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Study Of The Properties Of Iron Compounds In Natural Water

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Abstract. This work considers the physicochemical properties of iron compounds present in natural waters, as well as factors affecting their form, behavior and stability. Particular attention is paid to the distribution of iron in divalent (Fe^{2+}) and trivalent (Fe^{3+}) forms, their interaction with components of the aquatic environment, as well as the processes of oxidation, reduction and precipitation. Water samples from various natural sources were analyzed to determine the total iron concentration and its individual forms, as well as the parameters affecting it - pH, Eh, temperature and degree of mineralization. The results obtained allow for a deeper understanding of iron migration in natural water bodies, as well as an assessment of the risks associated with exceeding the maximum permissible concentration. The work may be useful for specialists in the field of water supply, ecology and hydrochemistry.

Keywords: natural water, iron compounds, Fe(II), Fe(III), redox conditions, pH, hydrochemistry, total iron, aquatic ecosystems, water quality, water treatment, iron precipitation.

Introduction. In recent years, increasing attention has been paid to the development of methods for cleaning industrial and domestic wastewater from organic environmental pollutants, which are characterized by increased resistance to biodegradation and toxicity to microorganisms. To solve the problem, along with other methods, it is proposed to use chemical treatment technologies that allow for the complete decomposition of pollutants or their conversion into forms capable of further biodegradation. Among such technologies, advanced oxidation systems that have shown high efficiency against a number of persistent pollutants, such as pesticides, surfactants, dyes, and pharmaceuticals, are the most promising and widely used [1].

Recently, there has been an increase in work aimed at solving practical problems in the field of colloidal chemistry. This is due both to the high level of study of colloidal systems and the need and possibilities of using them in the chemical industry and mechanical engineering, as well as in agriculture and animal husbandry, for example, to increase productivity, and in medicine to create highly effective medical products. To obtain colloidal systems, the most modern technologies for dispersing substances and stabilizing colloidal solutions are used. Various types of colloidal systems exist in nature or are formed unintentionally in industrial and natural processes. This happens, for example, during the extraction and purification of natural waters, which is associated with the high stability of colloidal solutions based on iron compounds. Colloids of iron compounds are present in natural waters of the USA, Germany, Finland, Russia, etc., and it has been established that humus-type organic substances also play an important role in their formation [2, 3]. In Russia, where wetlands occupy half of the country's territory and almost all water sources contain iron ions, the problem of removing colloids is very urgent.

Despite the abundance of open water bodies in the Siberian regions, groundwater is mainly used for drinking water supply [4, 5]. The composition of impurities in groundwater varies in qualitative composition and quantitative ratio. The main impurities that affect the quality of groundwater in this region and cause significant problems in water purification are colloidal iron compounds. The enrichment of groundwater with these compounds occurs as a result of leaching and dissolution of ferrous minerals and rocks located in the regions, and the presence of swamps in rivers with humus-type organic matter probably contributes to the formation of stable colloidal iron compounds. To develop new, more effective purification methods, information is needed about the composition of impurities at all levels: atomic, molecular phase, structure of molecules and colloidal particles and their interaction with water. Direct determination of these properties in natural waters is not always possible and is not effective due to the complexity of the composition, which does not allow them to be accurately correlated with the properties of the system. In this regard, experimental modeling of the studied systems and their comparison with natural systems is more successful.

The main parameter used to assess the effectiveness of various methods of water purification from colloidal impurities is coagulation stability. This value is most adequately determined by the coagulation rate constant - k, but the time of sedimentation associated with it is often and successfully used (coagulation time - k).

In the case of bimolecular coagulation, the initial concentration of colloidal particles C0, the coagulation time k and the coagulation rate constant k are related by the equation:

$$k = \frac{{}^{1}/_{\alpha} - 1}{C_0 \cdot \tau_k},$$

where α=Ck/C0 is the coagulation degree corresponding to the concentration of Ck particles at which precipitation is observed.

The coagulation stability of hydrosols can also be qualitatively characterized by the concentration of electrolytes at which precipitation occurs, which is called the coagulation limit [6, 7]. The stability of hydrosols associated with coagulation with electrolytes is usually associated with the mutual repulsion of charged colloidal particles. The charge on the particles arises due to the difference in the adsorption energy of cations and anions, which is accompanied by the formation of an electric double layer (EDL), characterized by the ζ potential. It was found that electrolyte ions (Na+, Ca2+, Cl–, SO42–...) reduce the charge and potential on the particles, and, accordingly, the stability of the colloid due to charge neutralization or compression of the EDL.

For example, with an increase in the ionic charge, its effect on the electric double layer (EDL) increases. When adding mono-, di-, and trivalent ions to a colloidal solution, the calculated coagulation limit gamma should change in the ratio 1.00 : 0.016 : 0.0013 [8].

It is noteworthy that experimental values \u200b\u200bare very different from these values, since the stability of colloidal solutions, including hydrosols, can be associated not only with the formation of EDL, but also with the formation and properties of thin films (solvent layers and various surfactants, solid reaction products) on the surface of the particles. When several impurities are present, the probability of various interactions, including chemical ones, increases significantly. In such cases, there is no clear relationship between coagulation stability and the charges of particles and ions in solutions.

The aim of this work was to synthesize colloidal systems based on iron compounds similar in composition to natural ones, to study the chemical properties of colloids, and to identify factors affecting their coagulation stability.

Experimental methodology. For synthesis and analytical studies, we used $FeSO_4 \cdot 7H_2O$, $Na_2SiO_3 \cdot 9H_2O$ reagents and distilled water. In the work, we used organic substances isolated from peat of the Samarkand region, the concentration of which was estimated by chromatographic methods depending on the content of dissolved organic carbon - carbon dioxide and diluted organic carbon. Initial solutions in the range of 0,05 ÷ 4,5 mg / l.

The molar mass of organic substances was determined by gel chromatography [3]. The samples we used contained fractions from 200 to 20,000 Da.

The amount of iron and silicon in the solution was determined using a Varian ICP-OES plasma optical emission spectrometer. The hydrogen indicator was measured using a МАРК-903 pH meter. The particle size distribution and the ζ potential values in the studied model solutions were studied using the Microtrac instrument, which allows measuring particle sizes in the range of 0,5÷5000 nm. When using this method, the particle size is determined by dynamic light scattering (scattering angle 170 °). The measurement result is obtained as a particle number distribution in the form $\varphi(r) = dN/dr$. Since the distribution functions are close to logarithmic, the mode - m was found from the maximum of this distribution, which was taken as the average particle size.

Results and their discussion. The chemical composition and indicators such as pH, Eh (oxidation-reduction activity of water) and color were determined for the waters sampled in the Urgut, Bulungur and Toylak districts of the Samarkand region. Table 1 presents the main indicators characteristic of all groundwater in these regions.

Table 1.

Chemical composition and parameters of groundwater in the Toylak district

Component and indicators	Measurement units	Quantitative indicators
pH environment	—	6,5÷7
of water oxidation-reduction activity , Eh	mV	−42÷−123
Color	degree	35÷140
Fe (II)+ Fe(III)	mg/l	0,9÷20
Na	mg/l	7,5÷22.0
K	mg/l	12÷5,4
Manganese (II)	mg/l	0,05÷0,5
Hydrocarbonate ions	mg/l	90÷450
General yogurt	°Q	1,5÷6,5
Permanganate oxidizability	mgO$_2$/l	5÷14
Si(IV)	mg/l	9÷26
$NH_3 + NH_4^+$	mg/l	0,01÷0,5

H_2S	mg/l	0.050÷0.5
Ca (II)/ Mg (II)	—	1:1 or 2:1
Cu	mg/l	0.025÷0,130
Zn	mg/l	0,005÷0,050
Pb	mg/l	0,002÷0,008

As can be seen from Table 1, the groundwater of the indicated areas is hydrocarbonate, contains a relatively large amount of iron, silicon and organic substances, and has a high reduction potential (due to the presence of Fe(II) and organic impurities). Among the impurities listed in the table, we can single out the most important ones in the formation and formation of colloidal particles. First, this iron is present in groundwater in the form of the Fe(II) ion. During oxidation, poorly soluble iron(III) hydroxide is formed in the form of a classic colloid, the properties of which are well studied [8, 9]. Second, these are organic substances of humus origin, the concentration of which is indicated in Table 1 in the line “permanganate oxidation capacity”, which contribute to the formation of stable iron-containing colloidal systems [10]. Third, these are silicon compounds, which can participate in the formation of colloids with both iron compounds and organic substances [11]. Based on this, iron, silicon, and humic organic compounds were selected to create a model solution and study the colloidal chemical properties of particles and compounds in natural waters.

Conclusion

1. The content of iron compounds in natural water is an important indicator of its quality, since exceeding the permissible concentration negatively affects the taste, color and odor of water, and can also lead to corrosion of pipes and equipment.

2. The study showed that iron in natural waters is mainly in the form of Fe (II) and Fe (III), and the ratio of these forms depends on the acidity of the environment (pH), oxidation-reduction potential (Eh), and the presence of organic and inorganic ligands.

3. Environmental factors (e.g., oxygen availability, temperature, biological activity) have a significant effect on the conversion of soluble forms of iron into insoluble precipitates, which, in turn, affects the mobility of iron and its bioavailability.

4. It was found that with a reduced Eh value and slightly acidic pH, an increase in Fe (II) is observed, while under oxidizing conditions with a neutral or alkaline reaction, Fe (III) predominates, prone to the formation of hydroxides and precipitation.

5. Using the experimental modeling method, the colloidal chemical properties of solutions containing iron ions, dissolved organic substances and silicon ions were studied. Dissolved organic substances and silicate ions are surfactants in relation to iron solutions, which increases their stability and complicates their purification from impurities.

References

1. Stasinakis A.S. Use of selected advanced oxidation processes (AOPs) for wastewater treatment – A mini review // Global NEST J. 2008. V. 10. №3. P. 376-385.]

2. Salanko J.T., Lakso E.J., Kamula R.L. The effect of ozonation on the size fractions of iron and total organic carbon in groundwater // Journal of Environmental Science and Health Part A. – 2007. – № 42. – P. 795–801.

3. Perminova I.V., Frimmel F.H., Kudryavtsev A.V., Kulikova N.A., Abbt Braun G., Hesse S., Petrosyan V.S., Molecular weight charac teristics of humic substances from different environments as deter mined by size exclusion chromatography and their statistical evaluation // Environ. Sci. Technol. – 2003. – № 37. – P. 2477–2485.

4. Зекцер И.С., Язвин Л.С. Ресурсы подземных вод и их использование // Водные проблемы на рубеже веков. – М.: Наука, 1999. – С. 80–91.

5. Еременко Б.В., Малышева М.Л., Самбур В.П. Устойчивость водных дисперсий микропорошоков карбида титана в растворах электролитов // Коллоидный журнал. – 1989. – Т. 51. – № 1. – С. 25–35.

6. Малахова А.Н. Коллоидная химия. – М.: Высшая школа, 1987. – 480 с.

7. Воюцкий С.С. Курс коллоидной химии. – М.: Химия, 1976. – 512 с.

8. Шелудко А. Коллоидная химия. – М.: Мир, 1984. – 320 с.

9. Serikov L.V., Tropina E.A., Shiyan L.N., Frimmel F.H., Meterve li G., Delay M. Iron oxidation in different types of groundwater of Western Siberia // Journal for Soils and Sediments. – 2009. – V. 9. – № 2. – P. 103–110.

10. Иванов М. Обескремнивание воды // Акватерм. – 2000. – № 3. – С. 12–14.