

# Development of Innovative Filtration System for Natural Water Treatment in the Chechen Republic

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**Abstract** – There is a pressing need for high-quality water supply to the population of Grozny. This is due to a specific mixture of salts of heavy metals and lithium, and microbial contamination in the surface water reservoirs. To ensure effective purification of severely polluted surface water, it is necessary to improve filtration systems with a disinfecting effect. The paper describes a method for producing bentonite- and brucite-based sorbent with improved adsorption properties to provide effective water treatment in the Chechen Republic. The authors propose some solutions for combined multilayer filtration systems. The paper presents a method for adsorption water treatment, which implies adsorbing chemical contaminants on mineral granules of high absorption capacity, with a disinfectant to provide an antimicrobial effect. The treatment effectiveness of water from the surface water reservoirs in the city of Grozny, particularly Chernorechensky, Goyta and Sunzha, is assessed in the laboratory with the developed filtration systems. The paper justifies a decrease in color by 96%, turbidity by 99% and 100% iron absorption as well as microbial pollutant extraction using the developed filtration system with improved adsorption properties.

**Keywords** – adsorbent; bentonite; brucite; adsorption; surface water; pollution; heavy metals; microbial contamination; disinfectant.

## I. INTRODUCTION

The long-term environmental monitoring of water bodies in the Chechen Republic (CR) shows that almost all water reservoirs, both surface and underground, are subject to anthropogenic and man-made impacts of different intensity. Water ecosystems concentrate pollution from the entire watershed area. A huge number of contaminants get into the surface water with wastewater from industrial, agricultural and municipal enterprises as a surface runoff from surrounding areas. One of the main contaminants of the surface water of the Chechen Republic are oil products, organics, heavy metals, etc. [1, 2, 3].

The problem of providing the population of Grozny with high-quality drinking water is a particular concern today. It is related to the modified natural properties of water from the main

water reservoirs (Goyta, Sunzha and Chernorechensky) due to a significant man-made impact [4].

A series of research conducted by A. A. Ataeva et al. (2009-2017) show that in the surface water reservoirs of the Chechen Republic there are ions of such heavy metals as strontium, zinc and nickel in combination with lithium and halogens that in some reservoirs were found in concentrations beyond maximum acceptable by an average of 12.9%. This contributes to the formation of a combined group of salts of these metals that are not eliminated in the process of water treatment and can affect the state of human vital systems and organs [5, 6].

According to many authors [7, 8, 9], clay materials, bentonites, etc. are effective for adsorptive purification of water from a number of contaminants. High adsorption capacity of bentonites is associated with the mechanisms of physical and chemical sorption of various contaminants, and ion exchange, as well [7].

It is known that water with a color of more than 30 degrees in platinum-cobalt scale and a suspended impurity content of more than 100 mg/l is purified through coagulation [9, 10]. Water treatment (clarification) is carried out in special tanks by adding coagulants like aluminum sulfate or aluminum oxychloride to the water under treatment, followed by purification through sand filters.

However, purification of polluted water by coagulation is time-consuming. It requires additional reagents and the presence of capacitive equipment. The contaminants in a dissolved state remain in the water being purified.

It is known that fine aluminosilicate-based adsorbent when added to the wastewater for a long time is an effective adsorbent for heavy metals. Thus, there is a method to purify water by a fine aluminosilicate sorbent obtained as a waste product [11]. The sorption of lead and cadmium is carried out by stirring the liquid phase with the sorbent for 6-32 hours. However, the rate of sorption is low, which calls for the need to separate a significant amount of a fine aluminosilicate adsorbent that is dispersed in water medium to micro-size.

Another water treatment method by the GLINT adsorbent is also known [12]. It is obtained by sintering clay and alkaline earth compounds. This adsorbent is used to purify industrial and surface wastewater by settling heavy metal cations. The advantages include a long service life of the adsorbent and the possibility of its multiple washings when used in the existing technological water treatment systems. The disadvantages of GLINT is a limited acidity of the treated effluent (pH 7.5–8.0), which requires preliminary preparation (2-3-step purification). Another disadvantage is a limited sorption capacity of GLINT for heavy metal ions (2.5–5.6 g/dm), which brings about the need for frequent flushings of the filtration system, thus significantly complicating the process of water treatment.

Therefore, to ensure effective purification of surface severely polluted water, it is necessary to develop the most reliable, environmentally friendly and cost-effective method of purifying surface water up to the regulatory requirements set for drinking water against maximum acceptable concentrations of contaminants.

The paper is aimed at the comprehensive research into the development of an innovative filtration system to improve the sorption technology for purifying drinking water from the main sources of water supply in the city of Grozny.

## II. METHODS AND MATERIALS

Bentonite from the Dash-Salakhly deposit (the Republic of Azerbaijan) and brucite provided by Russian Mining and Chemical Company were used in the trial. The original components, bentonite and brucite, were ground to a particle size of no more than 10 microns. This particle size of mixed substances makes it possible to achieve a high degree of homogeneity of the adsorption material. The increased absorptive capacity of the adsorbent was achieved due to the resulting gel formulation, its ultrasonic activation, and the particulate firing mode (heat treatment) [13]. The composition of the gel is bentonite:water:brucite = 10:30:2. This composition was experimentally determined as the best based on the stability of the obtained particulates in a weak acid medium. The gel was produced in two stages in the ultrasonic (US) field of a reactor with a capacity of more than 10 W/cm<sup>2</sup>. In the first stage, a brucite suspension was prepared in water in the ultrasonic reactor for at least 5 min. In the second stage, bentonite was added, with the resulting gel to be processed for 8-10 min. Under the action of ultrasound, the mixed components were equitably distributed, followed by the formation of the gel. After that, the gel was dried to predetermined moisture (50-60%). The particulates from the obtained gel were molded by extrusion. The heat treatment of the obtained particulates took 2 hours at 550°C - 600°C. Due to the optimal heat treatment mode it is possible to obtain particulates with a developed surface and water resistant in a wide pH range [14].

The surface morphology of the obtained sorbent was studied by means of TESCAN MIRA II LMU scanning electron microscope. The surface area of granular non-modified and modified bentonites was studied by the method of low-temperature nitrogen adsorption on the Quantachrome NOVA 4200e gas sorption analyzer.

Water sampling from the surface water reservoirs in Grozny: Chernorechensky, Goyta and Sunzha was conducted in 2018 according to GOST R 51593-2000. Turbidity and color were measured, nitrites (Federal Environmental Regulatory Act 14.1: 2.3-95), chloride ions (Federal Environmental Regulatory Act 14.1: 2.96-97), nitrates (GOST 18826-73), total salt content (Federal Environmental Regulatory Act 14.1: 2: 3: 4.121-97) were determined. Sanitary-microbiological analysis of water was performed in accordance with the MG (4.2.1018-01 and 4.2.1884-04) [15].

In laboratory settings, water samples were filtered using experimental filtration systems: from the developed sorbent (filter No. 1) and the sorbent coupled with a bactericide (filter No. 2) [16].

The results were considered reliable at  $p \leq 0.05$ .

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## III. RESULTS

Table 1 shows the main physical and chemical parameters of the developed granular sorbent (Fig. 1).

TABLE I. PHYSICAL AND CHEMICAL PROPERTIES OF THE DEVELOPED SORBENT

Parameter	Value
Density, $\rho_s$ , g/cm <sup>3</sup>	3.20 ± 0.06
Humidity, $w_s$ , %	13.00 ± 0.02
Dry density of sorbent, $\rho_{di}$ , g/cm <sup>3</sup>	2.80 ± 0.05
True density of sorbent, $\rho_{di}$ , g/cm <sup>3</sup>	2.64 ± 0.04
Packed density of sorbent, $\rho_v$ , g/cm <sup>3</sup>	1.26 ± 0.01
Porosity, $P$ , %	54.00 ± 0.24
Humidity relevant to lower liquid limit, $W_L$ , %	51.0 ± 0.5
Humidity relevant to plastic limit, $W_p$ , %	12.0 ± 0.1
Placticity index of sorbent, $I_p$ , %	37.0 ± 0.3



Fig. 1. Type of developed granular sorbent after heat treatment at 550°C (abrupt heat treatment)

Fig. 2 shows the findings of the chemical composition of the developed sorbent. The abscissa axis is the characteristic radiation energy in kilo-electron volts, and the ordinate axis is the intensity proportional to the counting of pulses per second.

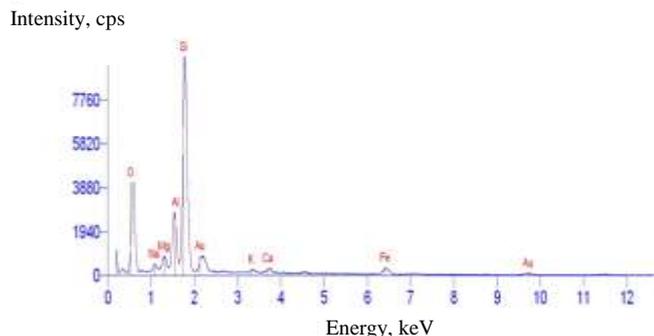


Fig. 2. Ultimate composition of developed sorbent

When studying the morphology of the obtained sorbent, the particles of its components were determined in the form of large and small aggregates and folded formations (Fig. 3).

Table 2 presents the comparative characteristics that show the advantages of the adsorbent developed by the authors over the GLINT adsorbent.

During the study the authors evaluated the effectiveness of the developed sorbent as a part of filters for purifying polluted surface water of the Chechen Republic. Table 3 shows the findings of water samples taken from the Goyta water intake in the early spring of 2018. A comparative analysis of water quality indicators was carried out before and after filtration.

TABLE II. COMPARISON OF THE CHARACTERISTICS OF GLINT AND THE DEVELOPED ADSORBENT

No.	Characteristics of GLINT	Characteristics of the developed adsorbent
1	Specific surface 3.7 m <sup>2</sup> /g, total pore volume 0.015 sm <sup>3</sup> /g	Specific surface 51 m <sup>2</sup> /g, total pore volume 0.105 sm <sup>3</sup> /g
2	Does not remove suspended water	Removes suspended water
3	Absorbs only heavy metal cations	Absorbs both heavy metal cations and anions
4	Does not absorb petroleum products	Absorbs petroleum products
5	Does not absorb surfactants	Absorbs surfactants
4	Needs frequent regeneration	Does not need frequent regeneration
5	Works in a narrow pH range of 7.5–8.0	Works in a wide range of pH 4.5–12.0

TABLE III. WATER QUALITY INDICATORS FROM THE GOYTA WATER INTAKE BEFORE AND AFTER FILTRATION

Indicators	Initial sample (n=10)	Filter No.1 (n=10)	Filter No.2 (n=10)	Consumption rate of drinking water
Salt content, mg/l	972.00±84.12	674.00±72.04	548.00±49.00	1000–1500
Smell, score	3.00±0.01	0	0	2
Color, °	216.00±6.12	28.00±0.78	8.60±0.19	20-30
Hardness, mg-eq/l	7.40±0.72	5.00±0.52	5.00±0.46	7 – 10
Alkalinity mmol/L	7.00±0.53	8.00±1.25	7.60±0.46	7
pH	6.40±0.03	8.10±0.20	7.40±0.01	6 - 9
Turbidity, mg/dm <sup>3</sup>	34.8±1.42	2.32±0.21	0.76±0.01	1.5-2
Nitrites, mg/dm <sup>3</sup>	2.94±0.56	0.84±0.34	0.49±0.05	3
Nitrates, mg/dm <sup>3</sup>	9.10±0.05	0.94±0.11	0.86±0.12	45
Ortho-phosphate, mg/dm <sup>3</sup>	14.65±0.46	5.62±0.18	4.65±0.08	3.5
Fe total, mg/dm <sup>3</sup>	1.50±1.16	0	0	0.3
TMC, μmol	4.60±0.25*10 <sup>3</sup>	140.0±15.6	0	No/no more than 50
COD, mg/dm <sup>3</sup>	10.52±0.18	5.18±2.32	5.02±1.84	5.0–7.0

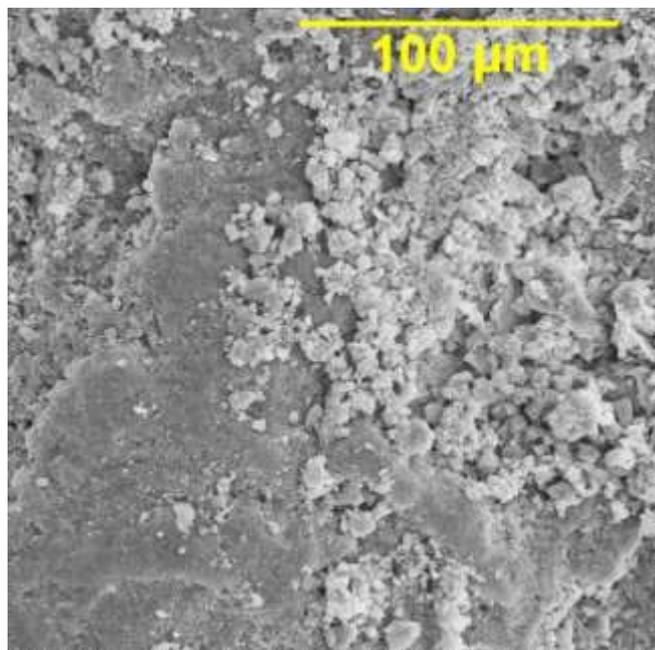


Fig. 3. Electron micrograph of annealed particulates of the developed sorbent ( $\times 250$  magnification)

Once filtered through a filter with the developed adsorption material, most of the determined water quality indicators increased by an average of 25%. Turbidity decreased by 80% and color – by 70%. The initial water samples from the Sunzha water intake were characterized by a high amount of humic substances causing the color, and suspended particles and sludge residues increasing the turbidity. The filtration of this water through an experimental filter with the developed adsorption material was accompanied by a decrease in color by 96% and turbidity – by 99%. Microbial treatment was effective when using filter No.2.

#### IV. CONCLUSION

The authors developed a type of bentonite- and brucite-based sorbent with improved adsorption properties. They developed combined multilayer filtering load from the developed sorbent with a disinfectant for purifying natural water of the Chechen Republic. They proposed the method for adsorption treatment of polluted surface water, which implied adsorbing different contaminants (humic substances, heavy metal ions, synthetic surfactants, salts, etc.) on the mineral granules of the sorbent with a high absorption capacity.

The authors evaluated the efficiency of water treatment from the surface water reservoirs in Grozny with the developed filtration system in the laboratory and production conditions. A decrease in color by 96%, turbidity by 99% and 100% iron absorption and purification from microbial contamination was demonstrated.

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