Low Flow Stacked Rapid Sand Filtration

August 16, 2012

Abstract

Low Flow Stacked Rapid Sand Filters are an adaptation of rapid sand filters optimized for flows less than 3 L/s that don't require any flow control or backwash. SRSF is a "game changing" technology invented by the AguaClara team that is significantly simpler to operate than conventional rapid sand filters.

- Skills: fluids, AguaClara water treatment processes, fabrication
- Location: AguaClara lab 2 right end of bench, HLS 160 R, and Project Lab Hydraulic Test Facility

Background

Filtration is the final step in water treatment before the clean water is chlorinated and sent to the distribution system. Stacked Rapid Sand Filtration makes used of a sand bed to remove the remaining particles at the end of the treatment process in an efficient manner. Unlike conventional Rapid Sand Filters, the SRSF uses multiple layers of sand and injection points to enable the filter to be backwashed using the same driving head that runs it during filtration. This eliminates the need for pumps, elevated storage tanks, and reduces the number of filters necessary to treat a given flow rate.

The possible flow rates in a given filter are dictated by the necessary backwash velocity to fluidize the sand bed and expand it by 15%. The dimensions of the filter are then dictated by the area necessary to achieve that backwash velocity at a given flow rate. Current filter dimensions are constrained by the area necessary in the filter bay for a person to move around to install and service the internal parts in the filter. This limits area of the filter to something on the order of a box 0.75 m on a side. The filter requires a backwash velocity of approximately 11 mm/s, this means that the lowest flow rate is about 6 l/s for a filter that is built with human access. The LFSRSF is designed to be fabricated without needing human access to the inside of the filter.

The goal is to transfer the Low Flow SRSF technology to Agua Para el Pueblo either during the fall semester or during the January 2013 trip to Honduras. This will require an aggressive schedule of testing to validate the design and uncover any problems that need to be resolved before deployment.

Scope of the project

There is a strong demand for plants with flow rates less than 6 l/s. Because of the constraints on dimensions, it is not possible to build a viable filter for these small flow rate using current fabrication techniques. The Low Flow Stacked Rapid Sand Filter prototype is built from 12" PVC pipe and can handle a maximum flow of 0.8 l/s. Several of these filter could be connected in parallel to accommodate a range of low flow plants. It may also be possible for the filter to operate as a stand alone treatment option if high quality influent water is available.

While construction of the filter is mostly complete, the testing apparatus still needs to be designed and built and then the filter must be tested and refined in time for the January 2013 trip to Honduras. The filter needs extensive testing before we can install it in a plant, this will include hydraulic testing to ensure that it operates in the way we intend it to. There will also need to be performance testing to ensure that it is effective in treating water and causes better performance in a plant. Finally the filter will need to undergo failure testing to find out what its limits of operation are and what possible failure modes might be encountered in the field.

The prototype filter was constructed during the summer of 2012 and made use of a variety of new techniques and construction methods. Many of these methods were developed as needed and were only developed as far as the "works-well-enough" stage. While these techniques might be appropriate for the construction of a prototype, they deserve more refinement before they are put to use making production scale filters. Materials, construction techniques, and designs should all be scrutinized and evaluated, then improved on if possible.

The filter may also have commercial applications outside of sustainable water treatment. If time permits, the filters performance should be tested for a variety of commercial applications including agriculture, aquaculture, remote water treatment, and industrial applications.

Challenges

1 Hydraulic Testing

The filter still requires some work before it is ready for testing. The first area is the flow control coming from the hydraulic test facility. The flow rates are not currently high enough because there is too much headloss in the delivery pipe. The flexible tubing should be replaced with 2" PVC and hydraulic analysis should be done to see if it is worth switching from a 1" ball valve to a 2" ball valve as the control device. Once a control system has been set up that can reliably provide 0.8 l/s, the filter should be filled with sand, then hydraulic testing can begin in earnest. The following areas should be investigated:

- Headlosses should be measured during filtration and backwash. These headlosses are what determine the placement of inlet boxes, outlet boxes, and backwash outlets in the plant. These headlosses should be compared to our theoretical understanding of the filter to see if it is functioning as we expect. If it is not, the inconsistencies in headlosses should be investigated and it should be determined whether or not the filter is functioning properly or not and whether our theoretical understanding is correct.

- The relative heights of the backwash outlet and outlet free surface should be adjusted relative to the inlet pipe and the impact on the hydraulic stability of the filter assessed. This will help to determine how a filter might connect to the rest of the plant.

- Check and see how much, if any sand is lost during the backwash cycle. If there appear to be large sand losses, determine if there is a better way to operate the filter to avoid these losses, and if necessary, design and fabricate a sand trap to keep the filter from losing sand.

- Investigate the control system for the filter (valves controlling backwash and indicators for bed fluidization and various water pressures) and assess their efficacy and easy of use. Propose changes if deemed necessary.

- If time permits after filter performance has been tested analyze flow patterns through the sand bed using the pressure sensor ports along the filter body. Attempt to determine if there is an even distribution of flow between layers.

2 Performance Testing

Before we install the filter in a plant, we would like to know whether or not it is effective at improving water quality. To do this, a recirculating filter system will need to be constructed that can also backwash effectively. 1 shows a schematic for a testing apparatus using the existing hydraulic testing facility.

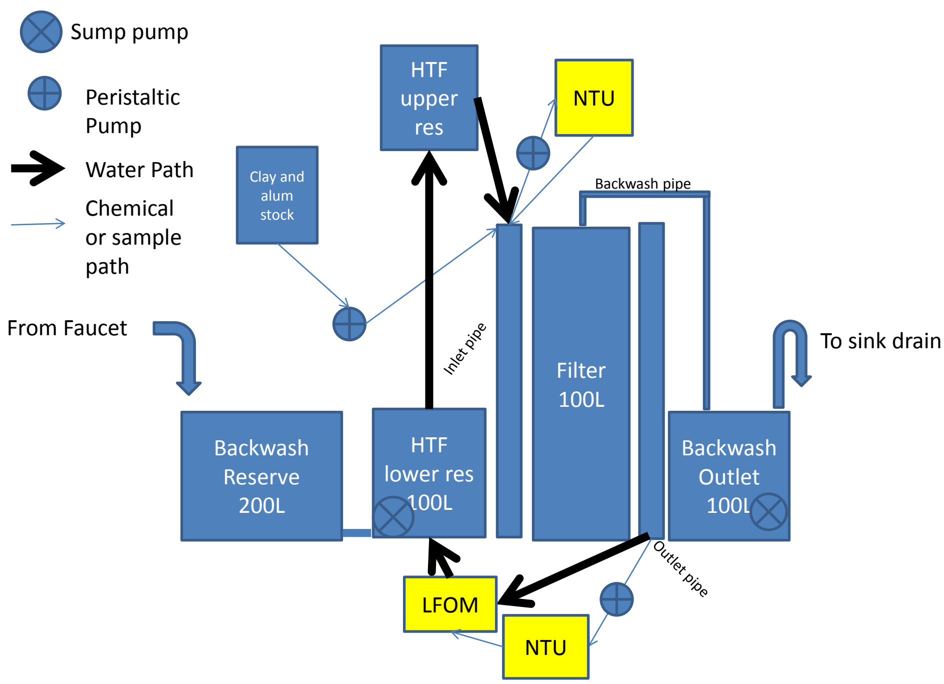

Figure 1: Recirculating filtration test facility

In order to backwash for six minutes, the filter will require approximately 300 l of water. This water will be stored in reserve tanks which are connected to the bottom of the hydraulic test facility. During backwash, these reserve tanks will be emptied. The water will flow through the filter and out through the backwash pipe which will terminate in another 50-100 l tank. This tank will also contain a sump pump which will pump the backwashed water up over the bench and into the sink. PACl, clay, and sodium carbonate will be metered in at the inlet pipe using a peristaltic pump. The water will also be sampled at this point using a peristaltic pump and turbidimeter which will send data to process controller which will control the dosing to the system. There will also be a turbidimeter sampling from the outlet pipe to determine filter performance. Challenges and tasks for this stage of the project include:

- Determine the correct relationship between sodium carbonate and PACl so that the sodium carbonate precisely matches the acidity of the PACl. The goal is to maintain a constant pH as the water cycles through the filter and is repeatedly dosed with PACl.

- Construct the testing apparatus based on 1. When building this system be sure to test that the sump pump removing water from the backwash tank can pump at least 0.8 l/s and that the sink can drain at the same rate. If the sink can not drain quickly enough, devise some method of water retention so that we do not flood the entire basement.

- Test the filter with an influent turbidity of 10 NTU and determine the length of time between backwash cycles, terminal head loss, and filter performance.

- Determine whether or not the technology is ready to install in plants and if not, propose and test changes to the design that might improve performance.

3 Improve on Construction Techniques

- Devise a way to drill the holes for the manifolds in the filter body without the use of a mill and potentially without the use of a drill press. Test the method on 6" pipe.

- Improve on the way the manifolds are constructed. The current method (see construction documentation) is slow and labor intensive. It is also very difficult to drill the holes in the 1" pipe for the 1/2" slotted pipe. Try and come up with a better way to make that connection that does not reduce the total number of slots in each section of slotted pipe.

- The plastic end caps on the filter are likely to fail due to fatigue. Evaluate the possibility of using aluminum to make the caps, special care will have to be given to how the bed tester connects in this setup.

- Evaluate the cost and feasibility of constructing the filter tank out of aluminum or stainless steel. Does it make sense to move in that direction?

4 Prepare to take the filter to Honduras

Coordinate plans with Agua Para el Pueblo to deploy the filter in Honduras either during the fall semester or during the January engineering in context trip to Honduras. Determine which components should be shipped to Honduras and which components can be fabricated in Honduras. Develop a plan to test the filter in a Honduran community and work to implement this plan as quickly as possible. The very slowest deployment schedule would be to test the filter during the January trip. Explore options for deployment earlier in the fall.

5 The Mini Plant inconsistencies

The filter opens the door to another way of treating water. Mini plants would consist of a dosing system and a filter. Ideally these mini plants could easily be packaged in a crate and delivered to a site. All a community would need to do with one of these systems is connect the inlet to a spring with a low turbidity, connect the outlet to the distribution system, and provide some sort of drain for the backwash and they could have clean water. Coordinate with the doser team to develop the control system for the mini plant and test it on the hydraulic test facility. Also propose design changes to the filter so that it will be easy to operate the mini plant, this might include moving valves and adjusting the position of plumbing.

6 Other Applications

The filter is a novel piece of technology that may be applicable to industries outside of sustainable water treatment. One area might be the aquaponics industry. Brainstorm and research other industries that might need low flow filters. Determine what their specific filtration needs might be and evaluate the filter in terms of those needs. Will the filter fulfill those needs? If not, what design changes might allow the filter to be useful for those applications? What might be a selling point for the low flow filters if we were to market in those industries?