Project Name: Crumb Rubber Water Treatment Technologies and Test Stand

Project Number:

Project Track: Sustainable Technologies for the Third World

Project Family: Open Source/Open Architecture Sustainable Water Systems

Start Term: Winter 2010

End Term: Spring 2011

Faculty Guide: Sarah Brownell

Faculty Consultants:

Customer Organization: Sarah Brownell

Principle Sponsor or Sponsoring Organization: Multidisciplinary Design

Project Overview:

This project is part of the Sustainable Water Systems family on the Senior Design Project Roadmap with the mission to provide a compelling solution to the problem of sufficient, accessible, economical and sustainable potable water supplies for the world's population. The goal of this particular project is to develop new applications for using crumb rubber in water treatment technologies.

Crumb rubber is made from ground up recycled tires and has been used on turf fields and as a construction material until recently when Dr. Yuefeng Xie at Pennsylvania State University suggested using it as a water filtration medium for ballast water on ships. For details, see: https://edge.rit.edu/content/R11007/public/Crumb%20Rubber%20Filtration.pdf. Dr. Xie's research led a DPM student to the idea of using crumb rubber for drinking water treatment.

Waterborne diseases kill approximately 2 million people a year. Most of these deaths could be avoided with simple treatment of the contaminated water before it is consumed. There are many types of water treatments systems, but they are often too expensive, too complicated, too slow, or otherwise inadequate for practical use in developing countries where they are most needed to prevent illness. The project team will develop the idea of using crumb rubber in filters, solar pasteurization, and other drinking water disinfection technologies. Much of the project will be design of experiments to determine if and/or how crumb rubber is a suitable material for drinking water treatment.

Crumb Rubber for Filtration: Ultraviolet disinfection is one type of treatment system that has been adapted for use in developing countries by various RIT groups including Senior Design teams, the Engineers for a Sustainable World student organization, and students working with B9 Plastics, a local not for profit company dedicated to social and environmental improvement through the use of plastics. For many types of water sources, UV disinfection requires a pre-filter, but current filter technology is expensive, heavy, or difficult to use. Sand filters are one of the least expensive and most common types of filters used in developing countries. However, sand filters have low flow rates with limited use volumes before a backwashing process must be performed. Based on Dr. Xie's findings, crumb rubber filters can be used with higher flow rates than sand filters and it is easier to backwash the system, making it easier to maintain. The performance of other disinfection systems (hypochlorite, SODIS or solar disinfection) would also be improved with the use of a pre-filter. Additionally, other filter media or treatments might be able to be added to the crumb rubber filter to improve its disinfection capability.

Crumb Rubber for Pasteurization: Because of its ability to retain heat during exposure to the sun, crumb rubber may also be able to be used to improve solar pasteurization technologies such as the solar pasteurizer developed by a Senior Design team in 2007 or to improve the SODIS (solar disinfection using clear plastic bottles in the sun) process. Solar pasteurization requires that water reach 65 C for disinfection. SODIS uses heat from the sun, UVA radiation which disrupts DNA, and visible light reactions to inactivate pathogens. Both technologies are appropriate for developing countries because they use a renewable resource (the sun) as a power supply, are relatively inexpensive to construct, and are easy to use. The main disadvantage to these technologies is that they are slow and have large footprints. Crumb rubber maybe able to increase the speed of disinfection or decrease the footprint.

Other Water Treatment Applications: As the team learns more about crumb rubber as a material and about the methods of water treatment, they may be able to suggest other uses for the material or other potential recycled materials that might be used in water treatment.

Staffing Requirements:

2 ME's: between them, they should have the following skills: materials science and/or interest or experiences in water chemistry, ability to design scientific experiments, fluid dynamics, CFD analysis, heat transfer, design for manufacture, ProEngineer or Solidworks.

1 ISE: (optional) human factors and ergonomics, economic and environmental sustainability analysis (life cycle analysis), ability to suggest other materials that would meet water treatment requirements while protecting the environment

Continutation, Platform, or Building Block Project information:

This project could be considered a continuation of project P07401, EPA Water Disinfection Project which developed a low cost water pasteurizer for Venezuela.

This project is not a direct continuation of previous UV disinfection projects, but would augment previous and continuing projects, including P07402 ISE Water Disinfection Project, by providing an inexpensive pre-filter.

There have also been a number of other UV disinfection projects conducted outside of Senior Design:

- B9 Plastic's Better Water Maker hand crank UV system
- William Larsen and Sarah Brownell's modification of a purchased UV system for use in developing countries which later became the design used by the non-profit founded by RIT alums, Clean Water for the World.
- ESW projects conducted to install UV units in Venezuela.

Detailed Project Description:

Customer Needs

1. Crumb rubber has not previously been used for drinking water applications, therefore, the following information must be determined by research and experimentation:
    a. Surface chemistry at work in filtration
    b. Heat transfer properties, solar absorption, etc.
    c. Potential for forming biofilms
    d. Potential leaching of dangerous chemicals
2. If crumb rubber is not determined to be a viable media for being in contact with drinking water at various temperatures and for various lengths of time, other novel media should be considered.
3. Technologies must be compatible with multiple water sources (wells, springs, river, etc.)
4. Filters must reduce surface water turbidity to less than 5 NTU so that it can be used as a precursor to disinfection processes.
5. Filters should remove particles larger than 5 microns.
6. Filters should accommodate a flowrate of at least 5 lpm, preferably 20 lpm or more.
7. Filter head loses must be minimized. It must be determined whether the filter operates better on a gravity or pressurized system.
8. Filter must incorporate a cleaning or recharging mechanism (scrubbing, backwash, etc.)

9. Disinfector applications must either improve disinfection capabilities, increase disinfection speed or reduce the solar footprint (or any combination).
10. If pasteurization is used, temperatures must reach 65 C.
11. Additional disinfection and chemical contaminant removal capability are considered a plus (for example, reduction of E. coli through biofilm activity or silver nitrate, removal of arsenic with rusty iron or taste and odor with activated carbon, etc.)
12. Increased cost from adding disinfector applications must be minimal.
13. Technologies should be household scale, but ideally scalable to larger applications.
14. Technologies should be able to be operated with minimal training. A low literacy manual will be needed.
15. Maintenance procedures should be simple.
16. There must be a way for users to know when the technology needs to be cleaned, maintained, or replaced (head loss, flow rate).
17. Technologies should be able to be made for less than $20 US and maintenance should cost less than $5 per year.

Customer Deliverables

March 2011

1. Specifications for filter dimensions that optimize filter performance while minimizing cost, space, and operating difficulty.
2. Specifications for the most appropriate type of crumb rubber.
3. Specifications for using crumb rubber to increase disinfection rates in pasteurizers, SODIS, or other applications.
4. Data on leaching of contaminants into the outlet water.
5. Specification for cleaning systems and interconnections with the rest of the water system.

May 2011

1. A model, fully operational filter ready for more extensive water testing.
2. A model, fully operation disinfection system ready for more extensive testing.
3. Preliminary chemical and biological test results indicating viable systems.

Project Constraints

- The team is expected to meet with *Storage, Collection, and Distribution project teams* from the R11007 roadmap prior to Week 2 to agree upon the appropriate interfaces to satisfy all team requirements.

- The cost of the final product (including storage, filtering, disinfection, distribution) available to customers, must not exceed 15% of the gross income of the community for which its use is intended.
- Technologies must work in a variety of environments on a variety of water sources.
- Technologies must interface with the appropriate subsystems in the OS/OA Sustainable Water Systems (R11007) roadmap.
- The filtering device must produce water that has improved turbidity and a decrease in particulates.
- Disinfection systems must be better at removing pathogens than SODIS.
- Technologies must be robust to damage and must be easily maintained and cleaned.
- The team must provide instructions on how to use and maintain the technologies.
- Students are expected to understand the social value of this project and the impact it has on people's lives.

Regulatory Requirements

- Must meet EPA requirements for drinking water contaminants and turbidity under the Surface Water Treatment Rules.
- Must meet NSF standards for pre-filters used with UV systems.
- Disinfection technologies should strive to meet US drinking water standards.

Project Budget

Prototype materials:	$ 400	
Test stand and water testing:	$ 600	(perhaps testing equipment can be borrowed from biology department)
TOTAL	$1000	

Intellectual Property

Not applicable. Open source/open architecture.

Other

<u>Detailed Course Deliverables</u>

- Test stand for validating water treatment devices.
- Experimental test plan.
- Summary of experimental results and recommendations.
- Design drawings and specifications for a filter design using crumb rubber or another novel media.

- Design drawings and specifications for a disinfector using crumb rubber to improve results.
- Model Filter.
- Model disinfector.
- Recommendations for further testing.
- Draft user manuals.

<u>Preliminary Work Breakdown:</u>

Research

- Crumb rubber chemistry, manufacturing processes, etc. to determine which chemicals might leach from the rubber during filtering.
- Heat transfer characteristics of crumb rubber.
- Filter surface chemistry.
- Characteristics of typical drinking water sources. Development of a "typical" water for experimentation.
- Economic sustainability criteria for developing countries
- User interfaces and requirements for household filters
- Filter validation techniques

Design of numerous filter prototypes exploring dimensions, crumb rubber sizes, and other potential additives.

Preliminary LCA

Design of experimental plan to determine

- Flow rates
- Levels of chemicals leached from rubber at typical flow rates
- Head losses
- Heat transfer characteristics
- Particulate removal
- Bacteria removal
- Biofilm formation
- Volume of water filtered before cleaning/recharge for typical water sources.

Experimentation
CFD analysis

Selection of the best filter dimensions (modifications made as necessary)
Brainstorming potential improvements to remove more contaminants (additional filter media)
Design of cleaning/backwash system and interfaces with storage, disinfection, and distribution systems.
Ergonomic and user considerations, safety
Design for Manufacture
Final LCA and economic analysis
Final design and testing.

Grading and Assessment Schedule

Three Week SDI Schedule