Cleaning natural water in the clarifier reactor

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Abstract. The problems of cleaning low turbidity high-color surface waters for drinking water supply are considered. A new design of the clarifier reactor is proposed, which increases the efficiency of water purification and at the same time reduces its operating costs. A detailed description of clarifier reactor design and its operation is given. The study results of the clarifier reactor operation in real conditions for the purification of low turbidity high-color waters are shown. Due to the weighted layer of dense loading use in a process of water purification, the structure productivity can be increased by 2-3 times in comparison with conventional clarifiers with suspended sediment. Using reagents for water purification, the clarifier reactor, due to the processes of contact coagulation, allows reducing the consumption of reagents up to 50%. Investigations of the clarifier reactor operation in technological schemes for various waters purification, including sewage, showed their effectiveness and prospects.

1. Introduction

Siberia's surface water for a long time and ground water for the whole year-round are characterized by low temperatures. The organic composition of many surface water supplying is formed with the participation of soil and peat humus, marsh feeding of rivers; plankton decomposition, higher water and soil vegetation in reservoirs and lakes. Organic colloids in natural waters, humic substances give a yellowish water coloration of varying intensity. Thus, the color of water in the Om River in Kuibyshev town in the Novosibirsk Region got 500 degrees at a turbidity of less than 3 mg / l [1-15].

A number of ground water sources also have an increased content of organic contaminants caused by peat bogs and high color of water at low turbidity in deep water. For example, in the village Namtsy of the Republic of SAHA-Yakutia, color of the water is noted at a level of up to 1500 degrees.

In addition, ground surface water is often characterized by high iron content (up to 20 mg / l), manganese (up to 4 mg / l) and other impurities of natural and anthropogenic origin.

Iron and manganese are present in natural waters in the form of mineral or organic fatty acids. In the second case, there is water with increased oxidation capacity, which has an aggressive nature. In particular, in the Om River water, the iron content is 3 mg / l, manganese is 1 mg / l, and permanganate oxidizability is 50 mg / l.

Traditional technologies of water preparation for drinking water supply do not suit for purification of initial water color more than 120 degrees. [1, Table 15]. As far as water viscosity increases and the decrease in kinetic movements of colloidal particles during the hydrolysis and their collisions, that causes agglomeration, coagulation purification of water proceeds unsatisfactorily.

With low water turbidity, the process of spatial structure formation is also difficult in clarifiers with a suspended layer due to the continuous movement of individual loose flakes of sediment in them.
In addition, during the processing of colored aqueous humic substances, sorbed on the surface of coagulating hydroxide and give it stability, preventing sorption.

The use of contact clarifiers with a single-stage cleaning scheme or contact pre-filters in front of the fast filters by a two-stage scheme for high-temperature waters treating in connection with high doses of coagulant with their washing operations frequency and large consumption of washing waters, which provides a useful productivity of water clarifying equipment.

The problem of preliminary cleaning of low turbidity high-color surface waters is partially solved by the use of clarifiers-recirculators in which a part of synthetic sediment from suspended layer is ejected into the initial water and flakes, which serve as additional centers for the condensation of hydrolysis products. This allows increasing the productivity of clarifiers by 30-60% and to process water with color up to 300 degrees. However, with low temperatures and turbidity of initial water up to 20 mg / L, the upstream velocity of the cleaning water does not exceed 0.8 mm / s and the productivity of recycler remains is still low [2].

To improve the coagulation processes in the low turbidity colored waters processing, the initial water is clouded with various materials, for example clay. The introduction of artificial opacifiers, including their particles, which serve as additional condensation centers of the hydrolysis products, promotes coagulation. Polyelectrolytes flocculating effect also increases. Turbidity of the treated water leads to a weighting of coagulated suspension flakes, increasing their hydraulic size and use of water purification effect. However, the supply of materials that meet sanitary, hygienic and technical requirements, preparation, turbidity suspension dosing, removal and utilization of the phyto-slime, significantly increases the cost of water clarifying equipment.

In order to increase the work efficiency and improve the systems for the preliminary reagent cleaning of low-temperature, low turbidity high-color surface, as well as iron-manganese-containing groundwater for drinking and technical water supply on the principle of contact coagulation in NSACU (Sibstrin), a new clarifier reactor was worked out [3]. (Patent of the Russian Federation No. 2307075)

2. Materials and Methods
Reactor- clarifier (RC) for water purification works as follows (figure 1). Through the water tube line for the (3) clarification, initial water treated with reagents is supplied to the (15) air separator that prevents air bubbles from entering weighed layer of the contact batch and through the (16) distribution standpipe and is evenly distributed to the device clarification zone. Then, the clarified water passes from the bottom up through the (2) contact batch layer, with speed, supplying with its minimal fluidization.

This eliminates stagnant zones, which are present near the places of particles contact in the layer stationary state and the porosity of charge begins to increase. As a contact batch, we use quartz sand or any other fine-grained material that meets the requirements for mechanical strength and chemical resistance. By increasing the volume concentration of solid phase in suspended layer, there are some process of catalytic acceleration of the hydrolysis process of coagulant, contact coagulation of hydrolysis products, adsorption of metal hydroxides by the weighed contact batch grains and the formation in the sediment layer, which is a sorbent for water impurities. Part of the sludge flakes is removed from the layer, retained by the (12) thin-layer module, slides down the inclined walls of its rings and settles on the contact batch surface.

As a result, a high water purification effect is achieved, a lower consumption of reagents is achieved, and also, the device productivity is increased. The clarified water is collected by a gutter (4) and discharged by the (5) pipeline from the device. After the expiration of the protective action of the weighed contact batch and deterioration of the clarified water quality, the contact batch is washed in the following sequence.

The gate valve on the tap of the rinse water outlet 6 is opened, and on the discharge line of the (5) clarified water is closed. Valves are opened on the (17) pipeline, connecting the ejector for (8) feeding pulp to the lower part of the device body and on the supply line 7 to the (8) washing water ejector. The supply of clarified water through the (3) pipeline through (15) the air separator and the (16) dipleg to the (2) contact batch is continued. The contaminated contact batch weight is piped into the ejector of
the (8) pulp feed, is transported to the upper part of the housing of the (9) device via conduit and through the (14) air ejector, it is tangentially introduced into the (13) semi-submerged cylinder below the water level at an angle to its surface. The contact batch intake in the (8) ejector is regulated by means of a valve installed on the (17) pipeline. The air introduced into the pulp with the help of the (14) ejector is released into the water - bubbles and water-air rinsing of the contact batch occurs.

It is strengthened by the separation of sediment particles and the contact- batch grains in the centrifugal force field in (13) semi-submerged cylinder. The washed grains of the contact batch are deposited in suspended layer, and the sediment is discharged with water. The removal of the contact batch in the collecting (4) chute is prevented by a thin-layer module. The valves are closed on the (17, 7, 6) pipelines after the washing. At the same time, the supply of washing water to the (8) pulp ejector is stopped and the device continues purifying water again. The contact weighted batch is used repeatedly during the cleaning process. If it is necessary to change the contact weight batch or to empty water purification device, the pulp is discharged from it through the tube line 11.

![Figure 1. Scheme of the Clarifier Reactor](image)

Experimental studies of the reactor-clarifier were carried out at a water treatment plant in Kuibyshev town. High-quality low turbidity high-color water of the Om River was subjected to purification. The composition of water purification technological scheme consisted consistently of the following main structures’ models: a clarifier reactor, an early granular filter, a sorption filter.

The experimental reactor-clarifier for preliminary clarification and bleaching of water had 100 mm diameter and 3 m height. The reactor was structurally in accordance with the above figure and was loaded with contact batch, including homogeneous quartz sand with 0.3-0.5 mm particle size. The height of the loading layer dense was 1.1 m. The model of the fast filter for further water purification consisted of three short pressure columns with 0.6 m height connected in series and loaded with crushed albitophyre with 2.5 average grain size; 1.8 and 1 mm, in the first, second and third columns, respectively. Each column modeled a separate filter layer of the RC. The sorption filter model, where dissolved organic and chemical contaminations were extracted, and the final water purification took place, consisted of one pressure column loaded with active carbon of AG-3 grade, 1-2.5 mm fractions with 1 m layer height.

3. Results

The observations results one of the characteristic cycles of water clarification in the clarifying reactor, rapid grains and sorption filters are shown below.
The color of the river water was 130 degrees, the turbidity was 2 mg/l, and the temperature was 2 °C. The water was pretreated with solutions of coagulant aluminum oxychloride with 20 mg/l dose, Prastol 650 TR cationic flocculant with 0.5 mg/l dose and introduced into the device through an air separator, dip tube.

25% weighing of the KM layer took place during the ascending movement of water. The air separator prevented air bubbles sucking into the device and the stability of the contact batch layer.

At the initial moment of clarification, a circular circulation motion of KM grains was observed along the entire height of the layer from below upwards and from top to bottom. At the same time, there was formation and separation of aluminum hydroxide precipitate main part from the water in the KM layer, sorption on the humic particles sediment, accompanied by discoloration of water to the drinking norm (up to 20 °C). A part of the sediment, that had not been retained in the contact batch layer, in the form of large dense flakes, was released in a thin layer module, drained downward and settled on the surface of the contact batch layer. Clarified water, containing small sediment flakes, came from the device for final cleaning on the fast filter model by a granular charge from crushed albitophyre.

4. Discussion

As the structured precipitate of aluminum hydroxide forms in the weighed contact batch, the adhesion of individual sediment structures and the KM grains consolidation, the layers of the suspended charge gradually went from bottom to top in a stationary state.

At the same time, the quality of the treated water did not change. After 6 hours of clarification, the load with all its individual grains took a stably stationary position. The process of water clarification in a suspended but immobile the KM layer become similar to the process of conventional filtration in granular layer with ascending movement of purified water. The ascending stream velocity on the clarifier reactor model was 1.8 mm/s. After 60 hours of the clarifier reactor operation, the clarified water quality gradually began to deteriorate both in color and in its turbidity. At 5 mg/l water turbidity, the clarification cycle was terminated due to the inadvisability of this quality water supply to the second stage of purification - the fast filter.

During 60-hour water clarification cycle on the reactor, subsequent water purification on the fast filter and sorption on the charcoal filter, based on the results of the Kuybyshev Sanitary and Epidemiological Surveillance Laboratory control analyzes, ensured the water quality corresponding to 2.1.4.1074-01 norms.

At the end of each water treatment cycle, an ejection washing of the reactor-clarifier contact batch was carried out according to the above procedure. The working fluid specific consumption of the water ejector was from 5 to 8 m3/m3 of sand. The residual contamination accumulation in the contact batch, controlled by initial losses of pressure in it, was not observed during semiannual period of the experimental studies, which indicated a high efficiency of the clarifying reactor washing.

The parameters of the clarifier reactor operation, obtained the technological simulation result, made it possible to calculate and optimize its design and technological parameters.

We used the results of our research to design the reactors-clarifiers production in the development of the project for the pump-filtering station reconstruction in Kuibyshev town.

5. Conclusions

1. With the clarification of low-humid, colored, weakly mineralized waters with long periods of low temperatures, the positive role of the granular medium lies in the fact that the flocculation processes take place in a closed pore space where the collision probability of coagulated suspension significantly particles increases and both of them adhere to each other and to previously formed aggregates. With the same quality of clarified water, the load on the clarification reactors can be increased by 2-3 times in comparison with ordinary clarifiers with a suspended sediment layer. This allows them to be placed in tight spaces of reconstructed clarifiers without expansion of buildings.

2. Grains of the contact batch are additional centers of flocculation and shift part of the coagulation process from the spatial structure formation that occurs in conventional clarifiers, to autocatalytic
coagulation, sorption and adhesion. As a result, the strength and density of newly formed flocs and, correspondingly, their hydraulic size began to increase.

3. The clarification process in the contact batch layer is similar to the process of contact coagulation in a granular filter load. However, the grains of the weighed contact batch participate in the process of coagulation and sorption by the whole surface, in contrast to filters which grains have "dead" non-working zones at their contact points, that reduces the actual porosity of the filter load and the filters performance.

4. The use of clarification reactors for pre-treatment of water allows reducing the reagents use up to 50%.

5. The mss of hydroxides flakes and water impurities is retained in the clarifier reactor, which reduces the pollution load on the fast filters and doubles their productivity.

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