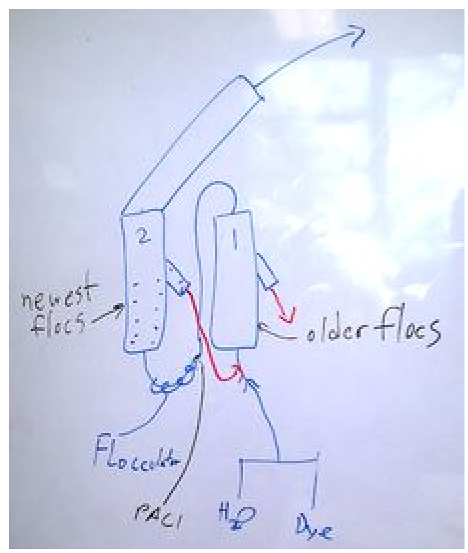
Countercurrent stacked floc blanket reactor

Big questions to answer

- Is the axisymmetric geometry of the jet reversor inferior to the plane jet used in AguaClara sed tanks because flocs bridge as they slide toward the jet reversor?
- What upflow velocity works well for a floc blanket that is made with PACl and no other suspended solids?
- Can flocs be transported in countercurrent flow between floc blanket reactors in series using the venturi effect at the base of the floc blanket connected to the floc hopper from the next floc blankets?
- Do PACl precipitate floc blankets effectively remove fluoride or arsenic? If so, what floc blanket depth is required in the first reactor?

Introduction

The goal of the stacked floc blanket reactor invention is to develop a novel reactor that efficiently removes fluoride and arsenic while reducing the volume of wastewater produced by producing a concentrated solid waste stream.



Filters loaded with PACl precipitate are efficient at removing arsenic (and presumably fluoride) in part because they are plug flow reactors and thus upstream PACl precipitate is in equilibrium with influent contaminant concentration and downstream PACl precipitate is in equilibrium with effluent contaminant concentration. This allows efficient use of the PACl because most of the PACl ends up being in equilibrium with influent contaminant levels and thus the maximum mass of contaminant is absorbed per mass of PACl precipitate.

Floc blankets have the potential to hold a large mass of PACl precipitate without generating high head loss and floc blankets can concentrate flocs in a floc hopper and thus eliminate the need for the wasteful process of backwashing. The disadvantage of floc blankets is that the fluidized bed is completely mixed over the residence time of the flocs. Thus flocs at the top of the floc blanket would include flocs that are in equilibrium with influent contaminant levels and thus the removal efficiency will be poor. To improve performance we propose to have countercurrent flow through 3 floc blankets with PACl injection and flocculation occurring at the influent to the 3rd floc blanket and the wasted flocs from the 3rd floc blanket being injected through a venturi (or other means) into the 2nd floc blanket. Similarly the wasted flocs from the 2nd floc blanket will be injected through a venturi into the first floc blanket. The wasted flocs from the first floc blanket will be in equilibrium with the influent contaminant and will be the waste stream from the treatment process.

Tasks

- Coordinate research with the fluoride team on optimal floc resuspension geometry of floc blanket reactors with sticky flocs made with PACl and red dye #40. Use approximately 1 mg of PACl (as aluminum) per mg of red dye #40. Try a very smooth bottom made using a countersink and build a reactor like the one taken to the EPA competition in the spring of 2016. Figure out what is required to get the bottom geometry so that it consistently produces a fluidized bed. This is the big mystery because the EPA apparatus works and the countercurrent floc team's apparatus doesn't work. The EPA apparatus also failed the first day at the competition. So it is possible that the geometry is not quite smooth enough and that the new smooth geometry will work. It is also possible that the axisymmetric, round jet, isn't reliable and we need to switch to a plane jet.
- After demonstrating a reliable floc resuspension geometry build a 2 floc blanket reactor with countercurrent flow to determine if performance can be improved with countercurrent flow. The reactors should be completely transparent and red dye can be used to test performance. The floc hoppers must be steep so the stick flocs slide down.
- If a 2nd floc blanket improves performance, then vary the floc blanket height to determine the required depth for transport of the red dye to the flocs.
- Develop a model for the removal efficiency of the red dye based on an adsorption isotherm of the dye to the PACl precipitates. Use that model to explain why the second floc blanket improves performance and then make a prediction about the potential gain from a 3rd floc blanket.
- Add a 3rd floc blanket reactor
- Switch from red dye to fluoride and measure fluoride removal efficiency using a PACl feed rate that is identical to the feed rate used by the fluoride team.
- Determine how many countercurrent floc blanket reactors should be used for the 0.1 L/s demonstration plant that will be shipped to India. At this point in product development the decision will be somewhat arbitrary because capital and operating costs will only be estimates and operating complexity may not yet be known.
- Develop a design for a gravity powered reactor system
    - Complete a hydraulic design of the venturi system to see if it is a viable method to generate countercurrent flow of the flocs.
    - Complete a hydraulic design of a countercurrent floc flow system that uses a small diameter tube that serves as a floc hopper and that takes advantage of the higher density in the floc hopper to cause reverse flow down to the upstream floc blanket.
    - Build whichever of these systems seems most likely to succeed or test both.