The intensification of water purification plant work

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Abstract. The results of studies of the main technological parameters of the process of water clarification with coagulant based on natural mineral raw materials are presented.

Introduction
In most cases, water from rivers and water-storage reservoirs is used as a source of cities and urban settlements water-supply engineering. However, nowadays water from surface springs cannot be used for drinking without defecation and decontaminating. It is because the water in natural resources contains finely divided chemical impurities which are in suspension state. Due to the fact that a degree of particles dispersion, which makes natural water turbid, has a high level (a size of the particles are from $10^{-4}$ to $10^{-6}$ mm), they are constantly contained in the volume of the purified water and cannot be deleted with the help of gravity force. That is why special reagents, called coagulants and flocculants, are widespread. Aluminum and ferrous salts are used as coagulants, which are hydrolysed in case of contact with water, and, as a result, poorly soluble substratum with flaky structure is formed. $\text{Al}_2(\text{SO}_4)\text{3}$ and $\text{FeCl}_3$ are widely used as coagulants. Sodium aluminates, aluminium oxychloride, ferrous oxide sulfate are less spread. In order to increase the amount of capitated flakes, flocculants, which are high molecular weight species and are classified as linear polymer, are also added into the natural water. These materials have good water solubility. Nowadays the flocculants, which are widespread, are polyacrylamide, flocculant ВА-2 (poly-2-vinyl-N-benzylalkonium chloride), active silicic acid (АК). A minimum amount of the flocculant is from 0,2 to 1,0 mg/l.

There is a disadvantage of using such a method. It is secondary water pollution with iron and aluminium in an ion state. The solution of the problem is to use a regent, which was got from the natural mineral resource. Its deposits were discovered in European part of Russia, Eastern and South Trans-Urals and in the South of the Sakhalin. There are some field developments which are being worked in our country. They are Зиkeyevskoye, Баканskoye, Дубенskoye, Каменноyarскoye, Уст-Gryaznuhinskoye, Шiryaevskoye, Вольskoye, Балашейскoye, Красногвардейскoye, Куринскoye, Саринскoye, Шебунинскoye ones. [1]. The field development of using the mineral resource is on the Volgograd region territory. The raw material has the following components: SiO$_2$ - 75-80%, Al$_2$O$_3$ - 18-22%, Fe$_2$O$_3$ - 0,5-1%, H$_2$O - 0,2-0,5%, CaSO$_4$ - 0,3-0,5%, CaCO$_3$ - 0,12-0,8%.

The way of getting the mineral coagulant based on the mineral raw material (MCO-1) consists of the following steps. Firstly, raw material particles with the weight of some kilograms were milled with a crusher. After that, the particles, which were from 1 to 3 mm in diameter, were chosen. Then these granules were milled up to the powdered condition on the colloid mill. This state of the particles
coincides to colloid one (the size of the particles from $10^{-4}$ to $10^{-6}$ mm), that is the size of the impurity, presenting in natural water and characterizing its turbidity.

The natural water treatment with the help of MCO-1 is intercoagulation of the finely divided natural water impurity with the coagulant particles. The main mass of the colloids presenting in natural water with the medium reaction from 6.5 to 8.5 have negative charge, but MCO-1 particles have positive one. It leads to the mutual attraction of the colloid impurity and MCO-1 particles under the electrostatic attraction force. Finely divided pollutants, presented in natural water, become larger and they capitate themselves. Natural water clarification with the help of the existing analogues also consists of making natural colloids larger. However, widespread coagulants get positive charge because of unfinished hydrolysis of their molecules in the water. On the other hand, the particles of the MCO-1 coagulants have electric charge because of their milling up to colloid size, as far as the pollutants, which characterize water impurity. This fact makes MCO-1 coagulant differ from widespread one.

Using MCO-1 consists in adding dry coagulant powder to the clarified water, mixing it with the water and further filtering ready mixture through the filtering granular structure which is sand. As a result, a cost of the water conditioning is reducing by 60-70% because of the considerable reducing of the cost (by a factor of 1.5 – 2, depending on used reagent so far) and the rate of reagent consumption (by a factor of 1.5 on the average in comparison with the known equivalents) and also reducing of the list of the necessary equipment of the chemical feed plant. Besides, using MCO-1 for natural water turbidity is able to exclude completely the water preparation equipment, where there is water sedimentation (water precipitation), from the technological scheme.

According to the sanitary norms and regulations, value for the natural water turbidity (1,5 mg/l) [2], using MCO-1 it is necessary to identify influence of the filtering filling on the efficiency of the water clarification process to get the minimum amount of turbidity.

One of the main coagulation stages is orthokinetic, which consists in adhesion and coarsening of colloidal impurities that are a part of the clarified water and MCO-1-particles. For this, it is necessary to ensure the optimal conditions, the fulfillment of which leads to an increase in the initially formed aggregates in the mixing purified water process. The contacting of the purified water and the coagulant occurs in facilities called mixers. At the same time, the mixing efficiency can be increased by the collisions maximum number conditions ensuring of individual aggregates between themselves, while the aggregates formation should not be destroyed.

When adding a coagulating reagent to the treated water, it is very important to ensure the uniformity of its distribution throughout the water volume. Otherwise, in that treated water area, where there will be little reagent, coagulation will not occur. In another zone, where the amount of reagent is too much, the formation of very large loose flakes will occur with a large admixture of molecules of “captured” water. As a result, their density will have a value close to the water density, and the flakes will not be able to precipitate. Therefore, only that part of the treated water volume, where the coagulant amount is close to optimal, will undergo coagulation. Therefore, the coagulant distribution uniformity in the entire volume of purified water is a necessary condition, the fulfillment of which will ensure the water impurities coagulation process proper effect [2].

In addition, the mixing the coagulant with water speed is of great importance on the coagulation effectiveness. Their quick and uniform mixing creates the prerequisites for the simultaneous onset of peri kinetic coagulation throughout the water volume, which has a significant effect on the cleaning process efficiency.

Researches of the influence were done on the water samples from the river Volga. The sampling was done according to the State Standard R 51593-2000 “Drinking water. Sampling”[3]. In this, before the researches a water turbidity evaluation was done according to the State Standard 3351-74 “Drinking water. The methods of taste, smell, colour and turbidity evaluation”. On average, original water turbidity in the river Volga was up to 30mg/l.

The initial water and MCO-1 mixing of was carried out using a PE-6110 ECOCHEM laboratory magnetic stirrer for 5 minutes. The volume of the processed sample was 1000 ml, the dose of the
reagent was 20 mg. The stirring speed ranged from 150 to 1500 rev. After stirring, the water was filtered through a sand loading bed. The results are presented in Figure 1.

Figure 1. The purified water turbidity dependence on the rate of its mixing with MCO-1.

The results obtained indicate that the turbidity normative value achievement for water used for household and drinking purposes, in accordance with the requirements of SanPiN 2.1.4.1074-01 “Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems. Quality control”- 1.5 mg / l, as well as the MCO-1 distribution maximum uniformity in the entire volume of treated water is achieved at a stirring speed of 900 rev/min. The indicated mixing speed is ensured by the mechanical propeller-type mixers use.

One of the main processing characteristics of the filtering filling is time of protective effect. It is the time when the filling is able to clarify water up to necessary level [4-7]. Before achieving the time, the proper quality water is got from the filling. After the time of protective effect, the quality of the filtrate is getting worse quickly. So, the research of the influence of the filtering filling on the efficiency of the water clarification process consists in the identification of the time of protective effect of the studied filtering materials and choosing the one with the largest value. During the identifying the time of protective effect the feed water, mixed with MCO-1, was added to the column of the laboratory model filter. Then it was filtered with the speed of 5m/h. During the experiment the results of the turbidity identification in the clarified water and pressure loss were recorded. The samples were collected with the interval of 1 hour. According to the results of the research the kinetic curves of filtering were made using the information of layer-by-layer measuring of the head in the filter bed. The results can be seen in the tables 2-4.

According to the analysis of the data received it is obvious that using quartz sand as a material of the filtering bed is the most effective because it has the longest time of protective effect of 20 h. That is why the researches of the technical characteristics of the filtering process were done using quartz sand as a material of the filtering bed. However, it must be mentioned that using casting box as a material of the filtering bed is also possible but under condition of making particles smaller.
Figure 2. Studying the kinetic filtering using the information of layer-by-layer measuring of the head in the filter bed (the material of the filter bed is quartz sand): a) graphical charts of the head losing measuring according to the filter bed height; b) time of protective effect measuring according to the filter bed height: 1- filtering time is 0 h; 2- filtering time is 1 h; 3- filtering time is 2 h; 4- filtering time is 3 h; 5- filtering time is 4 h.

Figure 3. Studying the kinetic filtering using the information of layer-by-layer measuring of the head in the filter bed (the material of the filter bed is casting box, size of the particle 1-3 mm): a) graphical charts of the head losing measuring according to the filter bed height; b) time of protective effect measuring according to the filter bed height: 1- filtering time is 0 h; 2- filtering time is 1 h; 3- filtering time is 2 h; 4- filtering time is 3 h; 5- filtering time is 4 h.

Figure 4. Studying the kinetic filtering using the information of layer-by-layer measuring of the head in
the filter bed (the material of the filter bed is casting box, size of the particle 3-5 mm): a) graphical charts of the head losing measuring according to the filter bed height; b) time of protective effect measuring according to the filter bed height: 1- filtering time is 0 h; 2- filtering time is 1 h; 3- filtering time is 2 h; 4- filtering time is 3 h; 5- filtering time is 4 h

The studies on the purified water filtration rate effect research on the clarification process efficiency were carried out under the laboratory conditions. When determining the optimal speed of filtering a mixture of water and MCO-1, the specified mixture was supplied to the filter laboratory model column and filtered at a speed of 1 to 10 m/h. Quartz sand was used as a filter material. During the experiment, the results of determining the turbidity and the effect of water purification were recorded. The samples were taken at intervals of 1 hour. The results obtained are presented in Figure 5.

![Figure 5](image-url)

**Figure 5.** The water purification effect dependence on the filtration rate

The studies’ results show that the optimal filtration rate is 6 m/h.

After the filter load protective effect time, it is washed. Rinsing is an auxiliary stage of filter operation; however, it is no less important for providing the necessary effect of water purification than direct filtering.

The above-mentioned studies on the filter media choice showed that for the MCO-1 particles extraction and the clarified natural water colloidal impurities trapped by them, the sand use is optimal. Theoretical studies, as well as experience in the sand-loaded filters operation, recommend the water-air washing use. Its mode is as follows: at the first stage, it is necessary to loosen the filter load by blowing it with air, an intensity of at least 15 - 20 l/(s·m²), a duration of 1 - 2 minutes; the second stage is washing with a water-air mixture, in which the flow rate of air is 15 - 20 l/(s·m²) and water 3 - 4 l/(s·m²) duration is 4 - 5 minutes. and the third stage - washing with water, water consumption 6 - 8 l/(s·m²), washing duration 4 - 5 minutes.

**Summary**

In the course of the work, new natural mineral raw materials for industrial enterprises and water supply and sewage farms of settlements received the following results:

1) The experiments were carried out to analyze the mixing conditions influence, the speed of mixing the developed coagulant with water and the uniformity of its distribution on the water clarification process; and it was found that the maximum uniformity of the MCO-1 distribution in the treated water entire volume is achieved at a mixing speed of 900 rev. To ensure the necessary distribution uniformity and the required mixing speed of the coagulant MCO-1 with clarified water, the use of a mechanical propeller-type mixer is necessary.
2) A study was carried out to study the filter loading material effect on the water clarification process efficiency: the most effective is the quartz sand use as the filter loading material, since it has the greatest value of the protective action time of 20 hours.

3) The work was carried out to study the effect of the filtration rate on the clarification of water process efficiency, which show that the optimal filtration rate is 6 m/h.

4) The parameters of washing the cleaning complex filter load are determined: at the first stage, it is necessary to loosen the filter load by blowing with air (intensity not less than 15–20 l/(s·m²), duration 1–2 min.), The second stage - washing with a water-air mixture (air consumption 15–20 l/(s·m²) and water 3–4 l/(s·m²), duration 4–5 min.) and the third stage rinsing with water (water consumption 6–8 l/(s·m²), washing time 4–5 min).

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