AguaClara POU (Foam Filtration) Challenges

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Abstract

Reticulated polyurethane foam with 90 ppi (pores per inch) has been shown to be an efficient filter for removal of turbidity from clay. The high filtration rate of up to 6 mm/s means that a very small filter would be adequate for a Point of Use, POU, application. The goal is to design a POU water treatment system that is easy to use, reliable, and cost effective. This treatment system will be an entire AguaClara facility in miniature. It will require alum or PACl to improve particle removal and will include flocculation, sedimentation, filtration, and disinfection. The AguaClara POU must be easy to use, easy to clean and provide safe drinking water even when given high turbidity water.

This AguaClara POU could also be a design for a community water kiosk.

Students	3 (this team size could be expanded given the broad scope of the project)
Skills	fluids, AguaClara water treatment processes, process controller, fabrication

1 Introduction

Porous media depth filtration for POU has been limited to two types of filters, intermittent slow sand filters (ISSF) and clay pot filters (CPF). The ISSF are large, heavy, and have poor hydraulic designs that require large filter boxes. The CPF are smaller, are inexpensive, and are prone to breakage. Both ISSF and CPF are limited in their ability to treat very turbid waters. The PUR system of water treatment is essentially a flocculation/sedimentation method. The AguaClara POU system is a combination of flocculation/sedimentation and porous media filtration. The goal is to create a method that requires fewer steps by the user than PUR (see the movieof the PUR process). The user should only have to pour the dirty water into the raw water bucket, add a tiny scoop of granular PACl, stir briefly, and add a few drops of chlorine (liquid bleach) to the treated water bucket. The filter system should deliver the clean water to the treated water bucket in a reasonable amount of time.

Previous foam filtration work has focused on showing that foam filtration (FF) is an effective filter media. Now that we have documented that the foam works well in a controlled laboratory setting it is time to begin testing and evaluating prototypes that contain all of the unit processes. The primary challenges for taking this technology to implementation are to create a simple, robust, hydraulic design that controls flow rates, prevents filter collapse, prevents air entrapment in the filter, and is easy to maintain.

One of the challenges with ISSF, CPF, and FF is to provide a cleaning method that minimizes the risk of contaminating the filtered water after cleaning. Stacked Rapid Sand Filtration (SRSF) provides a mechanism to automate the filter media cleaning process, but it also has the risk of contaminating filtered water immediately after cleaning.

It would be useful to consider the foam filtration as a component of a complete AguaClara POU plant in miniature. This miniature plant will operate in batch mode to simplify chemical addition and eliminate the need for chemical dosers. The miniature plant will likely incorporate tube flocculation and a tube settler prior to filtration. The tube settler will have a sludge trap with a sludge drain. There are likely opportunities for synergy between this project and the demo plant. It is even possible that a miniature SRSF would provide a better filter than the FF.

2   Design Strategy

Create a detailed Mathcad worksheet with design equations for each unit process. Create equations for all relevant dimensions.

2.1   Flow Rate and Hydraulic Design

Determine a target flow rate (perhaps 20 L in 30 minutes for the POU device) so that 1 hour later the finished water has all had at least 30 minutes of contact time with the chlorine. The target flow rate for the demonstration unit could be approximately 1 mL/s. Create a preliminary hydraulic design and estimate the flow rate variability due to the decreasing water level in the raw water bucket. Note that this flow variability can be reduced by increasing the head loss through the POU device. The tradeoff is that increased head loss will require increased elevation of the raw water bucket. Evaluate hydraulic designs that will minimize flow variation through the filter. Explore methods to eliminate spilling of treated water when the treated water container fills.

2.2   Tube Flocculator

Design a tube flocculator to be as short as possible given the maximum flow rate predicted above.The velocity gradient, G, will likely be in the range of 30 to 100/s. We can explore the relationship between G and maximum floc size to determine the optimal value for G.

$$\overline{G} = \frac{64Q}{3\pi D^3} \tag{1}$$

The equation for G (equation 1) can be used to determine the optimal diameter of the flocculator. The collision potential for a laminar flow flocculator is proportional to the product of the velocity gradient and the residence time, θ.

$$G\theta = \frac{16L}{3D} \tag{2}$$

The fractal flocculation model predicts that for 50 NTU water that $G\theta$ of 1400 would be adequate to produce 70 μm flocs and those flocs should be able to settle out with a capture velocity of 0.12 mm/s. Thus for demonstration purposes it may be adequate to use a relatively short residence time. Equation 2 can be solved for the length of the flocculator.

3   Sedimentation tank

The sedimentation tank should be designed to to take advantage of a tube settler to reduce the size (and residence time) of the tank. The sedimentation tank should concentrate the flocs and have a method to drain the sludge.

4   Preliminary Design

Create a preliminary design for an entire prototype POU unit including materials, a realistic sketch, and reflection on how a homeowner would use the device.

Build the prototype and as you build the prototype evaluate methods to improve the design. Test the prototype under simulated real conditions. Evaluate for ease of use, ease of fabrication, release of unwanted air during start up, and cost.

Evaluate the tradeoff of flocculator length. Longer flocculators will make it possible to remove more particles with the sedimentation tank rather than with the filter.

Make sure to calculate flow rate through the filter as a function of time based on the imperfect flow control system and ensure that the filter is sized appropriately to handle the maximum flow rate.

Develop a method to add alum or PACl to the raw water bucket.

Find a source of foam.

Run a series of experiments with the prototype. This will show how well the unit actually works and if we can get the same performance achieved with the foam column experiments. These experiments will also help refine the design of the filter making it more user-friendly. These experiments should include a study regarding the long term structure and re-usability of the foam

Further investigate the possibility of using an alum or PACl pretreatment of the foam. This would eliminate the need for an alum doser in the POU unit. This research was begun in the fall of 2010 by Sarah Stodter, though more research needs to be done in order to make any conclusions.

Investigate the effect of natural organic matter (humic acid) on filter performance.