RASĀYAN *J. Chem.*
Vol. 18 | No. 1 |229-239| January - March | 2025
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

PURIFICATION OF WATER BY ALUMINUM-SILICON COAGULANTS-FLOCCULANTS

Zh. K. Bakhov[1], A.I.Ishchanova[2], M.I.Sataev[3], A.M.Azimov[3], A.T. Meirbekov[1] and G.M. Iztleuov[3,✉]
[1]S. Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan
[2]A. Baitursynov Kostanay Regional University, Kostanay city, Kazakhstan
[3]M. Auezov South Kazakhstan University, Taukehan Street 5, 16000, Shymkent, Kazakhstan
✉Corresponding author: iztileuov.gani@inbox.ru

ABSTRACT
One of the goals of sustainable development is to ensure the accessibility and rational use of water resources and sanitation for all. The aim of the research was the synthesis of aluminum-silicon coagulants-flocculants for water purification, which is based on the use of mechanical activation of raw materials with various additives. According to the results of the conducted studies, it can be noted that aluminum-silicon coagulants-flocculants based on refractory clay and bauxite usually contain several compounds with coagulating and flocculating abilities. According to the results of the tests, the following data were obtained: - the chemical composition of the bauxite of the Krasnooktyabrsky deposit was determined. The main part of bauxite is gibbsite (33.8%) and kaolinite-1A (26.9%). A smaller amount contains hematite (12.5%), goethite (10.3%), titanium dioxide oxide (7.4%), hercynite (4.7%), and aluminum silicate (4.4%). The chemical composition of the refractory clay of the Arkalyk deposit has been determined. Its main part is kaolinite-1A (52.3%). A smaller amount contains gibbsite (32.6%) and titanium oxide (14.9%). The effectiveness of the proposed coagulant-flocculants was evaluated by analyzing the untreated drinking water of the Kostanay Su KGP enterprise for odor, color, and turbidity before and after the application of the coagulant-flocculant. In general, bauxite and refractory clays of the Kostanay region can be used as raw materials for the production of aluminum-silicon coagulants-flocculants as they are sufficiently effective for natural water purification and are not inferior to similar preparations.
Keywords: Aluminum, Silicon, Coagulants, Floculants, Purification, Activation.
RASĀYAN *J. Chem.*, Vol. 18, No.1, 2025

INTRODUCTION

Coagulation and flocculation are an integral part of the treatment of natural and wastewater, as well as drinking water. In drinking water treatment, water clarification using coagulating agents has been practiced since ancient times.[1] In modern water treatment, coagulation and flocculation are still important water purification processes.[2] Although these are two separate processes, they are often used together and sequentially,[3] Their main purpose is to overcome the forces that stabilize suspended particles in water. It is well known that coagulants neutralize charges on particles, and flocculants allow them to bind to each other, accelerating sedimentation due to the enlargement of particles.[4] Now these drugs are obtained from both inorganic and organic raw materials. Last time In order to improve the environmental safety of coagulants-flocculants, more and more attention is being paid to obtaining them from biological raw materials.[5-10]

The most commonly used inorganic chemical coagulants in water treatment are aluminum sulfate, sodium aluminate, ferrous sulfate, and ferric chloride.[11-13] Coagulants and, especially, flocculants are not always available everywhere. In such conditions, the synthesis of coagulants from locally available raw materials is of particular interest. These include bauxite and fire clay. The synthesis of aluminum-silicon coagulants-flocculants from bauxite and refractory clay can be carried out by various methods. The chemical method for the synthesis of aluminum-silicon coagulants-flocculants[14-19] is based on the hydrolysis reaction of aluminum and silicon salts in an acidic or alkaline medium. The thermal method for the synthesis of aluminum-silicon coagulants-flocculants is based on the use of high temperatures for the treatment of bauxite and clay.[20,21,22] The article by Gupta VK and Kumar R describes the synthesis and characterization of a composite coagulant based on aluminum and silica.[23] They used bauxite and fire clay

http://doi.org/10.31788/RJC.2025.1819038

as starting materials. In the process of coagulant/flocculant synthesis, the method of dry mixing and subsequent heating of the mixtures, as well as pressing the resulting materials, was used. Wang J. and Chen Y. presented a method for the synthesis of a flocculant based on kaolin and bauxite.[24] They described the process of mixing and processing materials and analyzed the properties of the resulting flocculant. In particular, its physicochemical properties (structure, surface properties, and chemical composition) were studied. Aluminosilicate flocculant is highly efficient and stable over a wide pH range and is effective in treating natural and wastewater. Liu J. and Zhang Y. obtained a composite coagulant from kaolin and bauxite waste.[25] The authors investigated the structure and properties of the resulting material, as well as its application in the field of water treatment; the preparation and use of a bauxite-based composite flocculant are considered. They propose a new approach to the synthesis of an effective flocculant using additives (for example, polyacrylamide and other polyelectrolytes) that improve the properties of the flocculant. Zhan Y. and Huang G. studied the influence of various factors, such as component ratio, temperature, and reaction time, on the properties of the resulting bauxite-kaolin composite coagulant.[26] They also analyzed the structure and composition of the resulting aluminosilicate composite coagulant using techniques such as X-ray diffraction and electron microscopy. They explored various synthesis methods, including hydrothermal synthesis and mixing of components followed by roasting. Preparation and application of aluminum-silicon flocculant/coagulant synthesized from bauxite and fire clays by Yan, X., and Hua, M.[27] Kuzin E.N. achieved significant success in the development of new types of coagulants-flocculants. and Kruchinina N.E. *et al.*[28,29,30] The scientific and technological basis for processing aluminum-containing raw materials has been developed to obtain cheap and effective reagents that combine the properties of coagulants and flocculants. They have also developed methods of chemical dehydration of aluminum hydroxide and the production of complex coagulants containing a modifying additive of titanium compounds from 1.5 to 6.5% wt. The authors[31,32,33] obtained composite flocculants-coagulants (ASFC and ISFC) and compared them with traditional aluminum and iron salts. To evaluate the effectiveness of using the obtained flocculant-coagulants with known products, a parameter such as their coagulating ability for the purification of highly colored water was used. The aim of the research was the synthesis of aluminum-silicon coagulants-flocculants for the purification of water, which is based on the use of mechanical activation of raw materials with various additives.[35,36,37] The method will include mixing bauxite and refractory clay along with various additives and mechanical processing of the resulting mixture in planetary mills[38,39,40], which allows, by pre-opening the structure of complex minerals, to facilitate the synthesis of coagulants-flocculants. In the process of mechanical-chemical synthesis of aluminum-silicon coagulants-flocculants, the size and shape of particles can be controlled[41,42], which makes it possible to obtain products with improved properties and high activity.

EXPERIMENTAL

Synthesis of Coagulant-Flocculant

The goal of the research is to develop the scientific and technological foundations for processing bauxite and refractory clay to obtain cheap and effective reagents that combine the properties of coagulants and flocculants. The objects of study in the study were bauxite from the Krasnooktyabrsky deposit and refractory clay from the Arkalyk deposit in the Kostanay region of the Republic of Kazakhstan. For use for technological purposes, bauxite is in accordance with ST RK 3272-2018 “Bauxite. Technical conditions" had to meet the requirements specified in Table-1.

Table-1: Chemical Composition and Particle Size of Bauxite

Mass fraction, %					Particle size, micron
Al_2O_3	SiO_2	Fe_2O_3	CO_2	S total	
not less than 37.0	no more than 17.5	no more than 28.5	no more than 7.5	no more than 0.80	not less than 2.12

Fireclay is a clastic rock of sedimentary origin, consisting mainly of highly dispersed hydroaluminosilicates. The chemical composition and physical and mechanical properties of refractory clay must correspond to the indicators of TU-14-8-43-92 “Fireproof clays of the Arkalyk deposit”, presented in Table-2.

The elemental composition of samples of raw materials and synthesized products was studied using an Inca Energy 350 energy-dispersive microanalysis system (Oxford Instruments) installed in a low-vacuum scanning electron microscope JSM-6490LV (Jeol). To do this, samples of bauxite and refractory clay were placed on a stage and fixed in a holder (grid) [82] (Fig.-1)))0. Next, the image was scanned, and the image was processed and analyzed.

Table-2: Chemical Composition and Physical and Mechanical Properties of Refractory Clay

Mass fraction, %			Fire resistance, 0C	Particle size, mm
Al_2O_3	Fe_2O_3	TiO_2		
not less than 40.0	no more than 2.5	no more than 3.5	not lower than 1730	no more than 500

Fig.-1: Samples of Bauxite and Refractory Clay on the Stage

For X-ray diffraction (XRD) analysis using a D8 Advance (Bruker) diffractometer, bauxite, and fire clay samples were pre-prepared (mechanical crushing, polishing, and coating with a thin layer of conductive material (carbon) to prevent the accumulation of charges on the surface of the sample). The bauxite sample was not subjected to preliminary sample preparation for X-ray diffractometry. The first preparation was fixed in the diffractometer holder and shooting was carried out in the angle range from 2 to 400 at a speed of 10 C/min. Then the preparation was saturated with glycerol and photography was again carried out in the angle range 2-280. The second preparation was fired in an electric furnace at a temperature of 550-600^{0}C for 30 minutes, cooled, and photographed in the angle range 2-280. The unfractionated sample was photographed in the angle range 2-650. The analysis parameters included the use of α-Cu and the following values: tube voltage of 40 kV and current of 40 mA. In X-ray phase analysis (X-ray diffractometry). The synthesis of aluminum-silicon coagulants-flocculants based on refractory clay and bauxite using the mechanical-chemical method includes several main stages (Fig.-2).

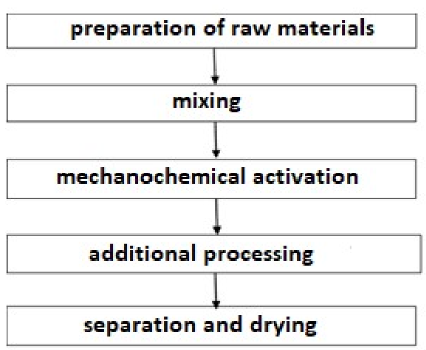

Fig.-2: General Scheme of the Synthesis Process of Aluminum-Silicon Coagulants-Flocculants

Preparation of raw materials: First, the preparation of refractory clay and bauxite is carried out. The raw materials undergo pre-processing, which includes removing impurities, grinding, and drying. As a result, we obtain pure and homogeneous raw materials, ready for subsequent synthesis. Mixing: Purified fire clay and bauxite are mixed in a 1:1 ratio. Mixing was carried out in a Retsch PM 200 planetary ball mill. Mechanical-chemical activation: a mixture of refractory clay and bauxite is subjected to preliminary mechanical-chemical activation. This is a process in which, through mechanical action on a mixture, intensive mixing, grinding, and activation of the surface of the particles is achieved. Additional processing: in some cases, after mechanical-chemical activation, additional processing (with sulfuric acid, with other additives), and high-temperature treatment of the product may be required. All this is aimed at improving the structure and properties of the resulting product. In particular, 50 ml of 9% H_2SO_4 was added to a sample of a mixture of bauxite and refractory clay. For bauxite, acid treatment is accompanied by a chemical reaction:

$$2Al(OH)_3 + 3H_2SO_{4разб} \longrightarrow Al_2(SO_4)_3 + 6H_2O$$

Sulfuric acid attacks the aluminum hydroxide, not the bauxite itself. Bauxite (Al(OH)3) is the main component from which aluminum is produced.
For refractory clay, the chemistry of the process is:

1. Reaction of sulfuric acid with kaolinite-A:

$$Al_2Si_2O_5(OH)_4 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + SiO_2 + 4H_2O$$

This reaction produces aluminum sulfate, silicon dioxide, and water.

2. Reaction of sulfuric acid with gibbsite:

$$Al(OH)_3 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$$

In this case, aluminum sulfate and water are formed.

3. Reaction of sulfuric acid with titanium dioxide:

$$TiO_2 + H_2SO_4 \rightarrow Ti(SO_4)_2 + H_2O$$

As a result of this reaction, titanium sulfate and water are formed. In both cases, the addition of acid results in the extraction of aluminum into the salt form Al2(SO4)3. The resulting solution was filtered through filter paper. This is necessary to remove undissolved residues or impurities that may be present in the starting materials or resulting from the reaction. The filtration process separates solids or sediment from the solution, yielding pure aluminum salt in dissolved form. The resulting filtrate was placed in a special porcelain vessel - a crucible, shown in Fig.-3.

Fig.-3: Filtrate in the Crucible

Next, the filtrate was subjected to thermal treatment in a PM-8 muffle furnace (Fig.-4).

Fig.-4: Muffle Furnace

Heating in the muffle furnace took place under the following parameters: the exposure temperature was 6000C for a duration of 10 minutes, 15 minutes, 20 minutes; at 800^0C, a duration of 5 minutes, 10 minutes, and 15 minutes.
1. At 600^0C for 10 minutes:
Dehydration. Some of the water from the solution evaporates, which can be represented as an equation:

$$H_2O(ж) \rightarrow H_2O(г)\uparrow$$

The water evaporates and turns into steam, which leaves the system.
2. Heating at 600^0C for 15 minutes:

More significant evaporation of water from the solution, similar to the reaction from the previous case. Transformation of titanium sulfate:

$$Ti(SO_4)_2 \rightarrow TiO_2 + SO_2\uparrow + O_2\uparrow$$

3.Heating at 600^{0}C for 20 minutes:
Additional evaporation of water from the solution, similar to the reaction from the previous cases. Decomposition of aluminum sulfate:

$$2Al_2(SO_4)_3 \rightarrow 4Al_2O_3 + 6SO_3\uparrow + O_2\uparrow$$

Exposing a mixture of bauxite and fire clay to dilute sulfuric acid and then holding it in a muffle furnace at 800^{0}C for various time intervals can lead to the following chemical reactions:

1. After exposure to hydrochloric acid on a mixture of bauxite and refractory clay, subsequent exposure in a muffle furnace at 800^{0}C for 5 minutes:
   Conversion of metal oxides:

$$TiO_2 \rightarrow TiO_3$$

Titanium dioxide turns into titanium trioxide.

2. When held in a muffle furnace at 800^{0}C for 10 minutes:
   Dehydration of organic components. Decomposition of sulfates and carbonates:

$$Ti(SO_4)_2 \rightarrow TiO_2 + 2SO_2\uparrow + O_2\uparrow$$

Titanium sulfate produces titanium dioxide, sulfur dioxide, and oxygen:

$$Al_2(SO_4)_3 \rightarrow Al_2O_3 + 3SO_3\uparrow$$

Aluminum sulfate during heat treatment at 800^{0}C decomposes into aluminum oxide and sulfur trioxide. The transformation of metal oxides occurs through the chemical reaction described above.

3. When held in a muffle furnace at 800^{0}C for 15 minutes:

Similarly, as with 10 minutes, only the resulting product will be more concentrated.
Thermal treatment of bauxite and fire clay can play an important role in the production of coagulant-flocculants. Here are a few reasons why it may be necessary: Activation and Stabilization of Properties: Heat treatment can improve the activity and stability of properties of bauxite and fire clay. This can occur by changing their phase composition, structure, and surface, which affects their ability to coagulate and flocculate particles in aqueous environments. Removing Moisture and Organic Matter: Heat treatment can be used to remove moisture and organic matter from bauxite and fire clay. This helps improve their efficiency and prevents potential problems associated with the decomposition of organic compounds when used in aqueous processes. Increase in surface and porosity: Heat treatment can result in an increase in the surface and porosity of bauxite and fire clay. This promotes increased surface activity, increases the area of contact with aqueous solutions, and improves their ability to capture and remove particles and contaminants. Improvement of mechanical properties: Heat treatment can help improve the mechanical properties of bauxite and fire clay, such as strength and stability. This can be important to ensure their durability and effectiveness in water treatment. Separation and drying: Once the synthesis is complete, the product is separated from the mixture, for example using sieves or centrifugation. The resulting product is then dried to remove excess moisture. To simplify the name in the text, we conventionally called the synthesized coagulant-flocculant MAKF-1 (mechanically activated coagulant-flocculant).

Testing the Effectiveness of the Coagulant-Flocculant

To test MAKF-1, in accordance with GOST 24481, untreated drinking water was taken from the Kostanay Su state enterprise. According to GOST 3351-74 “Drinking water. Methods for determining taste, smell, color, and turbidity." Organoleptic quality indicators, water turbidity, and color were determined. The intensity of the odor of water was determined at 20 and 60 °C and a five-point system was used. To determine color, a photometric method was used. To prepare a color scale, use a set of Nessler cylinders with a capacity of 100 ml. In each cylinder, solutions No. 1 and No. 2 were mixed in the ratio indicated on the color scale in Table-3.
The solution in each cylinder corresponds to a certain degree of color. The color scale is stored in a dark place. It is replaced every 2-3 months. The calibration graph is constructed according to the color scale. The obtained values of optical densities and the corresponding degrees of chromaticity are plotted on a graph. Photometric method for determining wire turbidity or no later than 24 hours after sampling. For

this purpose, standard kaolin suspensions were prepared. It contains about 4 g/dm3 of kaolin. If the color of the sample being measured is above 10° Cr-Co scale, then the control liquid is the test water, from which suspended substances have been removed by centrifugation (centrifuge for 5 minutes at 3000 minutes) or by filtration through a membrane filter with a pore diameter of 0.5-0.8 µm. The turbidity content in mg/dm3 was determined according to the table compiled by the Kostanay Su enterprise with a coefficient of 0.0157.

Table-3: Color Scale

Solution No. 1, cm	0	1	2	3	4	5	6	8	10	12	14
Solution No. 2, cm	100	99	98	97	96	95	94	92	90	88	85
Color degrees	0	5	10	15	20	25	30	40	50	60	70

Since 6 samples were prepared MAKF-1. Also, 6 samples of untreated natural water (used to obtain drinking water) of 100 ml each were prepared. Next, 10 ml of the resulting product was added to them. Next, the water after treatment with the purifier was subjected to the same analysis as before.

RESULTS AND DISCUSSION

Elemental analysis of bauxite and refractory clay samples was carried out using electron microscopy. An electron photograph of bauxite under a scanning microscope and its spectrum are presented in Fig.-5.

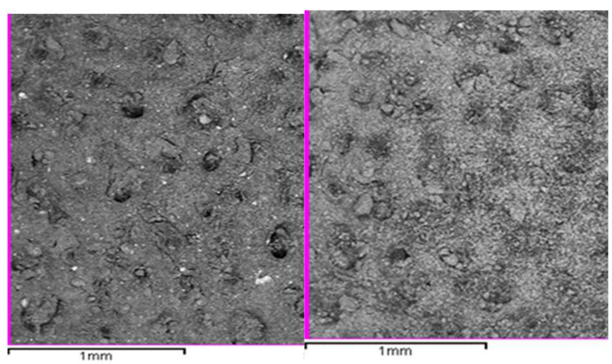

Fig.-5: Electronic Photograph of Bauxite (1) and Refractory Clay (2)

From the electron image, we can conclude that the bauxite sample has particles of different sizes. Refractory clay is more homogeneous, but it also contains larger particles. The content of the main chemical elements of the bauxite sample under study is presented as a spectrum in Fig.-6.

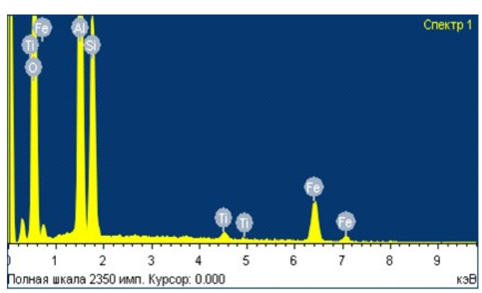

Fig.-6: Bauxite Spectrum

Based on the spectrum data, we can say that bauxite consists of elements such as oxygen, titanium, iron, and aluminum. The chemical composition of bauxite is presented in Table-4. According to the data obtained, we can conclude that the main part among the elements is oxygen (57.27%) and aluminum (20.07%). Less in mass content is silicon (13.23%), iron (8.64%), and titanium (0.79%). The diffraction pattern of bauxite obtained by X-ray diffraction is shown in Fig.-7.

Table-4: Chemical Composition of Bauxite

Element	Weight %	Oxide	Weight %
O	57.27	-	-
Al	20.07	Al_2O_3	37.93
Si	13.23	SiO_2	28.30
Ti	0.79	TiO_2	1.32
Fe	8.64	Fe_2O_3	12.36
Total:	100.0		

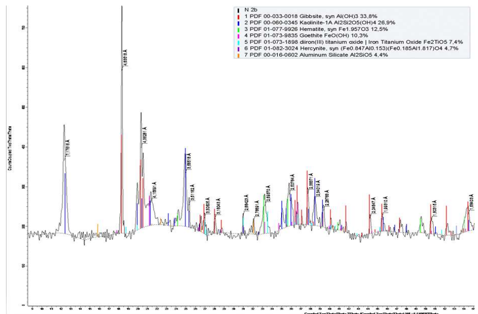

Fig.-7: Bauxite Diffraction Pattern

The diffraction patterns of bauxite contain characteristic peaks that indicate the presence of certain crystalline phases. According to the diffraction patterns of bauxite, it follows that the following substances were discovered: gibbsite $Al(OH)_3$, kaolinite-1A $Al_2SiO_5(OH)_4$, hematite Fe_2O_3, goethite FeO(OH), diiron titanium oxide Fe_2TiO_5, hercynite, aluminum silicate Al_2SiO_5. The content of the main chemical elements of the bauxite sample under study is presented as a spectrum in Fig.-8.

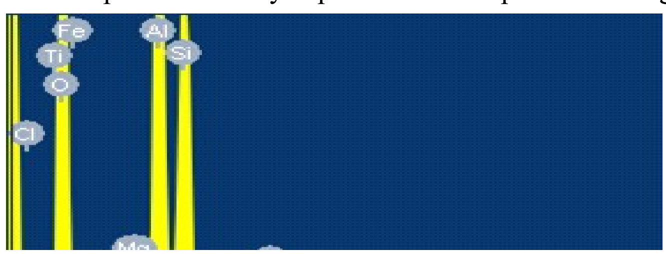

Fig.-8: Spectrum of Refractory Clay

According to the spectrum data, we can say that refractory clay consists of elements such as chlorine, oxygen, titanium, iron, sodium, magnesium, aluminum, silicon, sulfur, and titanium. The chemical composition of refractory clay is presented in Table-5.

Table-5: Chemical Composition of Refractory Clay

Element	Weight, %	Oxide	Weight, %
O	60.18	-	-
Na	0.41	Na2O	0.65
Mg	0.33	MgO	0.55
Al	19.16	Al2O3	36.21
Si	16.75	SiO2	35.83
S	0.39	-	-
Cl	0.94	-	-
Ti	1.02	TiO2	1.70
Fe	0.81	Fe2O3	1.16
Total:	100.0		

According to the data obtained, we can conclude that the main part of the elements is oxygen (60.18%), aluminum (19.16%), and silicon (16.75%). Titanium (1.02%), chlorine (0.94%), iron (0.81%), sodium (0.41%), sulfur (0.39%), and magnesium (0.33%) are present in smaller quantities). Many of the elements that make up fire clay are in the form of oxides. The highest content is aluminum oxide (36.21%), silicon oxide (35.83%), titanium dioxide (1.70%), and iron (III) oxide (1.16%). Chlorine (0.39%) and sulfur

(0.94%) are not in oxide form. The diffraction patterns of fire clay are shown in Fig.-9. The diffraction patterns of fire clay contain characteristic peaks that indicate the presence of certain crystalline phases. According to the diffraction patterns of bauxite, it follows that the following substances were discovered: kaolinite-1A $Al_2SiO_5(OH)_4$, gibbsite $Al(OH)_3$, titanium oxide TiO_2.

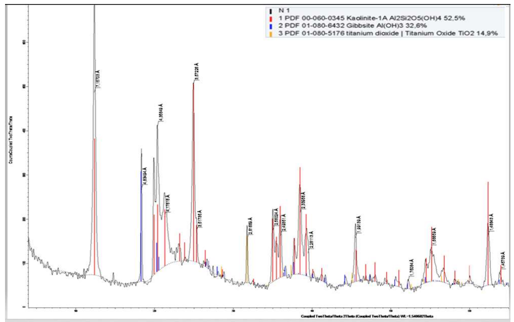

Fig.-9: Diffractogram of Refractory Clay

2 Stage of testing the effectiveness of the coagulant-flocculant. The effectiveness of the synthesized coagulant-flocculant MAKF-1 was tested on the drinking water intake of the Kostanay Su State Enterprise (Kostanay City, Republic of Kazakhstan). The obtained MAKF-1 samples: No. 1 – at 600^0C, held for 10 minutes; No. 2 – at 600^0C, held for 15 minutes; No. 3 – at 600^0C, held for 20 minutes; No. 4 – at 800^0C, held for 5 minutes; No. 5 – at 800^0C, held for 10 minutes; No. 6 – at 800^0C, held for 15 minutes. Organoleptic odor evaluation before (untreated) and after treatment of six drinking water coagulant-flocculant samples is shown in Table-6.

Table-6: Results of Water Odor Determination

Untreated drinking water	Purified drinking water	
Very strong. The smell is so strong that it makes the water unfit for drinking.	Sample No. 1	No. There is no smell
	Sample No. 2	No. There is no smell
	Sample No. 3	Distinct. The smell attracts attention and makes you refrain from drinking.
	Sample No. 4	No. There is no smell
	Sample No. 5	Distinct. The smell attracts attention and makes you refrain from drinking.
	Sample No. 6	Distinct. The smell attracts attention and makes you refrain from drinking.

The results of determining the turbidity of untreated and purified drinking water are shown in Table-7.

Table-7: Results of Determining Water Turbidity

Untreated drinking water, mg/dm3	Purified drinking water, mg/dm3	
6.24	Sample No. 1	4.14
	Sample No. 2	4.08
	Sample No. 3	6.24
	Sample No. 4	4.14
	Sample No. 5	4.14
	Sample No. 6	6.24

The results of determining the color turbidity of untreated and purified drinking water are shown in Table-8.

From the experimental data, it follows that prepared samples No. 1. No. 2, and No. 4 exhibit coagulating and flocculating properties because Water quality indicators are improving. The characteristic smell of contaminated water disappears, and turbidity and color indicators decrease. A comparative study of the effectiveness of MAKF-1 with sodium aluminate (hereinafter referred to as AN) and ferrous sulfate (hereinafter referred to as SF) was carried out on the drinking water intake of the Kostanay Su State Enterprise (Kostanay City, Republic of Kazakhstan). Coagulant-flocculant MAKF-1 was added in equal quantities in terms of Al2O3. The experimental results (Figures 10-12) showed that MAKF-1 is an effective coagulant-flocculant that helps reduce the turbidity and color of water. In terms of effectiveness, MAKF-1 is not inferior to known coagulants. All samples of MAKF-1 at a concentration of 20 mg/l or more ensured the pH of purified water within the standard (pH = 6-9). The efficiency of purification of natural water from suspended solids using MAKF-1 was compared with the indicators obtained using AN and SZh. For this purpose, a model suspension was used with an initial content of suspended solids of 340 mg/l at the same doses of coagulants applied to Al_2O_3.

Table-8: Results of Determining Water Color

Untreated drinking water	Purified drinking water, color grade	
25 degrees color	Sample No. 1	18
	Sample No. 2	19
	Sample No. 3	24
	Sample No. 4	17
	Sample No. 5	25
	Sample No. 6	25

CONCLUSION

Based on the results of the studies, it can be noted that aluminum-silicon coagulants-flocculants based on refractory clay and bauxite usually contain several compounds that have coagulating and flocculating abilities. The two main components that perform these functions are Aluminum (Al): It is the main active component that has coagulating properties. Aluminum forms polyaluminate and polyaluminosilicate compounds when interacting with refractory clay and bauxite. These compounds are highly electrophilic and are capable of forming hydroxide precipitates, which promote thickening and coagulation of aqueous solutions and suspensions. Silicon (Si): It is an important component for the flocculation properties of aluminum-silicon coagulants-flocculants. It may be present as silicon oxides (SiO_2) in fire clay and bauxite. Silicon promotes the formation of flocs, prevents the formation of strong coagulating deposits, and facilitates the formation of more stable and larger flocs. A literature review on the research topic showed that the synthesis of aluminum-silicon coagulants-flocculants from bauxite and refractory clay can be carried out by various methods (chemical, thermal, and mechanochemical). Based on the results of the tests, the following data were obtained: - the chemical composition of bauxite from the Krasnooktyabrsky deposit was determined. The main part of bauxite is gibbsite (33.8%) and kaolinite-1A (26.9%). Smaller amounts contain hematite (12.5%), goethite (10.3%), diiron titanium oxide (7.4%), hercynite (4.7%), and aluminum silicate (4.4%). The chemical composition of refractory clay from the Arkalyk deposit was determined. Its main part is kaolinite-1A (52.3%). Smaller amounts contain gibbsite (32.6%) and titanium oxide (14.9%).

Mechanical-chemical activation of aluminum-silicon raw materials was used by additional grinding in a planetary mill, followed by acid treatment with sulfuric acid and thermal exposure. The exposure parameters in the muffle furnace were set at a temperature of 6000C with exposure durations of 10, 15, and 20 minutes. At 8000C the exposure time was 5, 10, and 15 minutes. An assessment of the effectiveness of the proposed drug was carried out by analyzing untreated drinking water from the Kostanay Su enterprise in terms of odor, color, and turbidity before and after the use of a coagulant-flocculant. In general, bauxite and refractory clay from the Kostanay region can be used as raw materials for the production of aluminum-silicon coagulants-flocculants. The preparation of natural waters for drinking and domestic consumption involves, first of all, bringing them into compliance with regulatory requirements for turbidity, color, and oxidability. MAKF-1 is sufficiently effective for purifying natural waters and is not inferior to similar drugs.

ACKNOWLEDGMENTS

The research work was carried out on the basis of project No. 30-PCF-23-24 dated January 25, 2023, subject: BR18574143 “Development and implementation of groundwater purification technology and provision of drinking water to the population and animals of an agricultural enterprise” financed Ministry of Science and Higher Education of the Republic of Kazakhstan.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

Zh.K. Bakhov https://orcid.org/0000-0001-8107-1027
A.I. Ishchanova https://orcid.org/0009-0006-9154-5576
A.M. Azimov https://orcid.org/0000-0002-1316-5854
M.I. Satayev https://orcid.org/ 0000-0002-5819-4480
A.T. Meirbekov https://orcid.org/0000-0003-1173-4344
G.M. Iztleuov https://orcid.org/0000-0002-5722-342X

REFERENCES

1. S. V. Getmantsev, I. A. Nechaev and L. V. Gandurina, Industrial wastewater treatment with coagulants and flocculants, Moscow: ASV Publishing House, p.271(2008)
2. J. Bratby, Coagulation and Flocculation in Water and Wastewater Treatment, *IWA Publishing,* London (2006), https://doi.org/10.2166/9781780402321
3. S. Maiti, B. Prasad, and A.K. Minocha, *SN Applied Sciences* **2,** 2151(2020), https://doi.org/10.1007/s42452-020-03892-8
4. N. Das, N. Ojha and S.K. Mandal *Water Science and Technology* **83(8),** 1797(2021), https://doi.org/10.2166/wst.2021.100
5. S.S. Al Moharbi, M.G. Devi, B.M. Sangeetha, et al., *Applied Water Science*, **1(0123456789),** 10(2020), https://doi.org/10.1007/s13201-019-1100-z
6. N. Bakhtiari, S. Azizian, S.M. Alshehri, N.L. Torad, V. Malgras, Y. Yamauchi, *Microporous Mesoporous Materials*, **217**, 173(2015), https://doi.org/10.1016/j.micromeso.2015.06.022
7. F. Pinakidou, E. Kaprara, M. Katsikini, E.C. Paloura, K. Simeonidis, M. Mitrakas, *Science of the Total Environment,* **551-552**, 246(2016), https://doi.org/10.1016/j.scitotenv.2016.01.208
8. Y. Tian, M. Wu, R. Liu, Y. Li, D. Wang, J. Tan, R. Wu, Y. Huang, *Carbohydrate Polymers*, **83**, 743(2011), https://doi.org/10.1016/j.carbpol.2010.08.054
9. U. Maheshwari, B. Mathesan, S. Gupta, *Process Safety and Environmental Protection*, **98**, 198(2015), https://doi.org/10.1016/j.psep.2015.07.010
10. B. Ramavandi, G. Asgari, *Process Safety and Environmental Protection* **116,** 61(2018), https://doi.org/10.1016/j.psep.2018.01.012
11. F. Fu, Q. Wang, *Journal of Environmental Management.*, **92(3),** 407(2011), https://10.1016/j.jenvman.2010.11.011
12. A. Zh. Shingisbaeva, A.A.Abduova, A.S. Taubayeva, N. Zhorabaeva, *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti*, **379(1),** 323(2019)
13. Y. Fu, Y. Shen, Z. Zhang, X. Ge, M. Chen, *Science* of the *Total Environment*, **646**, 1567(2019), https://doi.org/10.1016/j.scitotenv.2018.07.423
14. J. Jang, W. Miran, S.D. Divine, M. Nawaz, A. Shahzad, S.H. Woo, D.S. Lee, S*cience of the Total Environment*, **615**, 698(2018), https://doi.org/10.1016/j.scitotenv.2017.10.023
15. S. Kizito, S. Wu, W.K. Kirui, M. Lei, Q. Lu, H. Bah, R. Dong, *Science of the Total Environment,* **505**, 102(2015), https://doi.org/10.1016/j.scitotenv.2014.09.096
16. M. Xu Y. Zhao, C. Zhanget al., *Applied Microbiology and Biotechnology*, **100,** 6509(2016), https://doi.org/10.1007/s00253-016-7646-x
17. M. Šćiban, M. Klašnja, B. Škrbić, *Desalination,* **229(1–3)**, 170(2008) https://doi.org/10.1016/j.desal.2007.08.017

18. T. M. Khudyakova, O. G. Kolesnikova, N. N. Zhanikulov, *et al.*, *Refractories and Industrial Ceramics*, **62(4)**,369(2021), https://doi.org/10.1007/s11148-021-00610-8
19. Y. Gao, R. Zhou, L .Yao et al., *Journal of Hazardous Materials* **424(A),** 127203(2022), https://doi.org/10.1016/j.jhazmat.2021.127203
20. Y. Gomravi, A. Karimi and H. Azimi, *Korean Journal of Chemical Engineering,* **38,** 1843(2021), https://doi.org/10.1007/s11814-021-0802-8
21. T.G. Asere, C.V. Stevens, G. Du Laing, *Science of The Total Environment,* **676(1),** 706(2019), https://doi.org/10.1016/j.scitotenv.2019.04.237
22. M. Gorgievski, D. Bozić, V. Stanković, N. Štrbac, S. Šerbula, *Ecological Engineering*, **58,** 113(2013), https://doi.org/10.1016/j.ecoleng.2013.06.025
23. Z. Aksu, İ.A. İşoğlu, *Process Biochemistry*, **40(9),** 3031(2005), https://doi.org/10.1016/j.procbio.2005.02.004
24. L. Castro, M.L. Blázquez, F. González, J.A. Muñoz, A. Ballester, *Science of The Total Environment*, **598(15),** 856(2017), https://doi.org/10.1016/j.scitotenv.2017.04.138
25. G. Zh. Akhmetova, M. A. Berdikulov, I. S. Polezhaeva, G. N. Agabekova, A. M. Yessirkepova, *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti*, **393(3)**, 30(2021).
26. W.S.W. Ngah, M.A.K.M. Hanafiah, *Journal of Environmental Sciences,* **20(10),** 1168(2008), https://doi.org/10.1016/S1001-0742(08)62205-6
27. S. Banerjee, S. Mukherjee, A. LaminKa-ot, S.R. Joshi, T. Mandal, G .Halder, *Journal of Advanced Research*, **7(5),** 597(2016), https://doi.org/10.1016/j.jare.2016.06.002
28. Y.S. Ho, C.T. Huang, H.W. Huang, *Process Biochemistry,* **37(12)**,1421(2002), https://doi.org/10.1016/S0032-9592(02)00036-5
29. S. Lu, S.W. Gibb, *Bioresource Technology*., **99(6),** 1509(2008), https://doi.org/10.1016/j.biortech.2007.04.024
30. M.A. El-Nemr, U.O. Aigbe, M.A. Hassaan, K.E. Ukhurebor, S. Ragab, R.B. Onyancha, O.A. E.l. Osibote, A. Nemr, *Biomass Conversion and Biorefinery,* **14(1**), 1(2022) https://doi.org/10.1007/s13399-022-02327-1
31. W. Zhang, J. He Q. Song, H. Wang, W. Lyu, H. Feng, W. Xionsg, W. Guo, J. Wu, L.Chen, *Journal of Hazardous Materials*, **384,** 121445(2020).
32. A.E.Ofomaja, E.B. Naidoo, *Chemical Engineering Journal,* **175(15),** 260(2011), https://doi.org/10.1016/j.cej.2011.09.103
33. M.A. Martín-Lara, N. Ortuño, J.A. Conesa, *Science of The Total Environment*, **613-614**, 418(2018), https://doi.org/10.1016/j.scitotenv.2017.09.116
34. M.Makeswari, T. Santhi, *Research on Chemical Intermediates*, **40**, 1157(2014), https://doi.org/10.1007/s11164-013-1029-z
35. R. Gündoğan, B. Acemioğlu, M.H. Alma, *Journal of Colloid and Interface Science*, **269(2),** 303(2004), https://doi.org/10.1016/S0021-9797(03)00762-8
36. T. Townsend, T. Tolaymat, K. Leo, J. Jambeck, *Science of The Total Environment***, 332(1-3)**, 1 (2004), https://doi.org/10.1016/j.scitotenv.2004.03.011
37. A. Eleryan, U.O. Aigbe, K.E. Ukhurebor, et al. *Biomass Conversion and Biorefinery,***14**, 9283(2022), https://doi.org/10.1007/s13399-022-02918-y
38. M. Satayev, A. Azimov, G. Iztleuov, L. Satayeva, *Water*, 16(1), 172(2024), https://doi.org/10.3390/w16010172
39. N.T. Mai, M.N. Nguyen, T. Tsubota, et al. *Scientific Reports* **11**, 14430(2021), https://doi.org/10.1038/s41598-021-93934-x
40. A.Z. Vela-Carrillo, R.J. Martínez, L.A. Godínez, et al., *Biomass Conversion and Biorefinery*, **14,** 733(2022), https://doi.org/10.1007/s13399-022-02367-7
41. I. Abbazov, R. Kaldybaev, Bektureyeva, A. Kolesnikov, *Polish Journal of Environmental Studies*, **32(4)**, 3007(2023), https://doi.org/10.15244/pjoes/163341

[RJC-9038/2025]