the number of ions absorbing the adsorbent in a unit mass or volume. Based on the studies, the feasibility of using a natural sorbent at sewage stations during wastewater purification from heavy metal ions and ammonium nitrogen has been proved.

2. Materials and methods
The wastewater treatment plant developed in laboratory conditions is a cylinder with a volume of 1000 ml, in which zeolite is filled with various fractions as a filter charge and a conical flask with a volume of 1000 ml for the filtrate to be taken. Before filling, natural zeolite was sieved through sieves of
various fractions. For layer-by-layer loading, 0.75 mm, 1.25 mm and 3.5 mm zeolite fractions were selected (Figure 1). A scheme of the laboratory installation of wastewater purification from heavy metals and ammonium ions is presented in Figure 1.

![Figure 1](image)

**Figure 1.** Scheme of the laboratory experimental installation of wastewater purification: 1 – wastewater; 2 – zeolite with a fraction of 3.5 mm; 3 – zeolite with a fraction of 1.25 mm; 4 – zeolite with a fraction of 0.75 mm; 5 – a layer of filter wool; 6 – container for taking the filtrate.

| Name of substance | Solution Numbers | Concentration value, mg / dm³ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------------|------------------|-----------------------------|---|---|---|---|---|---|---|
| Common iron       | 0                |                             | 0.1| 1.0| 3.0| 6.0| 10.0| - |
| Iron (II)         | 0                |                             | 0.05| 0.1| 1.0| 3.0| 6.0| - |
| Iron (III)        | 0                |                             | 0.1| 0.4| 0.7| 1.0| 1.2| - |
| Chromium          | 0                |                             | 0.03| 0.1| 0.5| 1.0| 1.5| 2.0|
| Zinc              | 0                |                             | 0.1| 0.5| 1.0| 2.0| 4.0| - |
| Copper            | 0                |                             | 0.05| 0.5| 1.0| 4.0| 8.0| - |
| Cadmium           | 0                |                             | 0.005| 0.01| 0.03| 0.06| 0.1| - |
| Ammonium          | 0                |                             | 0.5| 4.0| 10.0| 16.0| 20.0| - |
Before filtering, samples of zeolite with a fraction of 3.5 mm in weight of 60 grams, zeolite in a fraction of 1.25 mm and a weight of 60 grams, and zeolite in a fraction of 0.75 mm weighing 80 grams were selected, and then the samples were weighed in layers into the cylinder. The investigated effluents were taken for chemical analysis to determine the content of harmful impurities before filtering. Calibration solutions were prepared using state standard samples with various concentrations of the impurities studied in the effluents (Table 1).

Next, filtering was carried out at various time intervals of 0.2, 1, 12 and 24 hours.

3. Results and discussion

The result of the chemical analysis showed that the content of heavy metals and ammonium exceeded the maximum permissible concentration, so wastewater purification is necessary, since they are not suitable as irrigation water (Figure 2).

![Figure 2. Content of harmful substances in the studied effluents, %.

Table 2. Determination of the absorption properties of the natural sorbent at different time intervals

| No. | Name of substance | Zeolite of various fractions 0.75, 1.25 and 3.5 mm | Maximum allowable concentration, mg/l |
|-----|------------------|-------------------------------------------------|--------------------------------------|
|     |                  | 20 minutes (0.2 h) | 1 hour | 12 hours | 24 hours |                                                  |
| 1   | Common iron      | 3.5                | 1.5    | 0.65     | 0.3      | 0.3                                               |
| 2   | Iron (II)        | 2.6                | 1.2    | 0.37     | 0.1      | 0.1                                               |
| 3   | Iron (III)       | 2.2                | 1.23   | 0.24     | 0.1      | 0.1                                               |
| 4   | Chromium         | 0.2                | 0.16   | 0.09     | 0.07     | 0.07                                              |
| 5   | Zinc             | 0.15               | 0.09   | 0.03     | 0.01     | 0.01                                              |
| 6   | Copper           | 0.1                | 0.01   | 0.0042   | 0.001    | 0.001                                             |
| 7   | Cadmium          | 0.09               | 0.01   | 0.0092   | 0.005    | 0.005                                             |
| 8   | Ammonium         | 7.4                | 4.4    | 2.9      | 2.0      | 2.0                                               |

The filtration was carried out through natural zeolite which was used as a sorption charge. A layer of filter wool was placed in the cylinder so that the sorbent would not spill, the first layer of zeolite with a fraction of 0.75 mm, the second layer of zeolite with a fraction of 1.25 mm and the fraction of
zeolite of 3.5 mm. After the preparation of the filter unit, the studied effluents were filtered for 0.2 hours, 1, 12, and 24 hours; after each period of filtration, a photocolorimetric analysis of wastewater was carried out for the residual concentration of heavy metals and ammonium (Table 2).

The studies show that the most effective absorption process is observed within 24 hours of filtering wastewater through a zeolite load (Figure 3).

![Diagram of the absorption properties of zeolite with a fraction of 0.75 mm, 1.25 mm and 3.5 mm after filtering.](image)

**Figure 3.** Diagram of the absorption properties of zeolite with a fraction of 0.75 mm, 1.25 mm and 3.5 mm after filtering.

After 24 hours of filtering wastewater through a zeolite filter with layer-by-layer sorption loading, a 3-fold decrease in the concentration of all studied impurities was observed [17, 18]. According to the results of the study, it can be seen that a zeolite load with a correctly selected fractional composition and particle size distribution works up to 100% of wastewater purification from impurities of heavy metals and ammonium ions.

As a result of statistical processing of the experimental data, dependences are obtained that are presented in the form of a power-law model and characterize the relationship between the concentration of the studied impurities and the contact time of wastewater with natural zeolite.

4. Conclusion

Based on the results of chemical analysis, it was found that wastewater purification must be carried out, since in most cases the content of heavy metals and ammonium exceeds the maximum permissible concentration. The studies carried out in a laboratory wastewater purification plant and graduated solutions developed with the help of state standard samples with different concentrations of the impurities studied in the effluent have shown that the optimal filtering time is 24 hours. Due to the sorption properties of natural zeolite with a correctly selected fractional composition, which was used as a filter load, the absorption of heavy metal compounds and ammonium ions is 100%. The concentration of all investigated impurities was reduced to the maximum permissible, which corresponds to sanitary standards in relation to wastewater; therefore, the use of these effluents as irrigation water has a high economic effect for irrigation of crops.
a) A graph of the effectiveness of the removal of total iron from wastewater.

b) A graph of the efficiency of copper removal from wastewater.

**Figure 4.** Efficiency of removing impurities from wastewater depending on the time of contact with zeolite.

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