



University of Idaho

College of Engineering

AUTOMATED BIOCHAR INJECTION SYSTEM

MEAN CLEAN WATER MACHINE

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ACKNOWLEDGEMENTS

- **Sponsor:** Gregory Möller Ph.D.
- **Clients:** Martin C. Baker
Gregory Möller Ph.D.
- **Lead Instructor:** Dev Shrestha Ph.D.
- **Graduate Mentor:** Jacob Miller
- **Team Support:** Allie



BACKGROUND

CURRENT OPERATION/ PURPOSE:

- ❑ Continuous Up-flow Sand Filtration System.
- ❑ Addresses nutrient pollution in agricultural wastewater.
- ❑ Dosage of biochar (charcoal created by burning wood products and other organic materials at anoxic conditions) to filtration system.
- ❑ Biochar removes organic contaminants from the wastewater, including phosphorous.
- ❑ Biochar is used to fertilize and retain moisture.
- ❑ Currently using manual biochar dosage system.



BACKGROUND

AUTOMATED INJECTION PROPOSITION:

- ❑ Create automatic dosage system for biochar.
- ❑ Allow for further innovations and create options for future experiments.
- ❑ Integrate cohesively with existing Clean Water Machine in an accurate, controlled, and recorded manner.
- ❑ Address settling, clogging, and mixing issues regarding biochar.

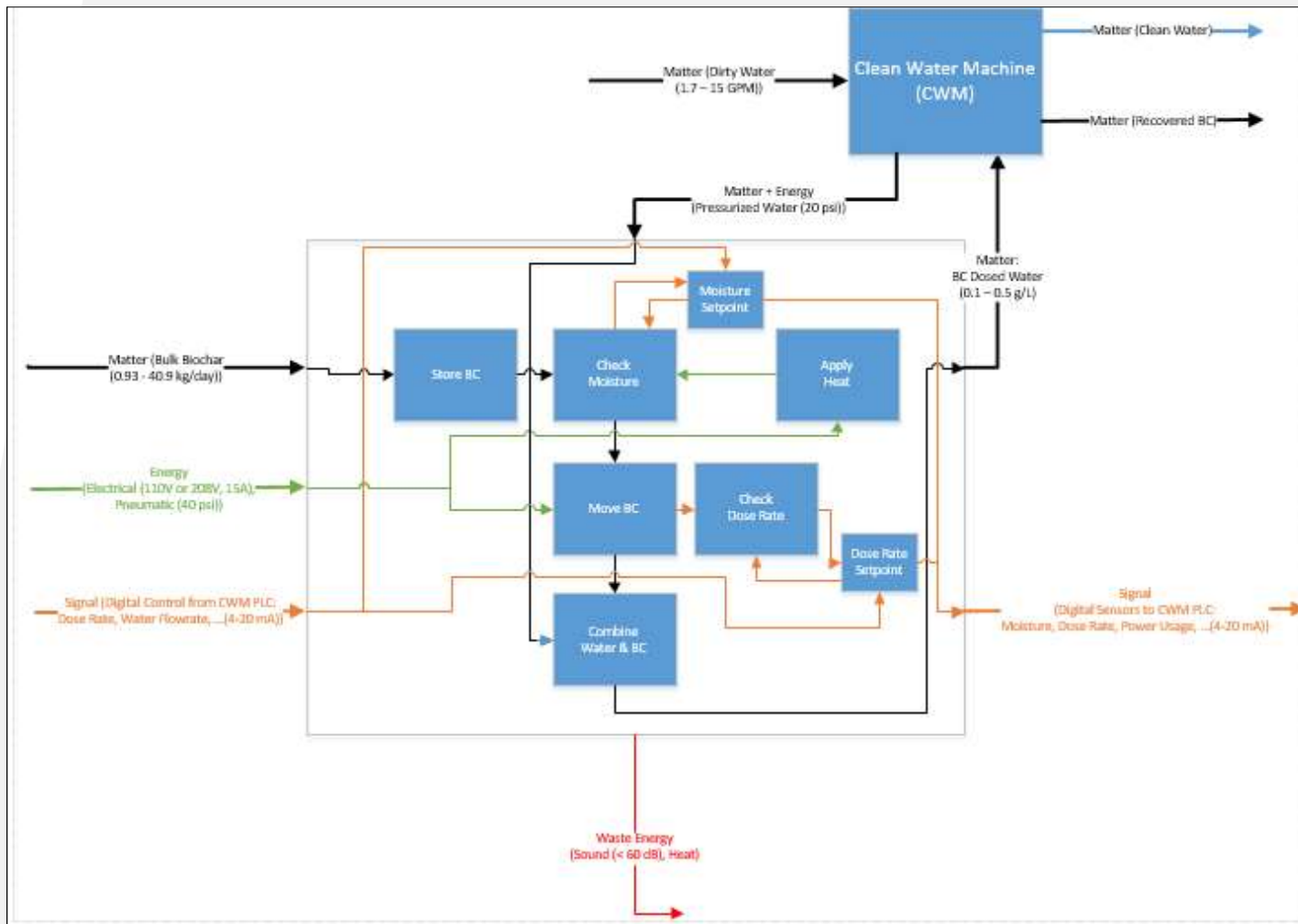


BACKGROUND

DELIVERABLES:

- ❑ Biochar storage system.
- ❑ Biochar modification system (create constant conditions regardless of input).
- ❑ Biochar mixing/ slurry creation system.
- ❑ Method for transporting slurry into pressurized pipes.
- ❑ Both automated and manual controls for injection system.
- ❑ Graphical I/O touch-screen display.
- ❑ Separate frame to allow for mobility of injection system.

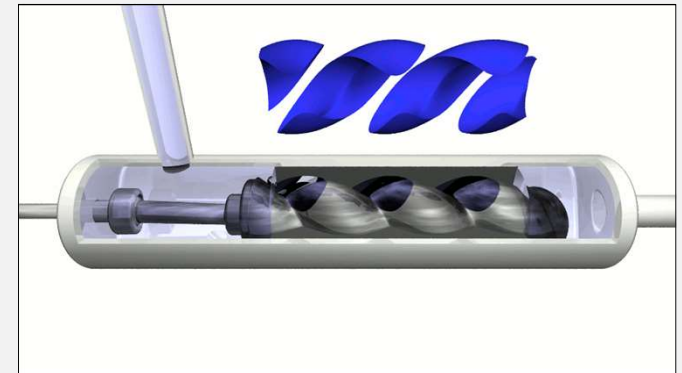
SYSTEM FLOW DIAGRAM



PROJECT LEARNING

PUMPS:

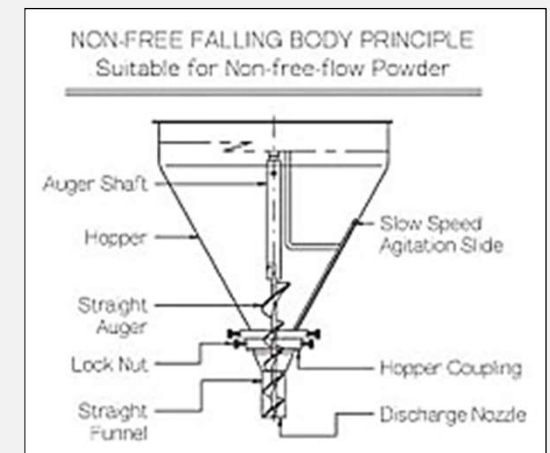
- Researched Pumps:
 - Centrifugal Pump
 - Lobe-Rotary Positive Displacement Pump
 - Reciprocating Positive Displacement Pump
- Possible Options:
 - Progressive Cavity Positive Displacement Pump (For Slurry)
 - Diaphragm or Membrane Pump (For Upstream Water Pressurization)



PROJECT LEARNING

METERING:

- Researched Systems:
 - Plunger and Piston systems with specified cavity size
 - Vacuum tubes with specified cavity size
- Possible Options:
 - Venturi Nozzle (For Slurry)
 - Syringe Pump (With Ultrasonic Horn for Slurry)
 - Small Auger (For Dry Biochar)
 - Tipping Scale or Cup and Load Sensor (For Dry Biochar)



PROJECT LEARNING

ELECTRICAL COMPONENTS:

- Ultrasonic Transmitters and Ultrasonic Horns
- Automation Direct and Arduino
- Pump and Motor power requirements
- Using a Pi to control a touchscreen
- Testing for static charge on the biochar under different conditions
- Testing for project validation





SPECIFICATIONS

FUNCTIONAL:

- ❑ Dose wet or dry biochar with 15% accuracy (within 1.5 mg; no under-dosing).
- ❑ Operate quieter than 60 dB at maximum capacity.
- ❑ Detect and account for variability in temperature, moisture content, and consistency.
- ❑ Maintain biochar at constant conditions (temperature, moisture content, and texture).
- ❑ Maintain ease of mobility as well as modular construction for maintenance.



SPECIFICATIONS

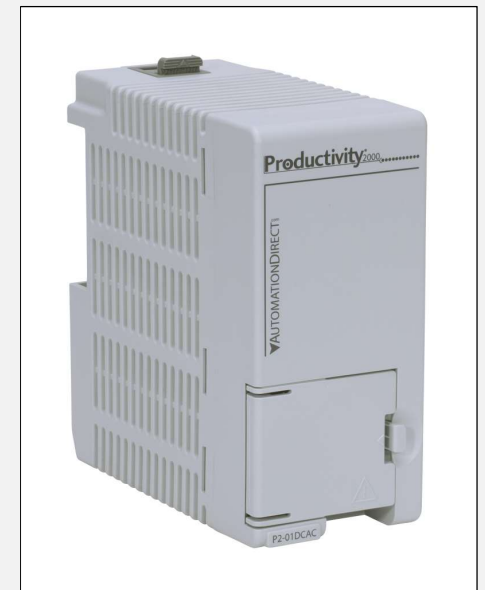
MECHANICAL:

- ❑ Pipe will withstand flow rate and pressure of 15 gal/min and 25 psi respectively.
- ❑ Must fit within a 8 ft tall x 2 ³/₄ ft wide (normal to handrail) x 2 ¹/₆ ft long (parallel to handrail) area, while maintaining full accessibility.
- ❑ Total system will not exceed 300 lbs with empty hopper.
- ❑ Clear materials used where possible with engraved labels and touch screen display.
- ❑ Stainless Steel required where corrosive elements contact.
- ❑ Operate for 8760 hours without scheduled maintenance; only 5-minute checks daily.
- ❑ Biochar supply in hopper must last 3 days minimum without refilling.

SPECIFICATIONS

ELECTRICAL:

- On the Machine
 - 110 or 208V
 - 4-20mA signal
- On the PLC
 - 100-240 VAC external power
 - 12-24 VDC external power/ 24 VAC external power
 - USB, ethernet, RS-232, RS-485 communication standards





SPECIFICATIONS

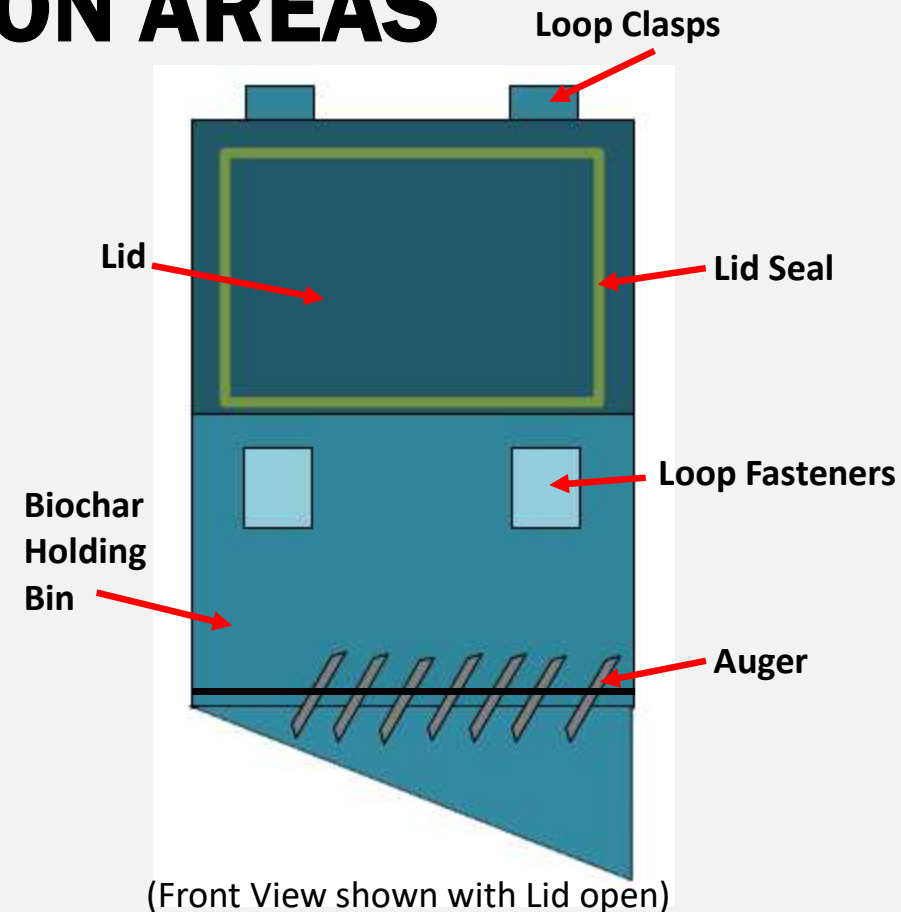
ENVIRONMENTAL:

- Consistently operate in conditions ranging from 20 to 100% humidity.
- Maintain function throughout temperatures ranging between at least 36 and 110 °F (preferably 32 to 80 °F or 0 to 27.67 °C).
- Must withstand corrosion (constant contact with water, ferric chloride, and ozone).
- Must withstand freezing conditions and keep water from solidifying (include a drain-plug at key points of system).

VIABLE DESIGNS: COMMON AREAS

HOPPER/ BIOCHAR CONTAINMENT:

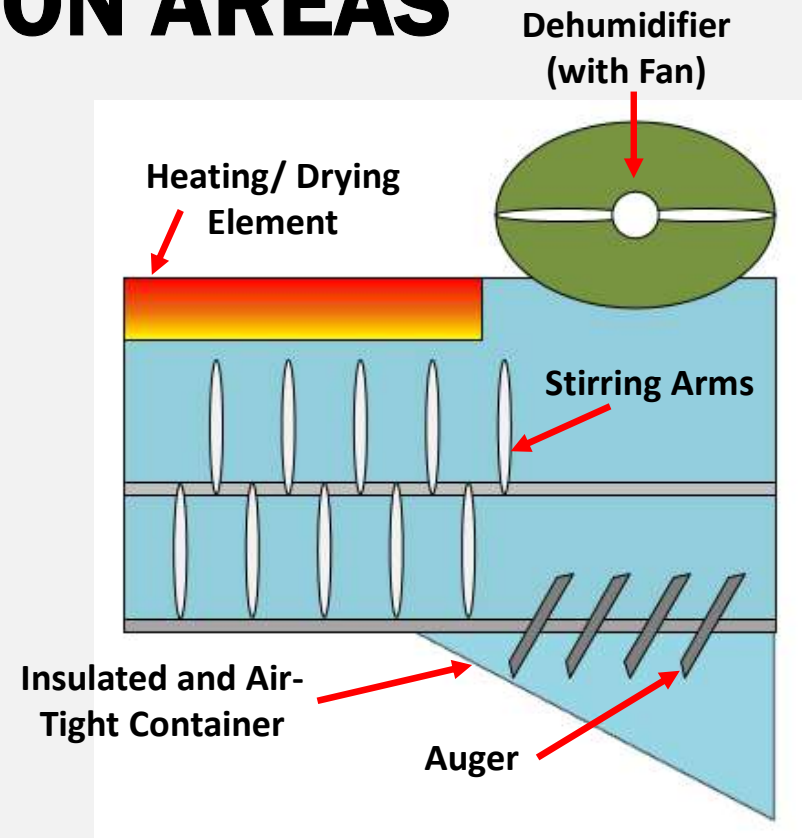
- ❑ Must hold enough biochar for 3 days without being over-sized.
- ❑ Must be air-tight and weather-proof.
- ❑ Must minimize dispersion of biochar in air and related inhalation risk while filling.
- ❑ Must not be placed above open areas of water.
- ❑ Must be accessible in height and distance from edge of catwalk for ease of and ergonomically safe filling.
- ❑ Must handle movement and transfer of variable types and conditions of biochar.



VIABLE DESIGNS: COMMON AREAS

BIOCHAR DRYER/ MIXER:

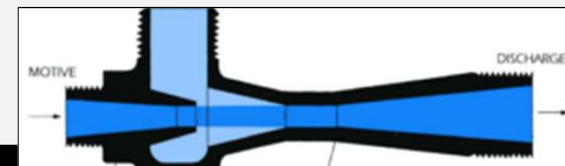
- Must dry, stir, and transfer biochar.
- Must create a constant biochar condition at output, regardless of input.
- Must be air-tight and insulated to operate in any type of weather.
- Oven/ Heat Lamps:
 - Fast drying; cheap; easy to replace
 - Fire hazard; biochar could stick to heating elements and reduce performance
- Dehydrator:
 - Low fire risk; consistent
 - Slow drying; possibly clog with biochar; requires venting; hard to replace



VIABLE DESIGNS: COMMON AREAS

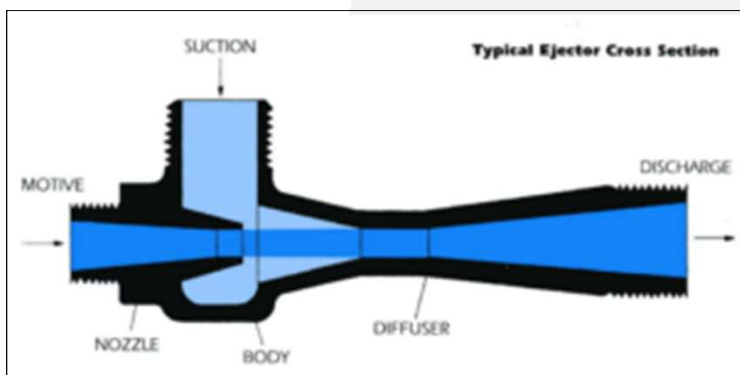
METERING:

Type:	Pros:	Cons:
Venturi Nozzle	<ul style="list-style-type: none"> -Continuous flow -Easily adjustable -Few moving parts 	<ul style="list-style-type: none"> -Slurry tends to clog -Needs extra tank and pump -Volumetric is difficult to measure accurately
Syringe Pump	<ul style="list-style-type: none"> -Extremely accurate -Continuous dosage -Used for nano-particles (carbon) 	<ul style="list-style-type: none"> -Possible slurry clog -Metering size restrictions -Volumetric is difficult to measure accurately
Small Auger	<ul style="list-style-type: none"> -Simple; no extra pieces -Less expensive -Vertical or horizontal use 	<ul style="list-style-type: none"> -Biochar can break down surfaces -Less accurate dosage ability -Variability in biochar could effect dose
Scale or Cup	<ul style="list-style-type: none"> -Gravimetric is easier to measure accurately -No clogging with dry biochar 	<ul style="list-style-type: none"> -Many moving parts -Have to close off from environment -Non-continuous
Compressed Tablets	<ul style="list-style-type: none"> -Consistent -Easy to transfer to wastewater 	<ul style="list-style-type: none"> -Difficult to break up and mix with flow -Variability in biochar moisture can effect dosage



VIABLE DESIGNS: METERING

ENLARGED IMAGES:



From top left, clockwise:
Venturi Nozzle Pump,
Compressed Charcoal Tablets,
Cup and Scale Combination,
Syringe Pump, and Auger.

VIABLE DESIGNS

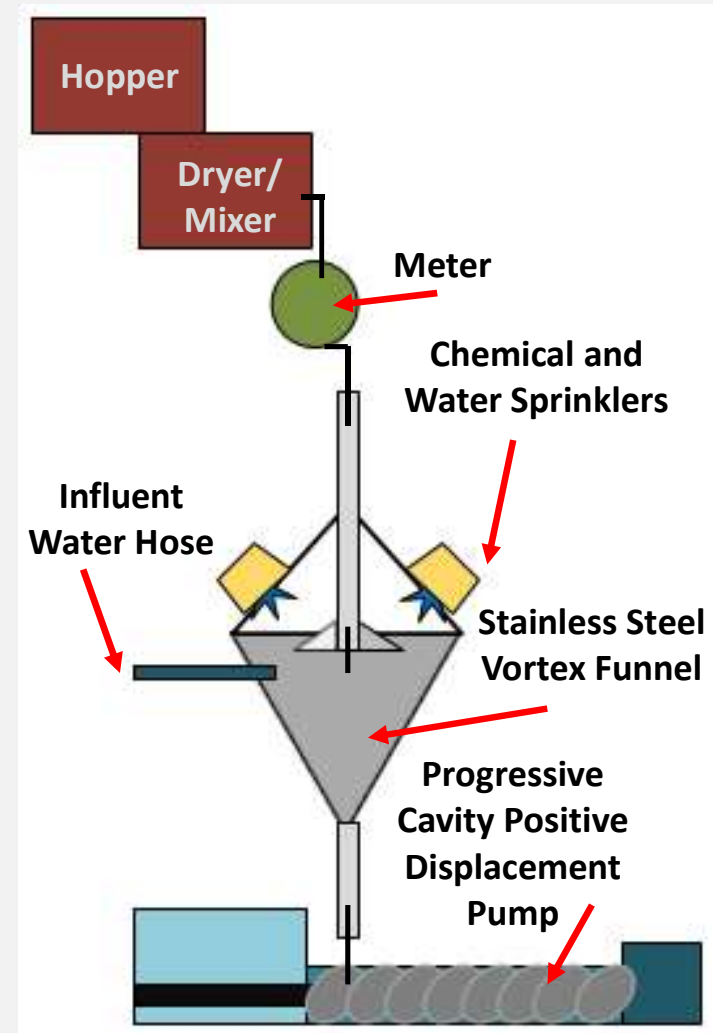
DESIGN OPTION 1:

Pros:

- Progressive Cavity Pump can handle slurry
- Large source of open water in funnel allows for easy application of chemicals in future
- Avoids clogging and settling of biochar

Cons:

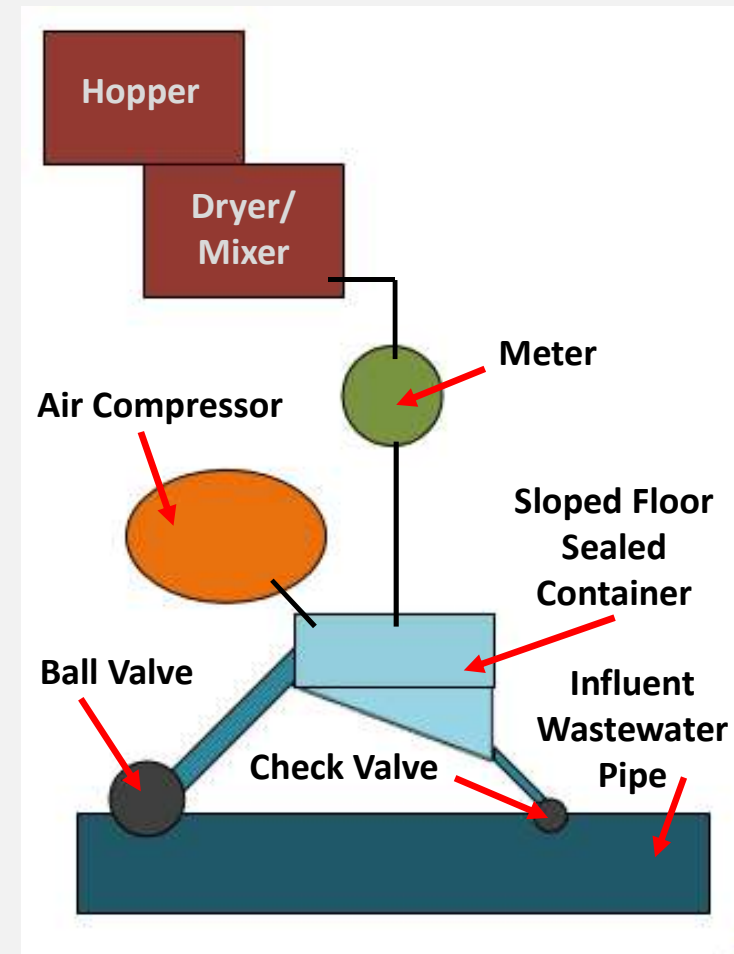
- Many moving parts
- Pump is expensive
- Open water is difficult to insulate from environment
- Pump must be horizontal, so requires more space.



VIABLE DESIGNS

DESIGN OPTION 2:

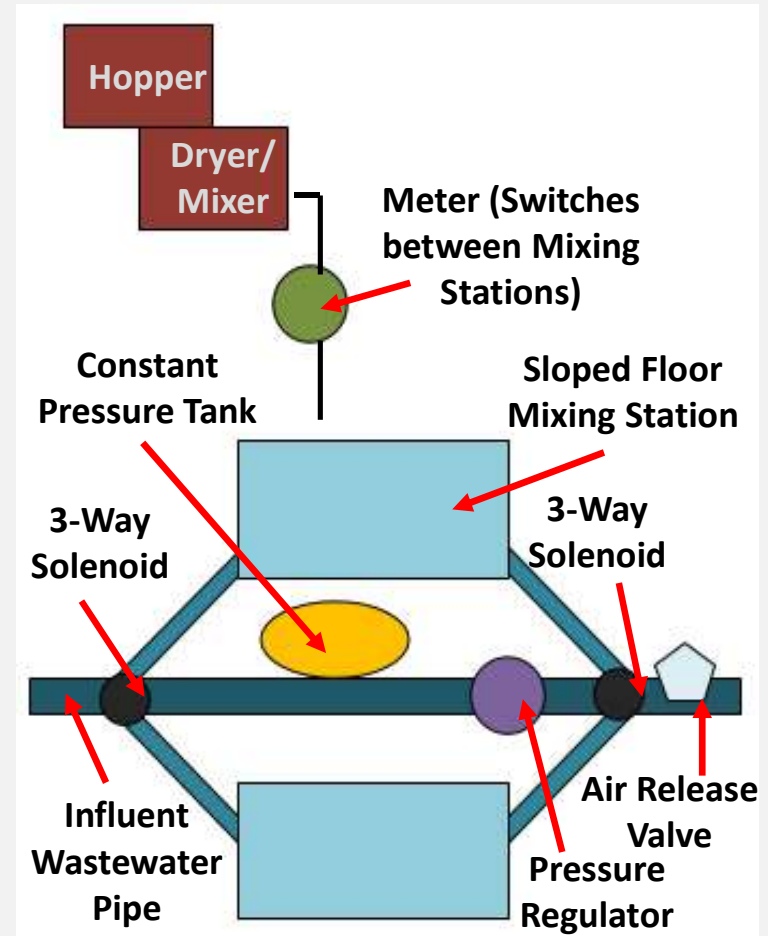
Pros:	Cons:
-No pump required	-Introduces compressed air to water pipes
-Avoids clogging and settling of biochar	-Timing of valves is crucial
-Small system; less space required	-Difficult to fully mix biochar and water



VIABLE DESIGNS

DESIGN OPTION 3:

Pros:	Cons:
-Avoids clogging and settling of biochar	-Meter system has to switch between two separate mixing areas
-No introduction of large quantities of air into pipes; better pressure regulation	-Complex system coordination
-Continuous dosage process	-Have to translate process to a vertical space
-Fewer moving parts	





PROJECT DESIGN COMPARISONS

COST ANALYSIS:

	Common Parts	Design 1	Design 2	Design 3
Electric Motors	\$100			
Arduino Uno	\$80			
Touch Display	\$80			
Sheet Metal	\$180			
Sensors	\$60			
Load Cells	\$600			
Pump		\$3,010		
Auger		\$400		
Blower		\$80		
Actuator Valves			\$82	
One-way Check Valve			\$43	
Pressure Sensor			\$112	
Three-way Solenoids				\$270
Pressure Sensor				\$112
Hopper Gate Valve				\$450
Hopper Heater				\$82
Total	\$1,100	\$3,490	\$237	\$914
Project Total		\$4,590	\$1,337	\$2,014



PROJECT PROGRESS

SCHEDULE:

Prototyping & Testing Pressurized Manifold For Injection Testing (MCB) Design Refinements	11/7/2018	12/19/2018	43d	
Report 1 & Presentation	12/15/2018	12/29/2018	15d	
Prototype 2	1/2/2019	5/2/2019	121d	
Review Needs, Metrics, and Specifications	1/2/2019	1/9/2019	8d	
Review Existing Solutions and Theory	1/10/2019	1/20/2019	11d	
Update Numerical Models	1/15/2019	1/25/2019	11d	
Embodiment Redesign	1/20/2019	2/11/2019	23d	
Budget and Purchasing	1/25/2019	2/10/2019	17d	
Update CAD Models	1/27/2019	2/15/2019	20d	
Fabrication and Testing	2/3/2019	3/9/2019	35d	
Design Refinements	3/12/2019	4/15/2019	35d	
Final Report & Presentation	4/10/2019	5/2/2019	23d	



THANK YOU; ANY QUESTIONS?
