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Enhancement of multi-media filter performance using talc as a new filter aid material: Mechanistic study

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ABSTRACT

The potential of using a new filter aid, namely, talc to enhance the removal of particles in a multi-media filter was investigated. In the case of the nano-scale particles the running time was enhanced by 300 min at a talc concentration of 67.5 mg/l. In the case of the micro-scale particles the running time was enhanced from 20 min to 40, 100, and 300 min at a talc concentration of 22.5 mg/l, 45 mg/l, and 67.5 mg/l, respectively. Coagulation was due to hydrophobic and chemical interactions between talc and the different suspensions.

Introduction

The world is facing different environmental concerns, of which the most vital is linked to the world's acute scarcity of water [1]. Integrated water resources management has become a must practice, of which water reuse is a critical element [2]. Limitations of conventional biological processes (secondary treatment) in treating domestic and industrial wastewater to meet the discharge standards became more evident. Therefore, secondary effluents should be further treated so that they would meet the more stringent environmental requirements. When tertiary or advanced treatment is used, the tertiary treatment may involve a sequence of unit operations e.g. coagulation/flocculation, multi-media filtration, and membrane separation technologies [3–5]. In a multi-media filter as water passes through the filtration media suspended particulates will accumulate on the surface of the filter granules themselves. Typically, the filtration run will be terminated either if the quality of the effluent, in terms of turbidity, does not achieve the required requirements anymore or if a high pressure drop occurs across the filter bed. At this stage, filter backwashing will be required [6]. The length of run of a sand filter before backwash highly depends on the largely variable influent quality. Granular media are highly efficient in removing a large range of particle types, starting with low density microbial particles to high density particles such as ferric and/or titanium oxide solids [7]. Generally, granular media filters can remove particles in the range of 0.1–1000 μm [8]. An increase in particle size will increase the chances of a particle to be captured by the filter medium. However, the collisions of the large particles will produce greater shearing forces at the surface of the medium. The high shearing forces could release the previously captured particles [8].

In order to enhance the filtration process chemical treatment has been considered. Several studies have been conducted to study the effect of different coagulants on the removal of suspended particles during the filtration process. The type and dose of the coagulant applied was selected based on the characteristics of the water to be treated and the targeted quality of the effluent [9,10]. The performance of a dual media filter coupled with granular activated carbon was compared with the performance of the same treatment configuration with the addition of a dosage of an organic coagulant [1]. The coagulant used was a high molecular weight cationic organic coagulant known as polyacrylamide. In terms of turbidity removal, the results of the study showed that the addition of the coagulant had increased the removal of turbidity by 15%. In another study an aluminum sulfate cationic polymer was tested [8]. The results showed that the addition of the coagulant led to the formation of a floc layer on top of the filter media. The size of the layer depended on the type and dosage of the coagulant

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used. In addition, the results showed that upon addition of the coagulant the rate of filter clogging was significantly decreased while the turbidity of the effluent has marginally increased. Other studies found that the addition of chemicals prior to filtration led to an increase in the pressure head within the filter [11]. It was found that upon the use of polymeric aluminum ferric chloride (PAFC) and poly aluminum chloride (PAC) as coagulants the turbidity of the effluent was significantly reduced while a major increase in the head loss through the filter bed occurred [12].

The objective of this study is to investigate the potential of using a new filter aiding material, namely talc, to enhance the removal of dispersed solids in a multi-media filtration process. Talc was previously investigated in adsorption applications and was found to have good potential for adsorbing toxic compounds from aqueous solutions [13,14]. However, no previous studies looked into the potential of using talc as a filter aiding material to enhance the removal of suspended particles from aqueous solutions. The performance of the filtration process will be evaluated based on two main parameters: effluent turbidity and head loss developed in the filter unit.

Materials and methods

Filtration system

A pilot scale multi-media filtration system was used to conduct the experiments in this study. Fig. 1 represents the flow diagram of the filtration system. The filter unit used is made of a 10.2 cm diameter and 122 cm long clear PVC pipe (Harvel Co., USA). The filter media consisted of a 25 cm anthracite layer at the top beneath it a 27 cm coarse sand layer followed by a 33 cm fine sand layer. All layers were supported by a 7 cm gravel layer. The characteristics of each layer are summarized in Table 1. The system included an inlet tank and an outlet tank with a capacity of 150 l each. The tanks were equipped with an upper and lower horizontal mini-float level switches (LVH-200, Omega Engineering Co., USA). These flow level switches were connected to sensors and are fixed in the tank at levels of 10 cm from the top and 15 cm from the bottom. The low level sensor is provided to ensure that the water level in the tank does not go below the minimum allowable level required to avoid pump cavitation problems. The upper level sensor that was installed in the outlet tank was mainly used to avoid flooding. The sensors were connected to the control panel of the system (FLECK7700 SXT, Pentair Water Co., USA) so that in case the water level in any tank reaches the maximum/minimum allowable limit, the system will automatically shut down. The two tanks are connected to a three-way valve (V-1). When the system is on service mode (down flow), the three-way valve is switched to allow feed water to flow from the inlet tank through the filter and then to the outlet tank. A 0.75 HP pump was used in the setup (CEAM 70/5, Lowara Co., Italy). The pump delivers the feed water from the influent tank to the inlet of the filter unit and a part of the flow is recirculated back into the inlet tank through a 1.4 cm PVC hose. The recirculated flow was designed to ensure proper and continuous mixing of the suspension in the inlet tank. The flow rate of the recirculated water was controlled by a recirculating globe valve (V-2).

Table 1
Physical properties of used filter media.

Property/media	Anthracite	Coarse sand	Fine sand
Particle size range (mm)	0.8–1.6	0.71–1.18	0.4–0.8
Uniformity coefficient	1.44	1.53	1.33
Effective diameter (mm)	0.9	0.85	0.45
Porosity (%)	44	36	31

The inlet and outlet flow rates are measured by panel mount flow-meters (FL50002, Omega Engineering Co., USA) where the inlet flow rate can be adjusted through the flow control valve (V-3) and the backwash flow can be controlled by another flow control valve (V-4). When the system is in the backwash mode, the three-way valve is switched to allow clean water from the effluent tank to the filter unit. The switching from service mode to backwash mode is fully controlled by a filter controlling system connected to the top of the filter vessel. The controlling system is a residential type valve (FLECK7700 SXT, Pentair Water Co., USA). In addition, the filter inlet and outlet ports were equipped with pressure gauges (PEM Economy Pressure Gauges, Winters Co., Canada) and valves for sampling the influent and effluent water.

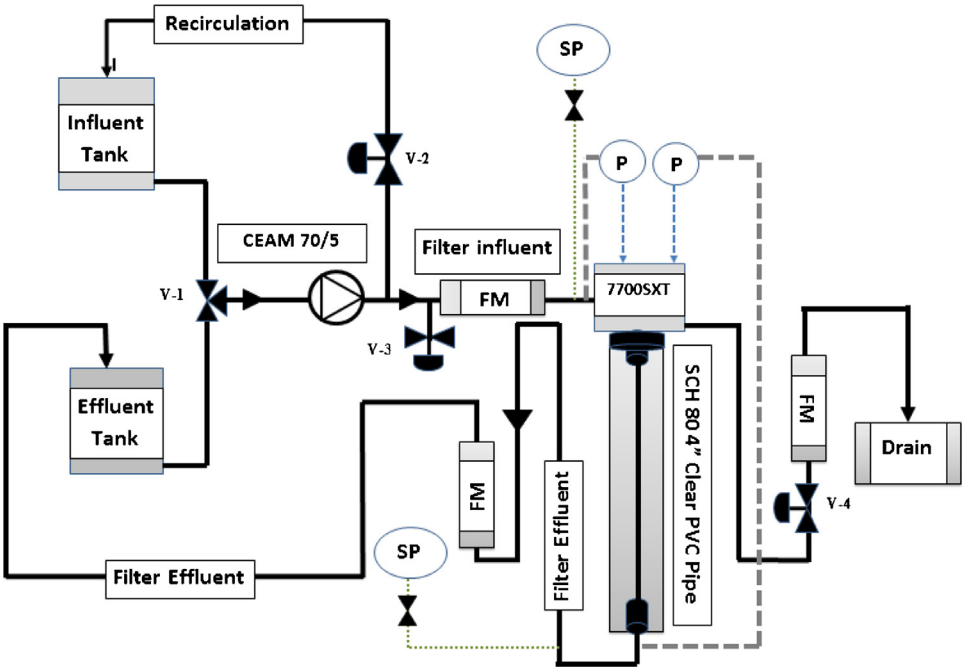

Fig. 1. Process flow diagram of the filtration system with piping and instrumentation details.