Stacked Rapid Sand Filtration Summer 2010 Reflection Report 1

Stacked Filtration Reflection Report

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Abstract

The objective of the Stacked Filtration team is to design and build a vertically stacked filtration system that meets the AguaClara project constrains.

Up until now the Stacked Filtration Team has conducted research on stacked filtration and rapid sand systems, completed a literature review of past research and technology, and developed a robust laboratory filtration system, which meets most of the given constraints. We then proceeded to test some of the fundamental principles governing the system. For example, we have verified the validity of predicted head lost values within the stacked filter-beds by measuring the influent and effluent flow rates. Our main challenges for the future are to test the effect of using 10 NTU influent water to backwash the system, and to determine the filtering capacity of the stacked filtration system.

Introduction

The purpose of adding a filtration system in AguaClara plants is to reduce the turbidity of the water down from 5 NTU to below 1 NTU so that chlorine could be safely used to treat the water coming out of the filtration plant. One of the filtration techniques that the previous semester's filtration team researched was stacked filtration. The previous semesters work focused on preparing an appropriate stacked filtration experiment design and researching many of the aspects behind stacked sand filtration. They have also designed a filtration system addition to the water treatment facilities that AguaClara designs. The previous semester's team came up with the idea that if each filter was stacked on top of the other then all of the filters could be backwashed with the same water. In the design there will be four filters stacked on top of each other, thus four layers of sand. Three slotted influent pipes and two slotted effluent pipes will be placed in 4" inner diameter PVC pipe. This semester we will mostly focus on building the experiment apparatus and testing the effectiveness of stacked sand filtration. We have already encountered some of the challenges the previous team had mentioned in the construction of the apparatus, such as leaks within the system. Troubleshooting the leaks and figuring out how to fix them have been challenges for the past two weeks, as well as achieving uniform flow through the influent pipes. We were able to fluidize the sand while the system is in backwash, which is one of our challenges for the semester. In the coming weeks, we will attempt to test the filtering capacity of the stacked filtration arrangement using 20 cm of sand, and four filter layers, with 5-10 NTU influent and 1.5 mg/L alum dose. It will be a challenge to pump the clay and alum into the line since the required flow rate for the filter is so high that the resulting pressure in the line is difficult for the pumps to overcome.

Literature Review

Rapid sand filtration of Cryptosporidium parvum: effects of media depth and coagulation

The contamination of many surface waters with *Cryptosporidium parvum* cysts provides an important impetus for the inclusion of granular filtration in the water treatment process. *Cryptosporidium* cysts present a danger to public health and are not readily inactivated by conventional chlorine disinfection; however, pilot-scale rapid sand filters have shown good results for removal of these cysts. Peak removal efficiency varied from 1.6 logs for a 10 cm sand bed depth to 4 logs for an 80 cm bed, and appropriate filter ripening time and coagulant dose were found to be important in achieving effective *Cryptosporidium* removal (Gitis, 2008).

Study on backwash wastewater from rapid sand-filter by monolith ceramic membrane

The article shows how the use of membrane technology instead of sand filters could be more beneficial in treating water processes. The article shows how in backwashing with rapid sand filtration protozoan parasites might accumulate in the water. The bacteria that was once removed before is now in the backwash water which is typically redirected again towards the rapid sand filtration. This may cause for dangerously high accumulation of bacteria is the raw water. AguaClara can look into alternatives instead of rapid sand such as membranes to prevent this from occurring.

Slow Sand Filtration: Theory of Biological Filtration

Biological or slow sand filtration consists of running raw water through a bed of sand. Upon contact with the surface of sand grains particulate impurities are retained. There are several different types of particulate impurities, which are removed by different mechanism of the filtration process. Those that consist of inert material are held in the sand until they are removed during the cleaning process. And the other type of impurities are those capable of chemical or biological degradation, which are converted into simpler forms that are then carried away in solution or remain, with the inert material which are later removed.

The mechanisms involved with each step are several. L. Huisman, classifies them into three different mechanisms: Transport, Attachment and Purification.

Transport Mechanism: processes by which particles come into contact with the sand grains, which consist of (a) screening or retention of large particles, (b) sedimentation, (c) centrifugal forces, (d) diffusion, (e) mass attraction or Van der Waals forces, and (f) Coulomb forces or electrostatic and electrokinetic attraction.

Attachment Mechanism: processes by which particles are held in place once they have contact with the sand grains referred to as adsorption.

Purification Mechanism: processes by which the trapped impurities within the sand bed are converted to simpler forms by means of chemical and microbiological oxidation.

Purification of Secondary Effluent in a Natural Sand Filter

The Lake George Village Sewage Treatment Plant has been providing treatment of wastes at a much lower cost than that of conventional methods by using rapid sand filtration. The filter effluent, provided with secondary sedimentation, is discharged onto natural deltas and a sand system made up of 21 rapid sand infiltration beds is used to purify the water. Through experiments they concluded that oxidizable substances such as ammonia and organic nitrogen were being subsidized into nitrate in the top 3 m of sand. This nitrate was nearly entirely removed once the water passed through 18 m of sand; however, water had nitrate levels lower than what's recommended for safe drinking water after just 8 m. The optimal depth of our rapid sand filters is something we will have to determine as well.

Detailed Task List

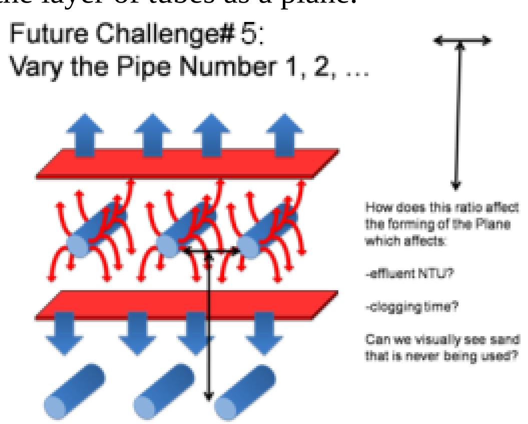
1. Complete Construction of the Experimental Apparatus

2. Attempt to Backwash the filter:
We need to first determine whether backwashing the filter will actually be possible.

3. Determine the filtering capacity of the stacked filter design:
After we are able to backwash the filter, we will need to then determine if the design is in fact able to achieve an effluent turbidity of less than 1, when using a raw water turbidity of 5-10 NTU. Please see Experimental Design section for more detail.

4. Determine if effluent from the sedimentation tank can be used to backwash instead of clean water:
Using effluent from the sedimentation tank will negate the need for a clear well. We need to determine if the sedimentation tank effluent (5-10 NTU) will effectively clean the filter, and if the filter will then still perform well.

5. Determine if we can model a row of tubes as a plane:
Our modeling of the area of filtration as a plane instead of a row of tubes needs to be tested as well. We can also the number of inlet and outlet tubes per plane to see if our modeling of the layer of tubes as planes of filtration is accurate. We can slowly decrease the space between the tubes to see what the necessary ratio between the sand layer and the space between the tubes needs to be to allow us to model the layer of tubes as a plane.



6. Model performance of the stacked filtration system:
If we can effectively filter water using the stacked filtration system, it will be important to understand under which parameters the system will work. We can vary parameters such as downflow velocity, influent turbidity, and the presence of organic matter. It will also be useful to compare the filter performance to results Po-Hsun has obtained through his filtration experiments.

Experimental Design

This study consid ers a bench-scale stacke d rapid sand filter apparat us constru cted as in the diagra m in Figure 1. Thi s filter is built in a 10.16 cm (4”)

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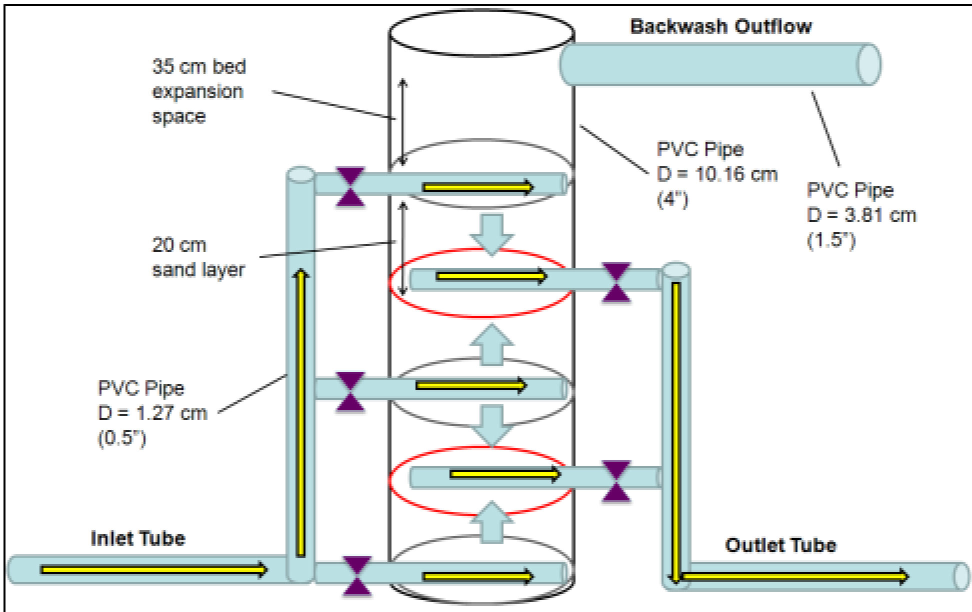

Figure 1 . Diagram of the bench-scale stacked rapid sand filtration system to be used for this investigation. Arrows show expected flow directions during normal filtration.

The filter media is sand arranged in four stacked beds, each of which is 20 cm deep. During normal operation, the total depth of sand in the filter is

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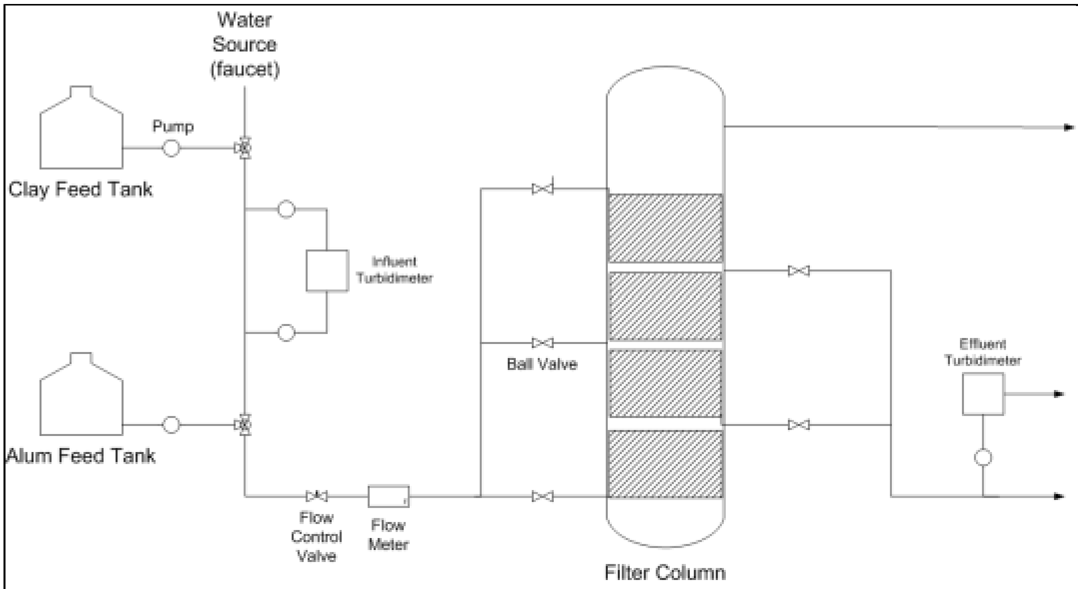

Figure 2. Process-flow diagram showing major system components for the proposed experimental trials.

The influent water for filtration and backwashing will be prepared by adding kaolinite clay and alum ($Al_2(SO_4)_3$ $18H_2O$, Fisher Scientific), which will be fed into the source water from stock tanks using peristaltic pumps. The clay will be added from a stock suspension to achieve an initial influent turbidity of 5-10 NTU,

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Future Work

Within the next two weeks we want to continue to test whether backwashing the filter is possible and if 4800 mL/min is feasible from the tap. If hot water is required to reach this flow rate, we also want to determine the effect that this will have on our experiments. Once we are successful at backwashing the filter, we will want to determine if achieving an effluent turbidity of less than 1 is viable and whether effluent from the sedimentation tank can be used to backwash the filter. If within the next two weeks we are able to accomplish these goals, we will also like to start testing the filter capacity with organic matter.

Team Roles and Expectations

Expectations for teammates this semester:

- Treat each other with respect
- No such thing as a stupid question
- Have fun
- Remember lab safety
- Come to meetings when you can

We will have team meetings Wednesdays at Noon. In addition, we will conduct experimental work at 11 on Mondays, and noon on Tuesdays and Thursdays in the Environmental Teaching Lab, (HO 150).

At this point in the semester, our team is still in the construction and set up phase. As a result, we are all performing roles jointly. Later in the semester, we will be able to designate specific roles once they have developed.

Bibliography

Aulenbach, Donald B., Robert R. Harris, Robert C. Reach. "Purification of Secondary

Effluent in a Natural Sand Filter." *Water Pollution Control Federation* 50. 1 (1978): p 86-94 . Web. 24 Jun. 2005.

Gitis, V. (2008). “Rapid sand filtration of Cryptosporidium parvum: effects of media depth and coagulation.” *Wa. Sci. Technol.*, 8, p 129-134.

Huisman, L. and Wood, W.E. “Slow Sand Filtration: Theory of Biological Filtration.” World Health Organization Publications, Geneva, 1974. p 27-43.

Weiying, Li; Yuasa, Akira; Bingzhi, Dong; Huiping, Deng; Naiyun, Gao. “Study on backwash wastewater from rapid sand-filter by monolith ceramic membrane.” *Desalination* , v 250, n 2, p 712-715, 15 Jan. 2010.