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Original scientific paper

Comparison of Filtration Capacity of two Non-Metalic Raw Materials for Fine Water Suspended Particles

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ABSTRACT: The basic parameters of two natural non-metallic raw materials from R.N. Macedonia have been defined: white opalized tuff from the locality of Strmosh and, diatomaceous earth from the locality of Slavishko Pole as potential materials for water filtration. Two different sets of water filtrations were carried out for each material with a previously prepared bentonite clay water suspension with a grain size of below 32 μm. A continuous filtration was performed in a column with a well-defined flow, and discontinuous flow under static conditions, i.e. diffusion active system. The percentage of retained clay grains was estimated, namely, by means of continuous filtration with white opalized tuff the percentage of retained clay particles was 12.88%, and 35.00% when diatomaceous earth was used as a filtration material. The filtration capacity under dynamic conditions for diatomaceous earth was 0.028 g/g material, and 0.011 g/g material for white opalized tuff.

Key words: water filtration, white opalized tuff, diatomaceous earth, water suspension, filtration capacity.

INTRODUCTION

Due to the increasingly rapid environmental development, the necessity for water is correspondingly increasing, which imposes the necessity for the application of more efficient methods in the processes of preparation of drinking water. Filtration is one of the oldest and simplest methods for the preparation of drinking water, which denotes a process of removing suspended substances from water by moving through a porous layer (Abdiyev et al., 2007, Wotton, 2002). Non-metallic raw materials are used as potential filtration materials due to their originating features. The R.N. Macedonia is rich in non-metallic raw materials with a wide range of possible use and application. The non-metallic materials play an essential role in enhancing the efficiency of water filtration methods. Primarily, they assist in the reduction of contaminants by acting as catalysts or adsorbents. Depending on the materials and their properties, several characterization studies had been accomplished (Bogoevski et al., 2014, Bogoevski et al., 2016, Reka et al., 2019, Pavlovski et al., 2011, Reka et al., 2012, Bogoevski et al., 2012). Several studies indicate that diatomaceous earth (DE) utilized as a filter have been able to remove microparticles, thus maximizing water quality. This extent of filtration unallowed tiny particles to be passed on including viruses, bacteria, algae, and additional microscale particles (Zhanna et al., 2020, Raunak et al., 2024, Flexicon, 2010, Bhardwaj & Mirliss, 2005). Nevertheless, in numerous studies, tuff has been used as a filtration material due to its properties (Blažev et al., 2014, Savić et al., 2019, Abeer et al., 2017). Therefore, for the sake of the present study, some of the basic parameters of the diatomaceous earth from Slavishko Pole and the white opalized tuff (WOT) from Strmosh were comparatively defined in order to utilize them as filtration materials.

MATERIALS AND METHODS

The white opalized tuff (WOT) from the locality of Strmosh belongs to the group of andesitic tuffs (Figure 1). The size of the pieces that make up the tuffs are different and vary from a few millimeters to a few tens of centimeters. These are gray-white, yellowish, and pinkish rocks. From a mineralogical point of view, WOT is a raw material predominantly composed of amorphous SiO_2. In minimal amounts, it also contains crystalline modifications of SiO_2 such as tridymite and quartz, as well as finely dispersed ore minerals. The WOT is characterized by high porosity, it is thermally stable up to 1740˚C, so since it exceeds the temperature limit of 1580˚C, it can be classified in the group of the refractory raw materials.

The mineralogical-petrographic examinations of the diatomaceous earth (DE) sample (bulk rock) originating from Slavishko Pole, consists of microscopic and X-ray examinations (Bogoevski et al., 2014, Bogoevski et al., 2016, Boškovski et al., 2015). The DE from the locality of Slavishko Pole is characterized by a white color and a fine-grained structure (Figure 2). It crumbles easily between the fingers, resulting in grains of small size but rough to touch. This suggests that the sample represents a weakly bound rock. The sample easily absorbs water, which indicates significant porosity, and it acquires a grayish-white color. It takes considerable time for it to release the absorbed water and regain its primary white color. With the microscopic examination, it was determined that the cryptocrystalline base mass was maximally represented (over 95%) in the sample. In the basic cryptocrystalline mass (probably predominantly amorphous), several percent of ultra-fine grains with dimensions from approximately 0.005 – 0.10 mm to approximately 0.05-0.1 mm of quartz and feldspar were encountered, i.e. visible (Bogoevski et al., 2014, Bogoevski et al., 2016, Boškovski et al., 2015).

Figure 1. WOT (fraction 2-4 mm)

Figure 2. DE (fraction 2-4 mm)

The average chemical compositions of WOT and DE expressed in mass percent (Bogoevski et al., 2014, Bogoevski et al., 2016, Boškovski et al., 2015) are shown in Tables 1 and 2, respectively.

Table 1. Average chemical composition of WOT (mass %)

Si_O2	90.26
Al_2O_3	2.64
Fe_2O_3	0.38
CaO	2.31
MgO	0.78
Na_2O	0.36
K_2O	0.25
SO_3	0.43
L.w.	2.24
Σ	99.65

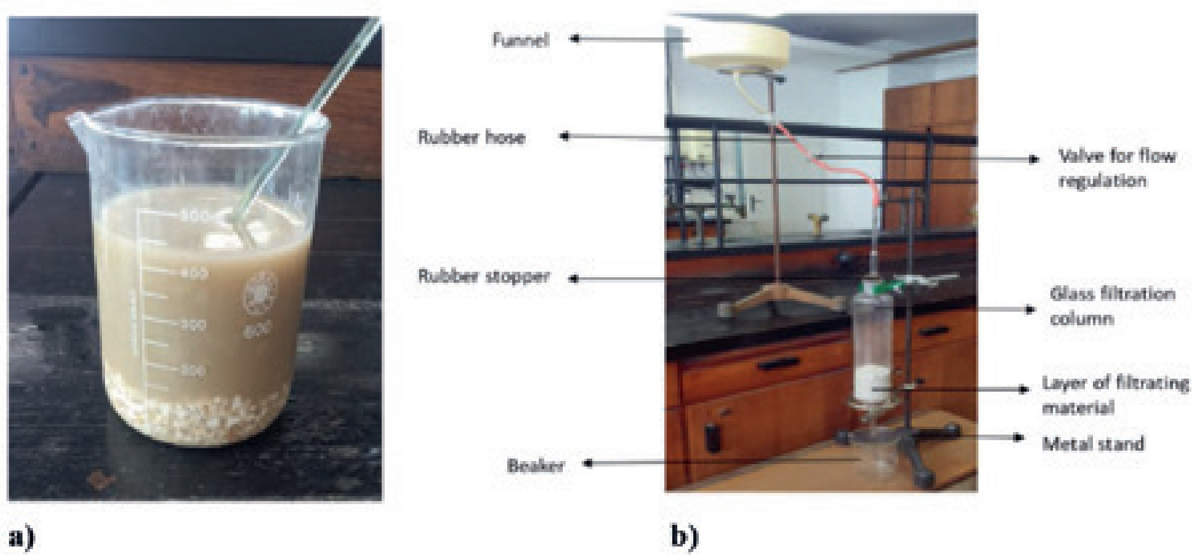
Table 2. Average chemical composition of DE (mass %)

SiO_2	72.07 %
Al_2O_3	12.09 %
Fe_2O_3	1.00 %
CaO	2.95 %
MgO	1.41 %
Na_2O	2.10 %
K_2O	1.90 %
SO_3	tr. %
L.w.	5.76 %
Σ	99.28 %

The preparation of white opalized tuff and diatomaceous earth as materials for the filtration procedure involves crushing and separating the appropriate grain size fractions. The materials were primarily crushed on a jaw crusher and afterward crushed twice on a roller crusher (distance between the rollers being 10 mm and 5 mm). Then, the dimensional fraction of grains (-4+2 mm) was separated via dry sieve process.

A pre-prepared suspension was filtered through the porous materials. The suspension used in the filtration process was consisted of bentonite clay with a grain size of below 32 µm. For this purpose, the appropriate dimensional fraction of bentonite clay grains was previously obtained through wet sieve analysis. The prepared suspension had a mass concentration of 13 g/l. Two types of filtrations were carried out, namely discontinuous and continuous. The discontinuous filtration/batch was realized in a beaker with an occasional stirring (Figure 3a). The continuous filtration was performed under dynamic conditions in a filtration column (Figure 3b). The laboratory apparatus was set up, and the used filtration material (diatomaceous earth and white opalized tuff) was positioned into the filtration column, occupying a volume of 300 cm^3.

Figure 3. Equipments for both methods of filtration



After the filtration materials was placed and moistened, the suspension of bentonite clay was poured through the funnel into the filtration column with a laminar mode and a continuous flow of 100 cm^3/min (Figure 4. Filtration layers of DE, and Figure 5. Filtration layers of WOT). The duration of the filtration was determined at 20 min (filtered 2 litres of suspension).

Figure 4. Filtration layers of DE

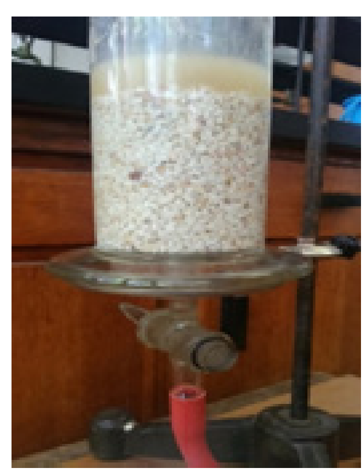


Figure 5. Filtration layers of WOT

The effect was determined through gravimetric control and microscopic comparison of the used materials before and after the process of filtration. The filtration efficiency of the materials was determined by defining the retained suspended clay particles.

RESULTS AND DISCUSION

The DE material compared to WOT, under dynamic column filtration conditions, displays higher efficiency. The weight percentage of retained clay particles in diatomaceous earth was 25.15%, and 9.46% in WOT, nearly 2.5 times higher in DE than in WOT (Table 3 and Figure 6). Likewise, the results of the stationary filtration in the beaker indicate the exact outcome. The weight percentage of retained clay particles in DE was 35.00%, and 12.88% in WOT, almost 3 times higher in DE as compared to WOT.

Table 3. Filtration parameters

	White opalized tuff	Diatomaceous earth
Mass of clay in suspension for continuous filtration	26 g	26 g
Mass of retained clay during continuous filtration	2.46 g	6.54 g
Weight percentage of retained clay during continuous filtration	9.46 %	25.15 %
Capacity of retained clay during continuous filtration	0.011 g/g	0.028 g/g
Mass of clay in suspension for discontinuous filtration	5.2 g	5.2 g
Mass of retained clay during discontinuous filtration	0.67 g	1.82 g
Weight percentage of retained clay during discontinuous filtration	12.88 %	35.00 %
Capacity of retained clay during discontinuous filtration	0.008 g/g	0.022 g/g

Both materials exhibit a greater degree of efficiency under static than dynamic filtration conditions. Under static filtration conditions, there is a lower diffusion energy because the material was previously dried, which makes it easier to extract the clay particles in the unclogged pores. For the “empty” macropores, less diffusion energy is needed to push out the air and allow a clay particle to penetrate. In contrast, in non-stationary filtration, the material is moistened before the filtration begins. Because of this, the retention of clay particles is more difficult due to the higher diffusion energy since the pores are filled with water, and thus the diffusion energy is higher.

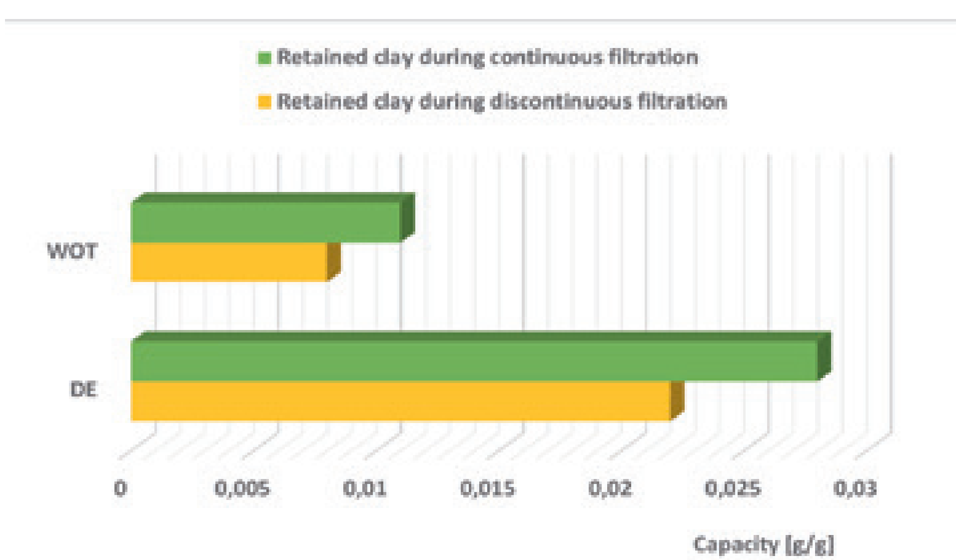
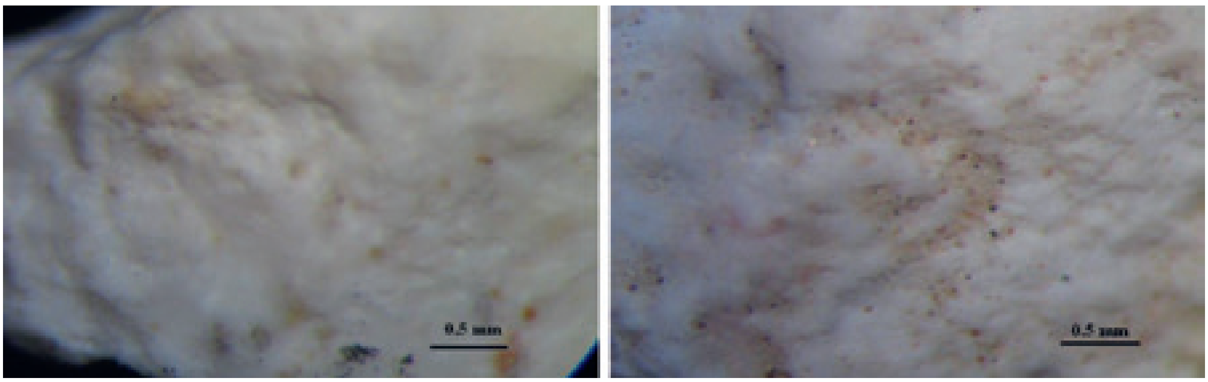


Figure 6. Filtration capacity of WOT and DE

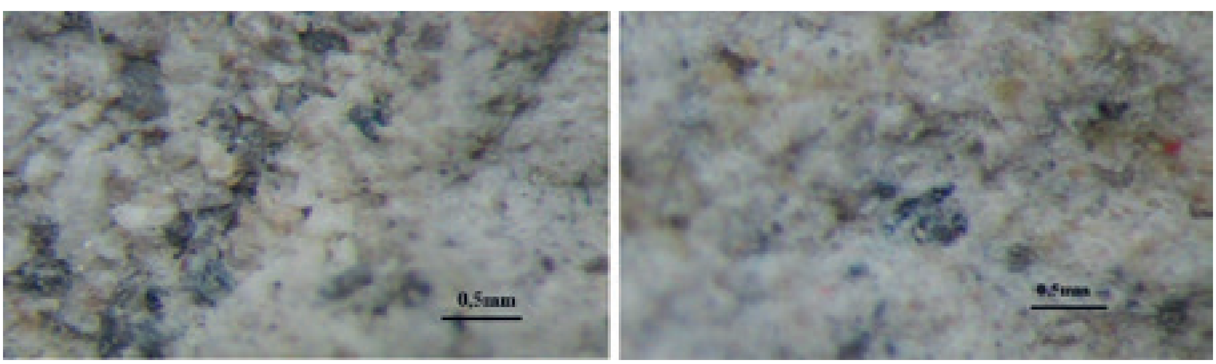
The filtration capacity (Figure 6) of DE was 0.028 g/g material under dynamic conditions and 0.022 g/g material under static conditions. The filtration capacity of WOT was 0.011 g/g material under dynamic conditions and 0.008 g/g material under static conditions. It can be observed that the filtration capacity of DE is much higher than WOT, as in the context of the aforementioned statements.

The figures of WOT and DE grains (Figures 7a and 8a) before filtration naturally show the surface macrostructure and the topography of the materials. With simultaneous examination of the micrographs, it can be observed that DE has a rougher structure and higher macroporosity than WOT.



a) b)

Figure 7. Surface of a WOT grain prior to filtration (a); surface of a WOT grain after filtration (b)



a) b)

Figure 8. Surface of a DE grain prior to filtration (a); surface of a DE grain after filtration (b)

When examining the figure of a cross-section of a WOT grain after filtration (Figure 7b) one can notice a larger range of distribution of particles of suspended matter, which coincides with the measured value or the filtered mass concerning non-stationary filtration. The same effect was due to the intenser diffusion in the system of pores in the grain that previously were filled only with air.

The particles of the suspended material that are gravimetrically proven to be retained in the porous system, during the filtration process, cannot be visually observed in the grains of DE after filtration, due to the colorfulness and diversity of the grains of the actual material (Figure 8b).

CONCLUSION

Regarding the obtained results, the used diatomaceous earth as a filtration material, shows better filtration capacity characteristics as opposed to the used white opalized tuff. The better efficiency of diatomaceous earth is due to the higher macroporosity, which is an important parameter for the filtration process. In the figures obtained by optical microscopy, it can be noticed that the DE particles have a rougher morphology than WOT, and the suspended material particles that are verified gravimetrically cannot be visually observed due to the colorfulness and diversity of the original DE material. The weight percentage of retained clay particles were nearly 2.5 times higher in DE than in WOT. After the static filtration, the percentage of retained clay particles was practically 3 times higher in DE compared to WOT. When simultaneously compared (under static and dynamic conditions), a higher degree of filtration efficiency under static conditions can be noticed by both materials. The filtration capacity is correspondingly much higher with DE than WOT, under both filtration regimes. However, both materials show a higher efficiency in static compared to dynamic filtration conditions due to the lower value of the diffusion energy in static compared to dynamic conditions. The low value of the diffusion energy is mainly because the pores of the dried material are filled with air, practically increasing the diffusion potential of the system.

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