Grainger Challenge Prize for Sustainability

Proposal Template **Due date December 31, 2005**

Name: Brian Wagner

Nationality: United States

Primary Work Institution: Chemists Without Borders

Address: 831 Monica Lane
Campbell, California 95008

E-mail: brianwagner@chemistswithoutborders.org

System Name/Identifier: Arsenic remediation via water hyacinth filtration

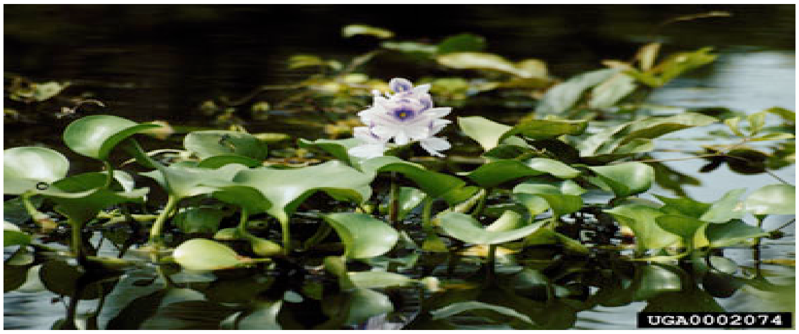
Introduction:

Chemists Without Borders is a non-profit, public benefit corporation designed to better the world through chemistry. We are trained professionals who combine science, technology, ingenuity, and cultural sensitivity to provide solutions to challenges facing people in developing areas. Our goal is to implement proven chemical technologies to alleviate human suffering regardless of profitability.

Our arsenic remediation system is based on current research that demonstrated significant arsenic removal from groundwater by a rhizofiltration process using the dried root of the water hyacinth (Eichornia crassipes) plant. The simplicity of the chemistry and overall system design make it a good fit for developing areas where large-scale public infrastructure is either not consistent or unavailable. Water hyacinth is a recognized persistent aquatic weed that grows in abundance throughout the world and could be harvested locally for use in this system.

Chemistry: Describe the basic unit operations and chemical reactions at work in your process. Provide stoichiometry, data on the quantity of the reactants used over time or per unit of water treated, the quantity of water treated, and other relevant technical information. Describe where this system or device has been used to remove arsenic from groundwater. If the device or system does not use a chemical-based process, provide full details.

Chemists Without Borders proposes to prepare an arsenic remediation system that is based upon research conducted by Dr. Parvez I. Haris, et.al.,(J. Environ. Monit., 7(4), 2005, 279-282). The research utilized a rhizofiltration system using the non-living dried root of the water hyacinth plant (Eichornia crassipes). A copy of the research paper is presented in ***Attachment 1****.*



Water Hyacinth

750 mg of dried water hyacinth root was suspended in 25 ml of tap water spiked with 200 ug/l As (III) or As (V). The pH was adjusted to 6 and the mixture was shaken for 120 minutes. The water was tested at periodic intervals for arsenic removal. A maximum removal was observed at 60 minutes residence time with the hyacinth root (93% removal for As (III) and 95% removal for AS (V)). Scaling the data required 30 kg of dried hyacinth root to treat 1000 liters of water.

Our system would require pumping water through a sediment filter to remove fines and oxidized iron before passing the water through a 55-gallon polyethylene drum that is filled with dried hyacinth root. The treated water is pumped into a 1000 gallon polyethylene storage tank, with a gate-valve spigot, for general usage. The pumping system would be powered by photovoltaic panels with a battery bank storage system or optional treadle pump.

2. Equipment: List and describe all components of the system or device, and provide a small schematic drawing or photo. Specify materials, size, weight, configuration, set-up procedures, and special handling requirements, if appropriate. Specify whether a typical householder with minimal skills and training could set up the system, or if it would require the services of a local artisan. The cost of set-up should be included in the annual cost.

Water Treatment Materials*:*

1 - 55 gallon polyethylene drum
1 - 1000 gallon polyethylene storage tank
1 - Sediment filter (cyclonic)
100 feet - _" black poly pipe – potable grade
1 - _" check valve
4 - _" cam lock fittings
Bushings – various sizes
140 kg of dried hyacinth root
Water totalizer

Solar Photovoltaic Pumping System:

1 - Submersible pump – 24 VDC
4 - 6 VDC batteries wired in series
2 - Float Switches
Misc. Cables and wires

2 - 75 watt photovoltaic cells w/ metal mounting pole and hardware
Optional load diverter to 24 VDC resistive heater element for hot water

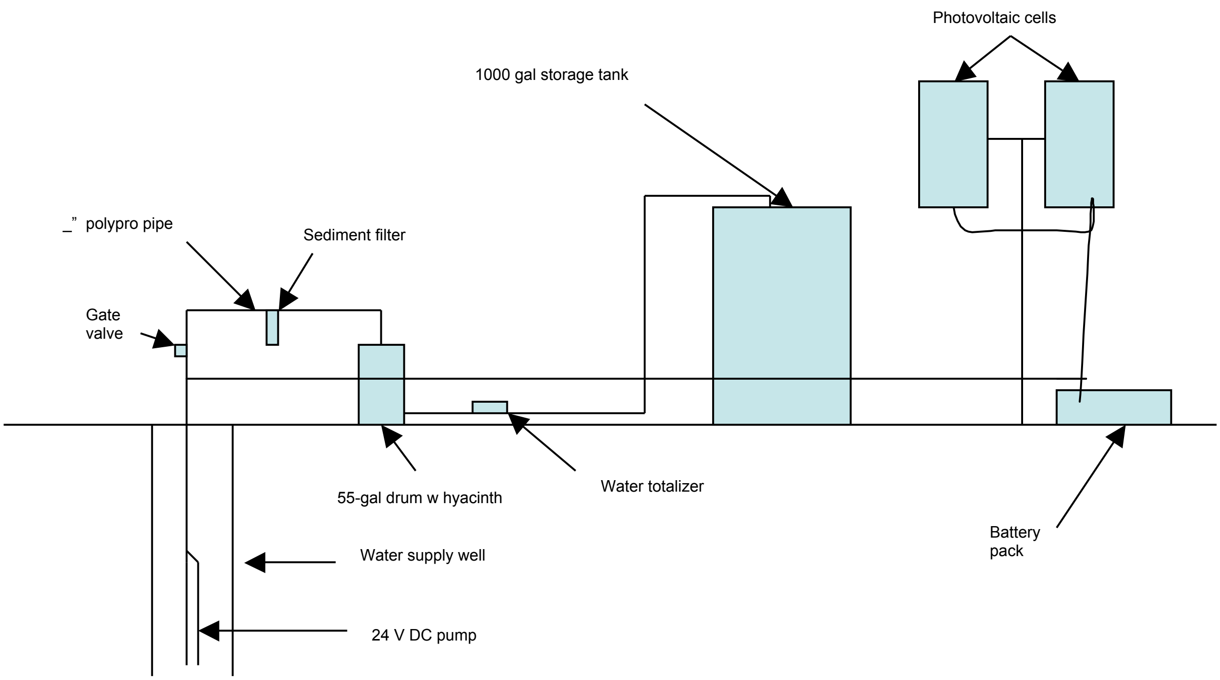
A treadle pump option could be manufactured in country and set-up on site. The pump consists of a sheet metal or cast iron pump-head, a bamboo frame with two treadles (pedals) and a bamboo or PVC strainer. It can lift water up to a maximum height of 7 meters but gives best performance, of 1-1.2 liters/second, at a pumping head of 3 to 3.5 meters. It is easy to operate, which allows the entire family to share the work load. The cheapest bamboo treadle pump costs around US $12. The more expensive metal and concrete pumps cost between US $25 to $35 dollars, complete with bore and frame.

Prior to installing a system in-country we would collaborate with Bangladeshi expatriates living in the United States to develop an appropriate training program that takes into account technological sophistication of the native population, cultural issues, and language barriers. Several examples of Bangladeshi organizations include The Bangladesh Environment Network (http://www.ben-center.org/) or The Expatriate Bangladeshi 2000 organization (http://www.eb2000.org). We would be on-site to set up the system and ensure proper operation. Local artisans would be trained on the system operation and maintenance.

Assembly and start-up of the system is estimated to take one (1) to two (2) days. This includes installation of the solar panels, wiring connections to the battery pack and submersible pump, connection of interlock features (float switches), filling the drum with dried water hyacinth root, and final plumbing connections.

System Schematic

Profile View



The approximate footprint of the filter, drum, storage tank, photovoltaic cells, and battery bank would fit in a 20' by 20' area.

The approximate weight of the individual elements in the system are:

55-gallon drum:	*25 lbs.*
1000-gallon storage tank:	*250 lbs.*
Photovoltaic cells:	*25 lbs.*
Battery Pack:	*452 lbs.*
Other Supplies:	*200 lbs.*

3. Performance: Describe how well the system removes arsenic from water. The system should be capable of providing 50 to 200 liters per day of treated water from test water that contains approximately 300 micrograms/liter of arsenic. Half of the arsenic would be reduced arsenic (III) and half oxidized arsenic (V). The groundwater would also contain reduced iron at a concentration of about 2 mg/L. The system must consistently reduce the arsenic concentration to 50μg/L. Specify how long the system can work between periods of maintenance and how performance might deteriorate during a typical duty cycle.

Based on the research conducted by Dr. Haris, et al., water hyacinth is capable of removing 93% of As (III) and 95% As (V) from an initial concentration of 200 ug/l arsenic.

We are in process of designing a pilot study in the United States to validate this data on a larger scale. Extrapolating Dr. Haris's data, the proposed system would treat approximately 4,500 liters of water before the water hyacinth absorption properties are saturated. 1,000 gallons (3785 liters) of water could be treated in approximately 17 hours at a constant flow rate of 1.0 gallons per minute (3.8 liters per minute). Assuming an average person consumes 7.5 liters of potable water per day, a single drum could provide potable water daily for 600 people. Our pilot study will be designed to test this hypothesis. A copy of the pilot study protocol is presented in ***Section 4****.*

Performance of the system could be impacted by high dissolved mineral or metal concentrations which may foul the hyacinth and reduce the absorptive properties. A sediment filter prior to the hyacinth could remove a significant amount of fines, minerals, and oxidized iron and manganese. Pressure gauges before and after the sediment filter and after the hyacinth drum would be used to determine if the system is clogging and needs maintenance.

A flow totalizer would also be installed after the water hyacinth drum to measure the volume of treated water. This data could also be used to determine when maintenance is necessary.

4. Testing: The system must have undergone testing, either in the laboratory or in the field. Provide test data that has been verified and can be replicated confirming system performance. Specify the quantities of water treated, chemical makeup, time period, and other relevant information. Specify the time and place where testing were done.

The results of Dr. Haris's research demonstrated that dried water hyacinth root can be an effective mechanism for removing arsenic from groundwater. 93% of arsenite (As III) and 95% arsenate (As V) was removed from a solution containing 200 ug/l arsenic within 60 minutes of exposure to a powder produced from the dried roots. The abundance of water hyacinth in Bangladesh minimizes the need for importing raw materials or potentially hazardous chemical treatments. Please refer to ***Attachment 1*** *for the complete research paper.*

A copy of our pilot study protocol is also provided below.

Chemist Without Borders
Arsenic Remediation System
Pilot Study Scope of Work

Introduction:

Arsenic contaminated drinking water is a major health problem in many areas of the world. Significant areas in Southeast Asia (Bangladesh and India) have identified this problem and are actively evaluating solutions. Long term health effects of arsenic poisoning include cancers of the skin, lungs, bladder, and kidneys, as well as skin disorders.

Many approaches have been developed and tested to remove arsenic from drinking water with qualified success. Chemists Without Borders is evaluating research conducted by Dr.Parvez. I. Haris, et al., (J. Environ. Monit., **7**(4), 2005, 279-282; http://xlink.rsc.org/?DOI=B500932D) to determine whether the results of this research can be expanded into a large scale treatment system. The premise of the research utilized the absorptive properties of the dried root from the water hyacinth plant (Eichhornia crassipes) to remove arsenic in both of its valence forms (As III and As V) from drinking water.

Chemists Without Borders will conduct a pilot study using a large-scale model to determine further the relationship between mass of water hyacinth root and removal of arsenic.

Preliminary Research:

Research conducted by Dr. Parvez I. Haris, et al., demonstrated that the dried root of the water hyacinth plant (Eichhornia crassipes) can readily remove arsenic from water through a rhizofiltration proccess.

A known mass of water hyacinth root was suspended in 25 ml of tap water spiked with 200 ug/l of As III or As V, pH adjusted to 6. The mixture was shaken for 120 minutes (a maximum removal rate was observed at 60 minutes). The subsequent testing of the tap water sample showed a 93-95% removal of arsenic, which would meet the World Health Organization guidelines of 10 ug/l maximum arsenic in drinking water.
Extrapolating the observed data, Dr. Haris concluded that 30 kg of root would be sufficient to treat 1000 liters of water, providing clean drinking water to a significant number of people.

Chemists Without Borders Treatment System Design:

The proposed treatment system from Chemists Without Borders utilizes a solar powered down well pump to move water through a cyclonic sediment filter trap and into a 55 gallon drum containing approximately 140 kg of dried water hyacinth root. The arsenic is removed by absorption within the root mass and the treated water is pumped into a 1000 gallon storage tank. The 24 VDC pump is powered by two (2) 75 watt solar panels with battery bank storage.

Chemists Without Borders is working with the State of California (Department of Boating and Waterways) to harvest water hyacinth for the pilot study. A significant amount of water hyacinth exists in California and the State has given preliminary approval for Chemists Without Borders to harvest following all state and local regulations.

Chemists Without Borders estimates that approximately 4500 liters of water containing a average arsenic concentration of 200 ug/l can be treated to meet World Health Organization standards of 10 ug/l with approximately 140 kg of dried root.

Pilot Test Activities:

The pilot test will be conducted over three (3) days. Equipment set-up and groundwater sampling will be conducted during the first day. The pilot study will be conducted during the following two (2) days with each day dedicated to testing removal efficiency under different operating parameters.

Day 1:
Equipment set-up and check operation.
Collect depth to water measurements from the supply well.
Collect water samples for on-site analysis of iron, manganese, sulfate, phosphorus, pH, specific conductivity, hardness, and temperature.
Collect water sample for laboratory analysis of arsenic.

Day 2:
Collect depth to water measurements from the supply well.
Start pumping and establish flow rate of 1.0 gpm.
Collect arsenic sample from the influent and effluent of sediment filter and effluent of hyacinth drum every hour.
Record pressure readings every 30 minutes.
Collect depth to water measurements from the supply well every 30 minutes.
At the end of the 8 hour test, collect a sample of hyacinth root from the drum for total arsenic and arsenic via TCLP analysis.

Day 3:
Fill drum with fresh hyacinth root.
Clean sediment filter (if necessary).
Collect depth to water measurements from the supply well.
Start pumping and establish flow rate of 1.0 gpm.
Collect arsenic sample from the influent and effluent of sediment filter.
Fill drum with water and allow to stand for 60 minutes.
Collect drum effluent sample for arsenic analysis.
Drain the drum and repeat on 60 min cycles for seven (7) cycles.
Record pressure readings every hour.
Collect depth to water measurements from the supply well every hour.
At the end of the 8 hour test, collect a sample of hyacinth root from the drum for total arsenic and arsenic via TCLP analysis.

Conclusions and Recommendations:

All data collected from the pilot study will be summarized in tables and discussed in a written report. Any changes to the treatment system design will be presented in the final report.

5. Operation and Maintenance: Provide a complete description of operation and maintenance procedures, including frequency of maintenance, material requirements, required skills, and cost. Describe how users will know when the chemical or other reactants should be replaced.

Water is drawn from a submersible 24VDC solar powered pump or optional treadle pump through a sediment filter to remove fines, iron, and manganese before flowing into a 55-gallon drum filled with dried water hyacinth root. The treated water is pumped into a 1000 gallon *storage tank. The pumping system has water level switches in the supply well and in the 1000 gallon storage tank to prevent drawing the well dry or overflowing the storage tank.*

Maintenance of the sediment filter should be evaluated daily after start-up for a least one week and may be modified depending on field conditions. Maintenance of the filter would require opening the ball valve at the bottom of the unit and flushing with water to remove any particulate matter.

In theory the water hyacinth in a single drum could treat approximately 4500 liters of water. The pilot study to be conducted will determine if that value needs revision. Spent water hyacinth root will be analyzed by TCLP during the pilot study to determine if it requires hazardous waste disposal. TCLP will be explained further in ***Section*** *7.*

Solar PV system maintenance would include checking electrolyte levels in the batteries periodically and filling with new electrolyte when necessary. Battery terminals would be cleaned two (2) times per year with a dilute solution of baking soda and water.

The expected lifetime of the photovoltaic cells is 15-20 years. The expected lifetime of the battery bank (provided proper maintenance is followed) is 5-7 years. Battery replacement costs are presented in ***Attachment 2****.*

The submersible pump may require diaphragm replacement at 3-5 year intervals depending on use. Costs for replacement parts are presented in ***Attachment 2****.*

Pressure gauges located pre-sediment filter, post filter, and post hyacinth drum would be monitored daily for changes that would indicate fouling of the system.

6. Manufacturing and Widespread Implementation: Describe how the system would be implemented throughout South Asia, including some local manufacturing and distribution on a commercial basis. Include a discussion of special manufacturing requirements. Describe how you would establish a manufacturing operation, a distribution network, and, perhaps, a credit facility in the region.

We would ship the original unit from the United States. We would be on-site to set-up the unit and ensure proper operation while teaching local artisans the basics of maintenance and operation. As discussed in ***Section 2****, our training program would be culturally appropriate to facilitate long-term utilization of this technology. Ideally, we could train local artisans to construct additional systems in neighboring villages using materials purchased within South Asia.*

We would also coordinate with in-country sources for solar PV systems and drums. Water hyacinth would be harvested and dried locally as it is an abundant pervasive plant. We could also coordinate with non-profit corporations specializing in micro-credit financing to start local water hyacinth process facilities. Benefits from this approach include local economic development and a steady, sustainable supply of dried water hyacinth root.

7. Residue Management: Describe how, by whom, and at what cost residues from maintenance operations would be treated. Because residues will contain elevated levels of arsenic, they will most likely have to be treated as hazardous waste according to local applicable guidelines. Describe how this would be done at the village level.

Residue management will be addressed after the completion of the pilot study.

A Toxicity Characteristic Leachate Procedure (TCLP) will be performed on the water hyacinth root after the pilot study is completed. The procedure approximates leaching conditions expected in the real-world and is used to determine whether an analyte is considered hazardous. If the test results determine that arsenic does not leach from the water hyacinth it may be possible to land farm the material.

Government regulations in Bangladesh regarding hazardous waste do not appear to be robust from a western perspective. Local villages are taking action to control the levels of pollutants that are released in their areas. We would work cooperatively with the Department of Environment and local village leaders to ensure that material disposal is performed in an environmentally sensitive manner.

8. Costs: Specify annual capital, operating and maintenance costs on a unit basis (per household). Costs should be based on mass production. Provide a bill of materials, with brief descriptions of each component, and annual costs for consumables, such as chemicals. Capital costs should be annualized over five years. Costs should be given in U.S. dollars.

Please refer to ***Attachment 2*** *– Arsenic Remediation System Cost Estimate*

9. Social Acceptability: Comment on the social acceptability of the system in terms of skills necessary to set the system up, operate it, and maintain it. Discuss convenience and other cultural issues that may arise associated with the technology. If the system has been used in the field, describe questions and problems that arose and how they were solved.

Our arsenic remediation system finds social acceptability in its ease of set-up, operation, use of renewable energy sources, and sustainability of the consumable component (water hyacinth root). We envision a scenario where this remediation system is constructed, installed, and maintained by local experts trained by Chemists Without Borders personnel. Water hyacinth processing facilities would be constructed through micro-credit financing resulting in local economic development and local sources of water hyacinth root.