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Improved Ballast Recovery in Water Treatment

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CHEMICAL AND LIFE SCIENCE

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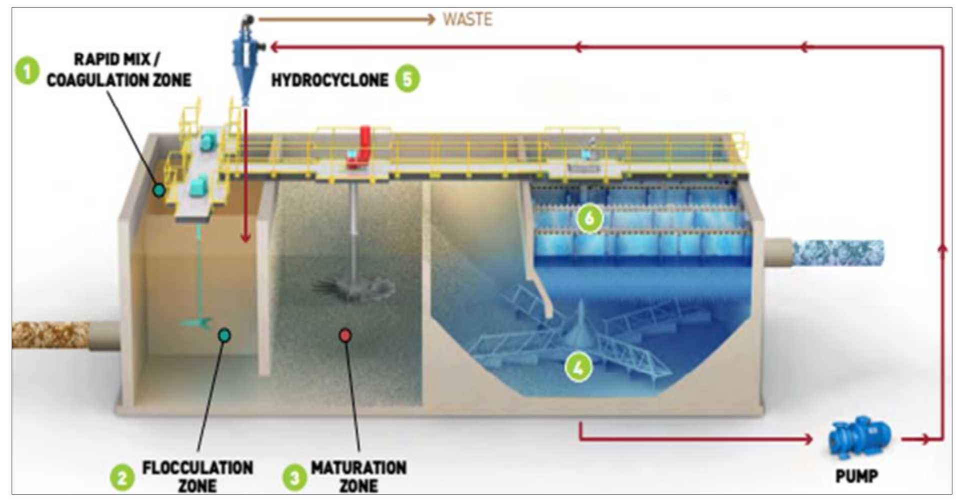
CAPSTONE DESIGN EXPO 2016

Problem

The Densadeg XRC™ is a high-throughput water clarification system that utilizes dense particles (ballast) to rapidly settle suspended waste solids. A hydrocyclone is then used to separate the ballast from the solids. Due to the inefficiency of the hydrocyclone, the current pilot unit of this system experiences ballast loss of 7-14 lbs per million gallon of treated water, costing $100-200 for additional ballast.



This project focuses on designing an effective system for ballast recovery that will significantly reduce both the costs associated with ballast replacement and storage, as well as the wear and tear of process units downstream of the clarifier system.

System Design

The primary goals:

- Determine the linear flow velocity of ballast-carrying stream to allow ballast particles to settle into a collection sump
- Observe the behavior of ballast in settling pipe by the use of transparent PVC as material of construction
- Determine optimum conditions for ballast settling

Variables tested:

- Linear flow velocities
- Settling pipe angles

Experimental Design

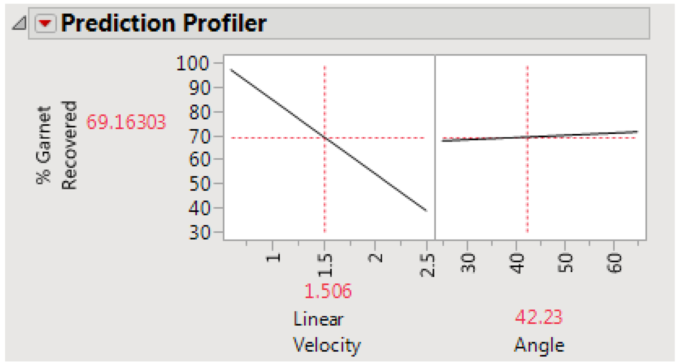
To fully characterize behavior of the ballast recapture system, a full factorial series of experiments was designed. The main factors of pipe angle and flow velocity, as well as the interaction between the two variables, were modeled. Experiments were first performed at three values of each factor, then subsequently refined to a two-level experimental design.

Each experiment consisted of a controlled ballast addition to the system, followed by running the recovery system for 15 minutes. Ballast concentrations were calculated from the stirred tank by a dipping method at 0, 5, 10, and 15 minutes. After the 15 minute run, the total ballast recovery in the collection sump was recorded.

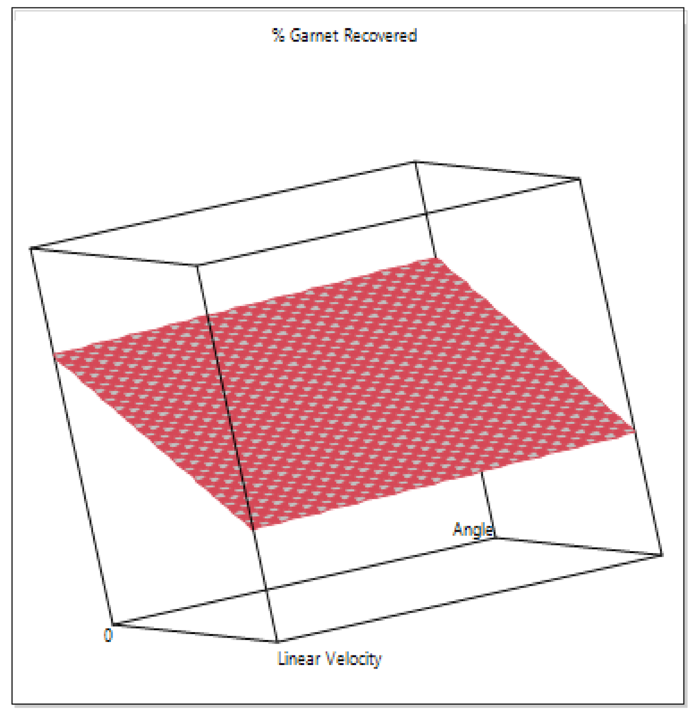
Experiment #	Angle	Flow rate
1	low	low
2	low	med
3	low	high
4	med	low
5	med	med
6	med	high
7	high	low
8	high	med
9	high	high

Data Analysis

Experimental data was analyzed using JMP Pro, a statistical analysis software. Through stepwise regression, the effects of the pipe angle and flow velocity on the system were modeled, producing factor interaction profiles.



Using the regression model, the settling pipe parameters were altered to optimize ballast recovery. The contour plot found to the right showcases the entire range of angles and velocities that yield a ballast recovery of 95% over 15 minutes.



Results

- At the scale of the test system, a pipe length of 40 inches or less was sufficient to settle the ballast.
- The effects of settling pipe angle are more complicated; a steeper incline yielded a higher recapture rate, but a shallower incline requires less pipe length.
- The length of the settling pipe may also be reduced by increasing its diameter, yielding an accompanying cost increase.

Economic Analysis

A capital cost estimate was performed to demonstrate the effect of changing diameter on the system's cost for the pilot unit. The cost estimate includes varying settling pipe sizes, ball valves, and a pressure gauge. Pipe length can also be customized to suit installation needs by altering its diameter.

Pipe Size (in)	Estimated Capital Cost	Years to Payback Period
4	$275	1 - 3
6	$455	2 - 4
8	$660	3 – 6

Conclusions

- While ballast recapture in the collection sump was not 100% over the course of 15 minutes, our optimal angle and velocity settings ensured no ballast left the recapture pipe.
- Altering the diameter of the settling pipe yields a significant cost increase, requiring a careful approach to installation.
- Further long-term studies would need to be conducted at the pilot unit to accurately monitor the wastewater solids and ballast behavior.

VCU School of Engineering

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Make it real.

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