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The study of surface parameters and sorption properties of aerated concrete-based sorbents for water purification from *E.Coli* bacteria

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Abstract
Development of cheap and reliable methods of water purification is worldwide challenge. Application of sorbents is one of the most efficient and universal method of water purification, but it has drawbacks. Designing of new efficient sorbent is topical task. The main goal of this study was investigation of the new sorbent based on the aerated concrete. The aerated concrete sorbentwas used in intact condition and after modification. The composition of thesorbents was determined by elemental analysis with emission spectroscopy. Zeta potential of water suspension was evaluated by Zetasizer Nano. The low leaching level into water for all tested sorbents was determined. The properties of the filtering materials have been determined by sorption test of removing bacteria Escherichia coli from the model suspension. The surface parameters were investigated, using the method of thermal desorption of nitrogen. The tested filters with fraction of less than 0.1 mm clean the bacterial suspension to the level of compliance with hygiene standards for drinking water. It was revealed satisfactory properties of the filtering material for water purification from microbiological contaminations. The results prove the possibility of using the aerated concrete for water purification.

Keywords: adsorbent, aerated concrete, E.coli, water purification

1. Introduction
Necessity of clean water in large quantities and limited available sources are worldwide problems. The acuteness of water insufficiency will continue to grow due to the increase in population and industrial growth. There are many difficulties in the purification of aqueous media appears due to the presence of microorganisms in the feed water or their occurrence during technological process, that requires additional bactericidal measures and specific modified sorbents [1, 2].
The presence of microorganisms in drinking water is strictly regulated. Contamination can lead to serious health consequences in the case of exceeding the norms, up to the development of serious pathologies, including dysentery and hepatitis. The main markers of bacterial contamination of drinking water are coliform bacteria. The presence of Escherichia coli reflects fecal contamination of water, which is an important and law-regulated indicator [2]. The costs of wastewater treatment increases with an increase in requirements for cleaning, and risk of environmental problems remains very high [3]. In many cases, it requires significant long-term investments [4]. This makes it necessary a continuing effort to improve the cost-effective methods and develop new sorption materials [5-7]. Recently, for the purification of water from inorganic and microbiological contaminants actively tested filter and sorption materials based on mixtures of oxides, hydroxides and oxyhydroxides of aluminum produced by electric pulse methods [8]. Antibacterial properties of sorbent are also enhanced by silver, especially in form of nanoparticles, but it found to be genotoxic [9,10].

In this work synthetic sorbent based on aerated concrete was used for the purification of aqueous media from microbiological contamination. Surface and sorption properties were investigated for different fractions of material. In addition to construction purposes, aerated concrete is used as biofilter carriers in biological aerated filters to solve the disposal problems of construction wastes [11]. There are many types of concrete with different fillers and properties. The mixed composition of aerated concrete and high porosity predict good sorption propertiesof the material [12]. Application of aerated concrete as a sorbent allows obtaining a new line of sorbent material with the improved properties for water treatment [12].

2. **Experimental**

2.1 *Preparation of Sorbents*

As a basis for development of new filter materials was used constructive insulating aerated concrete blocks mark D700 (producer Tomskgazoblok Stroy ltd, Tomsk, Russia), which is cheap and affordable material. Blocks were milled to the appropriate fractions. Inclusions of nanoparticles in concrete imply increasing of sorption properties. High porosity of aerated material provides a high surface area. Modification of the surface by the following procedure was performed to improve the properties of the material.

2.2 *Technique of aerated concrete modification*

Take a sample of aerated concrete in an amount of 20 g and placed in a glass beaker volume of 2000 dm3, which is then poured in 1,000 dm3 hydrochloric acid 10 wt.%. The material was kept in the solution for 2 hours, and then hydrochloric acid solution poured off. Aerated concrete was washed with distilled water to neutral pH. After washing, the material was dried in a laboratory drying oven muffle (SNOL 23/10). The pretreatment included exposure at 120°C for 4 hours, followed heat treatment at 450 ° C for 5 hours, that provides cleaning material from organic contaminants and formation of active nanostructure centers on surface.

2.3 *Elemental analysis of the samples.*

Elemental analysis of the material samples based on aerated concrete performed by atomic emission spectrometry with inductively coupled plasma spectrometer iCAP 6300 Duo, Thermo Scientific, UK, 2007.

2.4 Determination of the components leaching of aerated concrete

Sorbent sample in amount 5 g was placed in double distilled water 500 cm^3 to determine the degree of leaching of components. The material was kept for 24 hours, then filtered and analyzed using the method of atomic-emission spectrometry with inductively coupled plasma.

2.5 Determination of surface characteristics.

During the experiment, the basic characteristics of the surface were determined, including the value of specific surface area and specific pore volume values. Method of thermal desorption of nitrogen (BET - Brunauer–Emmett–Teller) with analyzer "SORBTOMETR-M" (Russia) was used to estimate the parameters of the surface of the test samples.The method allows to measure of a specific surface area at different partial pressures of the adsorbate gas (nitrogen) and determine the volume micropores.

2.6 *Zeta potential measurements*

The suspension of tested samples of concrete was prepared in water for measuring zeta potential. To this experiment weighed sample (fraction less than 0.1 mm) in an amount of 0.02 g was placed in 20 cm^3 of distilled water and subjected to brief sonication (about 3-4 s). Then the aliquot (approximately 1 cm3) was placed in the measuring cell. Measurements were carried out on the instrument Zetasizer Nano ZSP automatically. Measurements were conducted 3 times.

2.7**.** *Filtration test*

Extraction of bacteria from the test suspension by the filter material was carried out in dynamic mode. The filter material based aerated concrete was loaded in the filling filtering module (glass tube, length 150 mm, internal diameter 8 mm) in an amount of 5 to 10 g (this quantity allowed to reveal bacterial sorption), depending on the particle size corresponding fraction. The bacterial strain ATCC 25922 Escherichia Coli was used to evaluate the quality of water treatment. The test bacteria suspension was prepared from tap water (separated during the day) by adding 24-hour culture suspension of bacteria in meat-peptone broth. The final suspension of E. Coli bacteria has a test concentration of microorganisms 2.5×10^7 CFU/cm^3 (colony forming units), that corresponds to extremely contaminated water. Model bacterial suspension was filtered through the system shown in Figure 1. The filter module was connected to the container with bacteria by hose and pumped through the peristaltic pump at a constant speed. The filter material was considered as sterile after pretreatment. After filtration 100 cm^3 of the suspension, a sterile filtrate sample was taken and investigated for the presence of the bacteria E. Coli.

2.8. Microbiological testing.

Filtrate samples were added to solid growth medium in petri dishes according to standard procedures. Then petri dishes incubated for 24 hours at 37°C and bacterial colonies were visually counted, the result was expressed in number of colony forming units (CFU) per 1 cm^3 of filtrate.

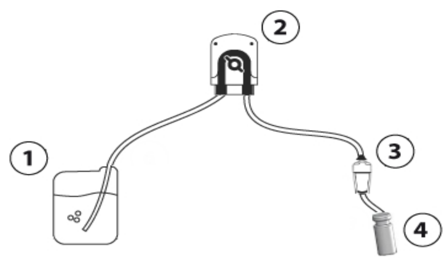

Figure 1. Filtration scheme. 1- bacterial suspension, 2 - peristaltic pump, 3- filtration module, 4 – sterile filtrate collector

3. Results and discussion

Development of mineral-based adsorbent to purify water from microbiological contamination is a complex task. The important factor is creation on the surface of nanoscale "needles" structures that can act as a microfilter to remove bacteria. The results of elemental analysis showed that silicon and calcium prevail in the composition, also a large proportion contain iron and aluminum (Table 1). These elements in specific treatment may create active sites on the surface of fine particles, improving the filter characteristics.

Table 1. The elemental composition of sorbent samples.

Element	**Content in the test sample, mg/kg**
Al	10390
Ca	125100
Fe	12810
K	4196
Mg	3479
Mn	360
Na	2911
Si	141370

Another important parameter for any adsorbent is the rate of components elution. In other words, the sorbent itself should not be a source of contamination. Table 2 shows the leaching degree from aerated concrete by the process of its settling in distilled water during 24 hours.

Table 2. Determination of the leaching degree of the various elements from the sorbent.

Element	Initial concentration in water, mg/dm^3	Final concentration after 24 hours settling, mg/dm^3	Permissible concentration in drinking water, mg/dm^3
Al	<0.01	0.165	0.5
Ca	0.148	41.1	100
Cr	<0.001	0.048	0.05
Fe	0.013	0.004	0.3
K	<0.05	4.56	12
Mg	<0.05	0.83	50
Mn	<0.001	<0.001	0.1
Na	0.548	13.1	200
Si	0.073	5.63	10

Obtained results shown that the values of element concentrations leachable into water are much lower than the maximum permissible values for all tested components.
The study of the morphology of the surface by thermal desorption of the nitrogen revealed the value of specific surface area and porosity of experimental samples sorbents (Table 3).

Table 3. Surface parameters of sorbents.

Fraction, mm	Specificsurface, m^2/g	Specific pore volume, cm^3/g	Averageporesize, nm
(< 0.1)	19.358	0.008	1.716
(0.1-0.5)	10.275	0.004	1.714
(0.5-1.5)	13.461	0.006	1.717
(1.5-2)	12.404	0.005	1.715
(2-2.5)	11.865	0.005	1.714
(2.5-4)	11.882	0.005	1.716

The experimentally defined surface characteristics of material allow to assume the high sorption properties for wide range of contaminants, including microbiological.
The most important characteristic of nanoparticles is the electrokinetic potential or zeta potential. The zeta potential corresponds to the slipping plane of particles. It is part of the potential of the diffusion layer and characterize the interaction force between the particles that determine the system stability and the ability of the particles to agglomerate. Experimental studies of Zeta potential in aqueous suspension of sorbent particles indicate that most of the particles has a value of Z-potential at -15 ± 4.06 mV (pH = 7), which does not assume a stable suspension. However, this characteristic play important role mainly in a static adsorption conditions. Under conditions of dynamic sorption, ie, when filtering the test suspension through the adsorbent, Z-potential value is not so significant, but it describes the properties of the particle surface in an aqueous medium.In the static condition Z-potential can directly influence on bacteria-particle interaction.
Results of extraction of microbial contamination from the test suspension in dynamic conditions are shown in table 4. Microbiological testing has revealed accurate correlation between the degree of removal of bacteria and the fraction of the sorbent composition. The small fraction after contact with water makes a short slits between particles that provide a very effective physical adsorption of bacteria.It should take into account very high concentration of bacteria in the initial suspension 2.5×10^7 CFU / cm^3. The large fractions slightly reduce the bacteria content of 2 to 10 times, that means low effectiveness of water purification, the big gap between particles decrease frequency of bacteria-surface contacts. In contrast, the filter modules with the sorbent fraction

of less than 0.1 mm clean the suspension from E. Coli strains to the level of compliance with hygiene standards for drinking water. It is important to note the higher flow resistance of this small fraction. Nevertheless, fine sorbents provided acceptable filtration rate during experiment.

Table 4. Degree of bacteria extraction by adsorbents based on aerated concrete.

Initial concentration of microorganisms, CFU/cm^3	**Fraction, mm**	**Filter load weight, g**	**Concentration of bacteria after filtration CFU/cm^3**
2.5×10^7	<0.1	6.7	0
	0.1-0.5	6.63	8.6×10^6
	0.5-1.0	5.9	1.6×10^7

The data in Table 4 shows that the big fractions removed only agglomerated bacteria, while a fraction of less than 0.1 mm provided sterile filtration. The results of conducted studies of the filter material prove the possibility of using the aerated concrete for water purification from bacterial contamination.

Conclusions

Thus, it was shown satisfactory water purification efficiency of the filter material based on aerated concrete. However, it seems promising to conduct extensive research of the aerated concrete with different surface modification and mixed fractional composition.

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References

1. Plotnikov E., Martemianova I., Martemianov D., Zhuravkov S.,Voronova O., Korotkova E., Silnikov V., *Procedia Chemistry* 15 (2015) 219.
2. Rotmistrov MN., Gvozdyak PI., Stavskaya SS. Microbiology of water purification. - M: Naukova Dumka, (1978).
3. Muharram EA.,Sorin CM., Ismail R., *J. Mater. Environ. Sci*. 7 (4) (2016) 1145.
4. Frog BN., Levchenko AP., *Water treatment*, Moscow: MSU, (1996).
5. Ouasif H., Yousfi S., Bouamrani M.L. El Kouali M., Benmokhtar S., Talbi M., *J. Mater. Environ. Sci*. 4 (1) (2013) 1.
6. El Haddad M., Mamouni R., Slimani R., Saffaj N., Ridaoui M., ElAntri S., Lazar S., *J. Mater. Environ. Sci.* 3 (6) (2012) 1019.
7. El Haouti R., Et-taleb S., Abbaz M., Lhanafi S, Azougarh Y., Ez-Zahery M, Aba-aaki R, El Alem N., *Arab. J. Chem. Environ. Res.* 2 (2015) 58
8. Zhuravkov S.P., Lobanova G.L., Martemiyanov D.V., Nadeina L.V., *IOP Conference Series: Materials Science and Engineering* 81 (1), (2015) 1.
9. Plotnikov E, Zhuravkov S, Gapeyev A, Plotnikov V, Martemiyanov D., *Advanced material research*. 1040 (2014) 65
10. Perevezentseva DO., Gorchakov EV., *Advanced Materials Research*. 1040 (2014) 297.
11. Bao T., Chen T., Wille M.-L., Chen D., Bian J., Qing C., Wu W., Frost R.L., *Journal of Water Process Engineering*, 9(1) (2016) 188.
12. Martemianov DV, Galanov AI, Yurmazova TA, Korotkova EI, Plotnikov EV., *Proceedings of the higher educational institutions. Chemistry and chemical technology*, 57(11) (2014) 30.