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IV. Executive Summary

NCER Assistance Agreement Project Report Executive Summary

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Project Title: **West African Technology, Education and Reciprocity (WATER) for Benin**

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Project Period: **Phase 1:** August 2007 to April 30th, 2008.
Phase 2: May 1st, 2008 to May 1st, 2009

Description and Objective of Research:

Water for Africa is an interdisciplinary approach to development attempting to balance technology and education while ensuring Reciprocity among project partners. The WATER (West African Technology, Education and Reciprocity) program is designed to meet the needs for a thirsty planet. As part of the WATER program 17 students from eight academic programs and 3 faculty members traveled to Benin in August 2007.

The WATER for Benin Program directly addresses the United Nations (UN) Millennium Development Goals (MDG). The people in Benin suffer health consequences from drinking water that is contaminated with pathogens. The WATER program provides a design for sustainable point-of-use drinking water filter. The technologies transferred to our partner, the Songhai Center in Benin, have provided the impetus for a cottage industry in making drinking water filters and the manufacturing equipment to produce the filters. We hope to expand upon this success by making activated carbon and training health care workers at the Songhai Center as part of second phase of the WATER program. Providing clean water and economic stimulation by using local materials and agricultural waste products will help protect the environment as well as human health.

The market for a point-of-use treatment technology is immense. UNICEF estimates at least 33% of the 8.4 Million people living in Benin lack access to potable water. Therefore, in order to meet the UN MDGs 200,000 people must gain access to potable water each year. Assuming an average of 5 people living in each home, 50,000 drinking water filters are needed each year.

The objective of the WATER program was to make available affordable and sustainable water treatment available for families in Benin.

Relationship and Challenge to Sustainability

The United Nations (UN) has developed the Millennium Development Goals (MDG) program to reduce poverty and improve access to water and sanitation throughout the developing world. The UN has specifically stated a goal to halve the number of people without access to clean water and sanitation by 2015. On March 19th, 2006, a statement by the UN noted this goal was in jeopardy in sub-Saharan Africa due to drought, poverty and political factors. In short, experts in the field of sustainable development believe providing clean water and sanitation for sub-Saharan Africa is one of the world's greatest challenges. International organizations describe, and on-scene interviews with residents confirm, that these diseases affect more than 50% of those living in poverty in Benin. In other words, the lack of access to potable drinking water is the leading cause of early mortality and disease for more than 1.2 million people in Benin.

Waterborne diseases spread pathogens by the ingestion of urine or feces contaminated water. Typhoid fever, amoebic dysentery, schistosomiasis and cholera are just a few of the diseases spread by contaminated water. Diarrheal diseases are the third leading cause of death in Benin after lower respiratory infections and malaria, respectively. Maternal mortality rates are estimated to be 850 maternal deaths per 100,000 births. It is estimated that 167 of every 1,000 children die before the age of five in Benin. Providing the technology to implement point-

source water treatment in the community can significantly reduce the percentage of children under 5 (7.1%) who die due to diarrheal diseases.

Summary of Findings (Outputs/Outcomes):

The Songhai Center has produced and tested over 300 fully functional point-of-use drinking water filters. The holistic approach of incorporated water treatment, waste reduction, economic development and promoted environmental and health awareness in the community.

The water filters were manufactured in Benin with local resources. Agricultural and industrial waste products such as sawdust, rice hulls, and waste motor oil were incorporated into the filter manufacturing process. The use of renewable energy sources such as biofuels has been investigated to decrease reliance upon non-renewable fossil fuels and decrease tree harvesting required for boiling water upon implementation in Benin.

Transfer of the technology will be most effective where there are existing facilities for manufacturing that already employ trained professionals. The technology can be easily adopted where there are community organizations such as community water boards or school boards. Clearly, the health and quality of life for millions of West Africans may be impacted at very low relative by this simple technology.

Integration of P3 concepts as an educational tool

"More than anything else, I've been shocked by how many people seem to brush off the issue of unhealthy water in developing countries. When they hear that we were there to work on a water filter project, they usually ask what I drank while I was there and if I got sick. Then at least half of the people I've talked to mention something about how I would get sick since I'm from the U.S. but that the people living in Benin don't get sick because they've built up enough antibodies. They're surprised every time when I explain that even though they do have some antibodies, they definitely get sick and children live with diarrhea daily. Where do so many Americans get this idea that people in other countries just adapt to living in less sanitary conditions?" (Maleena Scarsella, 2007 after returning from Benin)

The educational outcomes from the water treatment project included developing:

- Increased cultural competence for working in developing countries
- Increased understanding of bilingual education in West Africa
- The ability to develop content-based curricula in science and health education
- Appreciation for political and economic conditions of West Africa
- The ability to apply basic epidemiological concepts to health initiative strategies
- Experience in applying principles of sustainability to engineered systems
- The ability to recognize challenges of engineering in developing countries

Conclusions:

- The Songhai manufacturing facility has produced over 300 cost-effective point-of-use drinking water filters was developed in conjunction with our partners, Engineers Without Borders, Potters Without Borders, and Rotary International
- The filters removed over 99% of potentially pathogenic organisms.
- A recipe for a biofuel made from agricultural wastes has been researched and is under development at Gonzaga University.
- A reactor to scale up activated carbon production for use in a Songhai center type kiln has been designed and demonstrated at Gonzaga University.
- Health and water educational materials were developed at Gonzaga University for implementation and training at the Songhai Center.
- Journals, surveys and external review all provided significant evidence and support that the educational outcomes associated with the WATER program were achieved.

Proposed Phase II Objectives and Strategies:

Challenge Definition and Relationship to Phase I

Achieving the UN MDGs is extremely challenging. Each of the eight goals is directly or indirectly applicable to the proposed project. Nearly 2 billion people who currently lack access to clean water are depended upon the successful implementation of programs designed to address the UN MDG program. Those who participated in the WATER program can relate a personal story that has motivated them to become personally motivated to take on this challenge.

The Songhai Center Director, Father Nzamujo, has been at the cutting edge of this challenge bridging the educational difference between the developed and developing worlds. He has outlined three points to improve upon the progress made in Phase I:

People: Father Nzamujo Godfrey has specifically requested assistance with health training and education. Gonzaga faculty and students will work with the Songhai Center to train Songhai Staff to provide basic first aid care and help with educational messages about the relationship between water, sanitation and health. The educational process is a necessary step in ensuring that the drinking water filters become widely and correctly used in homes in the communities surrounding the Songhai Centers. The WATER program will not significantly affect people's health until the technology is widely adapted in homes in the community.

Prosperity: Current agricultural waste products, especially corn stalks and coconut shells can be turned into valuable biofuels and activated carbon, respectively. However, the technology needs to mature and be transferred to the Songhai Center. More work is needed to improve the process for manufacturing both the activated carbon and the biofuels. Once the process is mature, these technologies can be transferred to the Songhai Center following the same successful model that was used to transfer the drinking water filter technology.

Planet: Processes to improve water quality that do not deplete local resources will significantly affect the quality of life and the environment in and around the Songhai Center. Many of the

people we worked with at the Songhai Center expressed the desire to obtain clean drinking water, but prior to our trip, the knowledge of **how** to do this was unavailable. We believe education is the key to improving environmental water quality, the quality of life and significantly improving the measures of human health in Benin.

Innovation and Technical Merit

The researchers, students and partners believe that this is a truly innovative approach to development that aligns with the mission and strength of each organization. The approach to technology transfer is the most innovative piece of the WATER program. Under the supervision of experienced experts, students work in tandem with program partners to identify needs, develop appropriate solutions and transfer these solutions to the community in need.

The objectives of the Phase 2 WATER program include:

- Conducting training on Basic First Aid and the relationships between water, sanitation and health for Songhai staff and interns.
- Developing a marketing plan for the drinking water filters produced at the Songhai Center.
- Hardening the Granulated Activated Carbon (GAC) manufacturing process.
- Hardening the agricultural waste biofuel manufacturing process.
- Continuing with the educational outcomes successfully demonstrated in Phase 1 for a second group of students that have applied to the WATER program.

Publications/Presentations:

1. Striebig, et. al. 2008. WATER: West African Technology Education and Reciprocity. Lulu.com. ISBN: 978-0-6151-9491-2
2. Striebig, B., et. al. 2008. "Activated carbon amended ceramic drinking water filters for Benin." *Journal of Engineering for Sustainable Development.* **2**(1):1-12.
3. Maxwell, J.A., et. al. "Water Filtration Facility for the Songhai Center. Presented at the Engineers Without Borders – USA's 2008 Annual International Conference: "Sustainable Engineering and Global Health". March 27-30, 2008. University of Washington, Seattle.
4. Striebig. Keynote speaker: International Society of Research Administrators Western Chapter. March 9-11th, 2008.
5. Striebig. Invited speaker: SINES (Society of Inland Northwest Environmental Scientists). November 14th, 2007
6. Striebig. Invited speaker: Engineers Without Borders – Inland Northwest Profession Chapter. October 24th, 2007.
7. Striebig. Invited speaker: ASCE Inland Empire Section. September 19th, 2007.

Supplemental Keywords: Sustainable development, community based, human health, drinking water, biofuel, sub-Saharan Africa.

Relevant Web Sites: http://web.mac.com/water_dr/

V. A. Summary of Phase I Results

1. Background and Problem Definition

Water for Africa is an interdisciplinary approach to development attempting to balance technology and education while ensuring Reciprocity among project partners. The WATER (West African Technology, Education and Reciprocity) program is designed to meet the needs for a thirsty planet. As part of the WATER program 17 students from eight academic programs and 3 faculty members traveled to Benin in August 2007.

The mission of the WATER program is to provide a service based learning experience to introduce Gonzaga University students and Songhai Center staff and interns to strategies for sustainable development in Sub-Saharan Africa. We believe education is the foundation of improving access to water and reducing poverty and early mortality in children.

The people in rural Benin lack access to clean water. As a result, they live in an environment that fosters many water-borne diseases, such as *E. coli* and dysentery. These diseases decrease the longevity and quality of life for the Beninese people. The United Nations recognizes that safe drinking water is the first step toward a brighter future for the people of Benin. The goal of this project was to design a manufacturing facility for an affordable, sustainable water filtration system that can be easily distributed throughout Benin.

Relationship to people, prosperity and the planet

Figure 1: Map of Africa

The WATER for Benin Program directly addresses the United Nations (UN) Millennium Development Goals (MDG).[1] The people in Benin suffer health consequences from drinking water that is contaminated with pathogens. The WATER program delivered a sustainable point-of-use drinking water filter. The technologies transferred to our partner, the Songhai Center in Benin, have provided the impetus for a cottage industry in making drinking water filters and the manufacturing equipment to produce the filters. We hope to expand upon this success by making activated carbon and training health care workers at the Songhai Center as part of second phase of the WATER program. Providing clean water and economic stimulation by using local materials and agricultural waste products will help protect the environment as well as human health.

The market for a point-of-use treatment technology is immense. UNICEF estimates at least 33% of the 8.4 Million people living in Benin lack access to potable water.[2] Therefore in order to meet the UN MDGs 200,000 people must gain access to potable water each year. Assuming an average of 5 people living in each home, 50,000 drinking water filters are needed each year.

Relevance and significance to developing or developed world

The United Nations (UN) has developed the Millennium Development Goals (MDG) program to reduce poverty and improve access to water and sanitation throughout the developing world.[1] The UN has specifically stated a goal to halve the number of people without access to clean water and sanitation by 2015.[3] On March 19th, 2006, a statement by the UN noted this goal was in jeopardy in sub-Saharan Africa due to drought, poverty and political factors.[3] In short, experts in the field of sustainable development believe providing clean water and sanitation for sub-Saharan Africa is one of the world's greatest challenges.

Benin lies in the heart of sub-Saharan Africa and 33% of its population lacks access to water and 68% to sanitation.[2] Benin has a stable government and excellent primary education system. However, the average income in Benin is approximately 530 US dollars per year.[2,4,5] Centralized water treatment is not a feasible option for community drinking water in Benin because it is extremely expensive to construct and maintain. As a result, decentralized or point of use technologies are the most appropriate choice for treating drinking water.

The water in rural Benin suffers from four primary types of contamination: pollution from particulates, biological constituents, anthropogenic sources, and natural sources.[6,7] Biological constituents consist of bacteria and viruses. These are the major concern in Benin drinking water because of their impact on human health. Benin water samples (see Table 1) had high concentrations (>160 MPN/100mL) of bacterial indicator organisms such as total coliforms. Pollution from anthropogenic sources primarily from latrines, animal feed lots, and dried-up wells used as garbage dumps are also a concern.

Figure 2: Pathoscreen test of well water in Porto-Novo, Benin. All three dilution indicate the likely presence of pathogens.

Table 1: Microbial and chemical contaminants measured in Benin water samples

Contaminant	Units	Concentration in Benin Water	WHO Standard[8]	US EPA Standard[9]
Total Coliforms	MPN/100ml	>1600	0	0
Fecal Coliforms	MPN/100ml	20	0	0
E. Coli	MPN/100ml	NA	0	0
Pathogens	MPN/100ml	>8	0	0
Lead	µg/L Pb	4	10	15
Arsenic	µg/L As	ND	10	10
Nitrates	mg/L NO_3^--N	>30.0	50	10
Phosphate	mg/L PO_4^{3-}	0.19	NA	NA

In rural Benin, the primary ways in which people obtain clean drinking water are by boiling water or purchasing imported bottled water.[7] Boiling the water requires wood and native

vegetation, depleting local resources and emitting smoke into households and the atmosphere. Buying imported water is not a cost-effective long-term solution for low-income populations. Furthermore, the link between drinking water, sanitation and disease is not clearly understood in Benin.[6] As a result, the people of Benin may not fully appreciate the value in filtering the water.

Waterborne pathogens are spread by the ingestion of urine or feces contaminated water.[10] Typhoid fever, amoebic dysentery, schistosomiasis and cholera are just a few of the diseases spread by contaminated water.[10] Diarrheal diseases are the third leading cause of death in Benin after lower respiratory infections and malaria, respectively.[2] Maternal mortality rates are estimated to be 850 maternal deaths per 100,000 births.[2] It is estimated that 167 of every 1,000 children die before the age of five in Benin.[2] Providing the technology to implement point-source water treatment in the community can significantly reduce the percentage of children under 5 (7.1%) who die due to diarrheal diseases.[6]

Implementation of the P3 team project as an educational tool

GU has made a concerted effort to focus attention on international issues. WATER (West African Appropriate Technology, Education and Reciprocity) was an interdisciplinary course with a three part focus: cross-cultural training and in-depth study of West African culture, study of health conditions and health promotion in developing countries including epidemiological research design and practical application using appropriate technologies for eradicating waterborne illnesses in Benin, West Africa. In multidisciplinary project teams, selected students developed and implemented educational materials and strategies using the course content as a foundation. This course was a service-learning course and addressed issues of social justice in West Africa including but not limited to health intervention, contemporary discussions of third world development and a critical examination of political and economic conditions of "periphery" nations.

This program added value to the curriculum of three programs and created international service learning opportunity for students. Students in the course studied one of the central problems of international relief through both classroom learning and a two week in country service learning experience of the water needs of a region of a developing West African country.

The P3 project was be integrated into the 2007-2008 curriculums in Broadcasting, Chemistry, Civil Engineering and Mechanical Engineering. Global sustainability issues were taught in the introductory *Environmental Engineering* course and in the *Water Resources* course. For instance, sampling methods and measurement of the organic, inorganic, and pathogen content of the water were utilized for laboratory exercises in the required *Environmental Engineering Laboratory*. Case studies in *Biological Treatment Processes* and *Low Impact Development* focused on similar rural water and wastewater design issues. *Material Science* and *Manufacturing Processes* each included a case study of material and process selection based on sustainable technologies. The emphasis of these case studies is to study how to design for third world application, where these designs must meet the regionally available materials and

manufacturing technologies, resulting in sustainable production, which will lead to economic advancement. Students in Chemistry, Civil Engineering and Mechanical Engineering may use this topic for their capstone design requirement.

The educational outcomes from the water treatment project included developing:

- Increased cultural competence for working in developing countries
- Increased understanding of bilingual education in West Africa
- The ability to develop content-based curricula in science and health education
- Appreciation for political and economic conditions of West Africa
- The ability to apply basic epidemiological concepts to health initiative strategies
- Experience in applying principles of sustainability to engineered systems
- The ability to recognize challenges of engineering in developing countries

Twenty-seven students utilized various aspects of the project as part of their senior design requirements.

The educational outcomes from the project were evaluated through four presentations to a panel composed of professional engineers throughout the 2007-2008 academic year. The most persuasive argument in attaining the educational outcomes came from the students journals:

Figure 3: A small group of the 40 people from Gonzaga University and the Songhai center that participated in the WATER program in Benin

"I definitely appreciate everything I have at home so much more, even the little things like drinking out of the faucet. I almost feel guilty being back and knowing that there are families in Africa struggling just to obtain clean water." (Luu, 2007)

"My pre-trip metaphor held up: I do feel like I was the gullible and naïve child entering school for the first time. I do feel as though the 'picture books' did not do our experience justice. How could they? In all actuality, I may feel more like the naïve child now than I did prior to leaving. I heard one of the students say - "You don't know what you don't know." I am now more aware of what I do not know. Now I have the choice on how I want to deal with that knowledge of ignorance. Awareness is half the battle though and the lessons I have learned from this trip are still very fresh. " (Hart, 2007)

"I do know that I have found my calling. It is such a great feeling, once you figure out what your passion is and just knowing that you are at the culmination of all your education and all your growing up. It is an intense feeling to wake up in the morning and knowing in your heart that you are exactly where you are supposed to be, geographically, emotionally, spiritually, and in life in general. " (Meeks, 2007)

2. Purpose, Objectives, Scope

The objectives of the WATER program were to make available affordable and sustainable water treatment for families in Benin. International organizations describe, and on-scene interviews with residents confirmed, that these diseases affected more than 50 percent of those living in poverty in Benin. [2,5-7,12]

Table 2: Objectives and partner responsibilities for Phase 1

	Objectives	Responsible Partner
1	Construct the manufacturing facility for manufacturing activated carbon and Filtróns™ at the Songhai Center in Porto-Novo, Benin.	Gonzaga University Songhai Center Potters for Peace
2	Begin production of drinking water filters at the Songhai Center for employees and guests.	Gonzaga University Songhai Center Potters for Peace
3	Design a solid biofuel system using agricultural waste products (coconut shell husks and other combustible materials) that minimizes the need for fossil fuels.	Gonzaga University Civil Engineering Mech. Engineering Potters for Peace
4	Scale-up and activated carbon manufacturing process for transfer of the technology to the Songhai Center.	Gonzaga University Chemistry Civil Engineering
5	Produce bilingual educational materials to promote the use of the water filters and proper sanitation among school children in Azové, Adja, and Porto-Novo, Benin.	Gonzaga University Language Dept. Nursing Dept. Broadcasting dept.

3. Data, Findings, Outputs/Outcomes

Three treatment technologies (shown in Table 3) with a proven and technologically appropriate track record were considered for drinking water purification. The advantages and disadvantages of each technology were evaluated by project partners. Each technology fits a specific niche in developing countries. The Biosand™ filter, however, was considered to be too expensive for an individual home and to difficult to maintain without a responsible party in the village. The SODIS system, while very affordable, was subject to variations in water quality and treatment effectiveness and could not achieve WHO standards for non-biological pollutants. The SODIS™ system would however, be a good technology to transfer to the Songhai Center as a complementary technology to the more reliable Filtrón™. The Filtrón technology appeared to be the best point-of-use system to deliver reliable high quality drinking water for individuals households in Benin.

Table 3: Point of use appropriate water treatment technologies

Technology	Description	Advantage	Disadvantage	References
Biosand™	Sand Filtration	High removal efficiency for microorganisms	Needs continual use and regular maintenance Cost	13-14
Filtrón™	Ceramic Filter	High removal efficiency for microorganisms Sized for households Relatively inexpensive	Requires fuel for construction Limited lifetime Requires regular cleaning	15-19
SODIS™	Solar Water Disinfection	Highly effective Inexpensive Can reuse a waste product (PET bottles)	Long treatment time (6 to 48 hours) Does not remove other pollutants Requires warm climate and sunlight	20-25

The Filtrón is a ceramic filter developed by Potters For Peace that is designed to fit within a five gallon plastic pail or clay container. In addition to porous ceramic filtration, colloidal silver is used to inhibit bacterial growth.[15, 16] The Filtrón has been cited by the UN in its Appropriate Technology Handbook and used by the Red Cross and Doctors Without Borders.[15,16,17] There are currently several countries around the globe that have employed this low-cost, appropriate technology filter with good results.[18] Most other water treatment technologies require more energy (ultraviolet disinfection systems) or chemical additives (chlorination or other chemical disinfectants). Energy and chemical intensive disinfection systems may provide comparable or even better disinfection, however, the cost and availability of energy and chemical supplies is not sustainable within the community.

Figure 4 Filtrón Ceramic Water Filter

As reported in literature and discussed in personal communications, the Filtrón performed very well in the removal of biological constituents.[15-19,26,27] The micro-pore structure of the ceramic filtration was able to prevent more than 99% of the total coliforms, fecal coliforms, E. coli, and pathogens from passing through with the filter with the water.[26]

Granulated Activated Carbon (GAC) was integrated into the Filtrón design to improve the efficiency and effectiveness of the filter system. Carbon activation occurred when carbonaceous material developed a porous structure, greatly increasing the surface area of the material with pores on the order of three to several thousand Å.[28]GAC was made from coconut

shells ,waste products of Benin agriculture. The raw coconut shells were initially carbonized or charred before they were activated to reduce volatile content.

Table 4: Reduction in microbial and chemical contaminants with Filtrón ceramic water filters and activated carbon water treatment in the Gonzaga University Laboratory

Contaminant	Units	Synthetic water	Filtered water	Average Removal[25]
Fecal Coliforms	MPN/100 ml	2575 ± 1300	< 2 ± 0	>99.92%
Total Coliforms	MPN/100 ml	6233 ± 5967	< 2 ± 0	>99.97%
E. Coli	MPN/100 ml	200 ± 0	< 2 ± 0	>99.0%
Pathogens (H_2S producing bacteria)	MPN/100 ml	637 ± 169	< 2 ± 0	>99.7%
Streptococci	MPN/100 ml	< 20 ± 0	< 2 ± 0	NA
Amoeba	MPN/100 ml	>7,000,000	37,000± 115,000	99.5
Lead	µg/L Pb	5 ± 2	1 ± 1	73%
Nitrate	mg/L NO_3^--N	18.3 ± 1.0	11.9 ± 1.5	35.1%
COD	mg/L	72 ± 17	25 ± 11	66%

Both chemical and thermal activation methods were researched. The chemical process used reacting agents such as catalysts, while thermal activation used heat and gas vapors to activate the carbon. The chemical activation process was generally used to produce GAC from cellulose material such as wood through the use of chemicals such as phosphoric acid, zinc chloride, sulfuric acid, and others which are relatively expensive.[29] While these chemicals produced GAC at an overall yield of 30-50 wt %, the need to separate and recycle the catalyst added to the cost and complexity of this method.[30] Consequently, it was chemical activation was eliminated from consideration for application in Benin.

Figure 5: Team members with the carbon activation chamber and kiln at Gonzaga University

The development of extensive micro-pores and meso-pores was accomplished in the lab by heating the carbonaceous material at higher temperatures while subjecting it to steam, or thermally activating the carbon source. Activation using steam was conducted at temperatures between 600-800ºC in a steam-embedded atmosphere.[29] The quality, quantity and effectiveness of the GAC depended upon the nature of the raw material, the duration of the burnoff period, the temperature and flow rate of steam within the kiln.[31] GAC can be produced via thermal activation on-site at the Songhai Center using recycled water for steam generation and renewable biofuel as the energy source.
The surface characteristics of the GAC were

studied in order to develop a sustainable method for quality assurance when evaluating adsorption capacity. The sample prepared by steam activation of coconut shells at Gonzaga University, GU GAC, was compared to two commercially available activated carbons, GAC#1 and GAC#2. The GU GAC compared favorably with commercial samples in terms of internal surface area and micropore volume. These parameters are generally considered the most critical in water treatment. GU GAC would be less efficient in removing acid species and large weight organic molecules than the commercially evaluated samples. Evaluations were conducted to determine the effectiveness of GAC in removing the pollutants found in Benin water.

Activated carbon significantly improved water quality. Activated carbon had high removal efficiency for Lead and the tested water met the WHO standards.[8] Activated carbon reduced nitrate concentrations by 47% to 69%. Phosphate removal was even better at 94% to 96%. After treatment, both nitrate and phosphate effluent concentrations met current WHO standards. A GAC depth of two centimeters was sufficient for meeting the water quality goals. GU GAC and water quality test results were confirmed with independent laboratory analysis.

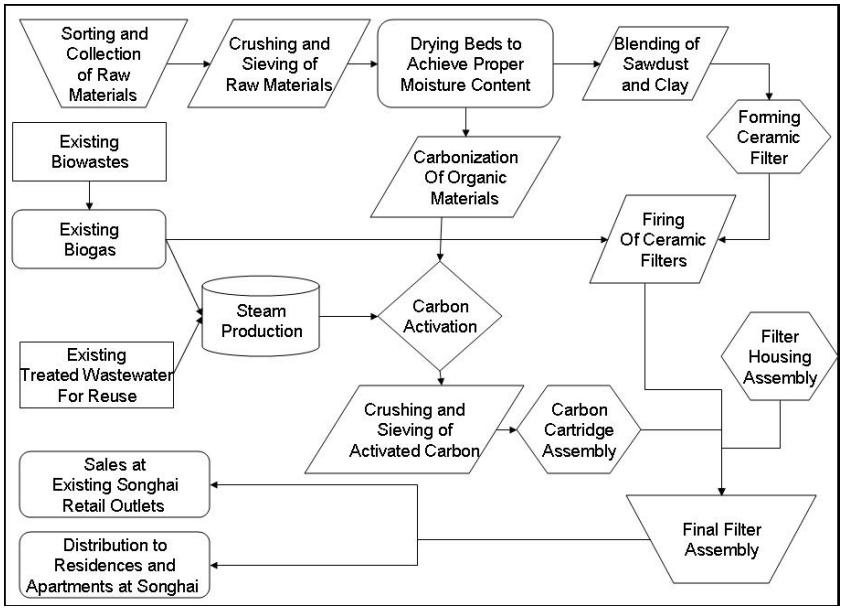

Figure 6: Songhai Center Phase 1 and Phase 2 drinking water filter manufacturing flow schematic

The filter manufacturing facility whose implementation was started in 2007 combined appropriate technological solutions to water treatment for developing communities. The holistic approach of incorporated water treatment, waste reduction and economic development and promoted environmental and health awareness in the community.

Over 300 filters have successfully passed the flow rate tested and subsequent microbial testing. The formula for producing the filters with greater than 99% removal of bacteria was determined in the field from various mixtures of screened sawdust and fine clay. Dry weight

percentages were used because they are easy to measure during manufacturing. An 80% by weight clay to sawdust mixture produced filters that regularly passed the flow rate test.

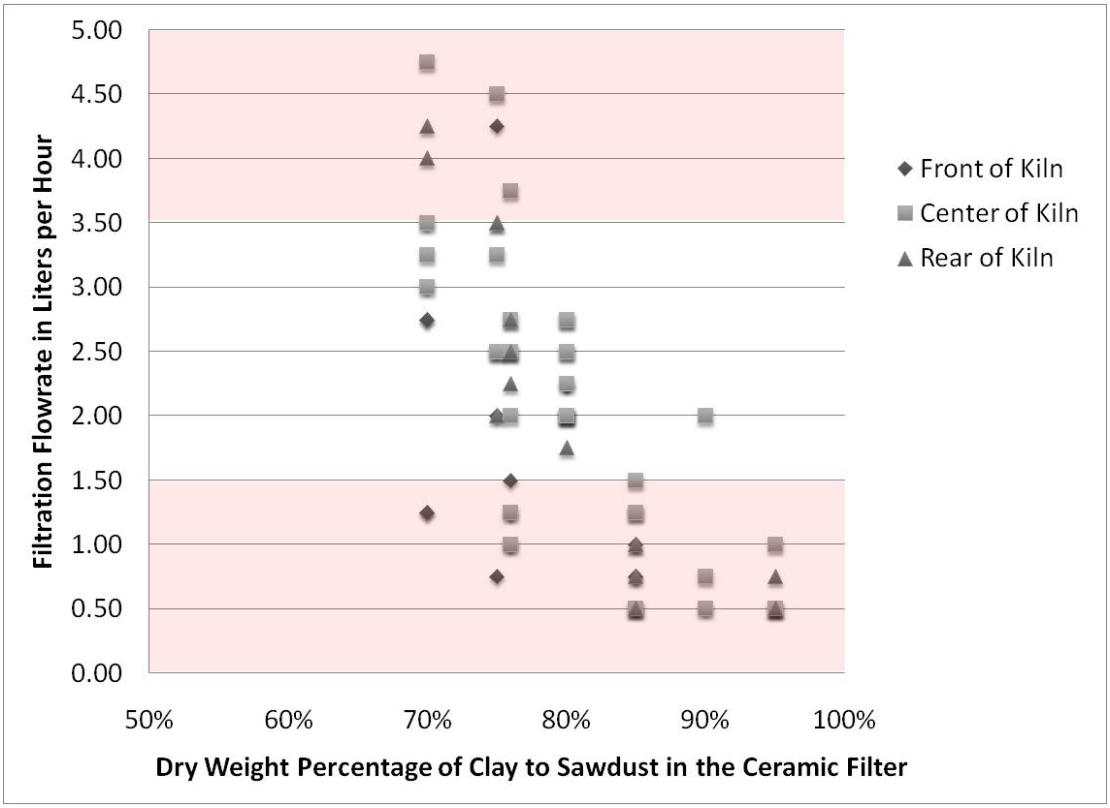

Figure 7: Flow test results from the first experimental production run of water filters at the Songhai Center

Streamlined life cycle costing and analysis

Life Cycle costs were estimated for the drinking water filters based upon the data provided by the Songhai Center and our experience in the field in Benin.

Table 5: Cost of the ceramic water filters in Central African Francs (CFA) and United States Dollars (USD) at a current exchange rate of 500CFA/USD

Description	Cost in CFA	Cost in USD
Clay	187	0.373
Sawdust/organic	0	0
Labor	783	1.567
Fuel	83	0.167
Plastics	3000	6.000
Ceramic Filter Element (2 years)	1053	2.107
Total Filter Cost over 10 years	= 3000 + 1053 x 5 = 8267	= 16.53

4. Discussion, Conclusions, Recommendations

The Songhai Center has produced affordable and reliable drinking water filters. Even at using relatively high start-up cost data, the filters can be produced for an initial cost of about 6 USD (3000 CFA) and a ten-year cost per family of 16.53 USD (8267 CFA). Over a ten-year period this would be approximately 1 days wages per year for clean water.

Figure 8: Finished drinking water filters that have been flow tested and tested for pathogen removal with the Pathoscreen test

This system can be duplicated where there are existing facilities for manufacturing. The technology can be easily adopted by community organizations such as water boards or school boards. With basic infrastructure in place to collect raw materials, the proposed facility can be fully operational within one year as demonstrated at the Songhai Center. However, in regions of the world where there are no existing educational or skilled infrastructure, this model would be difficult to adopt without first addressing shortcomings in governmental and physical infrastructure. Clearly, the health and quality of life for millions of West Africans may be improved by an average investment of 2 dollars per year in the filter.

Quantifiable and qualitative benefits to people, prosperity and the planet

1. A manufacturing facility to produce cost-effective point-of-use drinking water filters was developed in conjunction with our partners, Engineers Without Borders, Potters Without Borders, Rotary International, and the Songhai Center in Benin, West Africa.

2. Drinking water filters that removed pathogens are being produced at the Songhai Center.

3. A recipe for a biofuel made from agricultural wastes has been researched and is under development at Gonzaga University.

4. A reactor to scale up activated carbon production for use in a Songhai center type kiln has been designed and demonstrated at Gonzaga University.

5. Health and water educational materials were developed at Gonzaga University for implementation and training at the Songhai Center.

6. Journals, surveys and external review all provided significant evidence and support that the educational outcomes associated with the WATER program were achieved.

V.B. Proposal for Phase II

1. P3 Phase II Project Description

Challenge Definition and Relationship to Phase I

The first phase of the WATER program was successful in transitioning an appropriate technology for manufacturing drinking water filters to the Songhai Center. There are several opportunities to improve the outcomes and likelihood of long-term success for the program at the Songhai Center. The foremost need identified to us by Father Nzamujo at the Songhai Center is for additional training in health care and health education. He also identified the production of biofuel and granular activated carbon as very high priorities to continue to provide a basis for sustainable economic development.

People

Father Nzamujo Godfrey has specifically requested assistance with health training and education. Gonzaga faculty and students will work with the Songhai Center to train Songhai Staff to provide basic first aid care and help with educational messages about the relationship between water, sanitation and health. The educational process is a necessary step in ensuring that the drinking water filters become widely and correctly used in homes in the communities surrounding the Songhai Centers. The WATER program will not significantly affect people's health until the technology is widely adapted in homes in the community.

Prosperity

Current agricultural waste products, esp. corn stalks and coconut shells can be turned into valuable biofuels and activated carbon, respectively. However, the technology needs to mature and be transferred to the Songhai Center. More work is needed to prefect the process for manufacturing both the activated carbon and the biofuels. Once the process is mature, these technologies can be transferred to the Songhai Center following the same successful model that was used to transfer the drinking water filter technology.

Planet

Processes to improve water quality that do not deplete local resources will significantly affect the quality of life and the environment in and around the Songhai Center. Many of the people we worked with at the Songhai Center expressed the desire to obtain clean drinking water, but prior to our trip, the knowledge of **how** to do this was unavailable. We believe education is the key to improving water quality, the quality of life and significantly improving the measures of human health in Benin.

Innovation and Technical Merit

The researchers, students and partners believe that this is a truly innovative approach to development that aligns with the mission and strength of each organization. The approach to technology transfer is the most innovative piece of the WATER program. Under the supervision of experienced experts, students work in tandem with program partners to identify needs, develop appropriate solutions and transfer these solutions to the community in need.

The objectives of the Phase 2 WATER program include:

- Conducting training on Basic First Aid and the relationships between water, sanitation and health for Songhai staff and interns.
- Developing a marketing plan for the drinking water filters produced at the Songhai Center.
- Hardening the Granulated Activated Carbon (GAC) manufacturing process.
- Hardening the agricultural waste biofuel manufacturing process.
- Continuing with the educational outcomes successfully demonstrated in Phase 1 for a second group of students that have applied to the WATER program.

Relationship of Challenge to Sustainability

Achieving the UN MDGs is extremely challenging. Each of the eight goals are directly or indirectly applicable to the proposed project. Nearly 2 billion people who currently lack access to clean water are depended upon the successful implementation of programs designed to address the UN MDG program. Those who participated in the WATER program can relate a personal story that has motivated them to become personally motivated to take on this challenge.

The Songhai Center Director, Father Nzamujo, has been at the cutting edge of this challenge bridging the educational difference between the developed and developing worlds. He has outlined three points to improve upon the progress made in Phase I:

The Songhai Center has built a health center to provide basic health education to its staff and the community. Through our Partnership with Songhai, we will train health care providers to address basic first aid issues and relate the importance of water and sanitation through promotional documents and native language (Fongbe) skits.

As an agricultural center, ways to turn waste products into economic resources are always being investigated. The ability to turn waste products from corn production into a useable fuel will create a cottage industry, reduce fuel costs and reduce deforestration.

In a similar fashion, coconut waste products will be used to produce Granular Activated Carbon (GAC). When integrated into the water filters being produced, the GAC will improve the taste of the water. In a similar fashion to Brita™ Filters sold in the US. This may be a luxury item or version of the filters that may improve their integration into homes, since taste is a sensory perception than can be easy associated with “clean” or potable water.

More process hardening is also desirable in the laboratories at Gonzaga University. Air emissions such as carbon monoxide and nitrogen oxides will be minimized by determining the best air-to-fuel ratio for the solid biofuel kiln heat source. Testing will be carried out using a factorial design strategy to create an activated carbon with the highest removal capacity and lowest required time and temperature. This will allow the Songhai Center to produce the highest quality drinking water filters with renewable energy sources and minimal air emissions (CO, NOx and CO2).

The people of Benin will directly benefit by significantly improving the drinking water quality with an affordable and locally manufactured technology. The technology utilizes existing skills, labor and infrastructure to turn agricultural waste products into an economic resource (fuel and activated carbon). The Principal Investigator saw firsthand the degradation of the environment as people are forced to walk farther and farther each day to find wood for boiling their water. The implementation of a sustainable drinking water filter will significantly decrease local deforestation. This work will ensure the filters are produced efficiently with minimal emissions of combustion by-products compared to boiling water on home stoves.

Measurable Results (Outputs/Outcomes), Evaluation Method, and Demonstration/Implementation Strategy

The new manufacturing facility will provide up to 30 jobs at six Songhai Center locations throughout Benin. Songhai Center staff will report the number of employees required to manufacture the activated carbon and ceramic filters. Most importantly the Songhai Center will produce affordable water filters which can be sold in their retail stores at cost to the public. The Songhai stores serve over 100,000 people in Porto-Novo, Savalou, Parakou and Kinwedji.

Economic opportunities extend well beyond the jobs that are expected to be created. For example, currently water is sold at markets in plastic bags without any assurances of the quality of the water. A small micro enterprise in the marketplace could buy two or three drinking water filters and sell high quality drinking water directly from the tap. Since the water would come out of the tap, the customers would have a reasonable assurance of clean drinking water. This type of micro-enterprise would help transfer the filters technology to surrounding communities such as Azové and Adja.

Assessments (examinations) both prior to and after the health care training will be used to document the level of training attained by the Songhai staff as basic health care and education providers.

Sales and cost of the water filters will be measured. Customers will be taught how to maintain the filters and asked how they learned of the filters. These records will be maintained by Songhai Center staff.

The water quality at Songhai can be improved through the use of activated carbon amended Filtróns. Gonzaga University students will test water and activated carbon samples according to standard methods in campus laboratories and in the field.[31-38] The objective of the proposal is to develop water filters which bring Benin water into compliance with the WHO water quality guidelines.[8]

Faculty advisors will coordinate implementation of the design including ordering supplies, training and education. Funding for construction will be supported by the Songhai Center and/or fund raising initiatives and donations to Engineers Without Borders-Gonzaga (EWB-Gonzaga). Funding from the School of Engineering and the Engineering Design Center will cover

a portion of project costs for analytical supplies that may be required. The Gonzaga University Missions program has instituted funding for an initiative in sustainability and is in the process of applying for several foundation grants to support and implement sustainability initiatives at Gonzaga.

The project design is modular, scalable and easily adapted to similar developing countries. Countries such as Columbia, Guatemala, Haiti, Nigeria, Rwanda and Togo would benefit from the proposed research. It is anticipated that the proposed drinking water filters will be widely adopted in Benin within a period of three to five years and may similarly be adopted in other areas in approximately five years.

Integration of P3 Concepts as an Educational Tool

Gonzaga University has made a concerted effort to focus attention on international issues. WATER (West African Appropriate Technology, Education and Reciprocity) is an interdisciplinary course with a three part focus: cross-cultural training and in-depth study of West African culture, study of health conditions and health promotion in developing countries including epidemiological research design and practical application using appropriate technologies for eradicating waterborne illnesses in Benin, West Africa. In multidisciplinary project teams, selected students will develop and implement educational materials and strategies using the course content as a foundation. This course is a service-learning course and addresses issues of social justice in West Africa including but not limited to health intervention, contemporary discussions of third world development and a critical examination of political and economic conditions of "periphery" nations. As previously described, the WATER program adds value to the curriculum of three programs and creates an international service learning opportunity for students.

The P3 project will continue to be integrated into the 2008-2009 curriculums in Business, Chemistry, Civil Engineering, Mechanical Engineering and Nursing. Students in Chemistry, Civil Engineering and Mechanical Engineering may use this topic for their capstone design requirement.

The educational outcomes from the water treatment project will include:

- Increased cultural competence for working in developing countries
- Increased understanding of bilingual education in West Africa
- The ability to develop content-based curricula in science and health education
- Appreciation for political and economic conditions of West Africa
- The ability to apply basic epidemiological concepts to health initiative strategies
- Experience in applying principles of sustainability to engineered systems
- The ability to recognize challenges of engineering in developing countries

Up to fifteen students in three teams will utilize various aspects of the project as part of their senior design requirements. In addition, students from the nursing department and language department will prepare health and educational materials to promote awareness about water quality and sanitation in Benin. After a thorough needs assessment and in collaboration with

Gonzaga University's Engineering Department, MA/TESL students would assist in developing language appropriate materials for health education and water safety with corresponding activities related to environmental issues including community forestry, soil conservation and environmental protection. Ideally, the project would build on existing work that other development agencies have introduced (e.g., Peace Corps' GLOBE project: Global Learning and Observation to Benefit the Environment). All Gonzaga students will be able to apply to work on the project. Team updates and task planning will occur at weekly meetings.

The educational outcomes from the wastewater treatment project will be evaluated through four presentations to professional engineers throughout the 2008-2009 academic year. Students will also assess the educational outcomes of the design process though surveys administered during the year. Results of the educational outcomes will be tabulated and reported in the literature at engineering education conferences and in engineering journals. Culture competency changes in participating students and advisors will be measured by the Intercultural Development Inventory (IDI) and administered by Raymond Reyes.

2. Project Schedule

Project planning and communication between Gonzaga University students and the project partners will be critical. Project planning will be reviewed throughout the entire duration of the project. The principal contact people, Bradley Striebig, Godfrey Nzamujo, and Ron Rivera, will set the project schedule and milestones and establish biweekly communications between partners. The communications will be in the form of electronic messages or conference calls. Interdisciplinary student design teams will be required to complete the major tasks and milestones shown in Figure 9.

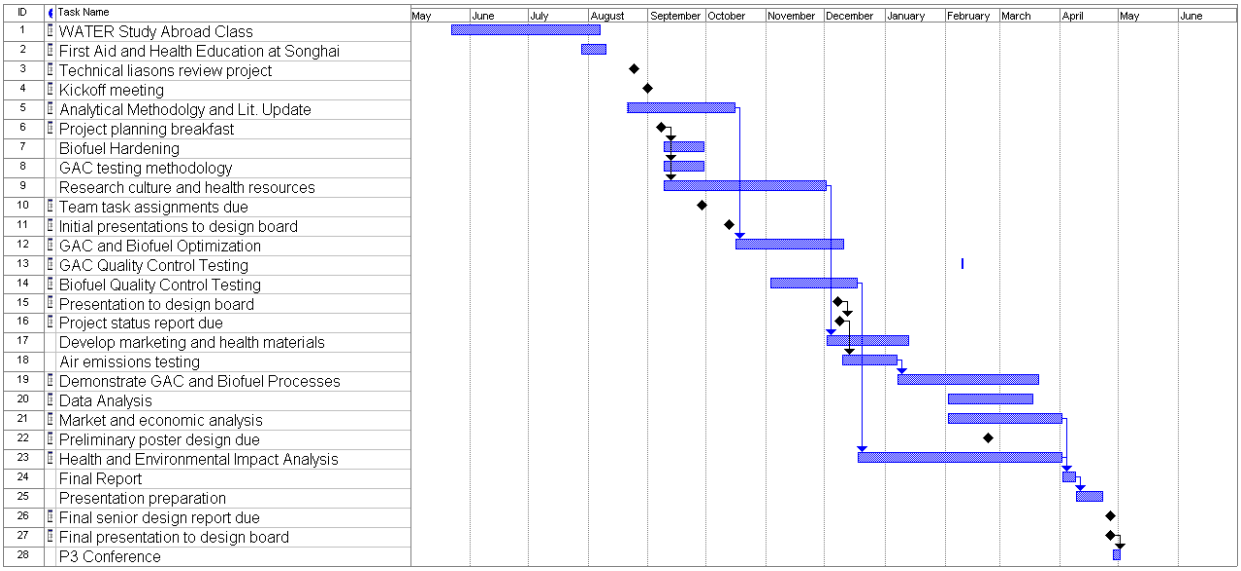

Figure 9: Gantt Chart including major project tasks, due dates and project dates

3. Partnerships

Millennium Development Goal 8: Develop a global partnership for development

This project involves partnerships between Gonzaga University and the following organizations: *Engineers Without Borders-USA*, *Rotary International, the Songhai Center* in Benin and *Potters Without Borders (also called Potters for Peace)*. Following is a list of partners and how they will assist or have assisted with the project:

- The Songhai Center, under the guidance of Godfrey Nzamujo, will continue to provide transportation, lodging, and an interpreter in Benin.

- Engineers Without Borders-USA will continue to contribute toward the completion of the project in labor, project oversight, and technical assistance.

- Gonzaga University will provide time from its staff and money used to purchase testing supplies and prototype materials valued at $186,754. Additionally, the Gonzaga University students will contribute over 2,000 hours of effort to the project.

- Potters without Borders has assisted with implementing the drinking water filter manufacturing process and kiln construction. They will continue to provide educational materials for Filtrón use and maintenance.

- Rotary International has contributed to the material costs of the water laboratory, filter facility and kiln construction.

Table 6: Responsible parties for communication between project partners

Name	Position	Affiliation
Bradley Striebig*	Associate Professor and Faculty Advisor	Civil Engineering, GU
Phil Appel	Assistant Professor	Mechanical Engineering, GU
Terry Gieber	Chair and Professor of Ceramics	School of Art, GU
Mary Jeannot	Assistant Professor, Director	English as a Second Language, GU
Susan Norwood	Professor	Department of Nursing, GU
Raymond Reyes	Associate Vice President for Diversity	Office of Diversity, GU
Joanne Smieja	Chair and Professor	Chemistry Department, GU
Nzamujo Godfrey	Director	Songhai Center
Thierry Andre	Head of the Mechanical Sector	Songhai Center
Wilson Elliota	Biologist	Songhai Center
Ron Rivera	Director	Potters For Peace (PFP) International Water Filter Program
Burt Cohen	Project Manager	Potters Without Borders

* - Principal Investigator

The Songhai Center was the site chosen for a safe and secure base of operations in Benin. The key personnel from the Songhai Center have been noted in the proposal. The staff and faculty of the Center will assist with the materials and cost assessment, provide information about the community and collect water samples if necessary. In addition, the Songhai Center will provide in-kind support during the implementation and construction of the sanitation facility. The Songhai Center will be responsible for maintenance and operation of water filtration manufacturing equipment. The Songhai Center shown below maintains a laboratory and internet communications center.

Figure 10: New Water quality laboratory and existing communications center at the Songhai Center

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VII. Supporting Letters

March 21, 2006

To Whom It May Concern:

I am writing this letter in support of Gonzaga University's application for the P3 grant for their project at the Songhai Center in Porto-Novo, Benin. Gonzaga University is undertaking this project with the full support of Engineers Without Borders – USA. EWB-USA is actively working with Gonzaga University on this project. EWB-USA professional staff and administration will support this project and provide technical review in conformance with EWB-USA guidelines. EWB-USA believes the project will provide sustainable benefits to the people and environment in Benin.

I am delighted to recommend the Gonzaga University project for the P3 Grant. If I can provide any additional information or answer any further questions, please contact me at Rick.Strittmater@ewb-usa.org.

Respectfully,

Rick Strittmater, P.E.
Project Manager
EWB-USA

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SONGHAI
ENGAGEMENT POUR LE MEILLEUR

Antenne de Lokossa
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Porto-Novo, 22 March 2006

To :
Bradley Striebig, Ph, D
Assistant Professor
School of Engineering
AD 25, 204 Herak Bldg
Gonzaga University
Spokane WA 99258

O/Ref.: SON-ADM/141-06/GL/SS

LETTER OF SUPPORT

Dear Sir,

The Songhai Center understands that you are submitting a proposal to the US Environmental Protection Agency (USEPA) in response to their P3 Award Competition. Improved drinking water will change the lives of thousands of people in Benin. As you saw it when you came to Benin, we have a long way to go in improving the quality of drinking water here. The Songhai Center is a non-profit center that promotes sustainable development and education. Father Nzamujo Godfrey who is the director of the center has received many awards for his work in the field of sustainable development, one of which is the African prize for leadership for the sustainable end of hunger. The Center has also been the recipient of USAID, UNDP and UNEP awards. Non-government organizations and educators visit the Songhai facilities from all over the world. This project is a multi-partnership between Gonzaga University, Engineers Without Borders-USA, the Songhai Center in Benin and Potters for Peace. The staff and faculty of the Songhai Center will assist with the accommodations, food, transportation and interpreters for partner teams travelling to Benin. In addition, the Songhai Center will provide in-kind support to maintain and produce the Filtrons and activated carbon and house the laboratory equipment necessary for water analysis. The Songhai engineering and science staff was trained in water analysis techniques during the site assessment visit in November of 2004. The Songhai center also has a computer center and Internet café to allow and assist communications between team members in the US and Benin. The Songhai Center is dedicated to this project. All participating teams firmly believe that community focused projects such as this one will significantly advance the Millennium Development Goals (MDG) set by the United Nations (UN).

Guy LOUEKE
For the Songhai Center

Letter of Support

Brad Striebig, Ph.D.
School of Engineering
Gonzaga University
Spokane WA 99258

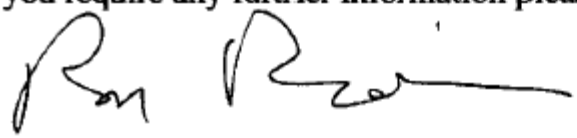
March 29, 2006

Potters for Peace is an international NGO that provides technical assistance to potters in developing countries. One of our projects is to assist in establishing small ceramic filter production facilities for the production of a low cost ceramic filter that removes micro biological contaminants in polluted water.

PFP staff and administration will support this project , provide technical review and we believe the project will provide sustainable benefits to the people and environment in Benin.

Over the past 5 years PFP has helped establish 16 sustainable filter production facilities worldwide and hope to assist that Benin become numer17.

If you require any further information please contact me.



Peace
Ron Rivera
International Coordinator
Potters for Peace www.potppaz.org
Managua, Nicaragua

pottersforpeace@yahoo.com

22 February, 2006

U.S. Environmental Protection Agency

To whom it may concern:

Hello, my name is Alyson Beste and I'm currently serving in Benin, West Africa with the Peace Corps as a health volunteer. I have been here for over a year and a half, thus giving me time to observe that the lack or shortage of clean and hygienic water sources serves as a big problem for the health of many Beninese Families. When one doesn't have clean water for daily consommation, the entire population is at risk of exposure to dangerous microbes, causing diahrrea, then causing malnutrition, thus evoking illness and even death.

There are many communities throughout Benin lacking hygienic water sources and are therefore obligated to use dirty river water sources for bathing, washing clothes, cooking, and drinking.

This water filter project head by the Gonzaga University will be very useful in exposing the dangers to the population of consuming water from such unhygienic sources, thus improving the general health and well-being of the

entire population! Living among the Beninese and seeing first hand the problems that consommation of dirty and unhygienic waters causes for the population, permits me to reflect on how this situation can be improved. As this group from Gonzaga University is looking into ~~inexpensive~~ creating inexpensive water filters made from local clay, I can garauntee that it will be a worthwhile project that is cost effective and will benefit the population young and old!

Thank you in advance for your kind considerations!

Sincerely,

Alyson ~~Beste~~

Alyson Beste