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Scientific article

ANALYSIS OF THE EFFECTIVENESS OF COAGULANTS IN WATER TREATMENT

S.N. Shelest, I.A. Trotsenko, Yu.V. Korchevskaya

Abstract

Background. Obtaining water suitable for domestic and industrial needs and safe for the consumer is the main task of water treatment. The search for ways to improve the coagulation process and methods that allow its intensification is currently still relevant. The article presents the results of studies of coagulants at various combinations and doses in laboratory conditions. Irtysh river water intended for drinking purposes is considered as an object of research. The efficiency of using different coagulants that allow to remove pollutants such as heavy metals, organic compounds, microbiological pollutants, etc. in a more qualitative way has been studied. This is especially important for the treatment of water from surface sources, which is often characterized by a high content of impurities. Experimental studies in the shop of operation of water supply networks and facilities of Rosvodokanal Omsk were conducted with the following coagulants "Brilliant-18", "Bopak-E", "OHA", "Aqua-aurat 30" and "ASA" in combination with flocculant FL 4540PWG. Coagulants were tested in the spring flood period at the source water temperature of 6-8°C. On the source water of the Irtysh River the best results were shown by coagulants such as "Bopak-E", "OHA" and "Aqua-aurat 30". The optimal dose for the most effective coagulants is Dk=1.5 mg/l (by Al_2O_3) when combined with flocculant with Df=0.1-0.13 mg/l. Coagulant "Aqua-aurate 30" shows better flaking, sedimentation and clarification, and accordingly better performance on water turbidity. To confirm the results of laboratory tests and select the most effective reagent, it is recommended to conduct production tests of coagulant "Aqua-aurat 30".

Purpose. The main objectives of the research are to test the used reagents in laboratory conditions and compare their efficiency in different seasons of the year, as well as to improve the water treatment process by introducing new reagents.

Materials and methods. According to the results of industrial tests it was found that water after treatment with liquid aluminum sulfate meets hygienic requirements

for water quality of centralized drinking water supply systems. In summer period the working dose of liquid SA 1.5 mg/l (by Al2O3) is similar to the working dose of OHA. But liquid aluminum sulfate can be used for water treatment at water treatment plants only in summer, as in winter time of the year the coagulation process is much worse. Therefore, the laboratory of the water supply networks and facilities operation shop conducted laboratory studies on the effectiveness of introduction of other coagulants based on aluminum polyoxychloride: “Brilliant”, “Bopak”, “OHA”, “Aqua-aurat 30” and “ASA”, which can be used in different seasons of the year.

Taking into account the current technology of natural water treatment at the facilities of Rosvodokanal Omsk the following methodology of trial coagulation (on automatic flocculator “Lovibond”) was adopted. Addition of reagents (coagulant and flocculant sequentially) in the source water and stirring for 3 minutes at a rotation speed of 146 rpm. Stirring is then continued for 10 minutes at a lower speed (43 rpm). This is followed by settling for 30 minutes. Trial coagulation was carried out with flocculant FL 4540PWG with a concentration of 0.1%. Samples of treated water were taken after settling from the middle layer of water. Water quality parameters were evaluated after the sedimentation process, excluding filtration.

Results. As a result of the tests, large flakes were formed only when “Aqua-aurate 30” and “ASA” were applied at a dose of (1.5/0.1 mg/l). Other coagulants formed small and medium flakes and all coagulants showed intensive sedimentation and clarification.

Tests of coagulants were carried out in the spring flood period at the source water temperature of 6-8°C On the source water of the Irtysh River the best results showed coagulants such as “Bopak-E”, “OHA” and “Aqua-aurat 30”.

The optimal dose for the most effective coagulants is Dk=1.5 mg/l (by Al_2O_3) when combined with flocculant with Df=0.1-0.13 mg/l.

During the laboratory tests, coagulants “Bopak-E” and “Brilliant-18” showed the same results of clarified water quality in terms of residual aluminum and water turbidity in comparison with the coagulant “OHA” used at Rosvodokanal Omsk, at doses as close as possible to those established at production (Dk=1.8 mg/l and Df=0.13mg/l).

Coagulant “Aqua-aurate 30” shows better flaking, sedimentation and clarification, and accordingly better indicators of water turbidity.

Under low alkalinity conditions, Aqua-aurat 30 coagulant increases this index, which contributes to solving the problem of poor coagulation. At optimum doses quality indicators of clarified water by residual aluminum, as well as filtered water by turbidity and residual aluminum, meet the quality assurance of drinking water in accordance with SanPiN 1.2.3485-21, GN 2.1.5.1315-03, GN 2.1.5.2280-07.

To confirm the results of laboratory tests and to select the most effective reagent, it is recommended to conduct production tests of coagulant “Aqua-aurat 30”.

Conclusion. In the process of laboratory testing, many reagents are tested. The purpose of the analysis is to find effective reagents under conditions when the water supply source changes its charge and alkalinity decreases.

Laboratory tests of coagulants based on aluminum polyoxychloride such as “Bopak-E”, “OHA” and “Aqua-aurat 30” show that the performance in conditions of low alkalinity is difficult, but the best coagulation ability is shown by the reagent “Aqua-aurat 30” because of its ability to increase alkalinity by 15-18%, which helps to improve the efficiency of coagulation.

Keywords: coagulant; organic compounds; flocculant; flaking; effective reagent

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Научная статья

АНАЛИЗ ЭФФЕКТИВНОСТИ КОАГУЛЯНТОВ ПРИ ОЧИСТКЕ ВОДЫ

С.Н. Шелест, И.А. Троценко, Ю.В. Корчевская

Аннотация

Обоснование. Получение воды, пригодной для бытовых и промышленных нужд и безопасной для потребителя является основной задачей очистки воды. Поиск путей усовершенствования процесса коагуляции и методов, позволяющих его интенсифицировать в настоящее время все также актуален. В статье представлены результаты исследований коагулянтов при различных сочетаниях и дозах в лабораторных условиях. В качестве объекта исследований рассмотрена вода реки Иртыш, предназначенная для питьевых целей. Изучена эффективность использования разных коагулянтов, позволяющих более качественно удалять загрязняющие вещества, такие как тяжелые металлы, органические соединения, микробиологические загрязнители и др. Это особенно важно для обработки воды из поверхностных источников, которая часто характеризуется высоким содержанием примесей. Опытные исследования в цехе эксплуатации водопроводных сетей и сооружений Росводоканал Омск проводились со следующими коагулянтами «Бриллиант-18», «Бопак-Е»,

«ОХА», «Аква-аурат 30» и «АСА» в сочетании с флокулянтом FL 4540PWG. Испытания коагулянтов были проведены в весенний паводковый период при температуре исходной воды 6-8°С. На исходной воде реки Иртыш лучшие результаты показали коагулянты, такие как «Бопак-Е», «ОХА» и «Аква-аурат 30». Оптимальной дозой для наиболее эффективных коагулянтов является Дк=1,5 мг/л (по Al_2O_3) при совместном применении с флокулянтом с Дф=0,1-0,13 мг/л. Коагулянт «Аква-аурат 30» показывает лучшее хлопьеобразование, осаждение и осветление, и соответственно лучшие показатели по мутности воды. Для подтверждения результатов лабораторных испытаний и выбора наиболее эффективного реагента, рекомендуется проведение производственных испытаний коагулянта «Аква-аурат 30».

Цель. Главные задача данных исследований – тестирование применяемых реагентов в лабораторных условиях, и сравнение их эффективности в разные сезоны года, а также совершенствование процесса водоподготовки за счет внедрения новых реагентов.

Материалы и методы. По результатам промышленных испытаний установлено, что вода после обработки жидким сульфатом алюминия соответствует гигиеническим требованиям, предъявляемым к качеству воды централизованных систем питьевого водоснабжения. В летний период рабочая доза жидкого СА 1,5 мг/л (по Al_2O_3) аналогична рабочей дозе ОХА. Но жидкий сульфат алюминия может использоваться для очистки воды на очистных сооружениях только в летний период, так как в зимнее время года процесс коагуляции протекает значительно хуже. Поэтому в лаборатории цеха эксплуатации водопроводных сетей и сооружений провели лабораторные исследования по эффективности внедрения других коагулянтов на основе полиоксихлорида алюминия: «Бриллиант», «Бопак», «ОХА», «Аква-аурат 30» и «АСА», которые могут быть использованы в разные сезоны года.

С учетом действующей технологии обработки природной воды на сооружениях Росводоканал Омск принята следующая методика пробного коагулирования (на автоматическом флокуляторе марки «Lovibond»). Добавление реагентов (коагулянт и флокулянта последовательно) в исходную воду и перемешивание течение 3 минут при скорости вращения 146 об/минуту. Затем продолжается перемешивание в течение 10 минут при меньшей скорости (43 об/мин). Далее происходит отстаивание в течение 30 минут. Пробное коагулирование проводили с флокулянтом FL 4540PWG с концентрацией 0,1%. Пробы очищенной воды отбирались после отстаивания со среднего слоя воды. Показатели качества воды оценивались после процесса отстаивания, исключая фильтрование.

Результаты. В результате испытаний крупные хлопья образовались лишь при применении «Аква-аурат 30» и «АСА» в дозе (1,5/0,1 мг/л). Другие коагулянты образовывали мелкие и средние хлопья, и все коагулянты показывали интенсивное осаждение и осветление.

Испытания коагулянтов были проведены в весенний паводковый период при температуре исходной воды 6-8°С На исходной воде р. Иртыш лучшие результаты показали коагулянты, такие как «Бопак-Е», «ОХА» и «Аква-аурат 30».

Оптимальной дозой для наиболее эффективных коагулянтов является Дк=1,5 мг/л (по Al_2O_3) при совместном применении с флокулянтом с Дф=0,1-0,13 мг/л.

В ходе лабораторных испытаний, коагулянты «Бопак-Е» и «Бриллиант-18»,» показали одинаковые результаты качества осветленной воды, по остаточному алюминию и мутности воды в сравнении с применяемым на Росводоканале Омск коагулянтом «ОХА», на дозах максимально приближённых к установленным на производстве (Дк=1,8 мг/л и Дф=0,13мг/л).

Коагулянт «Аква-аурат 30» показывает лучшее хлопьеобразование, осаждение и осветление, и соответственно лучшие показатели по мутности воды.

В условиях низкой щелочности, коагулянт «Аква-аурат 30» повышает данный показатель, что способствует решению проблеме слабой коагуляции. При оптимальных дозах показатели качества осветленной воды по остаточному алюминию, а также фильтрованной воды по мутности и остаточному алюминию, удовлетворяют обеспечению качества питьевой воды в соответствии с СанПиНом 1.2.3485-21, ГН 2.1.5.1315-03, ГН 2.1.5.2280-07.

Для подтверждения результатов лабораторных испытаний и выбора наиболее эффективного реагента, рекомендуется проведение производственных испытаний коагулянта «Аква-аурат 30».

Заключение. В процессе проведения лабораторных испытаний, проверено множество реагентов. Целью анализа является поиск эффективных реагентов в условиях, когда источник водоснабжения меняет свой заряд, а также снижается щелочность.

Проведение лабораторных испытаний коагулянтов на основе полиоксихлорид алюминия таких как «Бопак-Е», «ОХА» и «Аква-аурат 30», показывают, что работоспособность в условиях низкой щелочности затрудняется, но лучшую способность коагулирования показывает реагент «Аква-аурат 30» из-за своей способности повышать щелочность на 15-18%, что способствует повышению эффективности коагулирования.

Ключевые слова: коагулянт; органические соединения; флокулянт; хлопьеобразование; эффективный реагент

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Introduction

The main objective of water treatment is to obtain water suitable for domestic and industrial needs and safe for the end user. At the same time, the most economically advantageous measures and the most effective treatment methods are considered.

Currently, surface water bodies of the Omsk region are classified as dirty, so the supply of water for domestic and drinking needs from them without preliminary treatment is impossible, because the concentration of chemical substances and values of organoleptic indicators exceed the normatively established values, in connection with which the question of developing new methods of purification is more acute [1-3].

Water treatment with coagulants is the most effective way to purify water from insoluble contaminants. Therefore, it is relevant to search for ways to improve the coagulation process, as well as methods that allow its intensification. Therefore, the work on search and testing of new brands of coagulants capable of providing stable water treatment is relevant.

Water treatment is complicated by seasonal changes in water quality. In the fall period this is due to the arrival of a large amount of rainwater, and in the spring melt water, resulting in an increase in the content of suspended particles and pollutants. Also, the decrease in temperature in winter, resulting in an increase in water viscosity, which leads to the use of a higher dose of reagents and increased content of residual substances in treated water.

Coagulation is a key process in water treatment where it is used to remove colloidal particles that can degrade water quality through undesirable tastes, colors, odors or turbidity. The process involves introducing certain chemicals known as coagulants into untreated water. These substances cause tiny, highly dispersed colloidal particles to clump together to form large flakes. These flakes can then be effectively removed by methods such as sedimentation, flotation and filtration during flocculation, allowing the solids to be separated from the liquid phase.

If the coagulation process is carried out correctly, taking into account external factors affecting the coagulation process (quality of source water, the amount of coagulant dose, pH environment, conditions of water mixing with the reagent, temperature of treated water, order of input) and subsequent clarification, it is possible to reduce the concentration of organic pollutants by 50-60%. In addition, heavy metal ions are removed (iron and manganese – up to 65-80%; lead, chromium – by 30%; copper and nickel – by 50%), SPAB from 30 to 100%, phenols, amines, as well as petroleum products, pesticides from 90 to 100% and radioactive substances by 70-90% [4, 5]. Coagulation partially removes biological water contaminants.

Changing the whole scheme of the water treatment process is impossible due to significant economic costs, so the alternative is to replace current coagulants with new highly effective substances.

The introduction of SanPiN 1.2.3684-21 "Sanitary and Epidemiological Requirements for the maintenance of urban and rural settlements, water bodies, drinking water and drinking water supply, air, soil, living quarters, operation of industrial and public premises, organization and conduct of sanitary and anti-epidemic (preventive) measures" and SanPiN 1.2.3685-21 "Sanitary and Epidemiological Requirements for the Safety and (or) Harmlessness of Human Habitat Factors" will inevitably lead to partial changes in water treatment technologies and the introduction of water treatment technologies [6-8].

In the shop of operation of water supply networks and facilities Rosvodokanal Omsk is constantly working on the search and testing of new brands of reagents that can ensure stable quality of drinking water. A comparative analysis of the introduction of different coagulants such as "Brilliant-18", "Bopak-E", "OHA", "Aqua-aurat 30" and "ASA" has been carried out.

The main objectives of the research are to test the used reagents in laboratory conditions and compare their efficiency in different seasons of the year, as well as to improve the water treatment process by introducing new reagents.

Purpose. The main objectives of the research are to test the used reagents in laboratory conditions and compare their efficiency in different seasons of the year, as well as to improve the water treatment process by introducing new reagents.

Materials and methods

The source of water supply for the city of Omsk is the Irtysh River. The condition of water in the Irtysh is determined by both natural and anthropogenic sources of pollution. Water intake from the river is carried out by two water intake structures, combined with pumping stations of the first lift: channel-type intake, combined with pumping station of the first lift "Zarya"; bucket-type intake, combined with pumping station of the first lift "Pad'".

In connection with aggravation of water and ecological problems of the Irtysh River, it is undoubtedly required to increase the level of ecological condition, which is a key block in the water protection system, by means of ecological monitoring. Ecological monitoring is carried out through special points of stationary observation network (five observation stations on water quality are organized). According to observation data, the leading polluting components for Irtysh River waters are: copper, zinc, nickel, chromium, mercury, aluminum and manganese [9; 10].

Currently, the city water supply in Omsk is fully capable of meeting the drinking water needs of residents (Wang, Zhang, Lian et al, 2020). Thanks to modern technologies and infrastructure, the water coming from the taps of Omsk residents undergoes strict quality control and meets all necessary safety and hygiene standards.

The source of water supply regularly changes its properties; therefore, it is necessary to study the process of change in detail, adjust to new criteria and find the most optimal and less costly ways of water treatment.

Currently, for the treatment of natural water, composite reagents are being developed to perform the functions of coagulant, flocculant, precipitant and adsorbent. Composite reagents are prepared from inorganic iron and aluminum coagulants, organic flocculants of different nature and properties, active additives of mineral and organic origin [11; 12].

The spring floods of 2022 and 2023 turned out to be very indicative in this respect. As a result of natural and anthropogenic phenomena in the Irtysh River the alkalinity index decreased and remained at low values for several months. Aluminum polyoxychloride, used for years and showing a good result of purification, did not cope with water clarification. Large, stable flakes did not form. Only a part of the contaminants precipitated in the sedimentation tank, the rest went into the rapid filter. Accordingly, the load on the rapid filters increased. To cope with this problem the number of filter washings was increased, but this solved the problem only for a short period of time and the filters clogged again. Emergency measures were taken, including changing the doses of reagents and combining their composition [13-15].

It was decided to conduct an industrial test of liquid coagulant aluminum sulfate in comparison with aluminum polyoxychloride in the summer period. The results of research of samples taken from the water supply source and from the outlet of the water treatment plant are presented in Table 1.

Table 1.

Efficiency results of coagulant liquid aluminum sulfate coagulant

Indicator, unit of measurement	Measurement methodology	Pumping station			Water treatment plant		
		OHA	SA	SA	POHA	SA	SA
		19.07.23	20.07.23	21.07.23	19.07.23	20.07.23	21.07.23
Temperature, degree C°	Operating instructions for the thermometer	23.6	22.9	23.0	-	-	-
Turbidity, mg/dm³ (daily average)	Operation manual for the turbidity meter	1.77	2.64	1.90	0.106	0.124	0.103
Chlorine residual free chlorine, mg/dm³ (daily average)	GOST* 18190-72	-	-	-	0.48	0.48	0.49
Colorfulness, degree	GOST 31868-2012	5.5	4.7	3.6	1.7	1.7	<1.0
Alkalinity, mmole/dm³	GOST 31957-2012	1.56	1.6	1.62	1.48	1.52	1.45
Oxidability, mgO/dm³	GOST P 55684-2013	1.14	1.55		0.64	0.98	
Residual aluminum, mg/dm³	GOST 18165-2014	-	-	-	< 0.04	< 0.04	< 0.04
*GOST – Russian National Standard							

According to the results of industrial tests it was found that water after treatment with liquid aluminum sulfate meets hygienic requirements for water quality of centralized drinking water supply systems. In summer period the working dose of liquid SA 1.5 mg/l (by Al_2O_3) is similar to the working dose of OHA. But liquid aluminum sulfate can be used for water treatment at water treatment plants only in summer, as in winter time of the year the coagulation process is much worse. Therefore, the laboratory of the water supply networks and facilities operation shop conducted laboratory studies on the effectiveness of introduction of other coagulants based on aluminum polyoxychloride: "Brilliant", "Bopak", "OHA", "Aqua-aurat 30" and "ASA", which can be used in different seasons of the year.

Taking into account the current technology of natural water treatment at the facilities of Rosvodokanal Omsk the following methodology of trial coagulation (on automatic flocculator "Lovibond") was adopted. Addition of reagents (coagulant and flocculant sequentially) in the source water and stirring for 3 minutes at a rotation speed of 146 rpm. Stirring is then continued for 10 minutes at a lower speed (43 rpm). This is followed by settling for 30 minutes. Trial coagulation was carried out with flocculant FL 4540PWG with a concentration of 0.1%. Samples of treated water were taken after settling from the middle layer of water. Water quality parameters were evaluated after the sedimentation process, excluding filtration.

Results

Before the experiments, the main characteristics of the initial natural water were obtained: temperature – 0.1°C; alkalinity – 1.45 mg/l; turbidity– 41.5 mg/l; color – 7.2 degrees; oxidizability – 2.82 mg/l; hydrogen index – 7.8 pH. The place of sampling is the water intake facility "Zarya".

Figures 1-3 show the results of coagulant tests at different doses of Al_2O_3 and flocculant.

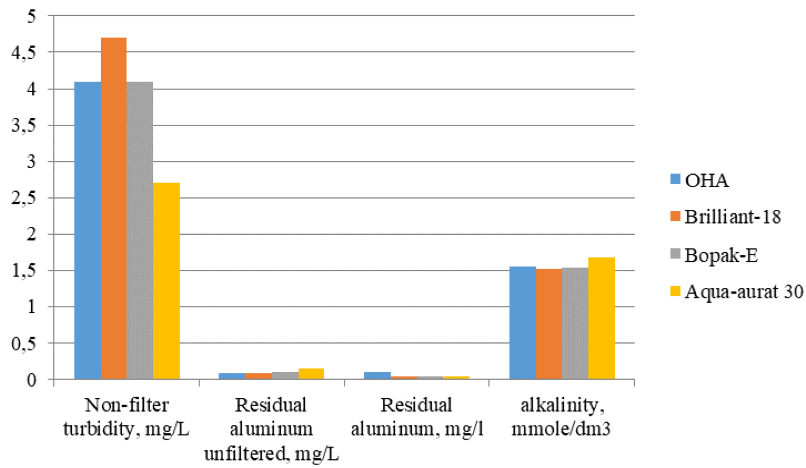

Fig. 1. Coagulant test results – dose by Al_2O_3 1.8 mg/L / flocculant 0.13 mg/L

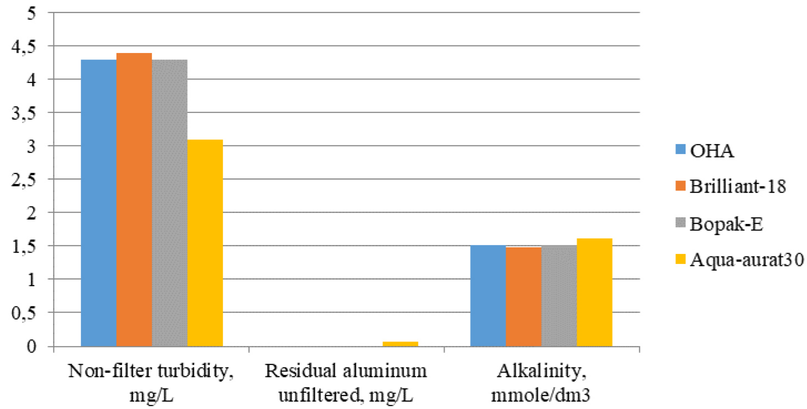

Fig. 2. Coagulant test results – dose by Al_2O_3 1.5 mg/L / flocculant 0.13 mg/L

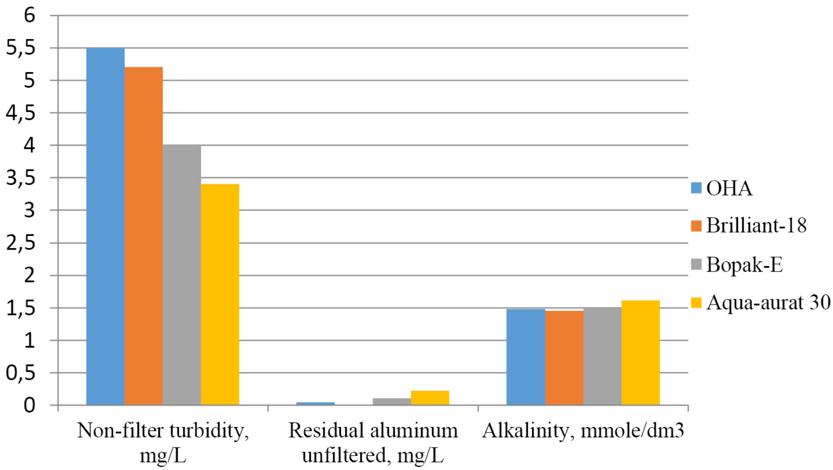

Fig. 3. Coagulant test results – dose by Al_2O_3 1.5 mg/L / flocculant 0.1 mg/L

As a result of tests at the first two combinations of coagulant and flocculant doses (1.8/0.13 and 1.5/0.13 mg/L) coagulants “OHA”, “Brilliant” and “Bopak-E” formed medium flakes, and when using “Aqua-aurat 30” – large flakes. In the third combination (1.5/0.1 mg/L), the coagulants “Bopak” and “Aqua-aurat 30” formed large flakes. In all combinations, all coagulants showed intense sedimentation and clarification.

Figures 4-5 show the results of tests of water samples at the water intake facility “Zarya” with the following characteristics of the initial natural water: temperature – 0.1°C; alkalinity – 1.45 mg/l; turbidity – 30.1 mg/l: color – 7.2 degrees; acidity – 2.82 mg/l; hydrogen index – 7.8 pH.

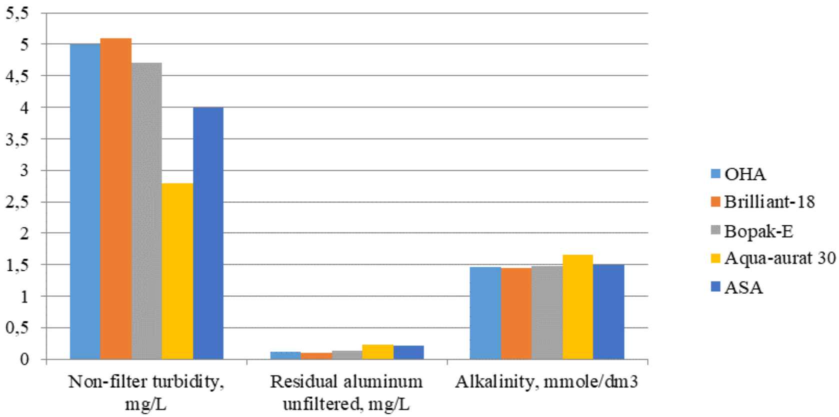

Fig. 4. Coagulant test results – dose according to Al_2O_3 1.5 mg/l / flocculant 0.1 mg/l (water intake facility “Zarya”)

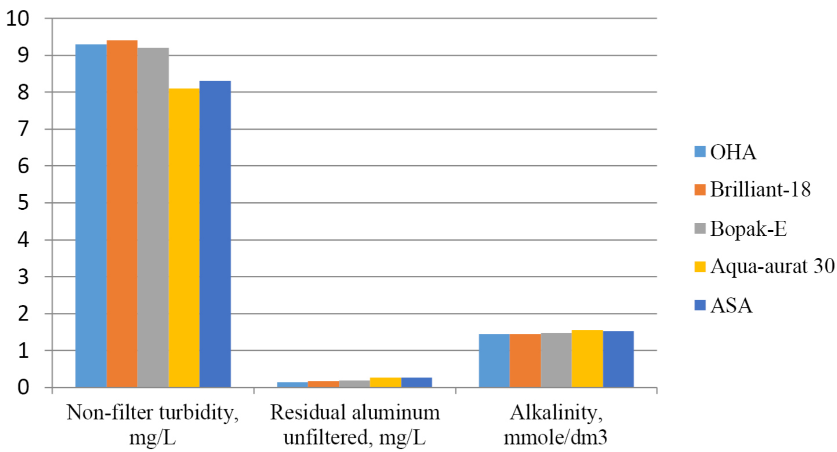

Fig. 5. Coagulant test results – dose according to Al_2O_3 0.8 mg/l / flocculant 0.1 mg/l (water intake facility “Zarya”)

As a result of the tests, large flakes were formed only when “Aqua-aurate 30” and “ASA” were applied at a dose of (1.5/0.1 mg/l). Other coagulants formed small and medium flakes and all coagulants showed intensive sedimentation and clarification.

Tests of coagulants were carried out in the spring flood period at the source water temperature of 6-8°C On the source water of the Irtysh River the best results showed coagulants such as “Bopak-E”, “OHA” and “Aqua-aurat 30”.

The optimal dose for the most effective coagulants is Dk=1.5 mg/l (by Al_2O_3) when combined with flocculant with Df=0.1-0.13 mg/l.

During the laboratory tests, coagulants “Bopak-E” and “Brilliant-18” showed the same results of clarified water quality in terms of residual aluminum and water turbidity in comparison with the coagulant “OHA” used at Rosvodokanal Omsk, at doses as close as possible to those established at production (Dk=1.8 mg/l and Df=0.13mg/l).

Coagulant “Aqua-aurate 30” shows better flaking, sedimentation and clarification, and accordingly better indicators of water turbidity.

Under low alkalinity conditions, Aqua-aurat 30 coagulant increases this index, which contributes to solving the problem of poor coagulation. At optimum doses quality indicators of clarified water by residual aluminum, as well as filtered water by turbidity and residual aluminum, meet the quality assurance of drinking water in accordance with SanPiN 1.2.3485-21, GN 2.1.5.1315-03, GN 2.1.5.2280-07.

To confirm the results of laboratory tests and to select the most effective reagent, it is recommended to conduct production tests of coagulant “Aqua-aurat 30”.

Conclusion

In the process of laboratory testing, many reagents are tested. The purpose of the analysis is to find effective reagents under conditions when the water supply source changes its charge and alkalinity decreases.

Laboratory tests of coagulants based on aluminum polyoxychloride such as “Bopak-E”, “OHA” and “Aqua-aurat 30” show that the performance in conditions of low alkalinity is difficult, but the best coagulation ability is shown by the reagent “Aqua-aurat 30” because of its ability to increase alkalinity by 15-18%, which helps to improve the efficiency of coagulation.

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