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Design and Optimization of a Fixed-Layer Adsorber for Enhanced Groundwater Treatment in the Suzak Region, Kazakhstan

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ABSTRACT

Water scarcity and quality issues in Kazakhstan, particularly in the Suzak region, necessitate innovative solutions for sustainable agriculture and improved water utilization. This study focuses on the development of a novel adsorber with a fixed adsorbent layer to enhance efficiency, apparatus compactness, and processing capacity. The design aims to minimize stagnant zones, ensuring stability in purified water quality within the compact apparatus. The adsorber utilizes activated carbon, and its distinctive features optimize useful volume utilization and adsorption capacity processing. The study investigated the impact of water flow speed and cleaning time on residual chlorine absorption by activated carbon, revealing optimal conditions at a cleaning process time of 0.5 hours and water flow speed of 2.78×10^{-3} m/s. Furthermore, the research established concentration-dependent adsorption of sulfates and fluorides. Notably, the fastest fluoride adsorption occurred at a concentration of 3 mg/l, reaching approximately 90% of the maximum achievable within 2hours. Additionally, the study explored regeneration efficiency, revealing optimal steam flow at 15 kcal, with an 88.5% purification degree after 40 cycles. In practical terms, this innovative adsorber design offers a promising solution for groundwater treatment, improving water quality, increasing efficiency, and contributing significantly to sustainable agriculture in the Suzak region of Southern Kazakhstan. The findings underscore the adsorber's potential impact on addressing critical water-related challenges in the region.

1. INTRODUCTION

The problem of providing agriculture with high-quality water is relevant for many countries, in particular for the countries of the Central Asian region. In Southern Kazakhstan, the problem of providing the population with high-quality drinking water, along with a natural shortage of water resources, is aggravated by the unsatisfactory technical condition of water supply systems, which leads to a deterioration in the sanitary and epidemiological situation and an increase in morbidity. Every second resident of Kazakhstan consumes low-quality drinking water. The situation is complicated by the fact that many chemicals in water are not detected by regulatory services. The water quality monitoring they conduct does not fully reflect the degree of suitability of water for drinking water supply [1, 2].

One of the goals of sustainable development is to ensure accessibility and sustainable use of water and sanitation for all. Important indicators for achieving this sustainable development goal are the percentage of the population that uses safe drinking water and has access to safe sanitation, improves water quality, improves water use efficiency, and secures fresh water supplies. Central Asia has enormous fresh water resources, but they are unevenly distributed throughout the country, as a result of which many areas of Kazakhstan and Central Asia lack water suitable for water supply to the population, irrigation and irrigation of agricultural land [1-3].

Agricultural intensification involves the increasing use of various insecticides and herbicides, which enter surface waters and make them unsuitable not only for drinking, but also for irrigating crops. In industrial zones, water pollution with heavy metals predominates; in megacities, household waste plays an important role among the factors deteriorating the quality of drinking water [3].

The human right to use high-quality drinking water was recognized in 2010 at the UN General Assembly. Every second person out of the entire population of the planet uses water from a tap [4]. As a result of the disastrous state of water supply systems in many cities and towns of the republic, an uninterrupted supply of water to the population is not ensured, and its quality does not meet sanitary and hygienic requirements that meet safety criteria for humans.

Development of new approaches to assessing the condition of water bodies used for their classification or ranking using quality assessment criteria, hygienic classification of water bodies according to the degree of pollution, a system of sanitary and hygienic regulation, preservation of the structure and functional characteristics of the entire ecosystem as a whole, criteria for sanitary and hygienic assessment of the danger of pollution drinking water and sources of drinking water supply with chemicals, assessing contamination of drinking water for compliance with hygienic standards, values recommended by WHO, ensures the fulfillment of the basic functions of assessing the class of water quality, explaining and predicting phenomena observed in nature [5, 6].

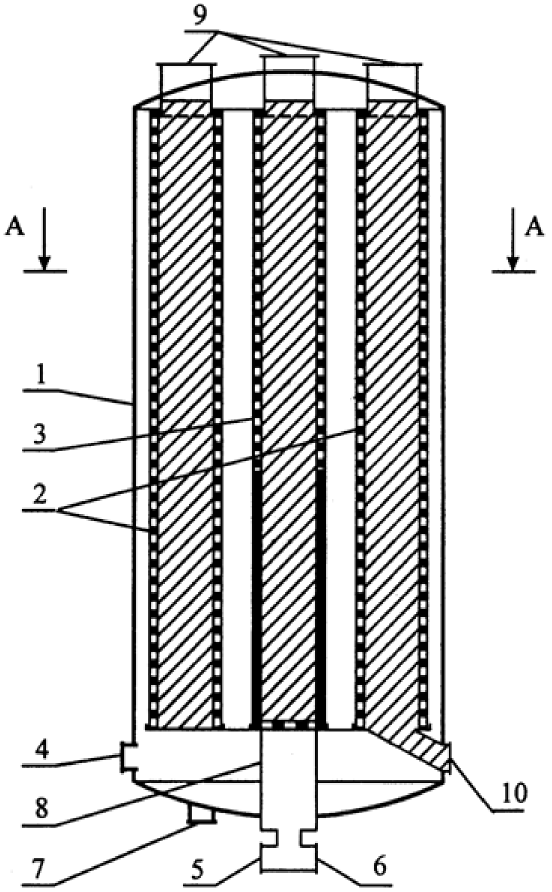
Purification of groundwater is the most pressing problem facing ecologists and water treatment specialists. One of the most promising adsorbent materials is activated carbon, which can be used to purify water from iron compounds, ammonium, heavy metals, organic compounds and various trace elements. Therefore, to purify groundwater, it is necessary to conduct comprehensive studies of adsorbents for the purpose of their use at water treatment plants [7, 8].

In this regard, the development and implementation of promising, low-waste and highly effective adsorption purification of groundwater, which is a source of drinking water supply, is especially relevant [9, 10]. Analysis of theoretical and experimental material on the study of the structure of adsorption layers, taking into account porous layers with a clearly ordered and chaotic structure, showed that during adsorption purification it is necessary to take into account the structural characteristics of the adsorption layer-porosity. The results obtained in this direction are necessary in the development of technology for adsorption purification of groundwater, which is a source of drinking water, which makes the topic relevant [10, 11].

Activated carbons are superior to conventional adsorbents in all main parameters: sorption capacity, binding force of sorbed molecules, sorption rate. The practical use of such a unique sorption composition is associated with a number of significant advantages that it has over other adsorbents: reducing the likelihood of the formation of channel effects during liquid flow; drop in hydrodynamic resistance to flow; the ability to quickly absorb pollutants from water, the ability to effectively remove trace concentrations of toxic substances [12, 13].

The disadvantages of known treatment facilities are the low efficiency of the equipment. Existing adsorbers do not fully utilize the adsorbent capacity, the low utilization rate of the useful volume of the apparatus and the degree of processing of the adsorbent capacity of the adsorbent in the layer [14, 15]. In this regard, the objective of the study was to develop an adsorber design (preliminary patent of the Republic of Kazakhstan No. 18435), which would improve the efficiency of the device, increase the utilization rate of the useful volume of the device and the degree of processing of the adsorption capacity of the adsorbent in the layer, the stability of the quality of the purified flow and the compactness of the device.

To study the adsorption purification of groundwater and determine the dependence of the concentration of pollutants in purified water and the value of adsorption on the equilibrium concentration, an adsorption installation was used, shown in Figure 1 and Figure 2.



1 - housing, 2 and 3 - external and internal chambers of contact of the adsorbent with the stream being purified, 4 and 5 - fittings for supplying and discharging the flow, 6 and 7 - fittings for supplying and discharging the regenerating agent during regeneration, 8 - pipe connecting the fittings for flow diversion and supply of regenerating agent, 9 and 10 - hatches for loading and unloading adsorbent.

Figure 1. Cross-section of the adsorber

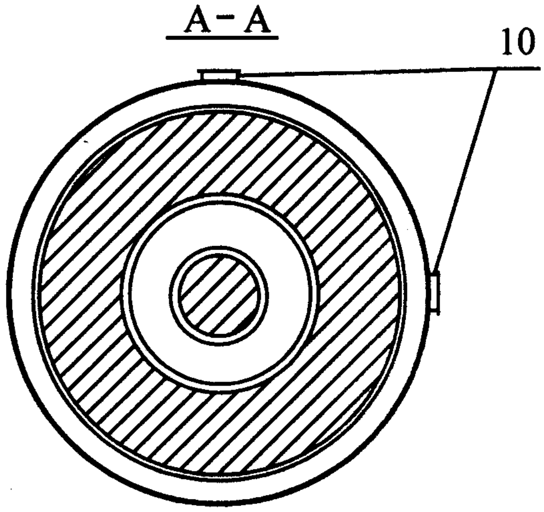
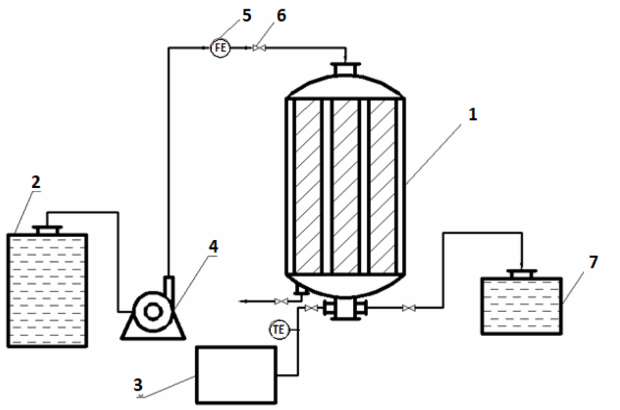


Figure 2. Section of the adsorber in section A-A

In the arid landscape of Kazakhstan, water scarcity and quality issues pose substantial challenges to sustainable agriculture and community well-being, particularly in the Suzak region. As the demand for high-quality water intensifies, there is an imperative need for innovative solutions to address these pressing issues. This study presents a significant contribution in the form of an advanced adsorber design tailored to the unique water treatment requirements of the region. The identified water quality problems in Kazakhstan are multifaceted, impacting agricultural practices, water-use efficiency, and the overall well-being of the population. This research strives to not only outline these challenges but, more importantly, to present a tangible solution in the form of an enhanced adsorber system. The adsorber, featuring a housing, a specialized contact chamber for the adsorbent, and additional components for flow control and regeneration, addresses the deficiencies of existing technologies. The key innovation lies in the incorporation of a vertical chamber along the apparatus's axis, designed for optimal contact between the adsorbent and the flowing water. This novel design, with a solid lower part in the inner chamber, aims to maximize the efficiency of the adsorption process. By introducing this unique configuration, the adsorber presented in this study stands out as a practical and effective solution to the water quality challenges faced in Kazakhstan. As we delve into the details of this research, it becomes evident that the proposed adsorber design has the potential to revolutionize water treatment processes in the Suzak region, significantly contributing to sustainable agriculture, improved water quality, and increased water-use efficiency. The subsequent sections will provide a comprehensive understanding of the methods employed in the development of this adsorber and offer insights into the practical implications and conclusions derived from the study [16-18].

2. MATERIAL AND METHODS

In order to study the adsorption purification of groundwater, an adsorption installation was used, shown in Figures 3 and 4.



1 – adsorber; 2 – water container; 3 – steam generator; 4 – pump; 5 – flow meter; 6 – water supply valve; 7 – container for purified drinking water.

Figure 3. Scheme of the experimental installation for adsorption purification

The purified water from the water tank 2 is supplied using a pump 4 to the adsorber 1. The flow of water can be controlled by means of a water supply valve 8 and its flow can be measured using a flow meter 5. The temperature of the incoming water is controlled by a THK thermocouple 6, which is connected to the indicating secondary device 7. Purified water then enters the clean water container 3.

Characteristics of an adsorber with a fixed layer of adsorbent [19, 20]:

Adsorber diameter, m 0.24
Adsorber height, m 0.31
Number of contact chambers, pcs. 2
Inner chamber diameter, m 0.056
External chamber diameter, m 0.188
Productivity, m^3/s $2.08*10^{-3}$
Water flow speed, m/s 0.003

1-adsorber; 2-water container; 3-container for purified drinking water; 4-pump; 5-flow meter; 6-thermocouple for temperature measurement; 7-indicating secondary device; 8-water supply valve.

Figure 4. Experimental installation for adsorption purification

2.1 Methods of research and testing

The quality of water is constantly monitored at the points of intake, before entering the water supply network, during treatment and at treatment plants. To assess the quality of water when using it, the following is determined: dry residue, which characterizes the content of salts and colloidal dissolved substances; calcined residue for the content of non-volatile substances; electrical conductivity, which characterizes the degree of contamination of water with electrolytes; biochemical oxygen demand BOD5, which characterizes the five-day consumption of oxygen necessary for the decomposition and oxidation of substances contained in water, or the intensity of biochemical processes; pH value; for a neutral environment pH=7, for an acidic environment less than 7, for an alkaline environment more than 7; pH within the normal range is 6.8-7.3; deviations from these values indicate water contamination with organic compounds; the presence of silicic acid, which contributes to the formation of difficult-to-remove scale, so this indicator is important when using water in heat exchange devices [21, 22].

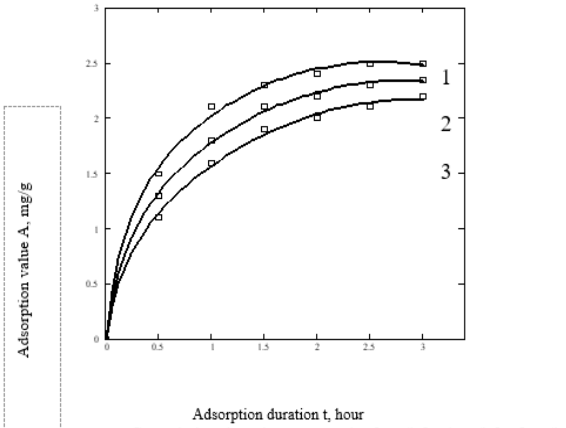
The essence of the adsorber's operation is illustrated by drawings, where Figure 1 shows a cross-section of the adsorber, and Figure 2 shows a cross-section of the adsorber in section A-A. The adsorber contains a housing 1, an outer 2 and an inner 3 chamber for contact of the adsorbent with the stream being purified, fittings for supplying 4 and draining the flow 5, fittings for supplying 6 and removing the regenerating agent 7 during regeneration, a pipe 8 connecting the fittings for diverting the flow and supplying the regenerating agent, hatches for loading 9 and unloading adsorbent 10 [23, 24].

The adsorber works as follows. The flow to be cleaned enters through fitting 4 into the inner part of the adsorber body 1, passes in the horizontal direction through the annular layer of coal located in the outer chamber 2 of contact between the adsorbent and the flow to be cleaned. Next, the stream to be purified is supplied to the upper part of the internal chamber 3 of the contact of the adsorbent with the stream being purified, where the stream is additionally filtered through a layer of adsorbent and removed from the apparatus through pipe 8 and fitting 5. As the degree of purification of the stream by the adsorbent decreases, as evidenced by the increase in the concentration of the absorbed substance in the purified flow, the filter media (adsorbent layer) is subjected to regeneration. To do this, using the taps of fittings 4, 5, the supply of the initial flow is turned off, a regenerating agent is introduced through fitting 6 and fed into contact chambers 3 and 2. The absorbed substance separated from the adsorbent in a mixture with the regenerating agent is discharged through fitting 7. The adsorbent is loaded through hatches 9, and its unloading is through hatches 10.

KAU activated carbon stands out due to its high surface area, pore structure, and superior adsorption capabilities. These characteristics make it highly effective in removing contaminants commonly found in the region's water sources. Its use contributes to the enhancement of the adsorber's efficiency, ensuring a robust performance in water purification. Furthermore, the decision to install an additional internal chamber within the adsorber is a strategic design choice aimed at maximizing the benefits of the selected KAU activated carbon. This internal chamber facilitates increased contact between the adsorbent and the flowing water, promoting more thorough adsorption processes. The circular cross-section and connection to a dedicated pipe for flow diversion and regenerating agent supply demonstrate a thoughtful integration to optimize contact and streamline regeneration processes.

Pretreatment steps for the KAU activated carbon are imperative for ensuring its optimal performance over time. While specific pretreatment details are not outlined here, it is essential to highlight that the researchers have considered and implemented appropriate pretreatment measures to enhance the adsorbent's efficacy. These measures may include activation processes, washing procedures, or any treatment necessary to prepare the activated carbon for its intended use in the adsorber. By combining the unique properties of KAU activated carbon with the innovative design of the adsorber, this study presents a comprehensive solution tailored to the water quality challenges in the Suzak region. The subsequent sections delve into the specifics of the adsorber's design and its performance characteristics, shedding light on the practical implications and outcomes of this integrated approach.

Figures 5, 6 and 7 show the dependence of the concentration of sulfates in purified water on the equilibrium concentration and the dependence of fluoride adsorption on the concentration and duration of adsorption [25].



Curve designations: 1 – concentration 3 mg/l; 2 – 4 mg/l; 3 – 5 mg/l.

Figure 5. Dependence of fluoride adsorption on duration

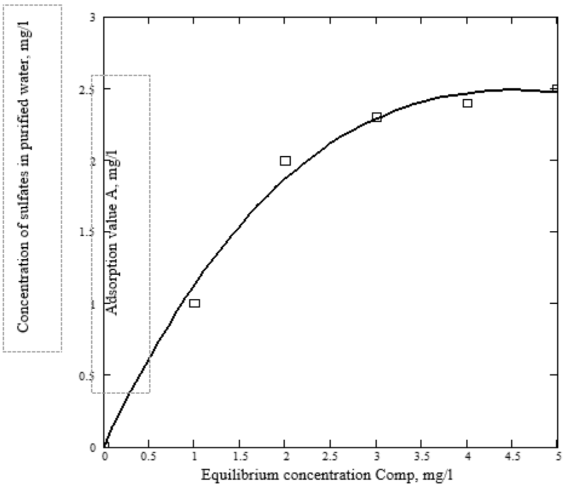
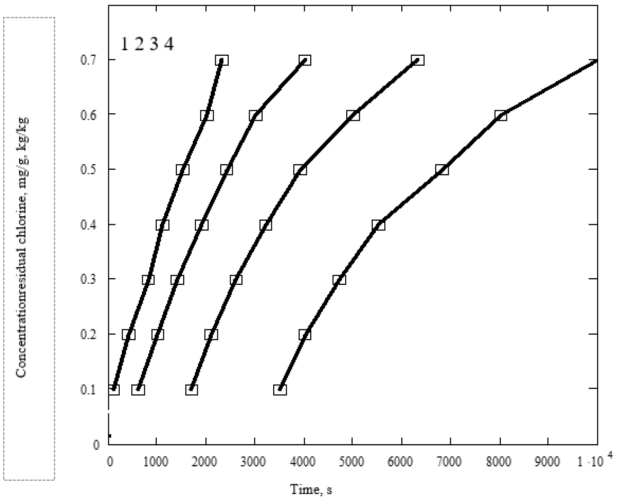


Figure 6. Dependence of fluoride adsorption on concentration



Height of active carbon layers: 1-0.06 m, 2 -0.09 m, 3 -0.12 m, 4 - 0.15m.

Figure 7. Dependence onconcentrationresidual chlorine over time at different heights of the adsorbent layer

2.2 Properties and characteristics of the objects under study

The object of study was groundwater, which is a source of drinking water in the South Kazakhstan region in the Suzak district of the village of Sholak-Korgan with a population of more than 20,000 people. Table 1 presents the quality indicators of the source water of the Sholak-Korgan groundwater.

Carbon used as an adsorbent (crushed active stone stone of the KAU brand) is active carbon produced under the influence of water steam at a temperature of 800-950°C with subsequent crushing. Activated carbon KAU is a porous material consisting mainly of carbon. It has a highly developed total porosity, a wide range of pores and a high specific absorption surface, with a long service life. Characteristics of activated carbon (stone activated carbon, KAU brand):

- main grain size, m 1-3.5*10^{-3}
- grain size>3.5mm, no more 2.5%
- grain size 1-3.5mm, not less 95.5%
- grain size<1mm, % no more 2.0
- bulk density, kg/m^3<260
- moisture contents, %<10
- ash content, %<10
- full capacity, m^3/g 1.5*10^{-6}
- micropore volume, m^3/g 0.26*10^{-6}
- volume of transition pores, m^3/g 0.27*10^{-6}
- specific surface area, m^2/g 1600

Table 1. Quality indicators of source groundwater Sholak-Korgan

No.	Indicators	Unit Change	Sholak-Korgan Water
1	Temperature, average annual	WITH	15
2	Smell at 200C no more	Point	3.0
3	Smell at 600C no more	Point	3.0
4	Taste and aftertaste 200C no more	Point	3.0
5	Color, no more	Hail.	80
6	Turbidity, no more	mg/dm^3	7.0
7	pH	units pH	5.8
8	General hardness, no more	mEq/dm^3	11.0
9	Dry residue, no more	mg/dm^3	1500
10	Fluorides	mg/dm^3	5.0
11	Iron, no more	mg/dm^3	1.0
12	Chlorine residual	mg/dm^3	-
13	Lead	mg/dm^3	<0.003
14	Total alpha activity	Bq/dm^3	<0.1
15	Total beta activity	Bq/dm^3	<0.1
16	Sulfates, no more	mg/dm^3	600
17	Chlorides, no more	mg/dm^3	510

3. RESULTS AND DISCUSSION

From Figure 5 it is clear that when the concentration of sulfates in source water increases to values higher than concentrations in natural underground water sources (1000 mg/l), the concentration of sulfates in purified water does not exceed the standards of GOST 2874-82, SanPiN 3.02.002.04 and the World Health Organization (WHO). As can be seen from the data in Figures 6 and 7, the fluoride adsorption isotherm has a convex shape and the maximum value of fluoride adsorption on the adsorbent is reached at an equilibrium concentration of 3 mg/l. The maximum adsorption of fluorides occurs within 2 hours, where we observe adsorption values of the order of 90% of the maximum achievable.

When comparing the adsorption capacity of stone activated carbon and industrial activated carbon OU-A, it is clear that the used stone activated carbon adsorbs more fluorides than OU-A carbon (0.03 kg/kg and 0.025 kg/kg, respectively).

At a mass concentration of fluorides of 0.1 kg/m^3, only 0.06 kg/kg of fluoride is adsorbed by the most coarsely porous brightening carbon OU-A, and 0.075 kg/kg of fluorides is adsorbed by stone activated carbon, which confirms the effectiveness of its use for removing fluorides from aqueous media.

Thus, experimental studies on the adsorption of fluorides by activated stone charcoal confirmed the possibility of increasing the degree of fluoride adsorption to a concentration that meets the requirements of regulatory standards [25].

Water can contain several types of iron compounds. In groundwater, iron is contained mainly in organic complexes (humates), and also forms colloidal and highly dispersed suspensions. It has now been established that long-term consumption of water with a high iron content (more than 0.3 mg/l) increases the risk of heart attacks and negatively affects reproductive function.

The influence of the water flow rate in the adsorbent layer on the turbidity index of the source and purified water is presented in Table 2. The table shows that the optimal water flow rate is $2.78 \cdot 10^{-3}$ m/s. Table 3 shows the results of fluoride adsorption by stone activated carbon at a mass concentration of fluorides from 0.05 kg/m^3 to 0.1 kg/m^3. Good adsorption properties are due to the developed external surface and transition porosity of the adsorbent.

Figures 6 and 7 show the sufficient adsorption capacity of activated carbons for iron, where for comparison with industrial samples of activated carbons, the sample brands OU (brightening activated carbon) and BAU (birch activated carbon) were taken. From a comparison of different types of adsorbents, CACs are the most effective. Research for different porous structures has shown that the most optimal ratio of micropores to mesopores is 1/3.

As noted, the presence of E. coli in water indicates contamination by human or animal secretions and the possibility of contamination of water with pathogenic bacteria. For those waters that contain relatively many harmful substances and bacteria, single chlorination is usually used with the introduction of chlorine and some chlorine-containing agents into the water in front of the clean water reservoir. In this case, as a rule, minimum doses of chlorine are used in the range of 0.0005-0.002 kg/m^3. When clarifying highly colored waters, as well as waters rich in harmful substances, toxic impurities and bacteria, double chlorination is often used. Dechlorination of water can be carried out by a physical method-by absorbing chlorine with an adsorbent. The advantage of this dechlorination method is that there is no need to add any additional reagents [24, 25].

To study the adsorption of chlorine, we used stone activated carbon [24], presented in section 2.1 (Properties and characteristics of the studied objects). The content of residual chlorine and the degree of removal as a percentage of the initial content are shown in Table 4. The table shows that the degree of chlorine removal is high enough for the use of this activated carbon and adsorption apparatus. The effects of water flow rate and cleaning time on the absorption of residual chlorine by activated carbon are presented in Figures 6 and 7.

It can be seen that the optimal factors of the regime are: cleaning time-0.5 hours; water flow speed-$2.8\cdot10^{-3}$m/s.

Table 2. The influence of water flow speed on the turbidity index in source and purified water

Water Flow Speed υ, **m/s**	**Turbidity Index**		**Degree of Purification A,%**
	In Source Water WITH_{ref}**, kg/m**^{3}	**In Purified Water** $\text{WITH}_{\text{very good}}$**, kg/m**^{3}	
$2.222\cdot10^{-3}$	0.05	0	99
$2{,}500\cdot10^{-3}$	0.05	0	99
$2{,}778\cdot10^{-3}$	0.05	0	99
$3.056\cdot10^{-3}$	0.05	0.002	96

Table 3. Comparative adsorption of fluorides by stone activated carbon and industrial OU-A carbons

Mass Fluoride Concentration $\text{WITH}_{\text{masses}}$**, kg/m**^{3}	**Industrial Activated Carbon Grade OU-A, A, kg/kg**	**Applicable Activated Coal KAU, A, kg/kg**
0.05	0.025	0.03
0.06	0.031	0.038
0.07	0.038	0.045
0.08	0.045	0.05
0.09	0.052	0.063
0.1	0.06	0.075

Table 4. Residual chlorine content and degree of removal as a percentage of the initial content

Adsorbent	**Residual Chlorine Concentration**		**Degree of Excretion ost. Chlorine from the Initial a, %**
	In Source Water Cis, mg/l	**In Purified Water Soch, mg/l**	
Activated carbon	0.6	0.001	99.0

Table 5. Calculated values of protective action time, adsorption wave speed, protective action coefficient

Diameter of Adsorbent Particles, d, mm	**Flow Rate, w, m/sec**	**Protective Coefficient, k, s/m**	**Adsorption Wave Speed, U, m**^{2}**/s**	**Layer Length Hm**	**Protective Action Time, τз, s**
1	2	3	4	5	6
1	0.0025	4,738×104	0.0000311	0.06	2300
				0.09	4300
				0.12	5900
				0.15	9800
2	0.0025	4,392×104	0.0000327	0.06	1900
				0.09	3200
				0.12	4600
				0.15	8550
3	0.0025	4,008	0.0000349	0.06	1450
				0.09	2850
				0.12	3900
				0.15	7300

The efficiency of the purification degree when using activated carbon in the process of extracting residual chlorine from water reaches 99%. This method of extracting residual chlorine using activated carbon can be used in natural water purification processes to remove residual chlorine, as well as formed chlorine compounds. To study the purification of water from residual chlorine contained in groundwater, studies were carried out on the adsorption extraction of residual chlorine, where from Figure 7, a sufficient adsorption value of 0.3mg/g is visible with an adsorption time of 2hours.

Figures shows the dependence of the degree of water purification on the porosity of the adsorbent layer. Figure 7 shows that increasing the porosity of the layer to 0.75 leads to a sufficient degree of water purification.

To study and analyze the time of protective action on the length of the adsorbent layer, we carried out at several heights of active carbon layers: 0.06m, 0.09m, 0.12m, 0.15m. The output curves at different heights of the adsorbent layer are presented in Figure 7. The calculated values of the protective action time, the adsorption wave speed, and the protective action coefficient are presented in Table 5.

An analysis of the nature of the output and kinetic curves of adsorption by active carbons showed that the mechanism of this process can be described by the parallel transfer method, which is established at an adsorbent layer height of 0.09m or more. Consequently, at these layer heights, the dependence of the protective action time will be described by the equation N.A. Shilova.

The dependence of the time of protective action on the length of the adsorbent layer is presented in Figure 5. From the figure it can be seen that an increase in the length of the working layer with an increase in the total length indicates that the initial layers, considered spent, actually continue to absorb residual chlorine during the adsorption process and, due to additional saturation initial layers, the static activity of spent layers increases.

A flow of water containing residual chlorine with a concentration of 0.7mg/l, during adsorption, enters the layer of porous grains and washes them, filling the intergranular voids of the adsorbent layer, which depends on the standing porosity and placement of the adsorbent grains. As a result of the transfer of residual chlorine to the outer boundary of the adsorbent grains and from the outer boundary of the grain through the pore system to its center, the residual chlorine molecules are adsorbed and its concentration as it moves along the layer drops from 0.7mg/l to 0mg/l. After residual chlorine appears in the purified water at a minimum concentration, the adsorber is stopped for regeneration. Thus, in the water filling the intergranular voids of the adsorption layer with a porosity of up to 0.75, the concentration at the moment of breakthrough of residual chlorine in the purified water changes from 0.7mg/l at the entrance to the adsorbent layer to 0.1mg/l at the exit from the layer adsorbent.

Due to the fact that the contact time of water with the surface of the grain is short, adsorption equilibrium is not achieved, and the degree of approach to equilibrium in the adsorbent grains at different layer heights is not the same, since the concentration of residual chlorine changes along the adsorbent layer.

To analyze the dynamics of adsorption of residual chlorine from water on activated carbon, we examined how the adsorbed residual chlorine is distributed along the layer and how its concentration in the flow decreases in the direction of its movement.

Since the adsorption rate is determined by the transfer rate, the absorption of residual chlorine from water does not occur instantly, but requires time, during which the concentration in water drops from 0.7mg/l to 0mg/l, and the residual chlorine itself moves a distance L. This section of the adsorbent layer, where the concentration of residual chlorine in the water drops from 0.7mg/l to 0mg/l, is called the “working layer”. When new portions of water enter the layer, they encounter adsorbent grains, in the pores of which there is already previously absorbed residual chlorine.

As a result of the fact that the driving force of the adsorption process decreases, the adsorption rate drops and the process of reducing the concentration of residual chlorine in water from 0.7 mg/l to 0 mg/l ends at a greater distance from the beginning of the layer. This change in the length of the section of the adsorbent layer, at which the concentration of residual chlorine drops from 0.7 mg/l to 0 mg/l, continues until the initial section of the “front layer” layer is saturated with residual chlorine to equilibrium with its concentration in the source water 0.7 mg/l.

Further, this initial section of the layer does not take part in adsorption and the beginning of the absorption of residual chlorine from water moves further along the adsorbent layer, where the adsorbent grains are not saturated to equilibrium. From this moment on, all conditions of adsorption from water are reproduced. The length of the working layer becomes constant, but its position in the layer constantly moves in the direction of the water. The curve depicting the distribution of adsorbed residual chlorine along the adsorbent layer; the adsorption front, maintaining a constant shape, moves parallel to the adsorbent layer. The adsorption front is characterized by an increase in the concentration of residual chlorine in purified water over time. After the length of the working adsorbent layer L becomes constant, the time during which it moves to the exit boundary of the adsorbent layer increases in proportion to the elongation of the adsorbent layer. Therefore, the output adsorption curve also moves with increasing length of the adsorbent layer parallel to itself due to an increase in the time of the protective action of the layer.

4. CONCLUSIONS

An analysis of the research object was carried out and the quality indicators of the source water were determined. Stone activated carbon was selected as an adsorbent, its characteristics were studied, and research and testing methods were determined.

The design of an adsorber with a fixed layer of adsorbent has been developed, allowing to increase the efficiency of the apparatus, increase the utilization rate of the useful volume of the apparatus and the degree of processing of the adsorption capacity of the adsorbent in the layer, the stability of the quality of the purified flow with maximum compactness of the apparatus, and reduce the formation of stagnant and unused zones.

The influence of water flow speed and cleaning time on the absorption of residual chlorine by activated carbon was determined, where the optimal mode factors are: cleaning process time-0.5hour; water flow speed-$2.78*10^{-3}$m/s. The dependences of the concentration of sulfates in purified water on the equilibrium concentration and the dependence of the adsorption of fluorides on the concentration have been established. The fastest adsorption of fluorides occurs on the adsorbent at a concentration of 3mg/l. The maximum adsorption of fluorides occurs within 2 hours, where we observe adsorption values of the order of 90% of the maximum achievable. A comparison of the nature of the output and kinetic curves of adsorption by active carbons showed that the mechanism of this process can be described by the parallel transfer method, which is established at an adsorbent layer height of 0.09m or more.

Methods for carrying out regeneration have been studied and an effective method of regeneration after adsorption of groundwater has been determined-stripping the adsorbate from activated carbon with water vapor. Identified and change in the overall degree of regeneration depending on steam consumption and addiction general degree of purification depending on the number of adsorption-desorption cycles. Optimal steam flow to achieve general degrees regeneration over 80% was 15 kcal, and a 5% drop general the degree of purification is observed within 15 cycles, then the decrease occurs slightly, and after 40 cycles the degree of purification was 88.5% of the original.

In summary, the research successfully achieved its objectives by developing an innovative adsorber design, understanding the influence of operational factors, and determining effective regeneration methods. These findings contribute significantly to addressing water quality issues in the Suzak region, presenting a comprehensive and practical solution for sustainable water treatment. The defined technical terms ensure clarity in interpreting the conclusions, emphasizing the importance of the research outcomes.

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