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Abstract

a. **Funding Opportunity Number(s) and Research Area(s):** FON: EPA-G2017-P3-Q4; 14th Annual P3 Awards: A National Student Design Competition for Sustainability Focusing on People, Prosperity and the Planet - Water
b. **Project Title:**Climate & Community Friendly Wastewater Treatment
c. **Principal Investigator (P.I.):** PI, Dr. Monroe Weber-Shirk (mw24@cornell.edu) and co-PI, Dr. Ruth Richardson (rer26@cornell.edu)
d. **Student Team:** Zoe Maisel, Undergraduate Student, wastewater treatment. The project will be used in a project-based course and interested undergraduate students will be selected for the team. Students in the course will have experience in wastewater treatment, fabrication, design, economics
e. **Institution(s):** Cornell University, Ithaca, NY
f. **Student Represented Departments and Institutions:** Civil and Environmental Engineering, Biological and Environmental Engineering, Chemical Engineering, Economics (varies each semester)
g. **Project Period and Location:** August 31, 2017 to August 30, 2018 in Cornell University
h. **Proposed EPA Project Cost:** $15,000
i. **Project Summary:**

Objective

Human wastewater is rich in organic matter and provides an ample opportunity for energy recovery during treatment given smart system designs. Up to 80 percent of wastewater is not treated globally and the contamination of ground and surface water sources by untreated wastewater is hazardous to environmental and public health (UN Water, 2014).

Currently in the United States, effective municipal wastewater treatment systems typically exist as large, centralized urban systems. These systems are not appropriate for applications in developing nations, as the high fixed cost of constructing these facilities make wastewater treatment unaffordable for smaller villages (Verbyla et al., 2013). Research and development of small-scale and decentralized wastewater treatment methods should be prioritized in order to make wastewater treatment accessible for all communities. In addition to clearing technological hurdles, we will work toward acceptance of UASBs in communities by relaying the positive benefit of offsetting cooking or heating fuel needs in the community itself.

Description

The goal of the Phase I research is to develop a novel pilot scale Upflow Anaerobic Sludge Blanket (UASB) reactor that improves the accessibility of wastewater treatment for small communities. Without treatment, discharged wastewater can spread disease and cause eutrophication that hinders the aquatic ecosystem from supporting life. The goals of Phase II research are to implement the pilot scale UASB reactor at a local wastewater treatment facility and test the reactor performance in: 1) efficiency of biogas production, 2) concentration of sludge blanket via sludge weir, and 3) BOD and COD removal rates. Electricity-free hydraulic water treatment processes will be explored and analyzed as post treatment options that will be coupled with the pilot scale UASB reactor to further clarify the effluent.

The proposed design will be analyzed and evaluated by students in Cornell University's AguaClara program as part of the **RIDE** innovation system. Student teams collaborate with partner organizations to **R**esearch, **I**nvent, and **D**esign improved water treatment technologies and then **E**ngage the end-user community to promote the sustainable management of wastewater.

Results

The primary deliverable of the Phase I research is a pilot scale UASB reactor. This project is at the very early stages where it is critical that the team explore a range of alternative solutions and compare economic and environmental costs as well as operation and maintenance challenges. Various reactor modifications and fabrication methods will be evaluated to determine the most efficient reactor design. The result will be improved UASB technologies with designs available on the AguaClara design server (http://designserver.cee.cornell.edu/designs/). Given the high uncertainty involved at this stage of the design process it is not possible to know if this RIDE will require one year or multiple years to get to the stage of testing the new technologies in collaboration with partner organizations.

j. **Contribution to Pollution Prevention or Control:** Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) decrease availability of dissolved oxygen in water. Direct discharge of untreated wastewater significantly increases the oxygen demand in natural waterways, harming aquatic ecosystems sensitive to changes in BOD and COD. UASB reactors, which are energy efficient, are proven to lower BOD and COD levels in wastewater. Eventually, hydraulic post treatment options will be coupled with the proposed UASB reactor to limit greenhouse gas emissions.
k. **Supplemental Keywords:** Wastewater treatment, UASB, GLS separators, plate settlers, scalable, phase separator

A. Research Plan

Section 1: Proposed Research

a. Challenge Definition

Conventional wastewater treatment systems have long retention times, require large land areas, and have a high fixed cost per capita (Chong et al,. 2012). Due to economy of scales, small systems have even higher fixed costs per capita and these high fixed costs make conventional wastewater treatment systems inaccessible for small communities. Many cities in the global south forgo wastewater treatment altogether due to the high cost and instead discharge untreated wastewater to the environment (Wang et al., 2016). Untreated wastewater has adverse environmental and health effects: (1) it lowers the dissolved oxygen content in natural waterways, preventing aquatic life from thriving and potentially causing dead zones, and (2) it increases waterborne fecal matter content and increases the risk of exposure to pathogens (Chong et al. 2012). The latter is of particular concern to global human health as communities downstream of wastewater outfalls often have inadequate drinking water treatment.

Conventional wastewater treatment in the United States is a multistep process that is energy-consuming, lengthy and costly (Kassab et al. 2010). In the US, wastewater treatment includes preliminary, primary, secondary and tertiary treatment, and disinfection. Preliminary treatment removes garbage and other large solids, typically through coarse screening. Primary treatment is a physical step of the treatment that removes settleable organic and inorganic solids by sedimentation. Typical hydraulic retention times for primary sedimentation tanks are two or three hours, and the settleable solids and sludge on the bottom require removal and treatment which is typically anaerobic digestion (Ma et al., 2015). Secondary treatment removes residual organics and suspended solids (Ma et al., 2015). Activated sludge, a common secondary treatment technique, requires intense aeration and can take have retention times between three and eight hours (U.S. Environmental Protection Agency, 1973). The activated sludge process requires pumping air to "supply oxygen to the activated sludge process" and aeration "is one of the principal needs for electrical energy" at wastewater treatment facilities (U.S. Environmental Protection Agency, 1973). The activated sludge process converts dissolved and particulate organic carbon into carbon dioxide. Excess solids and sludge from primary and secondary treatment are waste products that require post-treatment and disposal (U.S. Environmental Protection Agency, 1973). However, anaerobic digestion of solids to burnable-biogas does enable facilities with generators to offset electricity usage. Tertiary treatment removes nitrogen and phosphorus, heavy metals, dissolved solids, and suspended solids through a variety of different techniques depending on the removal target. Disinfection by chlorine is the last step of the process. The treatment system described above is expensive, energy intensive, and requires large excavation. Existing wastewater treatment technology needs to be modified to be constructed and operated using available resources in small communities.

<u>UASB Technology</u>

Upflow Anaerobic Sludge Blanket (UASB) reactors are a well established technology for wastewater use in the global south for a number of different reasons. First, they are anaerobic reactors, meaning they do not require energy-intensive and expensive aeration. Second, UASB reactors convert organic pollutants into biogas, a useful product that can be used locally for fuel

(Tilley et al. 2014). Lastly, they create less sludge waste than comparable aerobic processes such as activated sludge (Saravanan & Sreekrishnan, 2006). They also contain microbial aggregates, called granules, which are more dense than water and tend to settle out of suspension creating a cleaner effluent (Saravanan & Sreekrishnan, 2006).

UASBs work particularly well where there are average temperatures above 20℃, which promotes sludge activity and increases removal efficiencies (Alaerts et al., 1993). Additionally, biogas that UASBs produce is primarily composed of methane (CH_4) and carbon dioxide (CO_2) and may also contain hydrogen sulfide (H_2S) and other trace gases (Abbasi & Abbasi, 2012). Biogas can be collected and either burned, to reduce greenhouse gases emissions, or used for fuel. Biogas as fuel is promising in areas that do not have access to electricity (Chong et al.,2012).

UASB Reactor Design

Figure 1 below shows the schematic for a traditional UASB reactor. As influent wastewater slowly flows up the reactor, microorganisms degrade organic compounds, producing biogas (Chong et al., 2012). UASB effluent contains nitrogen, phosphorus and reduced levels of dissolved and suspended organics. Depending on the treatment goals additional processes can be coupled to the UASB reactor and used to reduce the levels of these contaminants.

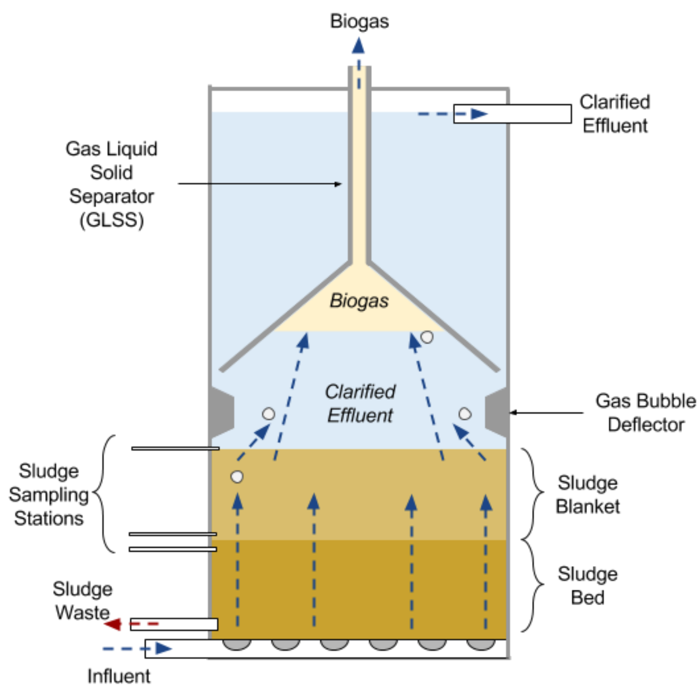

Figure 1: Conventional UASB reactor.

UASBs offer a lot of promise for hydraulically powered, low-cost, low-maintenance wastewater treatment, but there is still great room for improvement. Additional research is needed to develop a UASB design that more efficiently treats wastewater, captures biogas for use as fuel, is easy to maintain and repair during operation, and produces less waste.

Innovations

Six areas to improve UASB reactors have been identified and will be described in more detail below. These improvements will be tested in our project laboratory for hydraulic performance, particle removal, and gas collection efficiency. Our longer term goal is to pilot these UASB innovations at a local wastewater treatment plant and eventually to develop a complete small scale wastewater treatment system, using the pilot-tested UASB improvements, coupled with post treatment and biogas-utilizing appliances like lights or cookstoves.

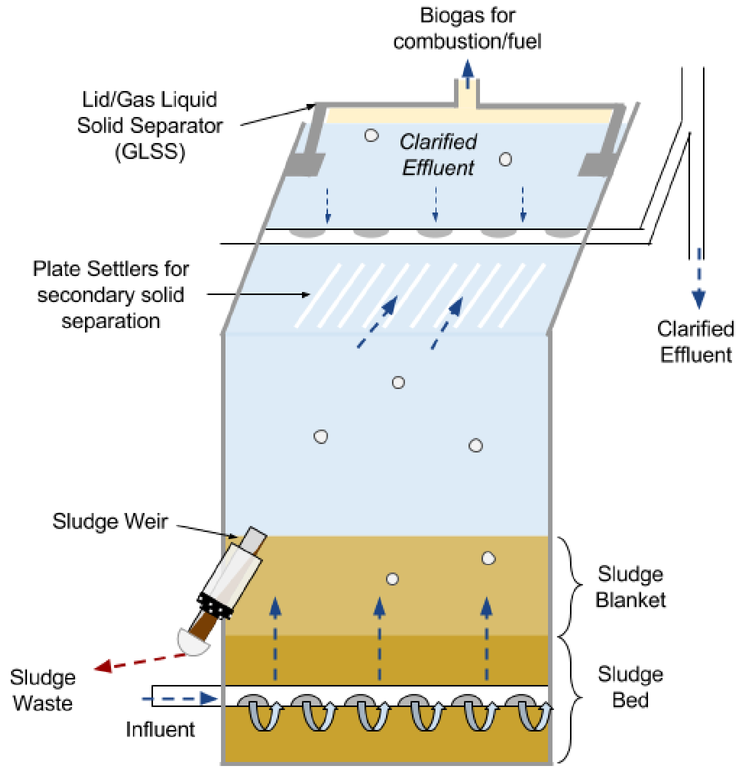

Figure 2: Design 1: Gas collection above plate settlers for pilot scale UASB reactor.

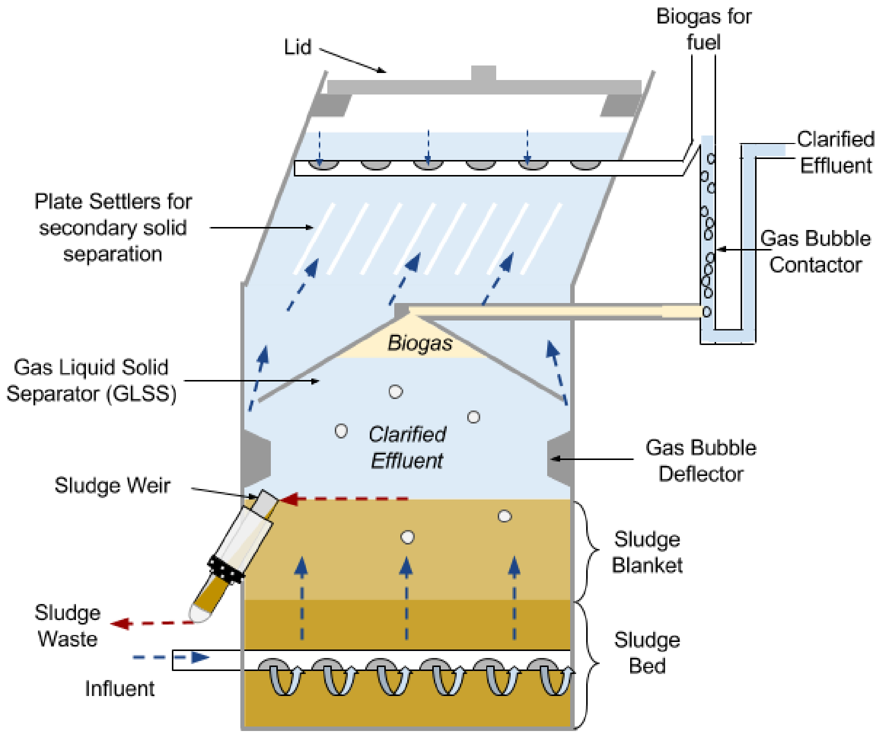

Figure 3: Design 2: Gas collection below plate settlers and a gas bubble contactor for enhanced methane capture.

Submerged Exit Launder

Gas bubbles that are not captured by the Gas-Liquid-Solid Separator (GLSS) can transport granules from the sludge blanket at the base of the reactor, to the gas-water interface at the top of the reactor (Lettinga & Hulshoff Pol, 1991; Hickey et al., 1991). These granules collect at this interface and degrade from their granule structure to create a layer of filamentous bacteria on the surface of the clarified water (Lettinga & Hulshoff Pol, 1991; Hickey et al., 1991). In a traditional UASB design, the effluent outlet is located at this gas-water interface, allowing for bacteria and other solids carried up by gas bubbles to escape untreated.

The proposed pilot scale UASB reactor design will incorporate a submerged exit launder, to reduce solids leaving with the clarified effluent. The submerged launder will bypass the gas-water interface where solids tend to accumulate, and release cleaner effluent than traditional UASB designs.

Efficient Phase Separator

The current low capacity UASB reactors used by the Honduran water ministry (SANAA) do not include a gas tight Gas-Liquid-Solid Separator (GLSS) (SANAA et al., 2016). As a result, methane is released to the atmosphere. Methane is a potent greenhouse gas, with each methane molecule contributing 25 times more to global warming than each molecule of CO2 (IPCC, 2007). For this reason, efficient capture and use of produced methane, as well as effective separation of solids from liquid, is an important goal of this project. It also maximizes potential biofuel utilization.

To increase both gas and solid separation from liquid, the proposed pilot scale UASB reactor incorporates plate settlers. These plate settlers will promote solids retention by capturing and redirecting solids back to the sludge blanket, producing a cleaner effluent. Plate settlers will also aid in directing gas bubbles toward the top of the reactor where biogas can be collected for downstream use (dos Santos et al., 2016).

The second proposed design (see Figure 3) adds another potential improvement to methane capture. Dissolved methane in UASB reactors exceed the concentration that would be in equilibrium with atmospheric pressure due to the static pressure of the water column, slow kinetics, and biogas-liquid interface (Hartley & Lant, 2006). It may be possible to improve methane capture by using the slightly pressurized biogas stream to create a gas bubble contactor with countercurrent flow between the clarified effluent and the biogas stream. The high air liquid interfacial area may enhance biogas capture efficiency.

This project will explore two alternatives for the phase separator system. The first design, shown in Figure 2, has a set of plate settlers directly above the sludge blanket and a GLSS at the top of the pilot UASB reactor. The second design, shown in Figure 3, has a GLSS directly above the sludge blanket and a set of plate settlers above the GLSS. Without experimentation, it is unclear which orientation will retain solids and capture biogas more efficiently.

Sludge Weir

UASB reactors maintain the sludge blanket height below the gas bubble deflector to efficiently collect biogas and remove organic matter. Operators must periodically sample the sludge to adjust the height of the sludge blanket to the target height. Samples are taken from multiple sampling stations distributed along the height of the sludge blanket(See Figure 1). If sampling suggests that the sludge blanket is above the target height, the operator will drain the reactor from the bottom, which removes sludge and water, until the target sludge blanket height is achieved.

This sampling method will be replaced by an adjustable weir system that automatically maintains the height of the sludge blanket, eliminating the need for operators to manually adjust the height of the sludge blanket (see Figures 2 and 3).

Prefabrication

Conventional UASB reactors are built on site using concrete (or masonry and mortar) and rebar. The civil works construction results in a high capital cost making this investment difficult for small communities. The construction costs will be lowered by prefabricating the UASB reactor off-site and by using low cost, lightweight, materials and an efficient structural design of corrugated plastic pipe. The plastic construction has the additional benefit of being immune to corrosion from hydrogen sulfide, a minor but potent component of biogas.

b. Research Description

Over the past 12 years the Cornell AguaClara program has developed innovative, sustainable, climate friendly drinking water treatment technologies. These technologies include a long list of inventions that grew out of the innovation system that combines a 60 student team of undergraduate and Master of Engineering researchers, a collaborative partnership with Agua Para el Pueblo (a Honduran NGO in the water sector), the water ministry of Honduras (SANAA), and the plant operators who are employees of their respective community water boards and who provide feedback on the AguaClara technologies. There are currently 14 AguaClara facilities serving 65,000 people in Honduras. These water treatment systems ranging in size from 1 L/s to 70 L/s, are gravity powered and operate off grid. They include semi automated chemical dosing, flocculation, floc blankets, plate settlers, stacked rapid sand filters, and chlorine disinfection. The AguaClara facilities are a fraction of the cost of conventional systems with turnkey project costs (design/build/operate/train/transfer) less than $10,000 per L/s ($440,000 per mgd) of flow capacity and operating costs (not including salary for one person on staff 24/7) of approximately $10 per million liters.

Based on the success in creating the next generation of sustainable and high performing drinking water treatment technologies, our Honduran partners have been encouraging us to use our innovation system to develop improved wastewater treatment technologies. We have been conducting laboratory studies of UASB and anaerobic fluidized bed reactors for the past 2.5 years under the guidance of Dr. Richardson and her graduate students. Additionally we have developed MatLAB code to predict the net biogas production and reactor sizes for communities of different sizes. This proposal represents the next step in moving the ideas that we are generating in the laboratory into pilot scale testing. Our experience with drinking water technologies suggests that our pace of innovation will accelerate when we begin deploying the technologies to the field.

Phase I research will optimize conventional UASB reactor design. During Phase II research, this novel UASB reactor will be combined with post-treatment to form a pilot scale wastewater treatment system. This pilot scale wastewater treatment system will be demonstrated at pilot scale in Ithaca and implemented in communities abroad under the supervision of partner organizations, such as Agua Para el Pueblo (APP) and AguaClara LLC. These partner organizations will select and train plant operators. Additionally, partner organizations will educate the local community about proper household waste disposal and its impact on public health.

The pilot scale wastewater treatment system will be implemented in small communities that currently do not have wastewater treatment. The introduction of wastewater treatment in these areas will lower the Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the municipal wastewater before its eventual release into the environment. AguaClara particle and pathogen removal technologies may be used as additional treatment steps to reduce waterborne disease.

We anticipate developing and testing multiple design configurations during the laboratory and field testing stages in Phase I. After the pilot scale UASB fluid, particle, gas, and reactor geometry has been tested in the laboratory, it will be field tested at the Ithaca Area Wastewater Treatment Facility. Once this technology is prepared for implementation, AguaClara will partner with NGOs in Honduras and India to introduce this wastewater treatment system abroad. AguaClara has experience working with Agua Para el Pueblo (APP) as an implementation partner to transfer technology, construct and maintain water treatment plants, and train community operators. Our lead partner in India is AguaClara LLC which works with Gram Vikas and the Tata Cornell Initiative. AguaClara will also publish the open source designs of the UASB on our website.

The goals of the Phase I research are to design, fabricate, and test hydraulics and performance of a low-flow, low-cost, low-maintenance, low-waste pilot scale UASB reactor. Efficiency measurements for gas, liquid, solid separation at the pilot scale are necessary to demonstrate the expected performance of a field scale UASB reactor. The following innovations make the proposed pilot scale UASB reactor more environmentally and user friendly: Submerged Exit Launder, Efficient Phase Separator, Sludge Weir, and Prefabrication.

Submerged Exit Launder

The liquid phase in UASB reactors is supersaturated with methane and carbon dioxide. The dissolved gasses come out of solution and tiny gas bubbles are often attached to suspended particles. The gas bubbles then carry the suspended solids toward the top of the reactor in the same way that dissolved air flotation is used. The floating solids mostly accumulate at the reactor air/water interface inside the gas collection system. Some of these solids reach the effluent collection system at the very top of the reactor. Since this layer, which is less dense than water, will not settle to the bottom of the reactor and can exit the reactor as effluent, the outlet system will be redesigned.

To prevent solids from leaving with the clarified effluent, the proposed pilot scale UASB reactor design will incorporate a submerged exit launder system. The floatable solids will not be able to exit the reactor as effluent if the outlet system is submerged. A submerged exit launder with orifices oriented along the top will replace conventional weir systems. The submerged launder system is already used in AguaClara sedimentation tanks. This submerged exit launder system will both reduce suspended solids concentration in the effluent and will reduce construction costs. The reactor will be challenged either with inorganic flocs or organic particles to simulate wastewater solids. Efficiency of solids removal will be measured in Phase I based on clarified effluent turbidity.

Efficient Phase Separator

There are multiple goals for the phase separator: reduce methane loss to the atmosphere, improve solids retention, and improve effluent water quality. At least two phase separator designs will be fabricated and tested in this project. Efficiency will be measured by injecting water that is supersaturated with oxygen and then measuring the clarified effluent dissolved oxygen concentration as well as the volume of collected gas using existing MatLAB code.

The first phase separator design will have a lid that functions as a conventional GLSS. This lid will employ a water seal to reduce methane losses to the atmosphere. The removable lid contributes to easy reactor cleaning and maintenance. Plate settlers will be placed between the exit launder and the sludge blanket to encourage the settling of solids that escape the sludge blanket.

The second phase separator design will be based on a conventional GLSS design but the biogas outlet will be on the side of the reactor rather than at the top. This will leave space for plate settlers to be placed above the GLSS. This design may include a gas bubble contactor to enhance biogas capture efficiency. The two designs will be constructed and tested to compare their ability to retain solids and capture biogas.

Sludge Weir

Operation of the pilot scale UASB reactor will be simplified by eliminating the need to sample the sludge to maintain a constant sludge blanket height. AguaClara's recently deployed 1 L/s drinking water treatment plant includes an adjustable weir system in the sedimentation tank to maintain the depth of the fluidized bed of flocs. This sludge hopper automatically removes suspended particles that exceed the target depth. A similar system will be used in the proposed

UASB design to maintain the target sludge bed depth and to concentrate the sludge before removal. Given that this is already a proven technology, it will not undergo performance testing in Phase I.

A clear pipe will go through the wall of the UASB reactor at an angle and serve as a sludge weir (see Figures 2 and 3). The maximum height of the sludge blanket will be adjustable and will be set by the height of the pipe end. Because sludge is more dense than water, it will preferentially spill over the weir to settle at the bottom of the pipe. The operator will monitor the level of collected sludge as it accumulates. The sludge at the bottom of the clear pipe will be more densely packed than the sludge bed that is removed from conventional UASBs while maintaining the constant sludge blanket height. This sludge weir will provide sludge consolidation and thus reduce the volume of sludge needing final disposal. Post-treatment traditionally requires drying the sludge before final disposal. By only draining concentrated sludge from a weir, this design allows for decreased drying space for sludge management. The sludge weir will be constructed and tested to see if the bed height can be successfully maintained with a weir.

Prefabrication

A 0.9 to 2 m diameter PVC or HDPE pipe will replace the concrete tank and make it possible to prefabricate the UASB and transport it to the site. In the past 12 months, the AguaClara team designed, fabricated, tested, and deployed to Honduras a 1 L/s prefabricated drinking water treatment plant (see Figure 4). The UASB project will build on the team capabilities and will incorporate relevant reactor geometry and fabrication methodologies. The project lab includes tools for fabrication including plastic welding.

Figure 4. Field testing of the AguaClara 1 L/s drinking water treatment plant. Many of the reactor design and fabrication techniques used for this drinking water treatment plant may be used to advance the design of prefabricated UASB reactors.

Prefabrication of drinking water and wastewater treatment units for small communities has the potential to dramatically reduce the per capita costs.

c. Results, Evaluations, Demonstration

Phase I research focuses on the design, fabrication, and hydraulic testing of a modified UASB reactor. Problems and challenges identified during fabrication will be used to inform reactor redesign to promote future work and testing. During this hydraulic testing period, the mechanics of the reactor will be evaluated so no biological components will be introduced. Hydraulic testing will serve to ensure that the reactor is watertight and stable, that the GLSS performs as needed, and that solids settle in the plate settlers.

The objectives for the Phase I research are to build a pilot scale UASB reactor and test its ability to maintain sludge blanket depth, collect gas, and produce a clarified effluent. These objectives will be evaluated based on the GLSS performance and gas capture efficiency as measured by percent of gas recovered.

Phase I is part of a long-term AguaClara program initiative to test improved and prefabricated UASBs in Ithaca and in Honduras and then explore post-treatment options to remove dissolved methane, pathogens, nitrogen, and phosphorus. Hydraulic flocculation and sedimentation successfully removes pathogens and phosphorus from municipal wastewater (Jaya Prakash et al., 2007). AguaClara pilot 1 L/s drinking water treatment plants already incorporate hydraulic flocculation and sedimentation and thus it is a post-treatment option. Post-treatment options will be somewhat site specific depending on environmental and regulatory requirements.

Once the pilot wastewater treatment system (the pilot scale UASB reactor with post-treatment) demonstrates removal of organic matter and dissolved nutrients, it can be implemented in communities that do not have existing wastewater treatment systems. The introduction of this wastewater treatment technology will prevent the spread of waterborne diseases and airborne fecal matter. Additionally, this treatment system will prevent sewage water with high BOD and COD from entering natural waterways. Lowering the BOD and COD demand of effluent water will maintain a healthy Dissolved Oxygen (DO) concentration for plants and aquatic life to flourish.

It is more difficult for small villages to fund infrastructure projects due to high base capital costs of construction. AguaClara has successfully overcome this limitation by creating new portable designs and fabrication techniques that use readily available plastic. These design and fabrication strategies will be employed for this proposed wastewater system to meet the needs of small communities.

Section 2: Relationship of Challenge to Sustainability (People, Prosperity, and the Planet)

For the Phase I portion of this research, we are striving to streamline costs by designing and fabricating the reactor using sustainable methods. The replacement of concrete with plastic for the construction of the reactor promotes implementation of wastewater treatment in regions where this was previously unfeasible.

After the completion of Phase I, post treatment technologies will be paired with the tested pilot scale UASB reactor. This pilot wastewater treatment plant has the potential to (1) improve water quality through the removal of nutrients and reduction of oxygen demand and (2) protect human health with the reduction of waterborne and airborne diseases spread through fecal matter.

The proposed UASB reactor will be affordable for smaller communities that require low-flow wastewater treatment systems. AguaClara will work with partner organizations such as APP and AguaClara LLC to implement the pilot wastewater treatment system that includes the proposed UASB reactor design from Phase I research and a post-treatment option from Phase II research. APP has worked with AguaClara to implement the pilot 1 L/s drinking water treatment plant in Honduras, so we expect a wastewater treatment plant to be implemented similarly. When this wastewater treatment plant has been designed and tested, a construction and operations manual will be prepared for partner organizations and plant operators to use. This training material will help operators competently/independently manage the wastewater treatment operation with minimal assistance from partner organizations or AguaClara. After implementation, research to improve the pilot wastewater treatment system will continue. There is a continuous demand for affordable wastewater treatment system at the small scale. Specifically, the Honduran Water ministry (SANAA) and APP are keenly interested in improved wastewater treatment technologies.

Section 3: Project Management

Schedule for milestones:

Fall 2017	Design phase separator systems that use plate settlers to enhance solid separation. Design a sludge weir system. Design an inlet manifold that ensures uniform flow distribution of wastewater into the UASB reactor. Develop a method to fabricate the phase separator system for a pilot scale UASB reactor. Begin fabrication of a pilot scale UASB reactor.
Spring 2018	Complete fabrication of the pilot scale UASB reactor. Test performance of the phase separation system in the pilot reactor using gas, water, and possibly biological or inorganic solids. Make modifications to improve gas extraction efficiency of the phase separator and the gas bubble contactor.
Summer 2018 (Phase II)	Implement the pilot scale UASB reactor at a local wastewater treatment plant and monitor the influent and effluent BOD and COD. Monitor the volumetric flowrate of the biogas through the phase separator. Monitor the turbidity of the sludge collected in the sludge weir system.
Fall 2018 (Phase II)	Continue to test the pilot scale UASB reactor at the local wastewater treatment plant. Explore post treatment options to couple with the pilot scale UASB reactor. Test the nutrient removal capacity of AguaClara flocculation and sedimentation unit processes. Design an energy efficient aeration system to remove dissolved nitrogen.
Spring 2019 - continuing (Phase II)	Fabricate a post treatment system to couple with the pilot scale UASB reactor from Phase I research. Test the complete package wastewater treatment plant (the combination of both the Phase I pilot UASB reactor and post treatment system designed for Phase II research) at a

	local wastewater treatment plant to observe how effective the pilot plant is at treating raw sewage.

Students on this team will have expertise in drinking water treatment, wastewater treatment, water chemistry, fabrication, fluids, biological and environmental processes, ecology, aquaculture, global health, sustainable infrastructure, structures, business, computer drafting, and economics.

The team will also have access to the AguaClara laboratory research space, Civil and Environmental Engineering (CEE) machine shop, and the Ithaca Area Wastewater Treatment Facility to conduct research. APP will provide designs for conventional wastewater treatment plants that have already been constructed in order to help the team better understand existing UASB designs and possibilities for improvement.

Research will begin in Fall 2017 and continue until the end of Summer 2018 in accordance to the schedule detailed above. Funds will be allocated as needed during this research period under guidance from the principal investigators (Drs Richardson and Weber-Shirk). Additionally, Dr. Weber-Shirk and an undergraduate research adviser will oversee the general progress of the team and ensure that deadlines set by the team are met. Dr. Weber-Shirk and the research adviser will be available to answer questions and provide guidance throughout the entire process to facilitate smooth work. Students on this team will have expertise in drinking water treatment, wastewater treatment, water chemistry, fabrication, fluids, biological and environmental processes, ecology, aquaculture, global health, sustainable infrastructure, structures, business, computer drafting, and economics. The team will also have access to the AguaClara laboratory research space, machine shop, and the Ithaca Area Wastewater Treatment Facility to complete the design, fabrication, and hydraulic testing of the pilot UASB reactor for the Phase I grant.

Section 4: Educational and Interdisciplinary Aspects of Research

AguaClara is a student research group in Cornell University. The AguaClara program prides itself on its commitment to providing sustainable water treatment systems to communities in the global south. Undergraduate and graduate students interested in drinking water and wastewater treatment technologies conduct research every semester on specific areas of the treatment train. The team assembled for this project consists of students from Cornell University's School of Civil and Environmental Engineering, Department of Biological and Environmental Engineering, School of Chemical Engineering, Department of Computer Science, and School of Applied Economics and Management. It should be noted that team identity shifts slightly every semester, so there is potential for representation of a broader range of disciplines over the course of the Phase I and Phase II grants. The multidisciplinary team of students will bring diverse perspectives on economic community, and environmental sustainability, climate friendly fabrication and design, and the physics of the interactions between liquid, gas, solids, and reactor geometry. Our decade long collaboration with Agua Para el Pueblo and the Honduran Water Ministry ensure that our work will be well grounded in reality and that our partners will be prepared to adopt innovations as they are developed.

The objective of our project is to provide wastewater treatment that is simple to operate, environmentally friendly, and economically sustainable on the community level. The insights we will collectively gain as we collaborate on the proposed research will be one of the main educational benefits of this P3 project.

The process of incorporating sustainable criteria into the design will encourage each member of the team to consider the long-term impacts. The AguaClara program's culture of sustainable project design will be communicated by members of the project team in presentations of the work and through their involvement in future design work with other teams. Additionally, we intend for the success of this project to be an example of the effectiveness of sustainable design in addressing important global needs.

Partner organizations will train pilot wastewater treatment plant operators to maintain and manage the plant. Once receiving training, operators will then be capable of independently maintaining the plants. Additionally, partner organizations will teach end users proper disposal of household waste and implications of wastewater mismanagement on public health. Through education and outreach, the community will learn about sustainable practices in wastewater treatment.

Researchers at Cornell University will be able to apply coursework and previous experience to the wastewater treatment sustainability challenge. This research will be shared and presented at several events on campus to engage the Cornell University community in encouraging sustainable design in a research setting.

Professors and wastewater industry professionals will be consulted for design modifications and experience working with wastewater. Team members involved in the project will have to consider many facets of sustainability from design robustness and usability concerns to material selection and fabrication techniques. Sustainable funding sources, revenue and expense studies will be conducted to understand the cost of construction, operator costs, and reactor operation costs.

B) EPA Human Subjects Research Statement

The proposed research does not involve human subjects. For current laboratory testing, samples are made from chemicals as opposed to sewage containing human excreta. Once a field-scale model is constructed, wastewater from a local wastewater treatment plant will be processed without identifiers.

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