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# The problem of natural deep groundwater pollution in Ukraine and ways of its solution

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**Summary to the submission webpage:** Deep groundwater with high iron content is widely used for drinking water supply. In Ukraine, physicochemical methods are used for treatment of such waters. Rapid filters are the main element in the technological schemes of physicochemical iron removal from groundwater. It is possible to significantly increase the reliability and efficiency of purification, reduce the cost of treated water due to a reasonable choice of rational process and design parameters and modes of operation of such filters. It is realistic to achieve such a result only by using mathematical modeling. The conceptual scheme of iron removal at the rapid filter, which served as a basis for the adopted mathematical model, is given, as well as the main tasks of technological modeling are formulated.

**Keywords**: deep groundwater; iron removal; depth filtration; mathematical modeling

Deep groundwaters in Ukraine are an important resource for drinking water supply. Their exploitable reserves are estimated at $15.1 \cdot 10^6$ $m^3/day$. At the same time, about 6% of these reserves is used in Ukraine as a whole, most of all in Lviv region (19.4%), Volyn region (19.7%) and Khmelnitsky region (18.0%). Often, they are an indispensable source of (conditionally) clean water, especially in rural areas. The rocks forming water-saturated strata, are often characterized by the presence of significant amounts of poorly soluble iron compounds. Water within high-pressure (artesian) horizon composed of such rocks, as a rule, contains an increased content of divalent iron due to lack of hydraulic connection between horizon and atmosphere. The iron concentration varies within wide range - from 1 to 20 *mg/l* and more. Such water is inadmissible to use for drinking needs without special treatment (iron removal) [1].

To remove excessive iron from groundwater, the physicochemical methods are widely used in Ukraine, which are characterized by relative ease of control, flexibility in changing the operation modes of water treatment plants and economic advantages [2]. When there is a high demand for clean water, the operation of the treatment plant must be intensified. Under such conditions, rapid filters have proven to be the best, which are capable of treating large volumes of contaminated water in in a short period of time.

However, as the extensive experience of practical use of specialized filters shows, it is rarely possible to implement their productive operation for a long period of time. Frequently emergency situations arise when the filter is not able to purify groundwater at all. More often, mechanical energy expenditure of the filter is too high and the water quality does not meet the established standards due to excessive contamination of the filter media. Then it is necessary to take emergency measures usually without proper justification. As a result, the cost of treated water is too high. Given the extent to which contaminated groundwater is used in the water supply, it is important to increase the efficiency of water treatment plants and structures and to prevent critical situations.

To achieve maximum efficiency from filtration facilities in principle is realistic only relying on reliable methods of calculating the operation of rapid filters for iron removal, provided they are supported by reliable baseline information. It is desirable to obtain such information in relation to specific technological conditions at the operating filtration facility, involving for the processing of measurement data a robust method of predicting the physical and chemical situation in the packed bed and at its outlet. Such a method can be developed only on the basis of an adequate mathematical model, which formally expresses the conservation laws and generalized patterns of transformation of iron compounds and their interphase exchange.

The structure of the basic mathematical model is visualized by the conceptual model shown in **Fig. 1**. This model reflects in general the essential differences in the behavior of divalent and trivalent iron (there

are two interrelated compartments in the mathematical model), peculiarities of the filtration flow process in the clogged granular medium (a separate compartment).

In order to formulate the underlying mathematical model, the formal representation of the rates of all the regime-forming processes depending on the desired characteristics (concentrations, head) is of key importance. As an illustrative example we can cite the corresponding dependence describing the oxidation process of ferrous iron

$$\frac{\partial S_a}{\partial t} = k_a f_a(S_h)(S_{ma} - S_a)C_a . \quad (1)$$

Here $S_a$ is the concentration of $Fe^{2+}$; $k_a$ is the reduced rate coefficient of $Fe^{2+}$ adsorption; $f_a$ is the autocatalytic function describing adsorption of $Fe^{2+}$ on the newly formed deposit; $S_h$ is the concentration of deposited hydroxide ($Fe^{3+}$) particles; $S_{ma}$ is the adsorption capacity of the filter material with respect to ions $Fe^{2+}$.

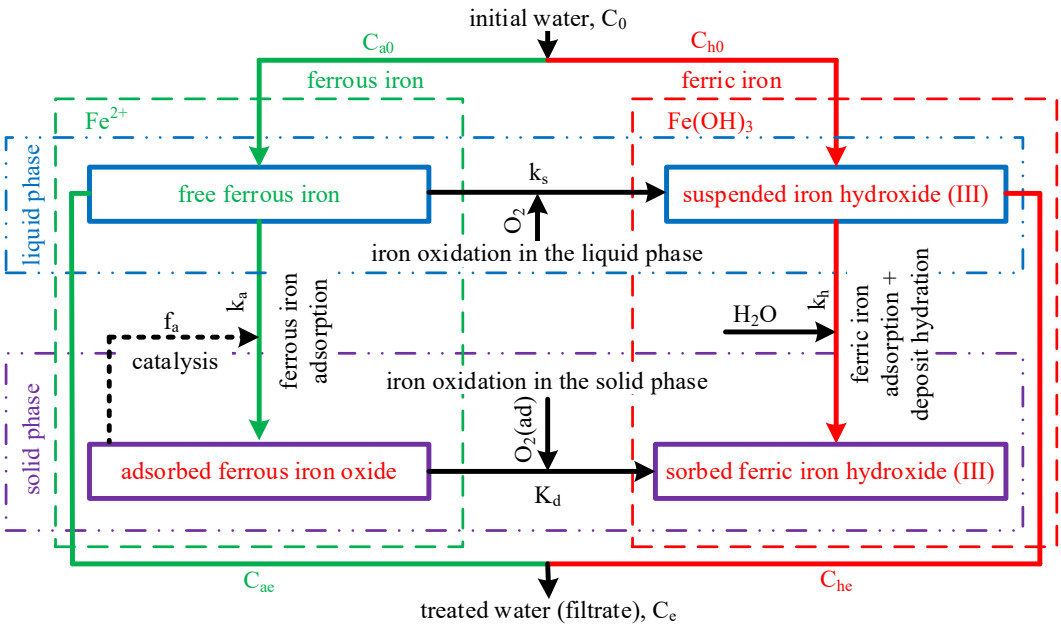


**Figure 1** Scheme of physicochemical removal of iron on the rapid filter

From a mathematical point of view, it is significant that this model of the of the process, which is crucial for the removal of excess iron from contaminated artesian water, as well as a number of other similar models, are non-linear. Thus, it greatly complicates the application of analytical methods, and consequently, the derivation of calculation dependencies and, as a result, the processing of experimental data and the determination of the values of the model coefficients.

In order to maximize the efficiency of filtration plants in iron removal from deep groundwater, it is necessary, on the basis of the technological modeling and using the procedure of applied optimization to establish the rational:

- control algorithm,
- design parameters (height of the filter media and effective grain size).

Such analysis is supposed to be performed on the basis of technological and economic calculations of reduced costs with separate accounting for their components (capital and operating costs).

## REFERENCES

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