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Applicability of Zeolite from the Daubabinsk and Chankanai Deposits as a Sorbent for Natural Waters

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Abstract: This article examined the characteristics of zeolites from the Chankanai and Daubabinsk deposits. In the field of water treatment, the purpose of investigating natural zeolite from the Chankanai and Daubabinsk deposits as a sorbent presents new opportunities and prospects, as this raw material is little studied. The effectiveness of the sorbents was assessed based on the results of the water specifications according to the following criteria: methods for determining the total hardness of water; methods for measuring the mass concentration of total iron in water; methods for the determination of chloride in water; methods for the determination of nitrogen-containing substances in water; methods for determining the dry residue content of water; methods for determining the sulphate content of water; on hygiene requirements and water quality control. Zeolite modifications were aimed at improving their adsorption properties, increasing the efficiency of pollutant removal and developing optimal methods of using zeolites in water filtration. Modified zeolite from the Chankanai and Daubabinsk deposits showed high efficiency as a filter. When it was used to treat natural water, which normally contains high hardness and alkalinity, the best results were achieved with zeolite from the Chankanai deposit. In terms of Fe^+ and Cl content, the best results were achieved using zeolite from the Daubabinsk deposit.

Keywords: sorbent; filter; zeolite; water treatment; Daubabinsk; Chankanai; sorption; drinking water; natural water

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1. Introduction

Modern scientific and technological progress is accompanied by increasing pressure on the environment, including the hydrosphere and natural water resources. This is due to the constant introduction of a variety of organic and non-organic substances into water bodies [1–4].

The development of industry, agriculture, urban development and other sectors of the economy leads to the emission of harmful substances into the environment [5]. Some of these substances may be naturally occurring, but most are man-made chemical compounds. Such pollutants include heavy metals, pesticides, industrial waste, petroleum products, pharmaceuticals and other substances [6].

By entering natural water systems, these substances can have a negative impact on ecosystems and human health [7,8]. They can accumulate in aquatic organisms and disrupt the biological equilibrium as well as pollute water resources, making them unfit for drinking and domestic use. It is, therefore, important to develop and apply effective natural water treatment methods that will remove pollutants and ensure the environmental safety of water resources. This includes the development of new cleaning technologies, strict control of pollutant emissions and measures to reduce the negative environmental impact of industrial and other activities [9].

There are several modern natural sorbents such as activated carbon, green alumina, biosorbents (bacteria, algae and other micro-organisms) and coconut charcoal, as well as ashes and ashes from various plants and wood materials. They effectively remove organic substances, pesticides, chlorine, chemical compounds, toxic metals, radionuclides and other pollutants due to their large surfaces, many pores, high adsorption capacity, chemical stability and natural origin, which are widely used to clean water from various pollutants [10,11].

The study of natural zeolite as a sorbent represents a novelty in the field of treatment of various types of water. Modified zeolite from Daubabinsk and Chankanai deposits is poorly studied and there is no industrial production of zeolite-based filters across the CIS.

The significance of the study is to determine the applicability of Daubabinsk and Chankanai zeolite as a sorbent after modification for natural waters.

Using the sorbents listed above, a number of methods are used to treat natural water from pollutants, with both advantages and disadvantages [10–12]. Filtration, coagulation and flocculation and ozonation are common water treatment methods. Filtration is based on passing water through a filter that traps pollutants [12,13]. Coagulation and flocculation involve the addition of coagulants to combine fine contaminant particles into larger ones, thereby facilitating their removal. Ozonation uses ozone to oxidize and break down pollutants and micro-organisms in water [14,15]. All methods except filtration have advantages and limitations and require appropriate equipment and costs to operate effectively; the filtration method is the most attractive as it does not require expensive equipment.

For wastewater treatment, an interesting work [16] presented a comparative literature review on the production methods, adsorption properties and mechanisms of adsorption and regeneration of metal oxides (hydra) (e.g., Fe, Zn, Al, etc.) with respect to phosphate removal. The adsorption of phosphate on metal oxides and hydroxides is a simple and effective way of purifying water from phosphate pollution, which contributes to the ecological equilibrium of water systems.

Additionally, in [17], micro (nanostructured) MgO hollow spheres with selective adsorption and their application for monitoring of fluoride content in water were considered, such use of micro (nanostructured) MgO hollow spheres for monitoring of fluoride content in water allows fast and accurate determination of the presence of this chemical element. This is important because high fluoride levels in drinking water can have negative health effects.

The most well-known and widespread method of treating natural water can be attributed to sorption. The sorption method is one of the best known and most widely used methods of natural water treatment. It is based on the use of sorbents capable of binding and retaining pollutants on their surface or in their structure [15,18]. The sorption method has several advantages that make it an important tool in natural water treatment; sorbents can effectively remove a wide range of pollutants, including organic substances, heavy metals, pesticides and other harmful compounds. This allows the sorption method to be adapted to remove specific contaminants by selecting a suitable sorbent and optimizing the process conditions. Some sorbents have a long service life and can be regenerated or reclaimed for reuse. This reduces the cost of purchasing new sorbents and reduces the negative impact on the environment. However, the sorption method also has some disadvantages. Sorbents have a limited capacity to retain pollutants, so periodic replacement or regeneration of the sorbents is required. The sorption treatment process may generate waste that requires further treatment or disposal. This may incur additional costs and have a negative impact on the environment. In general, despite some disadvantages, the sorption method is widely used in industry, utilities and other areas as it provides effective water treatment and helps ensure the safety and quality of water resources.

Using the sorption method, natural sorbents were recently increasingly used for natural water treatment [18,19]. Natural sorbents are materials that originate from natural sources such as zeolite and others.

Zeolites have numerous properties, including the ability to remove contaminants from water [19]. One way to use zeolites in water treatment is to create filters based on their properties.

Zeolites have a structure that contains micropores and channels of varying sizes. These pores and channels enable zeolites to effectively trap and remove various contaminants from water, including heavy metal ions, ammonia, pesticides, organic compounds and other substances. They are also able to exchange some ions, such as sodium or potassium, for other ions in the water.

In general, the use of zeolite filters for water treatment has a long history and the technology is widely used in a variety of applications, including domestic water treatment systems, industrial processes and city- and community-scale drinking water treatment.

In terms of structure and morphology, zeolites have a layered structure, which is formed by a three-dimensional network of silicon and aluminium oxide frameworks with included cations; this provides a microporous zeolite structure and high surface activity, the chemical composition of zeolite contains silicon (Si), aluminium (Al), oxygen (O) and other elements in its chemical composition. Cations such as sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) can also be present in the zeolite structure; the physical properties of the zeolite have different physical properties, such as different particle sizes, permeability, density and strength. These properties may vary depending on the specific conditions of the deposit and processing.

2. Materials and Methods

2.1. Materials

The Chankanai deposit is located in Gvardeisky district of Almaty region, 25 km south-east of Saryozek railway station and 5 km southeast of Chankanai RTS (RTS—radio and telecommunications military station), 1 km from an asphalt road. The area is economically developed and it opened in 1990.

Daubabinsk (Daubaba) deposit is located in Sayram district of South Kazakhstan region, 45 km north-east of Shymkent city, 11 km south-east of Sastobe railway station, 5 km east of Keltemashat settlement.

In general, zeolites are a group of microporous aluminosilicate minerals with good sorption capacity and are used for water treatment and other industrial processes. They have a layered structure and contain cations in their structure, such as sodium, potassium, calcium and others. General characteristics are similar to zeolite from the Chankanai deposit.

The object of the study is zeolite from the Chankanai and Daubabinsk deposits as a filter. To assess the effectiveness of zeolite as a filter, the natural water of the Bolshaya Almatinka in Almaty with a natural degree of contamination and the drinking water of Almaty were the object of the study.

2.2. Methods

The zeolite samples from the Chankanai and Daubabinsk deposits were analyzed by X-ray microanalysis. The electron probe microanalyser used was a Superprobe 733 from JEOL, Tokyo, Japan [20]. The X-ray microanalysis method is an analytical method used to determine the elemental composition of samples at the micro level. It is based on measuring the energy and intensity of X-rays emitted by a sample when it is irradiated with an electron beam.

In our case, an electron probe microanalyser, Superprobe 733 from JEOL, Japan, was used for XRF analysis. This instrument was designed for high precision and microanalytical examination of samples.

A Superprobe 733 electron probe microanalyser was used to perform spot analysis, element mapping and qualitative and quantitative information about the composition of the sample.

Study of the structural and elemental-oxide composition of zeolites by electron-probe microanalysis. Elemental composition analyses and photomicrography of the samples were performed with a Superprobe 733 electron-probe microanalyser at an accelerating voltage of 25 kV and a probe current of 25 nA, and they were reflected and secondary electron images at magnifications of 40× to 300,000×.

Modification of zeolite samples from Chankanai and Daubabinsk was carried out in 20% hydrochloric acid solution [20].

Zeolite modification involved the following work steps:

Step 1—Preparation of the zeolite: The rock was pre-crushed in a blast crusher MShL-1P, SINOWATT MACHINE LLP, Moscow, Russia (alternatively, a ball mill can be used) to the required particle-size ratio (hereinafter referred to as the particle-size ratio).

Step 2—Preparation of the solution: A 20% hydrochloric acid solution was prepared by diluting concentrated hydrochloric acid in distilled water.

Step 3—Modification reaction: The zeolite was placed in a hydrochloric acid solution and heated to a temperature of 95–100 °C for 1.5–2 h.

Step 4—Filtration and washing: After treatment, the zeolite was extracted from the hydrochloric acid solution and filtered to remove residual acids and other inorganic compounds. The zeolite was then washed with distilled water to remove residual acid reagents and reaction products to a neutral pH.

Step 5—Drying: The purified zeolite was dried to a constant mass, usually in a muffle furnace ECPS-10 SPU, NV-LAB laboratory equipment center, Moscow, Russia, to remove moisture and the liquors formed during washing.

The modification process involved interaction of the zeolites with hydrochloric acid at a specified concentration.

Modification with hydrochloric acid led to a change in the chemical and physical properties of the zeolite. Hydrochloric acid is highly reactive and has the ability to react with the surface of the material. This allows the chemical structure and surface properties of the zeolite under study to be altered.

The process of modification in hydrochloric acid solution led to various effects including changes in surface activity, formation of new functional groups, changes in ion exchange, etc. Such changes improve the adsorption and catalytic properties of the zeolite, as well as its interaction with pollutants in the water treatment process [18].

The following filter apparatus was used to filter the water (Figure 1).

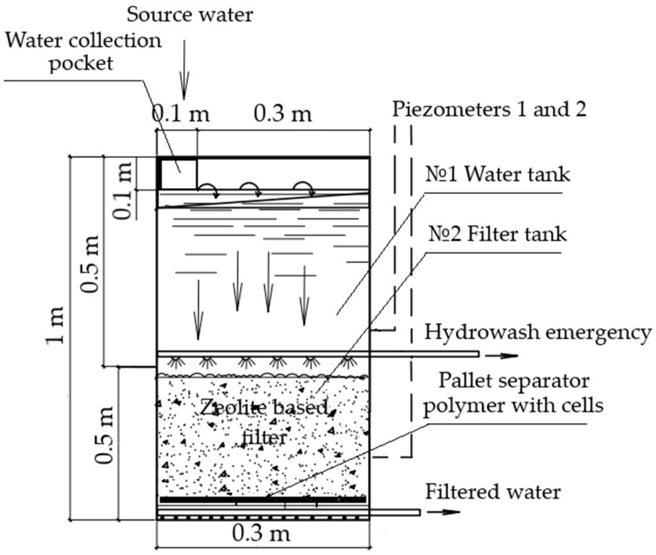


Figure 1. Schematic diagram of a filter unit.

Filtration procedure consisted of the following: a cylindrical polymer tank No. 1 received water with the volume V = 0.03534 m^3 or 35.34292 L for 0.2–0.5 min, water passed through the filter No. 2 with the volume V = 0.03534 m^3 for 1.5–10 min and filtered water was then poured into caustic vessels to determine purification degree. The transit time through the filter depended on the Mk (Size modulus) of the modified zeolite.

The qualitative index of natural water and drinking water was determined according to the following standards:

GOST 4151-72 (GOST—Government standard) "Drinking water. Method for determination of total hardness"; this standard applies to drinking water and establishes the complex metric method for determination of total hardness. The method is based on the formation of a strong complex compound of Trilon B with calcium and magnesium ions. The volume of the water sample for the determination of total hardness was at least 250 cm^3. If the hardness cannot be determined on the day of sampling, a measured volume of water diluted with distilled water 1:1 may be left for determination until the next day [21]. According to GOST 4011-72 "Drinking water. Methods of measurement of mass concentration of total iron", total iron levels were in water were determined, the present standard applied to drinking water and established colorimetric methods of measuring mass concentration of total iron. The volume of the sample for measuring the mass concentration of iron shall not be less than 200 cm^3. The method was based on the interaction of iron ions in an alkaline medium with sulphosalicylic acid to form a yellow colored compound. The color intensity proportional to the mass concentration of iron was measured at 400–430 nm. The measurement range of the mass concentration of total iron without sample dilution was 0.10–2.00 mg/dm^3. In this interval, the total measurement uncertainty with probability $p = 0.95$ was between 0.01 and 0.03 mg/dm^3 [22]. Using GOST 4245-72 "Drinking water. Methods for determination of chloride content", the amount of chloride in water was determined, the present standard applied to drinking water and established methods for determination of chloride (chlorine-ion) content. The volume of the water sample for the determination of chloride content was at least 250 cm^3. The method was based on the precipitation of a chlorine ion in a neutral or slightly alkaline medium by silver nitrate in the presence of potassium chromate as an indicator. After precipitation of silver chloride at the point of equivalence, silver chromate was formed, with the yellow coloring of the solution changing to orange-yellow. Method accuracy was 1–3 mg/dm^3 [23]. To determine hygienic indicators, we used GOST 2874-82 "Drinking water. Hygienic requirements and quality control". This standard defined the epidemic safety of water as determined by the total number of micro-organisms and the number of *E. coli* bacteria, the toxicological indicators of water quality characterize the harmlessness of its chemical composition [24]. To determine the maximum allowable limit of nitrogen-containing substances, we used GOST 33045-2014 (ISO 6777:1984, NEQ) "Water. Methods for determination of nitrogen-containing substances"; this standard applies to drinking (including packaged in containers), natural (surface and ground) and waste water and determination of ammonia and ammonium ions (total) with Nessler reagent [25]. The dry residue was determined according to GOST 18164-72 "Drinking water. Method for determination of dry residue content", which applied to drinking water and established a weight method for determination of dry residue content. The value of the dry residue characterized the total content of non-volatile mineral and partly organic compounds dissolved in water (methodology standard-chemistry). The volume of water sample for determination of dry residue was not less than 300 cm^3 [26], and for determination of sulphates in water, we used GOST 4389-72 "Drinking water. Methods for determination of sulphate content", which applied to drinking water and established methods for determination of sulphate content. The volume of the water sample for sulphate determination must be at least 500 cm^3. The determination of sulphate content was based on the precipitation of SO_4^{-2} ions with barium chloride as barium sulphate in an acid medium. Determination accuracy ±2 mg/dm^3 SO_4^{-2} [27].

3. Results

3.1. Initial Data of the Object of Study

The initial composition of zeolite from the Chankanai deposit is presented in Tables 1 and 2, and the composition from the Daubabinsk deposit is presented—in Tables 3 and 4. Figure 2 shows the structural feature of zeolite of the Chankanai deposit and Figure 3 shows the structural feature of the Daubabinsk deposit zeolite.

Table 1. Initial elemental composition of zeolite sample 1 from the Chankanai deposit (in weight, %).

Spectrum	O	Na	Mg	Al	Si	K	Ca	Ti	Fe
Max.	45.36	1.89	2.12	9.11	31.10	1.86	4.54	0.63	5.81
Min.	43.39	1.74	1.81	8.90	30.80	1.71	4.45	0.26	4.74

Table 2. Initial oxide composition of zeolite sample 1 from the Chankanai deposit (in weight, %).

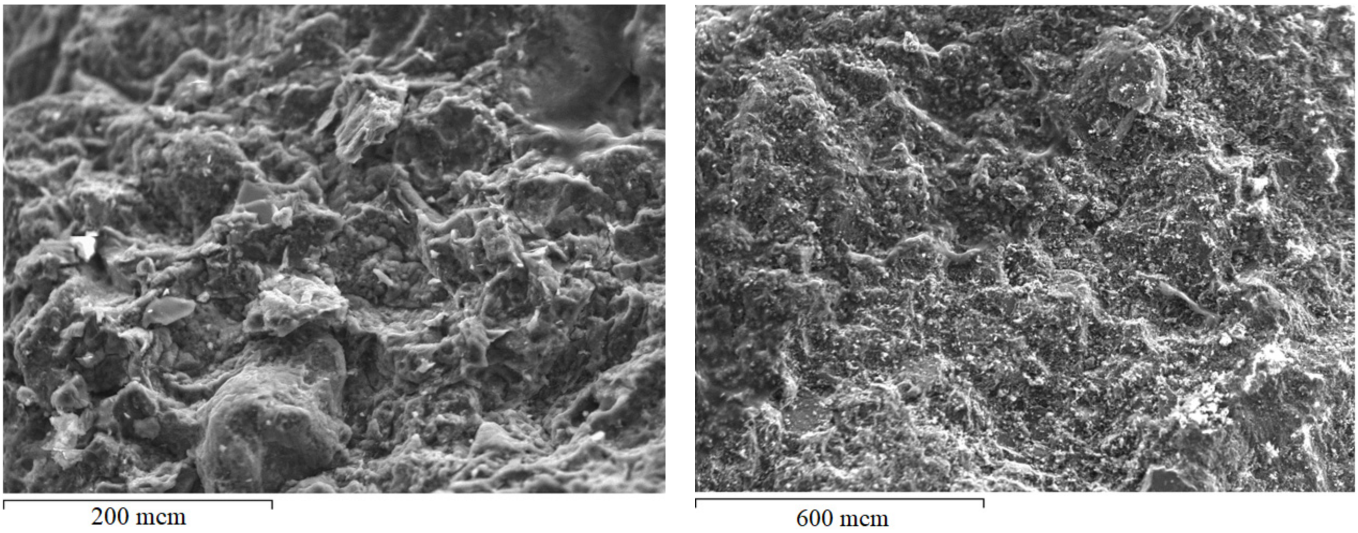
Spectrum	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	FeO
Max.	2.44	3.35	16.68	63.72	2.10	6.00	0.99	7.03
Min.	2.25	2.93	15.99	62.15	1.99	5.91	0.42	5.89

Table 3. Initial elemental composition of zeolite sample 2 from the Daubabinsk deposit (in weight, %).

Spectrum	O	Na	Mg	Al	Si	P	K	Ca	Ti	Fe
Max.	44.15	0.77	3.10	9.17	24.17	0.39	5.51	9.87	0.73	6.35
Min.	43.21	0.53	2.65	8.85	22.62	0.31	5.02	6.89	0.62	5.66

Table 4. Initial oxide composition of zeolite sample 2 from the Daubabinsk deposit (in weight, %).

Spectrum	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	FeO
Max.	1.04	5.09	17.12	51.21	0.87	6.53	13.87	1.22	8.05
Min.	0.70	4.41	16.77	48.58	0.72	6.07	9.50	1.04	7.31



(**a**) (**b**)

Figure 2. Structural features of zeolite from the Chankanai deposit (Sample 1): (**a**) structure at an increase of 200; (**b**) structure at an increase of 600.

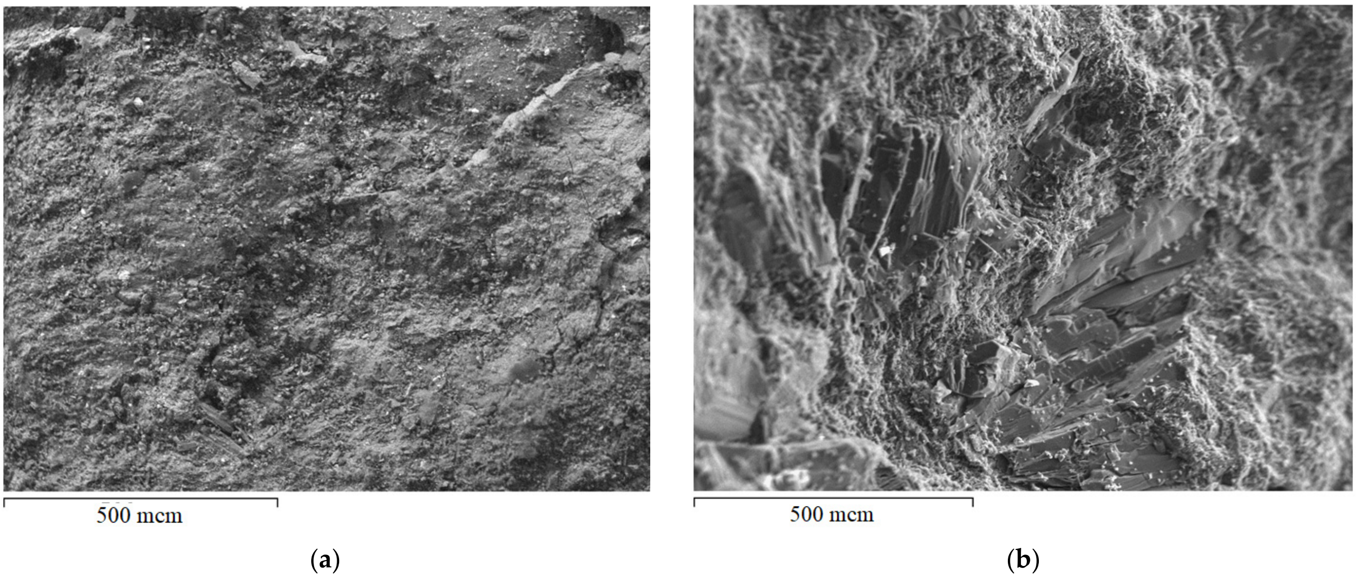


Figure 3. Structural features of zeolite from the Daubabinsk deposit (Sample 2) at an increase of 500 at different filming points (**a**,**b**).

Figures 2 and 3 show that the main and probably the most important feature of zeolite structure was the system of intracrystalline pores and cavities, in which small molecules easily occluded and released and, as a result, the zeolite exhibited adsorptive and desorptive properties.

3.2. Qualitative Indicators of Water Used to Assess the Effectiveness of Modified Zeolite Application

Water quality assessment: Drinking water must be epidemiologically safe, chemically harmless and organoleptically good. At the same time, it should be physiologically complete, have an optimum level of mineralisation and contain a range of macro- and micronutrients [9]. The main integral indicator of drinking water quality is its impact on human health.

To assess the water quality index, baseline water data were taken (Table 5).

Table 5. Baseline data for samples 1 and 2.

Water Sample	Total Hardness (μg-eq/L)	Alkalinity (μg-eq/L)	Chlorides Cl (μg-eq/L)	SO_4^{-2} (μg/L)	Dry Residue (μg/L)	Fe^+ (μg/L)
No.1 drinking water	4.8	2.0	14.9	14.6	28	400
No.2 natural water	1.4	0.6	2.1	15	82.8	1200

To assess the water quality index, the initial water data were taken. Table 5: No. 1—drinking water of Almaty city; No. 2—natural water of Bolshaya Almatinka of Almaty city.

From the analysis of samples No. 1 and No. 2, it appeared that water from different sources had a difference in "hardness" and "alkalinity". Sample No. 1 and No. 2 had Fe^+ exceeding the norm of 300 μg/L.

3.3. Preparation of a Zeolite-Based Filter from the Chankanai and Daubabinsk Deposits (Modification)

Zeolite, a material with a high clinoptilolite content, was designed for the treatment of natural and drinking water and was most suitable for the treatment of natural water. Filters of the following Mk fraction were prepared in advance (Table 6).

Table 6. Fractional composition of zeolite from the Chankanai and Daubabinsk deposits.

Zeolite from Chankanai Deposit Fraction		**Zeolite from Daubabinsk Deposit Fraction**	
(1) 7.5–5 mm (2) 5–2.5 mm	(3) 2.5–1.25 mm (4) 1.25–0.63 mm	(1) 7.5–5 mm (2) 5–2.5 mm	(3) 2.5–1.25 mm (4) 1.25–0.63 mm

The separation into fractions was carried out in order to improve the filtration efficiency of zeolite of different size fractions, which had different properties and sorption ability of the pollutant. The separation into fractions made it possible to optimize the filtration process to capture and remove the largest amount of pollutants from the water, the coarse fraction being used to filter out large particles and sludge, while the fine fraction efficiently sorbed fine pollutants and organic matter. To improve the permeability of the filter, fractional separation of the zeolite also allowed for a more permeable filter. The coarse fraction formed the base of the filter, providing space for free flowing water, while the fine fraction filled in the gaps and provided a surface for sorbing pollutants. Fractional separation allowed the use of different zeolite fractions in different filter layers. This increased the overall capacity of the filter and improved its ability to retain pollutants. Larger fractions in the upper filter layers can prevent premature clogging by smaller fractions below.

Hydrothermal treatment in 20% hydrochloric acid at an elevated temperature (95–100 °C) and the subsequent evaluation of the filter for suitability for purification of water samples were important steps in the process of preparing zeolite for use as a sorbent. These steps helped to improve the sorption properties of the zeolite and to prepare it for effective water treatment.

The hydrothermal treatment of the zeolite resulted in a change of the surface groups, the interaction of hydrochloric acid with the zeolite surface caused deprotonation of some of the active groups on the sorbent surface. For example, hydroxyl groups (OH^-) can transform into chloride groups (Cl^-), which changed the surface charge state. As zeolites have a definite porous structure, which plays an important role in the process of sorption, modification with hydrochloric acid changed the size of pores and their shape, as a result of which there is an availability for sorption.

In general, surface modification of zeolite-based sorbents using 20% hydrochloric acid leads to changes in their structure, surface properties and adsorption activity [28].

The sorption efficiency of the obtained filters prepared from zeolite fractions of Chankanai and Daubabinsk deposits was evaluated for applicability as a sorbent for water treatment of samples No. 1 and No. 2 (Table 5).

4. Discussion

Water filtration was carried out by the sorption method. As sorption water filtration is a highly effective method of deep purification, the effect was achieved by binding chemical particles and various impurities at the molecular level. Mk 7.5–0.63 mm sorbent (Table 6) filtered natural and drinking water (Table 5) separately and checked the degree of water purity. The effectiveness of the use of modified zeolites as sorbents for drinking water and natural water is presented in Tables 7–10.

The following values were found when analyzing the characteristics of drinking water filtered using a zeolite filter from the Daubabinsk field. Water hardness was reduced from an average of 4.8 at baseline to 2.9 at norm 7.0, water alkalinity was reduced from an average of 2.0 at baseline to 0.9, Cl in water was reduced from an average of 14.9 at baseline to 2.1 at norm 350, with no trace of SO_4^{-2} in water at baseline 14.6 and no dry residue in water at baseline 28, Fe^+ in water was reduced from an average of 400 at baseline to 0.02–50 at norm 350.

An analysis of the characteristics of drinking water filtered using a zeolite filter from the Chankanai deposit showed the following results. Water hardness was reduced from an average of 4.8 in the original to 1.2 with a norm of 7.0, water alkalinity was reduced from an average of 2.0 in the original to 0.4, the amount of Cl in the water was reduced from an average of 14.9 in the original to 1.0 with a norm of 350, with no traces of SO_4^{-2} in the water with a norm of 14.6, dry residues in water with a norm of 28 were found, Fe^+ in water was reduced from 400 in the original to 0.03–75 with a norm of 350.

Table 7. Effectiveness of the use of a zeolite-based sorbent (filter) from the Daubabinsk deposit.

Number of Sample. Fraction, (Sorbent Mk)	**Total Hardness (µg-eq/L)**	**Alkalinity (µg-eq/L)**	**Chlorides Cl (µg-eq/L)**	**SO_4^{-2} (µg/L)**	**Dry Residue (µg/L)**	**Fe^+ (µg/L)**
No. 1 drinking water (baseline water data)	4.8	2.0	14.9	14.6	28	400
			Results of experiments			
Mk 7.5–5 mm	3.0	1.2	3.68	-	-	0.02–50
Mk 5–2.5 mm	3.0	0.9	6.1	-	-	0.02–50
Mk 2.5–1.25 mm	3.5	2.0	2.17	-	-	0.04–100
Mk 1.25–0.63 mm	2.9	1.6	2.1	-	-	0.03–75

Table 8. Effectiveness of the use of a zeolite-based sorbent (filter) from the Chankanai deposit.

Number of Sample. Fraction, (Sorbent Mk)	**Total Hardness (µg-eq/L)**	**Alkalinity (µg-eq/L)**	**Chlorides Cl (µg-eq/L)**	**SO_4^{-2} (µg/L)**	**Dry Residue (µg/L)**	**Fe^+ (µg/L)**
No. 1 drinking water (baseline water data)	4.8	2.0	14.9	14.6	28	400
			Results of experiments			
Mk 7.5–5 mm	1.4	0.4	1.0	-	-	0.34–850
Mk 5–2.5 mm	1.2	0.5	1.9	-	-	0.21–522
Mk 2.5–1.25 mm	1.9	0.7	1.7	-	-	0.075–185
Mk 1.25–0.63 mm	1.5	0.01	5.5	-	-	0.03–75

Table 9. Effectiveness of the use of a zeolite-based sorbent (filter) from the Daubabinsk deposit.

Number of Sample. Fraction, (Sorbent Mk)	**Total Hardness (µg-eq/L)**	**Alkalinity (µg-eq/L)**	**Chlorides Cl (µg-eq/L)**	**SO_4^{-2} (µg/L)**	**Dry Residue (µg/L)**	**Fe^+ (µg/L)**
No. 2 natural water (baseline water data)	1.4	0.6	2.1	15	82.8	1200
			Results of experiments			
Mk 7.5–5 mm	0.7	0.6	1.12	-	-	0.2–50
Mk 5–2.5 mm	1.0	0.55	1.76	-	-	0.02–50
Mk 2.5–1.25 mm	0.9	0.6	1.57	-	-	0.3–7.5
Mk 1.25–0.63 mm	1.38	0.57	1.11	-	-	0.02–50

Table 10. Effectiveness of the use of a zeolite-based sorbent (filter) from the Chankanai deposit.

Number of Sample. Fraction, (Sorbent Mk)	**Total Hardness (µg-eq/L)**	**Alkalinity (µg-eq/L)**	**Chlorides Cl (µg-eq/L)**	**SO_4^{-2} (µg/L)**	**Dry Residue (µg/L)**	**Fe^+ (µg/L)**
No. 2 natural water (baseline water data)	1.4	0.6	2.1	15	82.8	1200
			Results of experiments			
Mk 7.5–5 mm	1.3	0.01	1.42	-	-	0.21–522
Mk 5–2.5 mm	1.0	0.01	1.9	-	-	0.34–850
Mk 2.5–1.25 mm	1.1	0.3	1.34	-	-	0.04–100
Mk 1.25–0.63 mm	1.24	0.01	1.55	-	-	0.03–75

For natural water filtered with the Daubabinsk zeolite, the following results were obtained. Water hardness was reduced from an average of 1.4 to 0.7 at a norm of 7.0, water alkalinity was reduced from an average of 0.6 to 0.55, Cl in the water was reduced from an average of 2.1 to 1.11 at a norm of 350, with no traces of SO_4^{-2} in the water at baseline 15, dry residue in the water at baseline 82.8 was not detected, Fe^+ in the water was reduced from an average of 1200 at baseline to 0.02–50 at norm of 350.

An analysis of the characteristics of natural water filtered using a zeolite filter from the Chankanai deposit showed the following results. Water hardness was reduced from an average of 1.4 to 1.0 with a norm of 7.0, water alkalinity was reduced from an average of 0.6 to 0.01, Cl in water was reduced from an average of 2.1 to 1.34 with a norm of 350, with no traces of SO_4^{-2} in water with a norm of 15, dry residue in water with a norm of 82.8 was not detected, Fe^+ in water was reduced from an average of 1200 to 0.03–75 with a norm of 350.

From Tables 7–10, we can say that the main indicators of natural and drinking water after filtration with zeolite from the Chankanai and Daubabinsk deposits were several times lower. Both zeolite deposits demonstrated effectiveness. The reduction in water hardness indicates the zeolite's ability to sorb the ions responsible for water hardness, and resulted in improved drinking water quality. The decrease in alkalinity of the water suggests that the zeolite was able to sorb alkaline components, which can help to balance the pH value and improve water quality. The decrease in the Cl content of the water indicates that the zeolite effectively sorbed chlorides. The absence of detected traces of SO_4^{-2} and dry residue in the water after zeolite filtration indicates the effective removal of these components. This can be important for removing unwanted pollutants and ensuring water safety. A high Fe^+ ion content in the water indicates the presence of iron impurities, which may be undesirable for consumption in addition to reducing the durability of the entire water supply system due to corrosion. The decrease in Fe^+ indicates that the zeolite worked successfully as a sorbent.

In general, the modified zeolite from the Chankanai and Daubabinsk deposits showed quite excellent performance as a filter. Judging by the purification of natural water, as it was most polluted by hardness 1.24 and alkalinity 0.01, Mk (Size modulus)-5–2.5 mm zeolite from the Chankanai deposit worked better. In terms of Fe^+ and Cl content, the Daubabinsk zeolite worked better, Mk 5–2.5 mm-Fe^+ was reduced to 0.02–50, Cl was reduced to 1.11 at Mk 1.25–0.63 mm.

5. Conclusions

The use of zeolite as a water filter has several advantages:

1. High sorption capacity: Zeolites have a large surface area and a microporous structure, which provides a high sorption capacity. They are capable of trapping various pollutants, including organic compounds, metals and other harmful substances.
2. Selectivity: Zeolites can be selective in the sorption of certain substances. Their structure and chemical properties can promote preferential sorption of certain pollutants, making them effective in removing specific types of pollutants from water.
3. Inertness and stability: Zeolites are chemically inert materials, which means that they are inert and do not degrade when in contact with water or other media. They are chemically and thermally stable, which allows them to retain their sorption properties over a wide range of conditions.

Based on the influence of the pore volume of the sorbents on the treatment of natural waters, the pore volume of zeolite-based sorbents is important for the efficiency of natural water treatment. Porous materials with many microscopic pores adsorb pollutants from water. The larger the pore volume in the modified zeolite, the more surface area is available for interaction with contaminants.

Based on the filtration results, it can be said that the studied zeolite-based sorbents have a sufficiently developed surface in terms of their structural characteristics and, as a consequence, are capable of absorbing pollutants from water. The modified natural zeolite is a cation exchange element and has high sorption properties, and the grain shape factor for zeolite was, on average, 5–2.5 mm and 2.5–1.25 mm in Mk. Zeolite from Chankanai and

Daubabinsk deposits works very well as a sorbent in water filtration and has a complex character as a sorbent, including removing in 100%-SO_4^{-2} and dry residue (Tables 7–10).

Maximum sorption takes place immediately in the first minutes, after which the sorbent is able to retain the sorbed substances for the test period (1.5–10 min).

It was established that zeolite-based sorbents are adsorption-active materials, due to their layered spatial framework structure.

When analyzing for chemical compounds, it was found that chemical compounds were found in all water samples within the maximum permissible limits.

Zeolite-based sorbents are recognized as adsorption-active materials due to their layered spatial framework structure. This means that they have the ability to effectively trap and retain various contaminants.

The possibility of using zeolites as sorbents for natural and drinking water treatment in the example of water of Almaty was established.

Four zeolite fractions from the Chankanai and Daubabinsk deposits were obtained, which were modified in a 20% hydrochloric acid solution and used as a filter.

The optimum conditions for activation of natural zeolite to produce modified zeolite with high adsorption properties were determined. Activation parameters such as time, temperature and reagent concentration were determined.

The effectiveness of zeolite-based sorbents was evaluated using different analysis methods and water specifications. Evaluation criteria included total water hardness, mass concentration of total iron, chloride, nitrogen, dry residue and sulphate in the water. Hygiene requirements and water quality control were also taken into account.

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