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Method of Water Filtration Using Ceramic Composite Materials Based on Bentonite

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Abstract
This paper presents a method of water filtration using composite filters based on bentonite powder, alumina ceramic particles and iron metal particles. The base of the composite material was developed from bentonite and alumina ceramic particles. Various percentages of iron metal particles were added to the base matrix of the composite and there were obtained several groups of materials. They were compacted in a metal mould to make cylindrical raw material samples. The samples were sintered at 1100 °C. There were obtained ceramic filters of Φ = 16 mm diameter and 14-16 mm high. In order to meet the purpose of the research, the ceramic filters were characterised in terms of compressive strength and there were determined some dependencies between their structure and properties. A laboratory installation was used to demonstrate the filtration of the solid components from water by means of CWF composite filters. Both parts of the filter were subjected to the action of the pressure generated by the centrifugal pump within the installation, which led to the displacement of the fluid. There was demonstrated the ability to retain the solid components in water by means of these ceramic composite filters.

Keywords
bentonite, ceramic filter, metal particles, ceramic composite materials

1. Introduction

Water resources are an essential component of life. But drinking water resources tend to become a problem in the future. The growing demand for water, also due to industrial development, larger cultivated areas, city development and demographic growth, makes this resource vital. According to the World Health Organisation [1], access to drinking water is a basic human right. Facilitating access to safe drinking water can certainly be considered a health benefit [2, 3]. Ceramics, due to their properties, have answered to this challenge. These are relatively cheap and offer good results [4, 5].

Liang Y et al. consider that ceramic filters with Ti^{3+}-doped TiO_2 nanoparticles on their surface are efficient in making water potable [2]. Huang Jing et al proposed the use of discs made of ceramic materials, covered with Ag/ZnO nanocomposite materials, to make water potable [4]. Bielefeld et al. noted that ceramic filters can be used on a large scale as a method of treating microbially contaminated water for drinking purposes [6]. Filters can be based on biomass and clay [5], or ingredients such as clay and organic components such as sawdust or rice husks [6].

2. Materials and Method Used

2.1. Materials used

There were made composite materials with matrix based on bentonite powder. Bentonite is a clayey sedimentary rock formed by the degradation of volcanic tuffs and it is characterised by a high water retention capacity [7]. It consists of a mixture of clayey minerals, the main component of which is montmorillonite. Other mineral components are quartz, mica, feldspars, pyrite and calcite [7]. Al_2O_3 ceramic particles, with a grain size of 50 μm, were added to the bentonite powder-based matrix. The ceramic powders provide the porous structure of the material obtained. Quantitatively, the composite matrix is made up of 40% bentonite powder and 60 % Al_2O_3 powder. The chemical composition of the composite obtained is given in Table 1.

Table 1. Chemical composition of the P-type composite matrix

Composite type	Bentonite		Al_2O_3	
	%	Weight [g]	%	Weight [g]
P	40	24	60	36

In order to control the size of the pores, metal particles of Fe (< 100 µm) were added to the base matrix, in percentages of 3 % and 12 %, respectively. The composite materials were registered with P-3Fe and P-12Fe.

2.2. Method used

24 g of bentonite powder were mixed for 15 minutes with 36 g of Al_2O_3 ceramic powder. They were mixed until completely homogenised. After homogenisation, there was added 12 % distilled water and the mixing continued for 5 minutes. The result was a material consisting of bentonite powder with the addition of alumina powder, denoted as P. Two parts were separated from the resulting mixture, and 3 % Fe metal particles were added to the first part, and this material was denoted as P-3Fe, and 12 % Fe metal particles were added to the second part, and this material was denoted as P-12Fe. The metal particles were mixed in the formed base until completely homogenised.

There were obtained groups of differently alloyed composite materials, having the same base. Raw samples were made from each group of materials by compaction in a metal mould, using a force F = 20 kN applied by a WDW-150S mechanical testing machine. The samples has Φ = 16 mm diameter and h =14 - 16 mm height. The samples thus obtain were stored in a room at temperature T = 20 °C for three days in order to evaporate the water. After their natural drying, they were sintered in a Nabertherm type heat treatment furnace at T = 1100 °C. The sintering takes place by binding the particles upon heating by mass transfer and surface transport mechanisms with the main purpose of obtaining a dense solid component.

There were thus obtained ceramic composite samples which were afterwards used in the water filtration process by means of a filtration installation. The filter-type ceramic composite samples were named CWF (Ceramic Water Filter), as shown in Figure 1.

Fig. 1. CWF ceramic composite samples

The making of CWF filter type ceramic composite samples to be used in a process of filtering drinking water involves knowledge of the structural aspects in correlation with their properties when subjected to mechanical stresses.

3. Experimental Tests and Results Obtained

The ceramic composite samples (CWFs) underwent a mechanical compression test by applying a force F = 20 kN using a WDW-150 S mechanical testing machine.

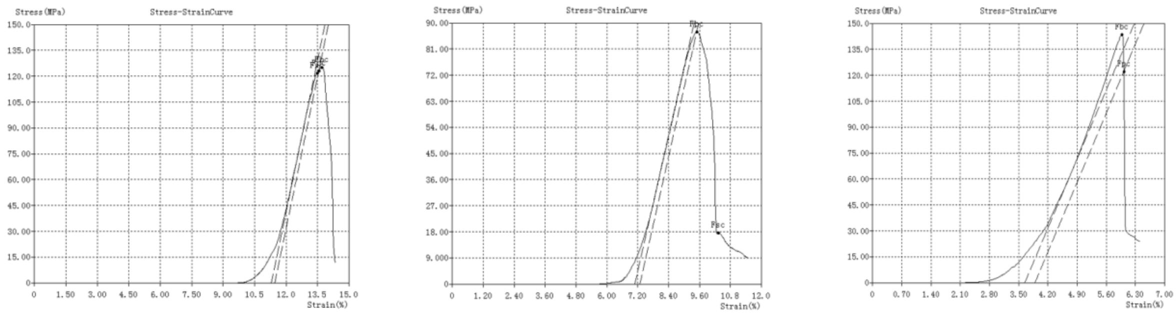
The mechanical testing machine is equipped with a software that allows the reproduction of some parameters: R_{bc} - maximum strength of the material, F_{bc} - the maximum compressive strength, E - the compressive elastic modulus.

There were carried out at least three tests for each batch of samples, and the average value of the results obtained is given in Table 2.

Table 2. Results of the compression test for the samples P, P-3Fe and P-12 Fe

Sample	The resistance of the material to the maximum force, R_{bc} [Mpa]	Maximum compressive strength, F_{bc} [kN]	Compressive elastic modulus, E [GPa]
P	103.8	20.91	4.55
P-3Fe	78	15.6	3.97
P-12Fe	143.7	28.89	5.86

The test diagrams for the composite samples P, P-3Fe and P-12Fe are shown in Figure 2.



a) b) c)

Fig. 2. Test diagrams for: a) P-sample; b) P-3Fe-sample; c) P-12Fe-sample

High compression values were recorded in the case of composite materials alloyed with high percentages of iron. The average values obtained in the case of P composite materials alloyed with different percentages of iron metal particles are shown in Figure 3.

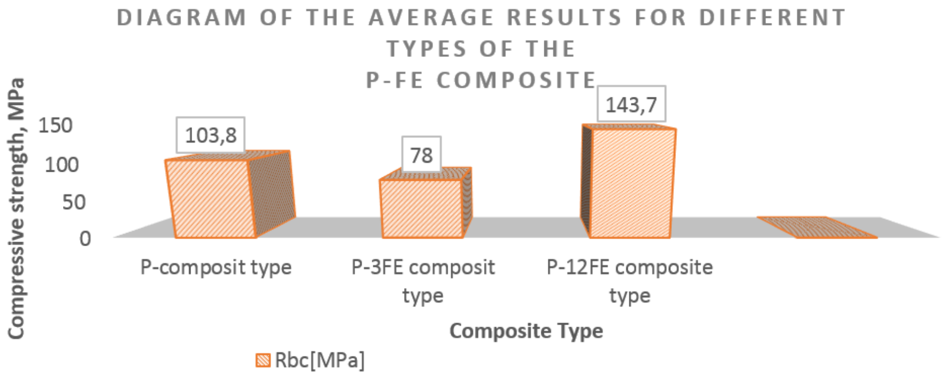


Fig. 3. Diagram of the average results for different types of the P-Fe composite

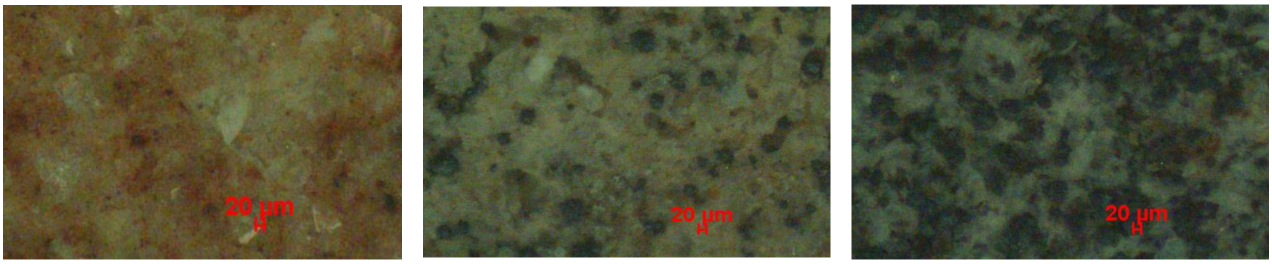
Based on the diagram, there can be noted that the iron oxides in the ceramic composite P generate a number of internal stresses that lead to the settling of the material and improving of the compressive strength. The decrease in the first phase of the compressive strength indicates that the oxides occur at first as a zone where the bonds are broken within the material.

The surface was analysed by optical microscopy using the Omnimet-Buehler structural analysis system. In the micrographs presented in Figure 4, the presence of the base mass and the reinforcement material can be observed. As the sintering was carried out in a furnace at a normal atmosphere, iron metal oxides could be found on the surface of the samples, generated by the reaction of iron particles with oxygen.

4. The Working Principle

4.1 Description of the installation

In order to fulfill the intended purpose regarding the CWF (P) ceramic filters, there was built and used a laboratory installation referred to as SCA-1700 (Figure 5).



a) b) c)

Fig. 4. Analysis of sample surfaces for sample: a) P; b) P-3Fe; c) P-12Fe

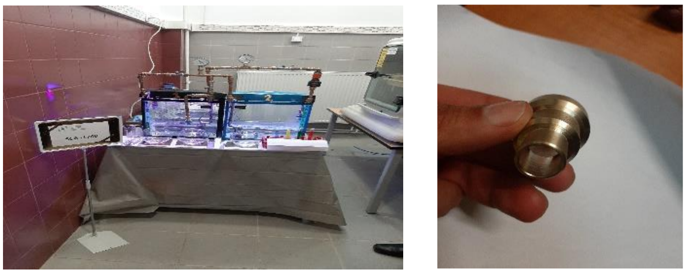


Fig. 5. Filtration installation type SCA-1700 and CWF filter mounting bracket

The installation consists of two tanks with a capacity of 40 liters each. In each tank there is a centrifugal pump of P = 7 W power. The CWF ceramic composite filter is mounted in a bracket attached to the installation. By applying a pressure on the filter parts, the water (tributary) is forced to pass through this filter, and the pipe system directs it into the second tank. The free flow of the pump is Q = 2.47 l/min. By inserting the ceramic filter into the bracket, at the same amount V = 600 ml of pumped water, there can be noted a flow rate decrease tendency over time. The flow rate was measured at regular time intervals, i.e. t = 5 min, 10 min, 15 min, 20 min. The values recorded for the composite ceramic filters (CWF) are shown in Table 3.

Table 3 Flow variations for various composite materials

Sample type	Q [l/min]			
	t = 5 min	t = 10 min	t = 15 min	t = 20 min
P	0.428	0.186	0.0432	0.0255
P-3Fe	0.396	0.128	0.0621	0.0346
P-12Fe	0.244	0.102	0.022	0.0014

5. Conclusions

The ceramic composite filters that have been made contain bentonite, alumina particles and metallic iron particles.

During sintering, the oxides generated by the reaction of the metal particles with the oxygen atmosphere in the furnace cause the occurrence of local tensional stresses which lead to an increase in the volume of the samples and a break in the bonds between the granular components.

Following the interposition of the filter in the installation, there can be noted a tendency of flow decrease in the case of all the samples, attributed to the loading of the filter with precipitate.

The water is forced to pass through the filter by the centrifugal pump. Ceramic composite filters have the ability to retain water impurities.

References

1. World Health Organization (2022): *Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda*. ISBN 978-92-4-004506-4, https://www.who.int/publications/i/item/9789240045064
2. Liang Y., Huang G., Li Y., Yao Y., Ding X., Li.X., Yin j., Gao S., Wu Y., Chen Y., Feng R. (2020): *Photocatalitic disinfection for point-of-use Water treatment using Ti^{3+} self-doping TiO_2 nanoparticle decorated ceramic disk*

filter. Environmental Research, ISSN 3566-0568, Vol. 212, part E, article 113602, https://doi.org//10.1016/j.envres.2022.113602

3. Batabyal P., Mookerjee S., Sur D., Palit A. (2013): *Diarrheogenic Escherichia Coli in potable water sources of West Bengal, India.* Acta Tropica, ISSN 2365-1909, Vol. 127, is. 3, pp. 153-157, https://doi.org/10.1016/j.actatropica.2013.04.015
4. Huang J., Huang G., An C., Xin X., Chen X., Zhao Y., Feng R., Xiong W. (2019): *Exploring the use of ceramic disk filter coated with Ag/ZnO nanocomposites as an innovative approach for removing Escherichia coli from household drinking water.* Chemosphere, ISSN 3186-4067, Vol. 245, article 125545, https://doi.org/10.1016/j.chemosphere.2019.125545
5. Chaukura N., Chiworeso R., Gwenzi W., Motsa M.M., Munzeiwa W. Chikurunhe I., Nkambule T.I. (2020): *A new generation low- cost biochar clay treatment "biscuit" ceramic filter for point -of-use water treatment*. Applied Clay Science, ISSN 0169-1317, Vol. 185, article 105409, https://doi.org/10.1016/j.clay.2019.105409
6. Bielefeldt A.R., Kowalski K., Summers S. (2009): *Bacterial treatment effectivenes of point-of-use ceramic filters.* Water Research, ISSN 1950-0815, Vol. 43, is. 14, pp. 3559-3565, https://doi.org/10.1016/j.watres.2009.04.047
7. Matei S., Stoicanescu M., Varga B., Tiron E., Crisan A. (2021): *Bentonite-based composites with ceramic and metallic powders additions for use as filters.* Advances in Mechanical Engineering, ISSN 1687-8140, Vol. 13, no. 4, pp. 1-15, https://doi.org/10.1177/16878140211011888