Task 1. Request for Proposals:

Wastewater Reuse for Rural Communities

Task proposed and developed by Wilson & Co; Souder, Miller, & Associates, and EPA ORD

Background

Water is a precious commodity that is becoming limited in availability, particularly in the southwest. Prolonged drought, elevated temperatures [1], reduced runoff [2], and depleted groundwater resources [3] are contributing to a critical need to reuse and recycle wastewater even in smaller communities.

Wastewater treatment for beneficial reuse is becoming increasingly sophisticated and some are expanding to accommodate reuse options. Larger cities have the resources to employ state-of-the-art treatment systems. Because these come at a high cost, they are economically feasible only when processing large volumes of water, and they require operational support and maintenance that are beyond the resources of small rural communities.

Historically, disadvantaged rural communities have not been able to incorporate treatment for reuse. They might use septic systems at individual properties or facultative ponds, neither of which allow the communities to reuse the water for beneficial purposes. Increasing water scarcity calls for upgrades to these systems that will allow small communities with limited resources to economically treat their wastewater for reuse.

Wastewater Treatment in Rural Communities: Current Practices

This task addresses the scenario of wastewater being minimally treated in simple ponds or facultative lagoons. The facultative lagoon is a wastewater-filled shallow (1.2 – 2.4 m deep) earthen basin that is characterized by a region of anerobic waters at the bottom and aerobic waters at the top. Facultative lagoons are not mechanically aerated or mixed. The typical composition of untreated domestic wastewater is provided in Table 1 [5].

Wastewater is piped into the basin, and solids settle to the bottom forming a layer of sludge that decomposes primarily by anaerobic fermentation. Biodegradable organic matter in the upper layer of water is degraded aerobically by algae. It is interesting to note that algae and bacteria (the dominant organisms in a facultative lagoon) are mutually beneficial to each other: bacteria ferments sludge and releases CO_2. Algae takes in CO_2 and releases O_2 during respiration [4].

After wastewater is treated, the typical rural community will allow the water to evaporate, but some will apply it to nearby fields or allow it to infiltrate into the substrate. However, in times of increasing water scarcity, rural communities are in need of affordable and maintainable ways of treating their wastewater for beneficial reuse to meet local water demands.

Some rural communities employ wastewater treatment, but they are not able to achieve the quality levels of larger towns and cities. The greatest limiting factor is cost of implementing a sophisticated water reuse system, including building expensive processing structures and conveyance to end use. Even if they were able to build the infrastructure, most small communities lack skilled technicians needed to operate and maintain the system.

Rural wastewater volume flow rates are considered to be in the "minor category," processing less than 1 million gallons per day (1 MGD). (Table 2 refers to "minor waste water treatment plants" (WWTP)). For example, the Village of Columbus, NM (population ~1050) has two separate lagoon treatment systems. One treats 6,300 gallons per day (GPD) and the other treats 95,860 GPD.

Water Reuse Parameters

As a baseline for water treatment, teams will follow the New Mexico Environment Department's guidelines for reclaimed wastewater. Your team's minimum goal will be to meet Class 1B requirements. Once that benchmark is achieved, teams are encouraged to refine their processes to meet Class 1A requirements. The Class 1A and 1B uses are described below; Table 2 lists specific water quality values for these two classes of reclaimed wastewater.

Class 1A Reclaimed Wastewater: This is the highest quality reclaimed wastewater. It can be broadly used, except for direct human consumption, food handling, or processing. Approved uses include backfill around potable water pipes and irrigation of food crops. [6]

Class 1B Reclaimed Wastewater: This is the second-highest quality reclaimed wastewater. It is suitable for uses in which public exposure is likely. Approved uses include recreational or ornamental impoundments; irrigation of parks, school yards, golf courses, and urban landscaping; snow making; street cleaning; toilet flushing; and backfill around non-potable piping. [6]

For more water reuse information, including complete water reuse tables, see NMED report. For example, not included in this RFP are values for Class 2 Reuse (such as for livestock watering) [6].

Although other parameters, such as coliform (which is treated by disinfection) are extremely important in wastewater treatment, the two parameters from Table 2 that are particularly challenging when providing low-cost wastewater treatment are:

- **BOD_5** – The 5-day Biochemical Oxygen Demand is a measure of undesirable organic matter in a sample of water. Usually expressed in mg of oxygen per liter of water (mg/L), it is the amount of dissolved oxygen (DO) that will be required by aerobic microorganisms to decompose the organic matter present in a sample of water. High BOD_5 values indicate that organic matter is high and requires more oxygen to help aerobic organisms consume it.

  BOD_5 will be a challenging parameter to achieve at low cost because it requires incorporating oxygen into the water. Historically, the amount of DO has been increased by mixers/aerators and blowing fans over the water. These are costly, energy-intensive process. Your team is challenged to develop inexpensive alternative solutions for increasing DO in the water.

- **TSS** – The total suspended solids consist of the dry weight of undissolved particles that can be trapped by a filter. Turbidity, which indicates the light penetrability of water, can be used as a surrogate measure of suspended particle levels.

  TSS can be challenging for communities in terms of delivering consistent quality, system maintenance, and waste disposal. Suspended solids removal is important for risk management as it can contain pathogenic microorganisms and other contaminants of concern. Solids in effluent can also impact the performance of downstream reuse processes, e.g., irrigation systems.

Task 1. Wastewater Reuse for Rural Communities

Problem statement

Your team will research, evaluate, and design a set of innovative treatments that can be added to current pond or lagoon treatments to enable wastewater treatment plants in rural communities to reuse their water.

1. Cost-effectively treat medium- to low-strength* wastewater for Class 1B reuse (Table 1).
2. Judges will consider giving additional points for achieving Class 1A Reclaimed Wastewater standards for medium- to low-strength* water.

   ** At the time of this printing, the water strength requirements have not been constrained. They are dependent on the sample of lagoon water that we will be able to source for the bench-scale demonstration at the contest – watch the FAQs for updated information—email us to get on our mailing list for this task*).
3. Based on water-treatment quality, effluent volume expected, and potential reuse options and demands, evaluate the cost vs benefit of implementing treatments beyond Class 1B.
4. In addition, your treatment will meet the specifications in Table 2 for the following parameters*.
   a. BOD_5
   b. TSS or Turbidity
   c. Total Coliform

   *Note that TKN, Nitrate, and Phosphate will not be evaluated at the contest because they are not specified in the NMED document for Class 1A/1B/2 wastewater standards. Be aware that these are extremely important water quality parameters. Acceptable thresholds for them vary according for fit-for-purpose reuse.
5. Your design should enable a rural community to implement, operate, and maintain the treatment systems simply and affordably.

Design requirements

Your proposed design should provide specific details and outcomes as follows.

- Design a set of treatment processes that will prepare existing lagoon wastewater to a minimum of Class 1B standard.
- Your team may choose to improve the water quality to Class 1A after Class 1B standards have been achieved.
- Your solution should prioritize:
  - Innovative solutions
  - Minimize environmental impact (including minimizing chemical and energy usage)
  - Simplicity of implementation
  - Minimization of cost, including minimizing chemical additives and power consumption
  - Minimization of waste and/or production of undesirable byproducts
  - Ease of operation and maintenance
  - Minimization of footprint
- Your solution should scale up to treat 100,000 GPD of wastewater.
- Provide a process-flow diagram of your treatment processes, complete with mass and energy balances.
- Address management of the residuals. If possible, identify a beneficial use of the solids (although it is beyond the scope of this project to treat the solids for reuse in the bench-scale demonstration).

- Present a Techno-Economic Assessment and Analysis (TEA) to construct your proposed water treatment processes at a full-scale rural wastewater treatment plant that treats 100,000 GPD (0.1 MGD) and compare these costs to typical existing water treatment in rural communities.

  The TEA will include your estimate of capital costs (CAPEX), operational costs (OPEX) for a full-scale solution, and appropriate graphical representation of your cost data.
  - Capital expenses typically include, but are not limited to, equipment, pipes, pumps, etc. Do not include costs of buildings and appurtenances to the treatment process.
  - Operating expenses (OPEX) should be calculated as cost/1000 gallons of treated wastewater, including, but not limited to, materials needed, including consumables (chemicals, sacrificial components, etc.). Include these operating costs: staff labor rate of $50/hour; solids disposal costs ($50/ton); electricity rate of $0.10/kWh.
  - Include a cost/benefit analysis to assess the potential water reuse demands and the value of treatment beyond Class 1B.
  - Consider the impact of the operating expenses on local consumer utility bills.
  - Teams are advised to create a multi-disciplinary team by inviting a business major to help draw up economic plans for full-scale implementation of your designs.
- Address any benefits of the selected treatment process. For example, providing wildlife habitat, green space, heat/power generation, nutrient recovery to offset costs in the TEA.
- To be considered for the WERC P2 Award, in a separate section of the report (titled "Pollution Prevention"), document success in improving energy efficiency, pollution prevention, and/or waste minimization, as it applies to your project.
- Address safety aspects of handling raw wastewater and any final products. Safety issues for the full-scale design should be addressed in the written report. Safety issues for the bench-scale demonstration should be addressed in both the written report and the Experimental Safety Plan (ESP).

Bench Scale Demonstration

Bench-scale demonstrations will serve to illustrate the design considerations listed above. In particular, your team's bench-scale apparatus will demonstrate that your process(es) can achieve effluent that will, at minimum, meet Class 1B requirements. The bench-scale apparatus should demonstrate a process that can be scaled up to a 100,000 gallon per day treatment system.

The bench-scale demonstration setup should include covers to contain odors.

In addition to the bench-scale demonstration, teams may include video productions, computer simulations, tabletop displays, and scale or architectural models to assist in the presentation; these inclusions can be extremely beneficial to your presentation, but shall not be substitutes for the bench-scale demonstration.

Provided at contest

Each team will be provided with one 18-liter (5-gallon container) wastewater sample to work with during the bench-scale demonstration. This will be a sample of lagoon effluent from a rural community in New Mexico.

Your team is not required to use the entire amount of the solution during the contest bench-scale demonstration. You will submit water samples for testing as described below.

Analytical Testing Procedures at the Contest

After treatment of the wastewater in your bench-scale apparatus, your team will submit three *125 mL* samples of the effluent.

Parameters will be measured using the following techniques.

- BOD_5—measured as COD (a rapid analysis that will be correlated with BOD_5)
- TSS—determined by gravimetric analysis.
- Turbidity —determined by turbidity meter
- Total Coliform—determined through Quanti-Tray analysis.

Task 1. Wastewater Reuse for Rural Communities

Pertinent Data

Table 1. Typical Composition of Untreated Domestic Wastewater [5]

Contaminants	Concentration (mg/L)		
	Low Strength	**Medium Strength**	**High Strength**
Total Solids (TS)	390	720	1230
Total Dissolved Solids (TDS)	270	500	860
Total Suspended Solids (TSS)	120	210	400
Biochemical Oxygen Demand (BOD_5)	110	190	350
Chemical Oxygen Demand (COD)	250	430	800
Nitrogen (total as N)	20	40	70
Nitrates	0	0	0
Phosphorus (total as P)	4	7	12
Total coliform	10^6 - 10^7/100mL	10^7 - 10^9/100mL	10^7 - 10^{10}/100mL
Fecal coliform	10^3 - 10^5/100mL	10^4 - 10^6/100mL	10^5 - 10^8/100mL

Table 2. Wastewater Quality Requirements and Monitoring Frequencies of Reclaimed Wastewater. [6]

Class of Reclaimed Wastewater	Wastewater Quality Parameter	Wastewater Quality Requirements		Wastewater Monitoring Requirements	
		30-day average	Maximum	Sample Type	Measurement Frequency
Class 1A	BOD_5	10 mg/L	15 mg/L	Minimum of 6-hour composite	1 test per 2 weeks for minor WWTP
	Turbidity	3 NTU	5 NTU	Continuous	Continuous
	Fecal Coliform	5 organisms per 100 mL	23 organisms per 100 mL	Grab sample at peak flow	1 test per week for minor WWTP
	TRC or UV Transmissivity	Monitor only	Monitor only	Grab sample or reading at peak flow	Record values at peak hourly flow when fecal coliform samples are collected.
Class 1B	BOD_5	30 mg/L	45 mg/L	Minimum of 6-hour composite	1 test per 2 weeks for minor WWTP
	TSS	30 mg/L	45 mg/L	Minimum of 6-hour composite	1 test per 2 weeks for minor WWTP
	Fecal Coliform	100 organisms per 100 mL	200 organisms per 100 mL	Grab sample at peak flow	1 test per week for minor WWTP
	TRC or UV Transmissivity	Monitor only	Monitor only	Grab sample or reading at peak flow	Record values at peak hourly flow when fecal coliform samples are collected.

30% Project Review
Suggested submission date: Feb. 6, 2023
Final submission date: February 24, 2023

An engineering "30% Project Review" reviews the engineering firm's preliminary design and aspects of a project with a client. It provides the client an opportunity to suggest modifications for inclusion in the final design. The goal is to define the scope of the project, present a project schedule, report progress to date to meet the final deadline, and determine fatal flaws, if any.

For the design contest, the review should not exceed four pages. Submit the project review as soon as possible. You are allowed to change your plans after submitting it. Although the review is not scored, your team will receive feedback from the judges for improving your project. (The higher the quality of your review, the more help you will get from the judges.)

At a minimum, the review must include:

- **A brief description of your project:** One bulleted list outlining: goals, planned solution to the problem, and any anticipated drawbacks.
- **A project schedule:** schedule for completion of the contest solution, including progress to date.
- **Process flow diagram** with all mass and energy balances, as needed.
- **Table of Contents** planned for the technical report (place topics in order, one line per topic)

Experimental Safety Plan (ESP)
The ESP outlines your team's plans for safely operating your bench-scale demonstration at the contest. This document is submitted in February (see dates below). Instructions are provided in the team manual. The Team Leader, or a designated team member, shall attend a mandatory short course that outlines the ESP process. Teams will not be able to run a bench-scale demonstration if the ESP is not received by the deadline. Your team should follow your school's safety procedures while conducting tests prior to attending the contest.

Evaluation Criteria
Each team is advised to read the 2023 Team Manual for a comprehensive understanding of the contest evaluation criteria. As described in the manual, there are five events: a written report, a formal oral presentation, a demonstration of your technology using a bench-scale representation, a poster presentation, and a Flash Talk. Criteria used by the judges in evaluation of these five components are described in the Team Manual.

For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: Guidelines | werc.nmsu.edu

Your response to the problem statement will include consideration of the following points.

- Potential for real-life implementation (ease of operation and maintenance, affordability, etc.).
- Thoroughness and quality of the technical analysis.
- Thoroughness and quality of the economic analysis.
- Originality and innovation represented by the proposed technology.
- The results of your bench-scale demonstration.
- Other specific evaluation criteria that may be provided at a later date (watch the FAQs online).

Task 1. Wastewater Reuse for Rural Communities

Short Courses

WERC is offering two short courses:

- ***Mandatory:*** Preparing the Experimental Safety Plan. The Team Leader, or a person assigned by them, must attend the course prior to submitting the ESP (and before February 20, 2023).
- ***Optional:*** Environmental Health and Safety (EH&S) Topics. The course is designed to prepare teams to complete the EH&S portion of their technical report. Course fees will be waived for contest-registered students, faculty, and judges. Watch the WERC website for schedules and registration information. Individuals who complete the course can earn a digital badge to add to their professional development portfolio.

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

- Today: Email us to let us know you are interested in this task. We will contact you with breaking news.
- Opening mid-December, 2022: Optional Course: WERC Safety and Environmental Topics. Live—See website for dates and times. See Team Manual for more information.
- Opening mid-December, 2022: Mandatory Course: Preparing the Experimental Safety Plan. February 20, 2023: deadline for attending. On-demand—See website & Team Manual for information.
- February 6 - 24, 2023: 30% Project Review due.
- February 6 - 24, 2023: Experimental Safety Plan (ESP) due.
- April 5, 2023: Technical Report due
- Weekly: Check FAQs weekly for updates:
    - Task-specific FAQs: 2023 Tasks/Task FAQs
    - General FAQs: 2023 General FAQs
- All dates or task requirements are subject to change. Check FAQs for updates online.

References

[1] EPA. April 2021. A Closer Look: Temperature and Drought in the Southwest. (A Closer Look: Temperature and Drought in the Southwest | US EPA). Accessed 7/11/2022

[2] NOAA. 2022. Water Supply Forecast Discussion (2022_06_01_Discussion (noaa.gov)). Accessed 7/11/2022.

[3] USGS. 2018. Groundwater Decline and Depletion (Groundwater Decline and Depletion | U.S. Geological Survey (usgs.gov)). Accessed 7/11/2022.

[4] EPA. Wastewater Technology Fact Sheet. Facultative Lagoons. U.S. EPA Municipal Technology Branch. (https://www3.epa.gov/npdes/pubs/faclagon.pdf) Accessed 7/17/22.

[5] Tchobanoglous, G., F.L. Burton, and H.D. Stensel. 2003. Wastewater Engineering Treatment and Reuse. Fourth Edition. Metcalf & Eddy Inc., New York.

[6] New Mexico Environment Department. January 2007. NMED Ground Water Quality Bureau Guidance: Above Ground Use of Reclaimed Domestic Wastewater. RS5582. (See Laws and Regulations (nm.gov)) (Wastewater Quality Tables and Approved Uses Tables — Accessed 7/15/22)