Stacked Rapid Sand Filtration

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Abstract

Stacked Rapid Sand Filters are an adaptation of rapid sand filters optimized for flows between 6 and 100 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.

Students	9 (divide between pilot research, bench research, and invent)
Skills	fluids, AguaClara water treatment processes, process controller, fabrication
Location	AguaClara lab 2 right end of bench, HLS 160 R, and Project Lab Hydraulic Test Facility

1 Research Tasks Pilot Scale (AguaClara lab 2)

These experiments will be conducted using a 10 cm diameter filter column.

- Test a sand removal system that uses a horizontal pipe through the bottom of the filter and then a vertical section of pipe to elevate the sand discharge location. Test this system for operation during filtration mode when the hydrostatic pressure at the bottom of the filter is highest. If that doesn't work, then test it during backwash.
- Optimize the backwash duration to minimize water waste, which will determine the water efficiency of the SRSF and will help determine if there is an advantage in water savings to having particles removed by the floc/sed system even when the SRSF would meet the effluent turbidity requirements without floc/sed treatment
- Measure flow distribution between layers
- Perfect hydraulic controls for cycling between filtration and backwash mode and transmit any new design criteria to the design team
- Build and test a 4 layer (30 cm per layer) SRSF and compare performance with the 6 layer SRSF

- Test the stratification of sand after backwash for various sand uniformity coefficients. Perhaps the sand can be completely mixed by providing a route for sand from the top of the fluidized bed to return to the bottom of the fluidized bed. A pipe with a slope would provide a means to return fine sand to the bottom of the filter.

- Based on observations at Tamara, devise improved methods to keep air out of the filter. Evaluate methods to remove air after the weir that divides flow into the filter boxes.

2 Research Tasks Bench Scale (HLS 160 R)

These experiments will be conducted with a 2.5 cm diameter filter column with full process control for chemical feeds, backwash, and turbidity measurements. It may be possible to install a two layer stacked filter in the small diameter filter column.

- Evaluate the possibility of using smaller sand grain size and determine if there would be advantages to making this change. Smaller sand size potentially changes backwash velocity, filtration velocity, filter manifold slot size, required layer depth, and filter solids capacity.

- Determine the solids loading capacity of the filter and ideally develop a mechanistic explanation for the solids capacity that would help us understand the influence of bed depth and approach velocity.

- Explore addition of a very low PACl dose (perhaps $100\frac{\mu g}{L}$ as aluminum) to improve filtration performance. Note that this can only be reasonably tested if a full flocculation/sedimentation step is provided upstream of the filter. Then the effect of PACl addition prior to the filter could be measured. The currently used test system of metering clay and PACl into the filter influent is incompatible with these test objectives.

3 Invent Tasks

3.1 Improved fabrication technique for full scale SRSF

The fabrication techniques used to build the filter at Tamara required detailed work in brick and concrete and resulted in a design that was not very easy to assemble. The goal is to simplify the fabrication method for the pipe manifolds. The pipe manifolds are to be assembled for each layer outside of the filter box and then inserted as a unit into the filter box. Proposed improvements include

- Use a 2" PVC pipe to connect the ends of the slotted pipes. This 2" pipe would be similar to the trunk lines and the slotted pipes would be inserted into the 2" pipe using compression slots.

- Improve the compression slotting method. Using a 0.2 mm slotting saw with the pipe held perpendicular to the axis of rotation of the slotting saw. Rotate the pipe to cut multiple compression slots. Reduce the number of compression slots required by using a drill for the hole that is closer to the pipe OD. Consider using a fostner bit to drill the hole in the trunk line.

- Develop a method to stack the manifold systems on top of each other that does not require any assembly inside the filter box. Each manifold layer must incorporate a spacer that sets the correct distance to the next manifold. The spacers must be located at 3 corners of the manifold excluding the corner where the trunk line will plug into the coupling embedded in the filter box wall

- Develop a tension member that will hold the manifold system together and keep the compression slots fully embedded in the trunk lines. This could be a cable wrapped around the trunk line and the 2" PVC pipe.

- Develop a method to hold the top manifold in place in the filter box and prevent vertical lift during backwash. This system must lock the manifold in place on the 3 corners excluding the corner where the trunk liine plugs into the embedded coupling.

3.2 Scaling to low flow rates (Project Lab using Hydraulic Test Facility)

A high priority goal for the spring semester is to design several ultra low flow AguaClara facilities. The target flow range is between 3 L/s and 0.3 L/s. Typical per capita demand is approximately 3 mL/s and thus a village with 100 people would need 0.3 L/s. Thus the flow range of 0.3 L/s to 3 L/s corresponds to populations between 100 and 1000 people.

Develop new construction methods that would make it possible to fabricate a SRSF at dimensions that are not large enough for a human to enter the filter box. The filter box could be constructed of large diameter PVC pipe and the manifolds could be assembled inside this pipe by reaching in from above and from below. See the capstone design results from CEE 4540 Fall 2011 for additional fabrication ideas. Evaluate pressurized vs open filter boxes including the possibility that the filter and controls can be at a similar elevation if the filter box is under a negative pressure during backwash.

Developing 1 to 3 L/s designs is critical because the number of small communities is so large. This is a very high priority and we need to have a full design ready by the end of the spring semester (or sooner!). This low flow filter system must be designed and built early in the semester and then undergoing hydraulic testing in the project lab. The hydraulic test facility should provide 3 L/s and should be used to power the low flow SRSF.

3.3 Automated Control

The filter could easily be designed to begin backwash at a set filter head loss by adjusting the length of the siphon tube in the siphon box. If we could add a method to end the backwash and revert to filtration then we could have a fully automated filter. This would be particularly useful for very small communities that can't afford to have an operator on site all of the time. The challenge is to have a delay for 10 minutes while backwash proceeds, open a valve to break the siphon for a few seconds and then close the valve again. Finding a solution for this will require some very creative hydraulics. The siphon air valve could be operated by a float that is in a tank that is emptied and filled. We need a whole series of ideas here.

3.4 Cost cutting review

The SRSF is a relatively expensive unit process because of the piping and the large amount of labor required to fabricate the highly detailed filter box and control system. We are looking for simpler construction techniques for holding the manifold piping systems in place. Ideally the filter box would simply be a rectangular box without any ledges or special cutouts. For example the cutout for the trunk lines is completely unnecessary. There are undoubtedly many other simplifications that can be made to reduce construction costs.