2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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On Site Water Treatment Research at Texas A&M

Gabriele Bonaiti[1], Ryan Gerlich[1], Anish Jantrania[2], June Wolfe III[2]

[1]Biological and Agricultural Engineering Department, Texas A&M University, TX.

[2]Texas A&M AgriLife Extension and Research Center, Temple, TX

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ABSTRACT.

Texas A&M University's On-Site Sewage Facility (OSSF) Research Team (AgriLife) was awarded three contracts to address topics requested by the Texas Commission on Environmental Quality 2019 OSSF research grant program. Proposals addressing black water non-potable reuse (BWR), low-pressure dosing systems (LPD), and aerobic treatment unit adequacy with higher strength wastewater and alternative dosing schemes (ATU) were funded.

BWR has been recognized as a partial solution for bridging the gap between water supply and demand in Texas, particularly for residential and commercial dwellings. AgriLife is conducting field scale research and testing of on-site reuse technology to evaluate BWR system performances under varying flow, maintenance, and monitoring conditions.

LPD offers an alternative to a standard gravity or pumped drain field system for disposal and treatment of septic tank effluent to overcome soil and site limitations. Common problems reported by regulators/owners/designers of LPD in Texas were identified by AgriLife and a field research design was conceived to determine if effluent distribution lines using spray emitters with downward orientation can be improved through reorientation.

Use of ATUs for treating domestic wastewater in Texas has increased sharply since the late 1990s. In addition, both organic strength and hydraulic flows of residential ATU's have changed due to water conservation devices and graywater reuse. AgriLife is evaluating performance of a most commonly used ATU for its adequacy over a range of experimental high organic strengths and two different dosing operations, timed- and demand dosing. A manufactured high-strength waste is added to raw sewage influent to produce the experimental organic load concentrations. ATU performance adequacy is being evaluated by comparing the five-day biological oxygen demand and total suspended solids concentrations of the ATU influent and effluent streams.

This paper reports the three projects' description, work plan, the field experiments design and monitoring schedule that are planned to be implemented at the Texas A&M AgriLife Wastewater Research Facility Center.

***Keywords.** Aerobic treatment unit, Black water non-potable reuse, Emitters facing up, High organic strengths, Low-pressure dosing systems*

Introduction

The 2019 Texas On-Site Sewage Facility Research Grant program Request for Grant Applications (RFGA) number 582-19-93772 called for research addressing four topics: black water non-potable reuse, implementation of low pressure dose systems with various configurations, dosing versus non-dosing in aerobic treatment unit (ATU) designs, and adequacy of current ATU designs with higher strength wastewater. Texas A&M AgriLife submitted three proposals to address all four research topics logically grouped (wastewater reuse, low pressure dosing, ATU), and was awarded three contracts.

The Texas Water Development Board 2017 State Water Plan reports that “Texas’ population is expected to increase more than 70% between 2020 and 2070, from 29.5 million to 51 million.” The report also suggests that a potential water shortage is also expected to increase from “4.8 million acre-feet in year 2020 to 8.8 million acre-feet in year 2070 in drought of the record conditions.” Wastewater reuse has been recognized as a part of the solution for bridging the gap between water supply and demand in Texas particularly for residential and commercial dwellings. In Texas, about 20% of the dwellings use On-Site Sewage Facilities (OSSF) to manage their wastewater (Bonaiti, et. al., 2017), and at the present time indoor reuse of wastewater is not an option for them. Toilet flushing accounts for about 20% to 30% of the total water demand in a typical home depending on where a home is equipped with water conservation fixtures or not (Crites and Tchobanoglous, 1998). For a commercial facility, water use for toilet flushing would be even higher depending on the type of facility. Indoor reuse of adequately treated wastewater is challenging for both centralized municipal systems and for individual on-site systems, mainly in-terms of having a reliable and dependable monitoring system to ensure the quality of reuse water. While significant progress has been made for the centralized municipal systems to ensure that the reuse water quality meets the required regulatory standard on a consistent basis, the same progress has not been made for on-site decentralized systems. Field scale research and testing of an on-site reuse technology is needed to evaluate the performance of on-site wastewater reuse technologies under varying flow, maintenance, and monitoring conditions. The proposed applied research and demonstration project is designed to assess feasibility of on-site wastewater treatment for non-potable reuse, mainly for toilet flushing

Low Pressure Dosing System (LPD) offers an alternative to a standard gravity or pumped drain field system that overcomes certain soil and site limitations for disposal and treatment of septic tank effluent. Three unique characteristics of the LPD system that help overcome soil and site limitations are: (a) uniform distribution of effluent, (b) dosing and resting of soil treatment area, and (c) shallow placement of trenches to enhance aeration. LPD systems are implemented in Texas mostly in the Central, South, and Southeast regions, especially in proximity of largest cities and along the Lower Colorado River. About 43,000 LPD permits (less than 5% of the total permits) have been issued since 1992. A properly designed, installed, and operated LPD system can overcome limitations associated with use of a standard system. However, field research is needed to determine if the commonly used design can be improved. This project is designed to identify problems reported by the regulators/owners/designers of LPD in Texas, set up and test performances of two new proposed configurations, and to make recommendations for overcoming those problems. Findings of our experiment could include improvements in septic tank effluent distribution, which in-turn would improve its treatment in soil, and long-term overall performances of the system by allowing for better maintenance.

ATU use for treating domestic wastewater in Texas has been increasing since the late 1990s. The TCEQ On-Site Activity Reporting System (OARS) database indicates that between 1992 and 2017 more than 350,000 ATU permits were issued. This represents approximately 43% of all permits issued in Texas. Efficient ATU operation is necessary to protect both private individual and public/environmental health interests. Both organic strength and hydraulic flows in residential ATU’s are changing due to the use of water conservation devices and interests in graywater reuse. Research defining the operational limits of National Sanitation Foundation (NSF) Standard 40 (STD40) designs and investigating effects of dosing operations is critical. This project is designed to determine how current trends in water use (i.e., water conservation and/or greywater reuse) potentially affects the treatment efficiency of a commonly used ATU in Texas, if an addition of time-dosing to the treatment train can maintain or improve treatment efficiency, and if long-term operational costs of ATUs are reduced when performing at maximum efficiency. Additionally, ATU sizing, area requirements, and installation costs may be reduced through improved ATU efficiency (i.e., optimized operational conditions).

This paper reports the three projects’ description, work plan, and deliverables, and the field experiments design and monitoring schedule that are planned to be implemented at the Texas A&M AgriLife Wastewater Research Facility Center.

Projects Description

On-site Wastewater Reuse (P1)

Study objectives are to expose the reuse technology in operation at the Texas A&M AgriLife Wastewater Research Facility (WWRF) Center, located in the RELLIS Campus, in Bryan Texas, to real-world conditions such as flow variability, neglected maintenance, and infrequent monitoring in order to assess their effects on exposure risk to the public. The project will focus on determining whether modifications of a typical on-site wastewater treatment train or maintenance/monitoring requirements are able to reliably meet regulatory water quality requirements for indoor indirect (non-potable) reuse.

Application of a membrane bio-reactor (MBR) is innovative in on-site wastewater treatment field and the proposed project involves field-evaluation of a proprietary on-site MBR technology, BioBarrier® MBR 0.5, and comparing with that of a conventional aerobic treatment unit Clearstream® NC3 under variable operating conditions including changing influent flow characteristics (quantity and quality) and under neglected operating conditions such as turning off aeration and/or discharge pump to simulate real-world situations anticipated in on-site industry. Field testing of effluent quality and laboratory testing of effluent quality will be conducted to determine if alternative maintenance and/or monitoring requirements could be proposed for on-site indoor indirect (non-potable) reuse.

BioBarrier® MBR 0.5 (NSF STD350) and Clearstream® NC3 (NSF STD40) units have been in operation at the AgriLife WWRF Center since March 2016. A thorough maintenance of both the units (i.e., pumping of primary and secondary tanks, membrane cleaning, and system control adjustments) will be conducted prior to experimental use for this project

Low Pressure Distribution (P2)

AgriLife will use a standard septic tank for treatment of raw wastewater and install a conventional Low Pressure Distribution (LPD) trench as a control and two configurations of alternative LPD trenches in which distribution holes will be facing up and protected with either orifice shields or with leaching chambers. The field experiment will be carried out at the AgriLife WWRF Center. Observation ports (large utility boxes) will be installed in each trench to provide observational access during the test period. Soil moisture probes and a video camera will be used for making observations and measuring uniformity of effluent distribution in the trenches.

Survey forms for OSSF license holders and LPD users (home and commercial system owners) will be developed to determine the type and magnitude of problems faced by various user groups of LPD systems in Texas. The results will help AgriLife and TCEQ better understand the current situation related to the use of LPD systems and to determine if any regulatory changes are needed. The field demonstration and research project will allow AgriLife to determine if the alternative design is significantly different from the conventional design and if the conventional design has significant problems in terms of getting adequate effluent treatment and ability to maintain the system. Results from both (survey and field research) would allow TCEQ to better regulate use of LPD systems in Texas and would assist OSSF designers in offering their services to a wider group of clients with improved design.

High Strength Waste and Dosing of Aerobic Treatment Units (P3)

Two identical, 500 GPD rated, ATUs representing the "most commonly" used ATU type in Texas will be purchased and installed at the AgriLife WWRF Center. A mixing tank will be installed upstream of the experimental ATUs for manipulating the influent organic strength introduced to each system simultaneously. The mixing tank has hydraulic access to a local wastewater stream which will be amended with a manufactured high-strength waste Three substances, milk powder, dextrose, and animal blood are being evaluated as amendments to raw wastewater for increasing BOD concentrations. ATU pumping and control systems will be configured to implement the demand-dosed loading schedule specified by NSF STD40 and an equalized timed-dosed loading schedule consisting of 12 uniform doses spread over 24 hours.

Various concentration-flow-dosing combinations will be evaluated over a range of organic loadings to improve the understanding of ATU performance under changing water use paradigms (i.e., conservation and greywater reuse). Four organic concentrations at two flow levels under demand-dosed and time-dosed operation are planned. ATU performance will be evaluated by comparing the five-day biological oxygen demand (BOD5) and Total Suspended Solids concentrations of the ATU influent and effluent streams.

Work Plan, Experimental Design, and Monitoring

Field and laboratory experiment activity will be conducted for a period of one year for all three projects, and will follow TCEQ and USEPA standards (EPA, 2001; TCEQ, 2014). Below are reported details for each project, including objectives, work plan, experimental design, and monitoring.

On-site Wastewater Reuse (P1)

This research addresses Research Topic (RT) 2.3.4 (black water non-potable reuse) described under TCEQ RFGA #582-19-93772. The project is designed to study feasibility of using NSF STD40 and NSF STD350 approved technology in "real world" conditions for reusing combined wastewater onsite. Wastewater reuse is being considered as a viable alternative source for meeting the water demand. Technologies are available for onsite indoor reuse of wastewater for toilet flushing, however, their use in Texas is still in an infant stage due to absence of real-world research and demonstration. The goal of this study is to fill that knowledge and experience gap. Performance will be assessed by differences between influent and effluent condition measured by five-day biological oxygen demand (BOD5) and total suspended solids (TSS) for both technologies.

Goals

- Compare performance of NSF STD350 and NSF STD40 approved technologies in a real-world operating condition against the effluent quality requirements specified in Chapter 210.82(b)(8) of the Texas Administrative Code, Title 30, Part I (30 TAC);
- Collect performance information on commercial reuse systems operating in Harris County and at TXDOT facilities.
- Prepare a concise report specifying the need for modifications of standard on-site wastewater treatment-train or maintenance requirements to improve quality and reliability of effluent for non-potable reuse purposes.

Objectives

- Perform necessary changes to the BioBarrier® and Clearstream® on-site wastewater treatment technologies and get them ready for this experiment.
- Finalize "normal" and "abnormal" operating conditions and operate the unit to collect data.
- Conduct phone interview and site visits with Harris County and TXDOT to gather design and operational information on their non-potable reuse facilities.
- Prepare data sets on effluent quality observed at the center and at other reuse facilities for analysis to determine answers to the research questions.
- Prepare detailed and summary reports along with PowerPoint presentation for submittal.

Research Questions

The proposed applied research and demonstration project is designed to answer the following three main questions:

Q1. Do NSF STD350 and NSF STD40 approved technologies operating in a real-world condition meet the effluent quality requirements specified in 30 TAC Chapter 210.82(b)(8)?

Q2. Is the experience with existing on-site reuse facilities operating in Harris County and at TXDOT rest-facilities satisfactory?

Q3. Are modifications needed to a standard on-site wastewater treatment train or maintenance requirements to improve quality and reliability of effluent for non-potable reuse?

Reuse Plumbing Configuration

As shown in Figure 1, a continuous wastewater flow will be supplied by the RELLIS Campus wastewater treatment facility to the existing lift station operating near the AgriLife WWRF Center. Raw wastewater will be added to the existing 3,000-gallon common tank that supplies raw wastewater to all three research projects. A dedicated pump will supply raw wastewater to the primary/trash tanks for both the BioBarrier® MBR 0.5 and Clearstream® NC3 reuse systems. Four automatic samplers (Sampler # 11, 12, 13, and 14) will be used for collecting composite influent and effluent samples during the experiment.

Experimental Design

The experimental design will include:

- Operating reuse system under "normal" conditions:
  - Influent flow within ±10% 225 GPD, BOD/TSS 300 mg/L, blower operation according to manufacturer's recommendations, alarm(s) attended within 24 hr.
  - Effluent sampling and observation for 9 months.
- Operating reuse system under "abnormal" conditions:
  - Influent flow variations as shown in the following table, blower operation on/off during a week, alarm(s) ignored for >48 hr. to simulate system abuse.
  - Effluent sampling and observation for 9 months.

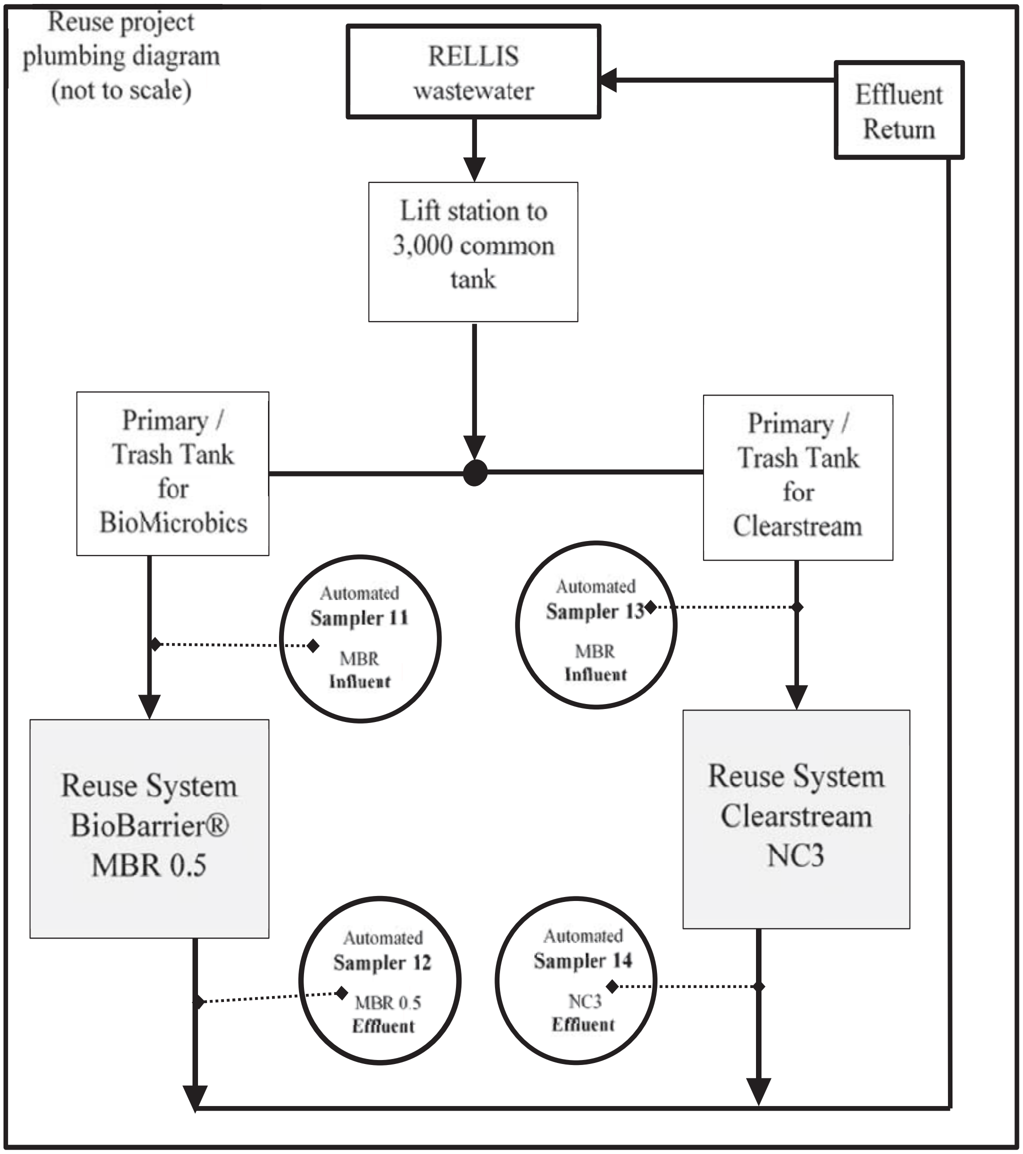

Figure 1. Onsite Wastewater Reuse experiment plumbing.

Table 1. Influent flow variation.

Test Run	gal/day	BOD5 mg/L	BOD5 lb/day
TR1	225.0	300	0.56
TR2	180.0	375	0.56
TR3	157.5	900	1.18
TR4	180.0	1,000	1.50

Neglected operation and monitoring conditions simulation during TR2, 3, and 4:

- Blowers turn off and remained off for three days or until odor is noticed;
- Alarms ignored for more than two days or until effluent surfacing noticed;
- System operation not monitored for three weeks.

Low Pressure Dosing (P2)

This research addresses RT-2.3.3, which questions the adequacy of North Carolina State Sea Grant College Publication UNC-SG-82-03 (Cogger et al., 1982) currently used to aid in low-pressure dosing field design. The Solicitation suggests that "research is needed into whether the design can be improved" in terms of effluent distribution over time, and ability to maintain the distribution system. AgriLife will compare two new designs of low-pressure dosing trenches with a control. Both new designs will have distribution holes facing up, but one will use orifice shields on top of each hole, and the other will use leaching chambers in which the distribution pipe will be placed. The control configuration will be designed with holes facing down following 30 TAC Chapter 285, and Publication UNC-SG-82-03. Septic tank effluent will be used to load the trenches at a loading rate based on the soil textures as outlined in 30 TAC Chapter 285.

Soil moisture probes, pressure gauges, and a video camera will be used to observe and measure the uniformity of effluent distribution in the trenches, pressure in the distribution lines, and bio-mat formation within the trench bottom area. Septic tank effluent samples will be collected and analyzed for Total Suspended Solids (TSS) and 5-day Biochemical Oxygen Demand (BOD5) to determine if the strength is within the typical septic tank effluent range for both of these parameters. Soil moisture will be measured continuously, while other monitoring will be conducted on a weekly basis.

Goals

- Identify problems reported by regulators, owners and designers of LPD systems in Texas;
- Evaluate alternative LPD system designs and install two alternatives for evaluation;
- Evaluate and compare alterative LPD designs with the conventional design; and
- Develop LPD design recommendations to overcome problems reported with the conventional design.

Objectives

- Create a survey form based on interviews with regulators, owners, and license holders;
- Obtain TCEQ approval of survey and conduct interviews and public education;
- Identify alternative LPD system designs and maintenance schemes based on literature review and additional surveys;
- Select design configurations, obtain TCEQ approval of experimental design, and obtain permit from county;
- Obtain permit and construct experimental LPD system at the research site;
- Run experiment, monitor waste distribution uniformity and maintenance requirements, and analyze the data to determine if the alternative designs perform better, worse, or the same as the conventional design; and
- Submit final report documenting surveys and field demonstration and recommendations for improving LPD design and maintenance along with suggested changes to Texas regulations.

Research Questions

The proposed applied research and demonstration project is designed to answer the following three main questions:

Q1. What are the operational problems faced by the users and operators with the current LPD design in Texas?

Q2. Can the current design with holes facing down be improved with holes facing up, to achieve better distribution of effluent and to allow for better maintenance of LPD systems?

Q3. Are changes required in the current design specifications of an LPD system in 30 TAC Chapter 285, and if so what changes are to be recommended?

LPD Plumbing Configuration

As shown in Figure 2, a continuous wastewater flow will be supplied by the RELLIS Campus wastewater treatment facility to the existing lift station operating near the AgriLife WWRF Center. Raw wastewater will be added to the existing 3,000-gallon common tank that supplies raw wastewater to all three research projects. A dedicated pump will supply raw wastewater to the Septic Tank for LPD System. One automatic sampler (Sampler #21) will be used to collect weekly samples from the septic tank effluent. A septic tank effluent will be used to time-dose the LPD field following the allowable loading application rate specified in the permit.

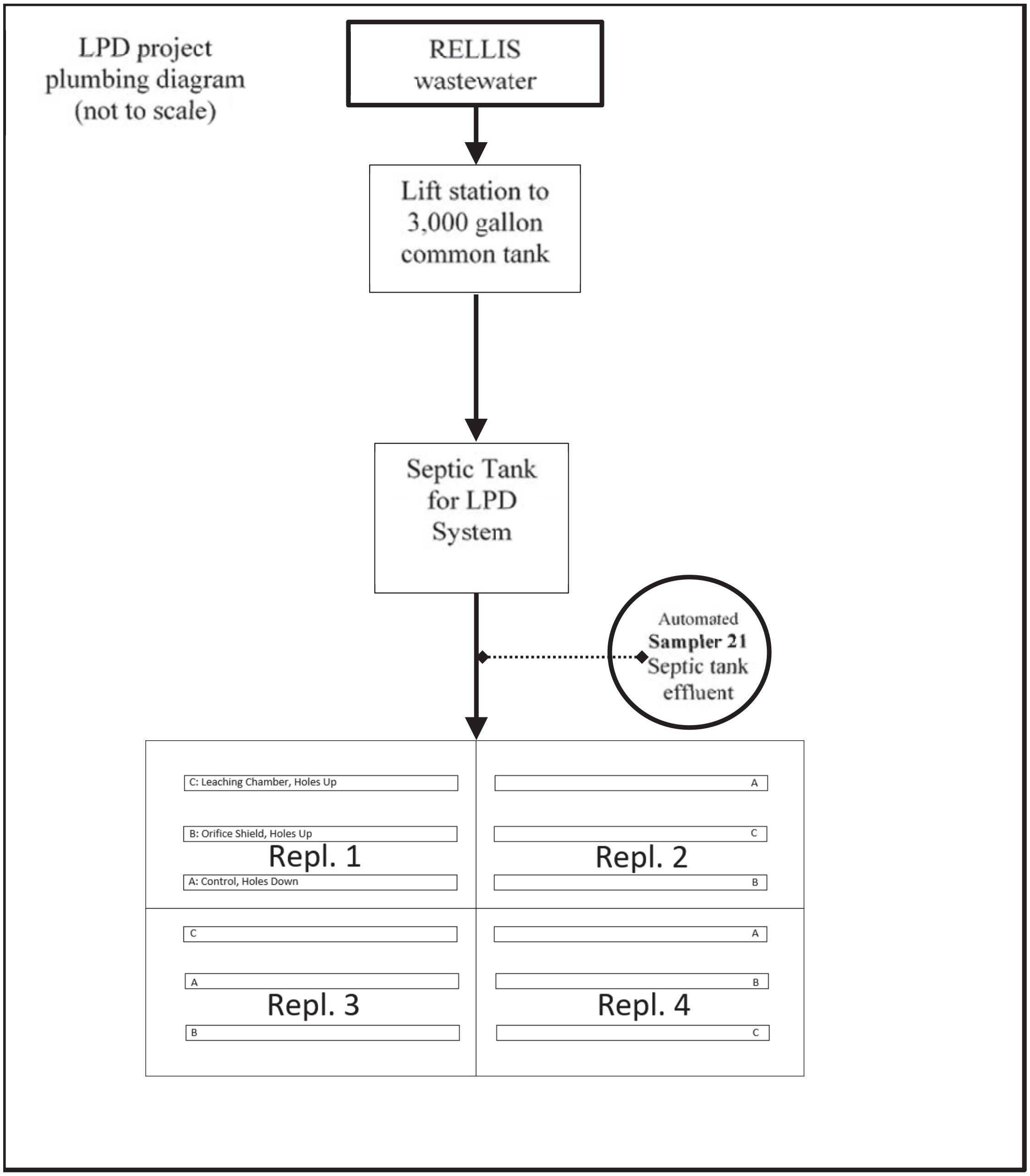

Figure 2. LPD experiment plumbing.

Experimental Design

The experimental design will be a randomized block with three (3) configuration treatments (Figure 3 shows the cross-section views) and four (4) replicates:

A. Holes facing down with no back-flushing laterals (control);
B. Holes facing up protected by orifice shields and back-flushing laterals; and
C. Holes facing up protected by leaching chambers and back-flushing laterals.

Treatments A and B will be back-flushed monthly. With the randomized block design, we will group treatments into blocks. Such design has the advantage that the variability within blocks is less than the variability between blocks; therefore, the effect of any variance on soil uniformity on results is minimized. Trenches within each block will be randomly assigned to treatments.

In each replicate, the tentative drain field design will include the following:

- Three (3) trenches sized according to 30 TAC Chapter 285 and excavated in parallel to the natural ground surface contours (e.g. 50 feet long, 18 inches deep, 24 inches wide, and 5 feet apart side to side); each trench will host one of the three treatments;
- Lateral lines will be 1 to 1 ¼ inch in diameter, placed on top of 12 inches of pea gravel or larger porous media gravel (or hanging on top of a 2-feet large leaching chamber), with 1/8 to 5/32-inch holes, spaced 3 to 5 feet; and
- Inspection ports, placed at the beginning, middle, and end of each lateral.

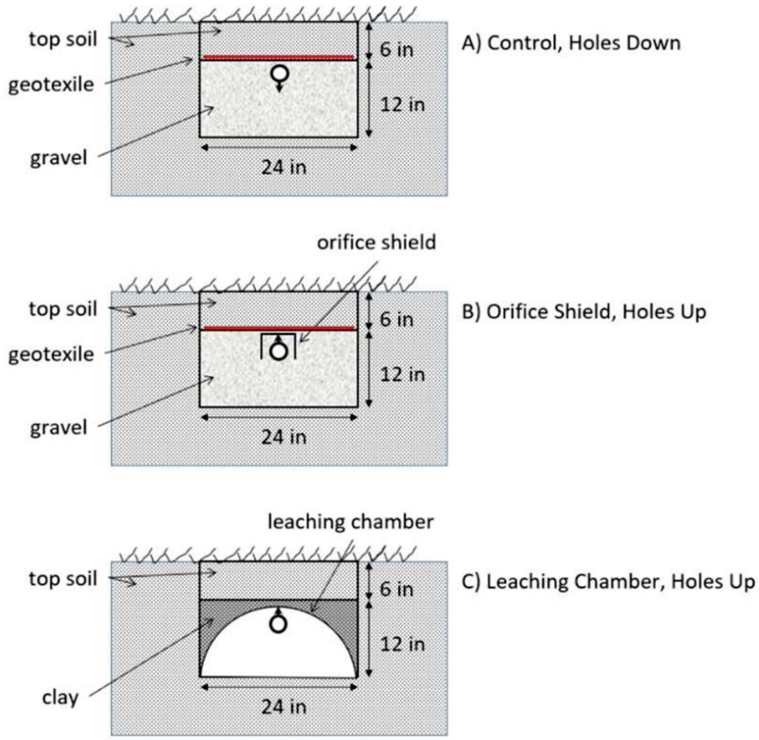

Figure 3. LPD experiment plumbing.

Sampling of septic tank effluent and monitoring of the LPD field will be conducted as following:

- Effluent uniformity and bio-mat build formation, recorded with a video camera, through the inspection ports in each trench, once a week;
- Pressure at the end of distribution lines, measured with pressure gauges, once a week;
- Soil moisture adjacent to the trench, measured with soil moisture probes (e.g. Time Domain Reflectometry) measured continuously and data down-loaded as needed; and
- Septic tank effluent sample taken once a week, sampling day changed on a weekly basis.

High Strength and Non-Dosing vs Dosing (P3)

This research addresses RT-2.3.1 questioning the performance adequacy of NSF STD40 Aerobic Treatment Unit (ATU) designs under increasing organic strength, and RT-2.3.2 questioning the effect of equalized dosing on NSF STD40 ATU designs. Eight concentration-flow-dosing combinations will be evaluated to improve the understanding of ATU performance under changing water-use paradigms. Four flow rates at 7 organic concentrations yielding 5 organic loads will be evaluated under demand-dosed and equalized time-dosed operation. Performance will be assessed by differences between influent and effluent condition measured by five-day biological oxygen demand (BOD5) and total suspended solids (TSS) during 8 experimental Test Run (TR) 2-week scenarios. Relative performance of equalized time dosing will be determined by comparison with simultaneous demand dosing results.

Goals

- Determine influent concentration at which a NSF STD40 approved ATU is unable to attain effluent quality criteria specified in the 30 TAC Chapter 285.32(e) when loaded with increasing strength wastewater under normal and reduced flow; and
- Determine if influent equalized dosing of a NSF STD40 approved ATU when loaded with increasing strength wastewater, at standard and reduced flows, improves ability to meet effluent quality criteria specified in the 30 TAC Chapter 285.32(e).

Objectives

- Identify the ATU most commonly used in Texas, based on issued permits and expert opinion;
- Install two identical 500 GPD ATUs at the AgriLife WWRF Center;
- Utilize a common tank upstream of parallel ATU trains to manipulate influent concentrations;
- Conduct 8 experimental scenarios examining different organic concentrations and dosing schedules based on NSF rules upon parallel ATUs;
- Assess individual ATU performance between influent and effluent BOD5/TSS and between demand dose (3Do/24Hr @ 35%, 25%, 40%) and equalized time dose (12Do/24Hr @ 8.33%) conditions.

Research Questions

The proposed applied research and demonstration project is designed to answer the following two main questions:

Q1. Is current ATU design adequate (meets NSF Standard 40 effluent requirements) when BOD5/TSS concentration increases due to: (a) water conservation fixtures and/or (b) graywater reuse?

Q2. Does equalized time dosing improve ATU performance under: (a) NSF STD40 design concentration, (b) increased concentrations and loads.

ATU Plumbing Configuration

As shown in Figure 4, a continuous raw wastewater stream will be supplied by the RELLIS Campus wastewater treatment facility. Influent will be directed from the influent metering tank to a common mixing tank upstream from the experimental ATUs. Organic amendments will be added to this tank to bring the influent organic concentration to target values. This tank will also serve as the influent sampling point, common to both ATUs (Automated Sampler #31). Parallel ATUs (A and B) will receive the amended influent at different dosing schedules. The effluent will be sampled after passing through each ATU (Automated Samplers #32 and #33) prior to return to the RELLIS Campus wastewater treatment facility. ATUs will be operated at 45% maximum hydraulic capacity (i.e., 225 gallons per day).

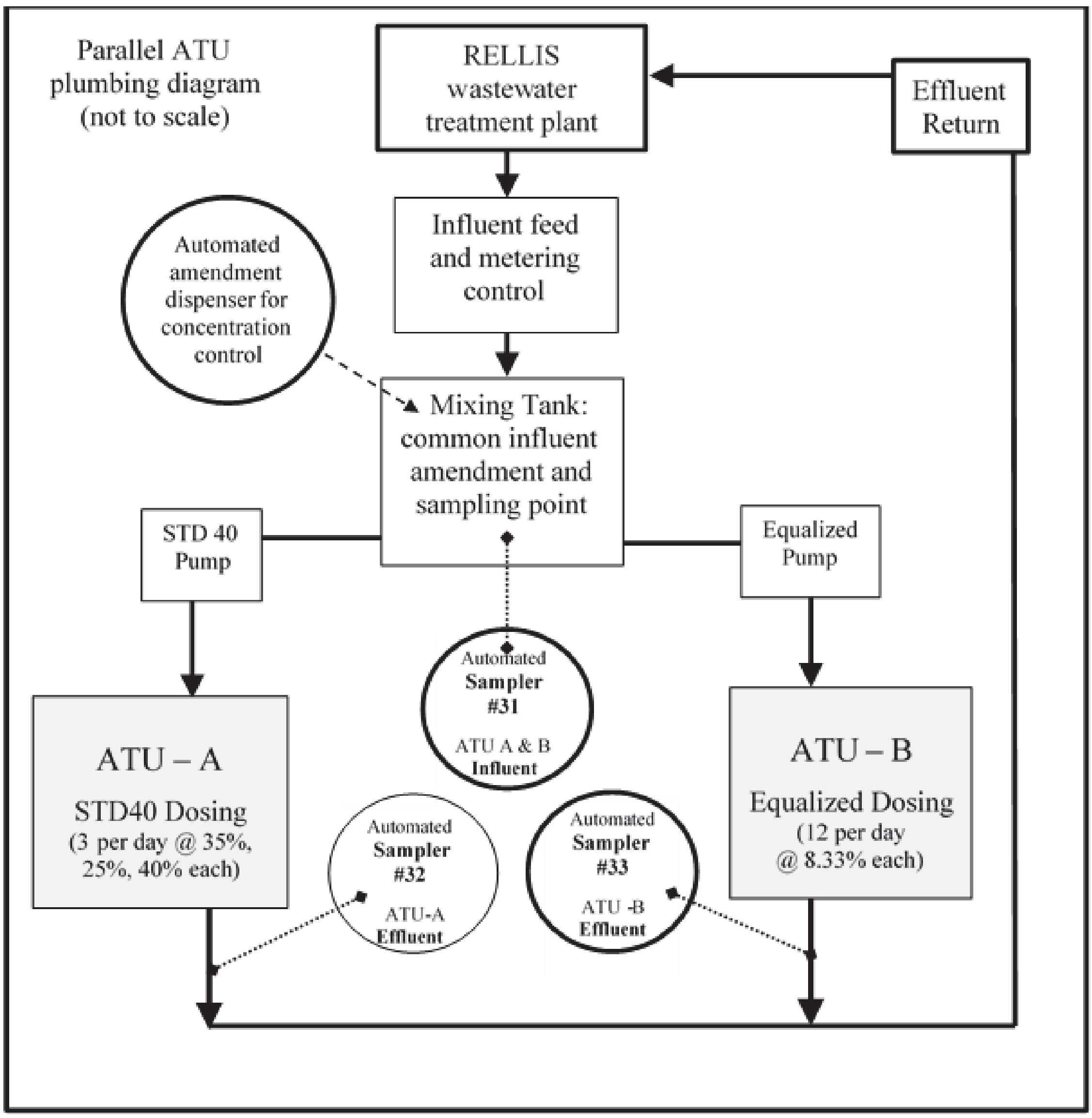

Figure 4. High Strength and dosing experimental plumbing.

Experimental Design

Required amendment component amounts have been estimated from an unpublished data source and an assumed raw wastewater influent concentration. Preliminary Manufactured High Strength Wastewater (MHSW) batches will evaluated to attain target concentrations prior to dosing of ATUs during experimental test runs.

Table 2. Experimental Design.

Test Run[a]	Week	Unit A (demand dose)		Unit B (equalized dose)		Organic Load
		[gal/day]	[mg/L]	[gal/day]	[mg/L]	[lb/day]
TR1	6	225.0	300	225.0	300	0.56
TR2	12	180.0	375	180.0	375	0.56
TR3	18	157.5	430	157.5	430	0.56
TR4	24	112.5	600	112.5	600	0.56
TR5	30	112.5	800	112.5	800	0.75
TR6	36	157.5	900	157.5	900	1.18
TR7	42	180.0	1000	180.0	1000	1.50
TR8	48	225.0	1000	225.0	1000	1.88

[a] 6-week format: 2-week equilibration, 2-week sampling, 2-week review/prep for next run

Table 3. Manufactured High Strength Waste Amendments.

Test Run	Target Organic Concentration [mg/L]	Dextrose [lbs]	Dried Milk [lbs]
TR1	300	9.87	2.06
TR2	375	13.58	2.83
TR3	430	16.29	3.39
TR4	600	24.68	5.14
TR5	800	34.56	7.20
TR6	900	39.49	8.23
TR7 and TR8	1000	44.43	9.26

Dosing Protocol

Hydraulic loading (i.e., flow rate in gallons per day) - to the experimental ATUs will be assessed by empirical records of pump capacity and operational time (i.e., pump cycles). Pump cycles will be recorded by system controllers. ATU dosing will follow two protocols; Standard 40 dosing (i.e., 35% of daily flow volume between 6 - 9am, 25% between 11am - 2pm and 40% between 5 - 8pm) and time dosing (i.e., 8.3% of daily flow volume at 2-hour intervals, 12 per 24 hours). Pump run times will be calibrated to deliver the flow volume required by each dosing method. Initial hydraulic loading will be imposed at 50% of ATU design flow rating (i.e., 250gpd for a 500gpd unit).

Sampling Protocol

During each experimental 2-week test run, a 24-hour composite sample, consisting of 24-100 mL sub-samples collected hourly, will be collected at the common influent and separate effluent streams of each ATU twice per week. A total of 8 samples will be collected from each monitoring point during each test run. Samples will be collected using automated refrigerated water samplers (Model: Avalanche, ISCO Lincoln, NB). Samples will be analyzed for BOD5 and TSS.

Conclusion

All three projects have the potential for impacting OSSF management and regulation in Texas, and field activity implementation has already started. Although COVID19 emergency is causing some delay with respect to the original scheduled timeline, we foresee that all planned research activity will be performed as listed in the contracts, and that we will be able to present preliminary results during the next year annual meeting.

Acknowledgements

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