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CULLET AS FILTER MEDIUM FOR SWIMMING POOL WATER TREATMENT

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Abstract. The control of water quality in swimming pool is accomplished by treatment, including filtration and application of disinfectants. Contamination of pool water cannot be always effectively controlled by normal treatment. Swimming pool sediments were investigated previously and insufficient filtration efficiency for sand filters was noticed. In presented experiments two filtration medium materials were compared: silica sand and recycled glass (cullet). Results show, that despite larger negative zeta potential of cullet particles, filtration efficiency was comparable and recycled glass can be a useful material for optional filtration medium.

keywords: swimming pools water treatment, filter medium, cullet as filter medium, laboratory filter

1. Introduction

The main aim of filtration is removal of turbidity to achieve appropriate water clarity. This is a key factor in ensuring the safety of swimmers. Poor underwater visibility is a contributing factor to injuries. Filtration is also the critical step for the removal of *Cryptosporidium* oocysts and other microorganisms (Angenent et al., 2005). There are a number of different types of filters available, whereas their choice is based on several factors including water source quality, amount of filter area available and number of filters, filtration rate, ease of operation, method of backwashing, and filtration rate (higher flows lower separation efficiency).

The cleaning of a filter bed clogged with solids is referred to as backwashing. It is accomplished by reversing flow, fluidizing the filter material and passing pool water back through the filters to wastewater stream.

Medium-rate sand filters can filter suspended particlulates down to about 7 μm in size with the addition of a suitable coagulant, such as polyaluminum chloride or aluminum hydroxychloride. Cleaning of sand bed is achieved by manual reverse flow backwashing, with air scouring to achieve removal of body oils and fats and improve the backwash efficiency. For indoor heated pools, the sand medium typically has a life from five to seven years. Medium-rate sand filters have typically large diameters, can operate under pressure and require large plant rooms. Regarding sand filters efficiency for microorganisms removal, drinking water treatment has shown that when operated with a coagulant, sand filters can remove over 99% of *Cryptosporidium* oocysts.

Swimming pool sediments were investigated previously and insufficient filtration efficiency for sand filters was noticed. This lead to a conclusion, that other filtration material can show better results (Korkosz et al., 2011). One of the possibilities for recycling waste glass is the preparation of cullet that can be a filter medium (Horan and Lowe, 2007). The use of recycled glass as a filter material can replace sand and gravel in filtration of various types of water. This can be an alternative to direct recycling application of cullet, which is also important due to increasing number of places where glass filters medium can be used.

The aim of the experiments was to evaluate cullet medium performance in comparison to sand at a larger scale, optimization of the media performance, and establishment of the material cost and so-called commercial viability. The results concluded that glass particles were as effective as sand, both at the filtration and backwashing stage.

Utilization of wastes as recycled materials is necessary for sustainable waste management. Additionally, there are many benefits that come out of glass recycling and using it as a filtration medium. Glass is a manufactured product and can be tailored to suit specific waters. What is more, it has lower specific density than sand and can be cheaper, lighter to transport and handle. It is known that glass is also smoother and more porous than sand, improving backwash efficiency, and making it easier to clean. It is also possible to add different properties to the glass media surface to achieve different results due to adsorption, and moreover, to encourage bio-film growth for nitrification and de-nitrification within the filter. What can also be concluded is that glass lasts longer than sand what is certainly a cost benefit, but can cause problems when the glass particles themselves have to be thrown away.

The cullet, which was used in present experiments, is a commonly used soda-lime-glass. The soda is used as a flux to decrease the melting temperature and the lime is added giving stability to the silica. The introduction of alkali metals lead to the formation of terminal –Si-O-M groups, where alkali earth metals lead to the formation of bridging –Si-O-M-O-Si- groups (Melcher et al., 2010). The introduction of these network modifiers plays an important role in the properties and durability of the glass. Corrosion of glass by liquids is well investigated in the literature. In general, ion-exchange processes leach out the mono- and bivalent network modifiers. H^+, H_3O^+ and water molecules fill the released spaces leading to a hydrated layer. The thickness of this layer depends on the glass composition, properties of the liquid, temperature and exposure time (Melcher et al., 2010). For example, a low pH and low ionic strength increase the corrosion rate.

2. Experimental

Filtration experimental setup is presented in Figure 1. Experimental conditions were set as close to those during treatment of pool water as it was possible in our laboratory.

Parameters of filtration column are presented in Table 1. Material of the filtration column was selected to be transparent in order to be able to observe filter while operating. The column is equipped with pressure sensors in its bottom part. The setup is also equipped with compressed air assembly, that was not, however, used during presented experiments. Height of the filtration bed was smaller for sand: 800 mm, compared to cullet: 1100 mm.

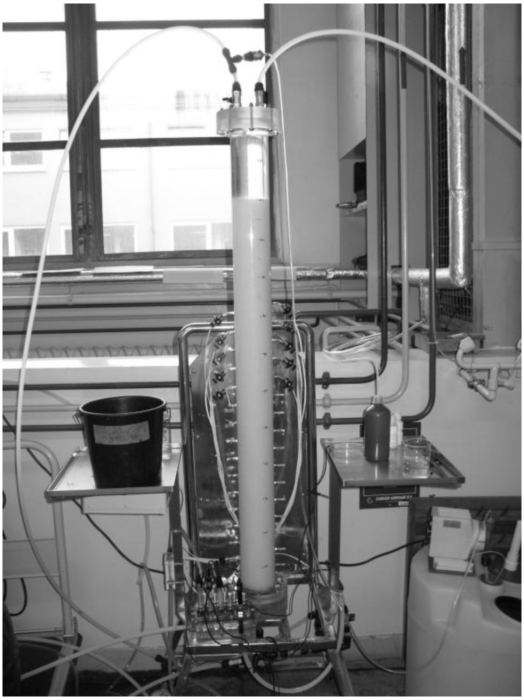

Fig. 1. Experimental filtration setup

Tabela 1. Parameters of experimental filtration column

Parametr	Data/Value
Material	polymethyl methacrylate (PMMA)
Height of filtration column	1350 mm
External diameter of filtration column	100 mm
External diameter of filtration column	80 mm
Filtration bed height – sand	800 mm
Filtration bed height – cullet	1100 mm

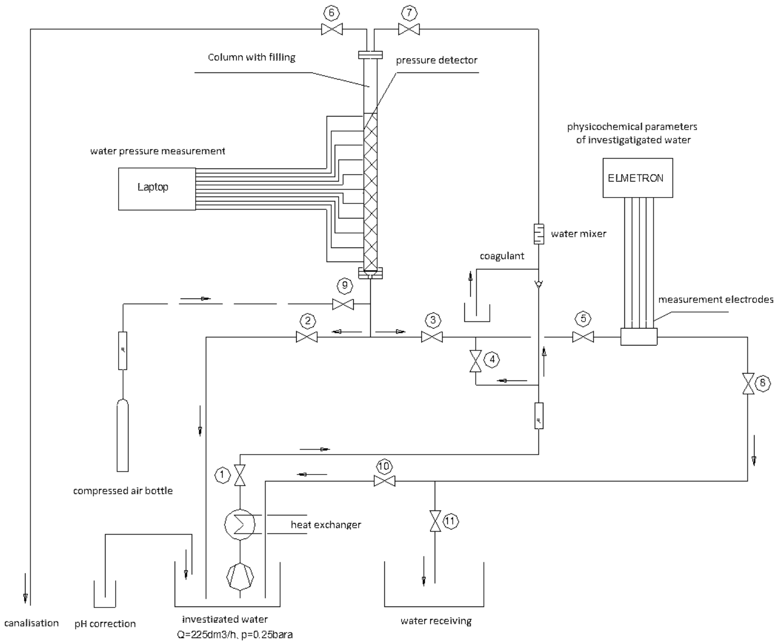

Fig. 2. Schematic of filtration experimental setup

Size distribution of sand particles and cullet is presented in Fig. 3 while characteristics of filtration media and filtration beds is shows in Table 2. Cullet had less uniform size and its filtration bed void fraction was greater: 53.9% compared to 42% in case of sand bed. Both materials had similar particle size range, 300 to 1,000 μm.

A model contaminated swimming pool water was prepared using collected from a pool "vacuum" cleaner sediment, which was mixed with tap water. After filtration experiments, samples of filtration beds were collected with a special pipe probe of length 16 cm and internal diameter 2.1 cm. Samples were subsequently split into four equal length sections and investigated for zeta potential of particles filtered and stopped by the filter. Amount of water contaminants in each section was also determined by mixing of filtering material from each section with water and total organic carbon (TOC) was measured.

Table 2. Characteristics of filtration media and filtration beds

	Sand	Cullet
Particle size range, μm	300-1000	300-1000
Effective size (d_{10}), μm	528	380
Coefficient of uniformity	1.23	1.64
Filter bed void fraction, %	42.0	53.9
Particle density, g/cm^3	2.65	2.50

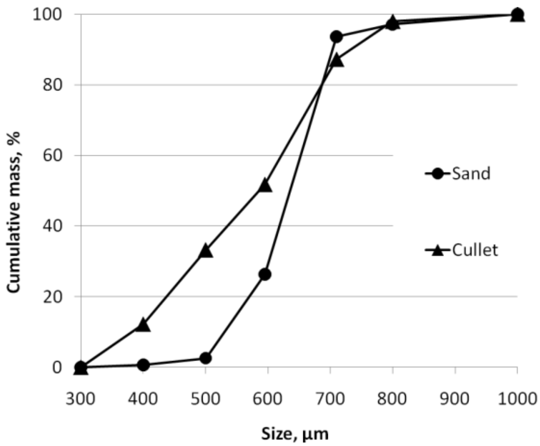

Fig. 3. Size distribution of sand and cullet particles used for filtration bed

3. Results and discussion

Filtration efficiency is presented in Table 3. Both filtration bed types were able to significantly decrease water turbidity to values below 1 NTU. Initial turbidities varied between 246 and 9.6 NTU. This result indicates, that regardless of bed differences, they similarly stopped suspended particles.

In order to explain filtration observations, zeta potential of the fine filtration particles of sand and cullet was measured and compared with zeta potential of particles collected from the filtration beds after experiments. Table 4 shows zeta potential values: sand, -13.4 mV, and cullet, -24.9 mV. Figure 5 presents zeta potential of sand particles for four sections of sampled filtration beds. Particles collected from the sand bed had zeta potential values varying between -11.3 and -18.9 mV, while particles collected from cullet bed between -13.5 and -14.9 mV. Thus, contaminant particles were not apparently affected by the filtering medium type.

Measurements of TOC and determination of contaminant amount in each of the four centimeter bed section did not show any definitive trend. It can be concluded, that for the present filtration setup, 16 cm length sampling was insufficient to find optimum filtration bed depth.

According to Stephan and Chasse (2001), zeta potential on both filtration medium and filtered particles needs to be compared to predict filtration efficiency. In the pH range 7.0 to 8.0, that was measured in treated water during the experiments, zeta potential did not exceed -24.9 mV and particles mostly exhibited values between -11 and -20 mV. This can indicate, that despite repulsion between similarly charged particles, the investigated filtration beds were able to significantly reduce water turbidity.

Table 3. Turbidity of swimming pool water before and after filtration

Filter medium	Before filtration	After filtration
Sand	21.9	0.47
	26.3	0.74
Cullet	9.6	0.56
	246	0.57

Table 4. Zeta potential of filtration medium

Filtration medium	Zeta potential, mV
Sand	-13.4
Cullet	-24.9

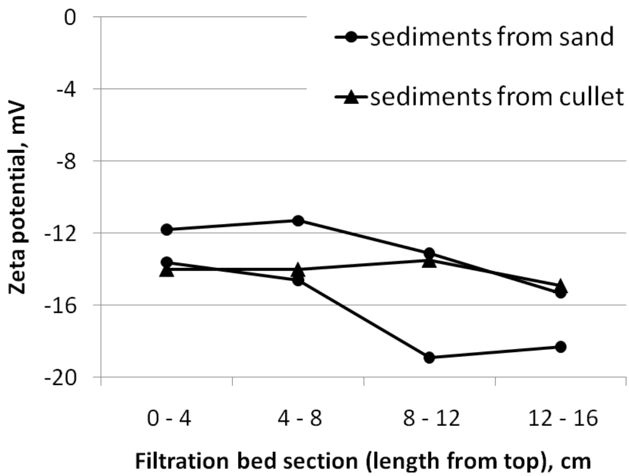

Fig. 5. Zeta potential of sediment particles obtained from filtration bed sampling

4. Final comments

Application of recycled glass (cullet) as filtration medium showed comparable results to filtration on sand regardless of larger negative zeta potential of cullet particles when compared to silica sand. It can be expected, that modification of glass can lead to enhancing filtration medium surface properties yielding better separation efficiency.

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