Consilience: The Journal of Sustainable Development
Vol. 4, Iss. 1 (2010), Pp. 155–166

Sustainability of Water Resources for the Poor

James Patrick Abulencia
Manhattan College, Riverdale, NY

Susan Gallardo
De La Salle University, Manila, Philippines

Nithin Abraham
Manhattan College, Riverdale, NY

Anne Caraccio
Manhattan College, Riverdale, NY

Nicholas Ruffini
Manhattan College, Riverdale, NY

Kevin McDonnell
Manhattan College, Riverdale, NY

Francis Tañala
De La Salle University, Manila, Philippines

Abstract

The availability of clean drinking water is a significant concern in many rural communities around the world. The contamination of resources directly affects locals by causing adverse health effects like diarrhea and other gastrointestinal diseases. Potential solutions such as sand filtration, chlorination, and solar disinfection are effective water purification technologies. Another method includes reverse osmosis, which is the main method for water filtration in the Philippines. However, mostly due to energy and cost concerns, these technologies are not feasible applications for poor communities.

To address this need for sustainable water resources, our team proposed a personal growth and service-learning program in the Philippine town of Nagcarlan. Our goals were to employ the knowledge of engineering students to use their technical skills in order to serve society. Students involved in this program have developed a personal water filter to remove contaminants, such as heavy metals, using activated carbon derived from natural resources that are biodegradable and the product of recycling waste products. Sustainability of water resources is further achieved through a community outreach program with the poor communities. Successful personal water purification at one location has the potential to motivate the replication of the proposed solution to other impoverished towns within the

Philippines, indeed it may help to bring clean drinking water to other nations without potable water resources.

Acknowledgements

The authors would like to thank Assistant Secretary Maria Lourdes Orijola of the Department of Science and Technology (DOST) for her help in connecting our groups with the town of Nagcarlan, as well as ITDI-DOST for generating the activated carbon. We are also grateful to Mayor Nelson Osuna for organizing the townspeople, as well as his hospitality during our stay in Nagcarlan. Finally, we would like to thank the National Collegiate Inventors and Innovators Alliance (NCIIA) for funding a portion of this project.

Keywords: water resource sustainability, poor communities, engineering servicelearning, activated carbon, heavy metal removal.

1. Introduction

One out of eight people today, or 884 million people across the globe, do not have access to clean water. For millions, local ponds, streams, irrigation canals, and unprotected dug wells are contaminated.[i] Among these people, approximately one-third live on less than $1 per day while more than two-thirds are living on less than $2 a day. More often than not, people living in impoverished communities pay 5 to 10 times more for a liter of water than wealthy people living in the same city.[ii] In the Philippines, a study by the Asian Development Bank in 2007 indicated that only about a third of river systems can be used as clean water sources while 58% of the groundwater sources are already contaminated.[iii]

Potable water resources are critical aspect of any healthy, functioning community, and are of special significance to small rural communities like many found in the Philippines. Contaminated water may affect surrounding vegetation and agricultural stocks, which communities depend on for sustenance and for profitable harvest. Food grown using unclean water sources not only threatens the community that eats it, but it cannot be sold at market, further reducing earnings and productivity of the community inhabitants. Second, contaminated water can lead to waterborne bacterial and viral disease outbreaks, including diarrhea, malaria, and cholera, very serious, potentially-fatal illnesses. Finally, even if a community recognizes that their water source is unclean, the process of water purification is energy-intensive. Firewood and animal-waste is the most common fuel used to boil water, but these resources can become unsustainable and should not be relied upon as the sole method of water purification. To this end, addressing the problem of unsafe water must become a primary focus for affected communities.

2. Drinking Water in the Philippines

The Philippines is one country with many communities in need of clean water. According to UNICEF, the number of Filipinos with no access to safe drinking water is approximately 17 million.[iv] Over 15% of the rural communities in the Philippines do not have access to potable water due to limited income.

Most rural areas in the Philippines consider natural ground water as their source of drinking water. In particular, the domestic water requirement of Nagcarlan, in the province of Laguna, is supported by six water springs along the slope of Mt. Banahaw.[v] Due to abundant rainfall, this municipality has no water supply issues. The accumulated rainwater percolates through Mt. Banahaw as natural water springs. However, because it is not covered by the National Water Resources Board (NWRB), Nagcarlan has a poorly managed water distribution system, increasing the risk of water contamination. First, there is uncontrolled application of pesticides by several farmers planting on the top of Mt. Banahaw. Second, there are established houses and piggeries with poorly constructed septic tanks and waste disposal systems in the upland area. Lastly, the pipes that are used to distribute water to the municipality are at least 50 years old and sometimes run through polluted canals. Pesticides, heavy metals, and bacteria are the main contaminants of Nagcarlan's water system. Therefore, there is a fervent need to purify water from the aforementioned sources in order to provide the community with clean drinking water.

The primary method used for water purification in the Philippines is reverse osmosis. In Nagcarlan, there are already five major water-purifying stations and several distributors of imported bottled drinking water. However, most of the residents of Nagcarlan cannot afford to buy purified drinking water, and thus resort to a crude method of treatment whereby chlorine is dripped into water with no stirrer to distribute the chlorine. Presently, most people boil their water as a means of water purification. Other residents buy cheap faucet filters from the local market in Nagcarlan. Sometimes they even drink tap water directly from the faucet, causing public health problems like diarrhea and other gastro-intestinal diseases. In fact, the Rural Health Unit in Nagcarlan has reported 11,523 cases of intestinal diseases in 2007.[vi] Therefore, due to the present contamination of water sources and the large expense to purify them, there is a strong need to develop a low-cost water purification system fit for a community in Nagcarlan using low cost materials.

3. Potential Solutions

There are several solutions to address this need for affordable water purification systems. One potential solution is the use of Rapid Sand Filtration (RSF). This technology uses sand to separate flocculated contaminants, preventing them from passing through into the then purified water.[vii] Although this seems to be an excellent candidate for use in rural communities due to its low cost, it has several disadvantages. First of all, Rapid RSF removes less pathogens compared to other filter methods.[viii] Second, these filters require a large amount of maintenance, namely the energy, labor, and effort required to backwash contaminants off of the filtration medium.[ix] Thus, RSF on its own would not be a good application for poor communities.

A second approach is chlorination. The major problem with using this technology is that a large effort must be made to educate the community on its use. By-products of water chlorination may be harmful to humans, thus requiring great care to properly employ. Moreover, price is an issue, thus making sustained use impossible for communities with limited resources.[x]

A third potential solution is the use of solar disinfection. Once again, this may appear to be an excellent candidate because sunlight is free; however, the cost and availability of materials to build these devices may be impractical for these poor communities.[xi] Also, the availability of continuous sunlight may be lacking during rainy seasons, a characteristic common for many of these communities in less developed nations. Finally, the logistics of employing solar disinfection make it difficult to implement. More specifically, it would require a central system with a single solar sill, and a distribution system to deliver water to members of the community. Thus, the resources and energy to create this necessary infrastructure are often prohibitive for these poor rural communities.

4. Specific Solutions

4.1 Characterization of Activated Carbon

The use of activated carbon for water purification is an affordable and manageable solution to clean drinking water. Coconuts, in particular, are a great source for the activated carbon because they are abundant in the Philippines. The activated carbon generated possesses favorable characteristics. They can attain higher surface areas compared to commercially available activated carbon, making them a more effective material as an adsorbent[xii], and have been shown to be more cost effective and equally successful at removing water pollutants than other methods.[xiii]

As a specific solution, it was important to study the characteristics of activated carbon derived from coconut shell. This was accomplished by collecting approximately 642 kg of raw coconuts shells from the farmers of Nagcarlan region. These coconuts were not harvested from the trees themselves, and therefore the collected fallen fruit are considered waste material because they would have typically found little use.

The processing of these fallen fruit involved the raw coconut shells being crushed to approximately one-inch pieces and screened to eliminate fine particles. A portion of the crushed coconut was then fed to the activation reactor, which was designed by the Industrial Technology & Development Institute (ITDI) of the Department of Science & Technology (DOST) of the Philippines. The shells were then ignited with kerosene prior to startup. Once the temperature reached 400°C, additional coconut was added until the reactor was filled to capacity. The activation process was carried out by supplying steam at a rate of 1.0-1.5. kg/hr to a temperature of 1000°C for a duration of twelve hours. After processing and activation, 94.75 kg of activated carbon was produced; this resulted in an overall yield of 14.76%.

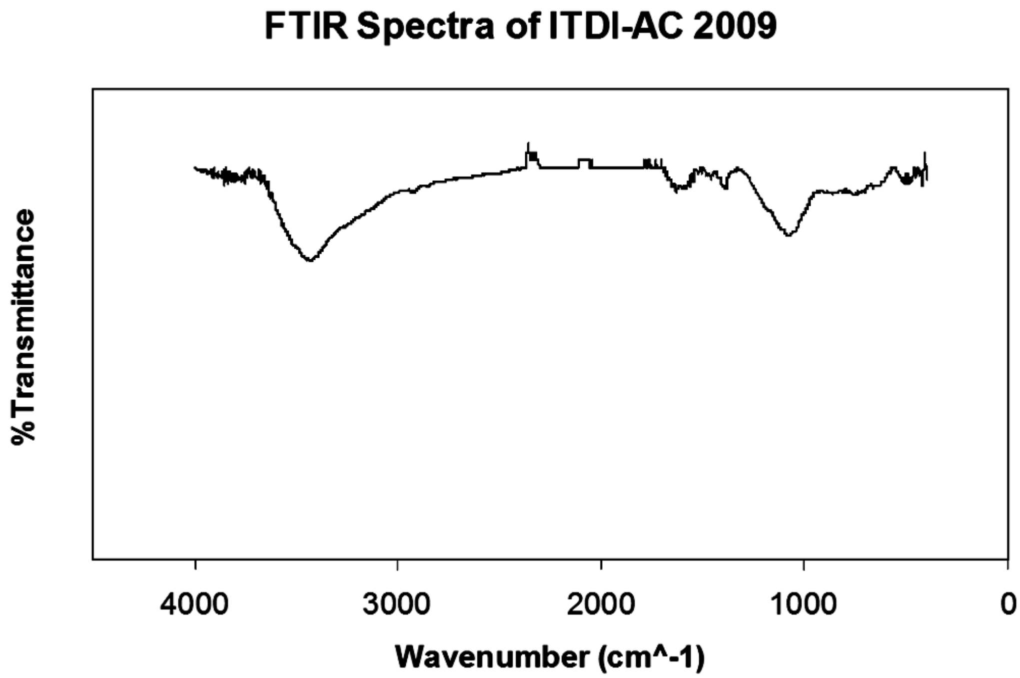

Figure 1: Fourier Transform Infrared Spectroscopy of Activated Carbon derived from Coconut.

The physical characteristics of the activated carbon in this process were determined with FTIR and Iodine number analysis by identifying surface functional groups and total surface area, respectively. The FTIR analysis of the activated carbon from coconut shells, shown in Figure 1, revealed the presence of a very broad peak at 3400 cm^{-1}. This suggested the presence of carbonyl compounds, which usually occur with very broad peaks at ranges 2500-3500 cm^{-1}. These peaks suggested carboxylic acids and it derivatives. Appearance of a peak at 1130 cm^{-1}, a short broad peak at 1640 cm^{-1}, and a very small sharp peak at 1400 cm^{-1} referred to ketones, alkenes, and a group of alkanes or alkenes, respectively.

Results from the Iodine number analysis provided a value of 1104 mg Iodine/g carbon. This number can be compared to the 600 to 1100 mg Iodine/g carbon measured for commercially available activated carbon. In addition, BET pore surface area was also measured to be 235 m^2/g.

4.2 Removal of Heavy Metals with Activated Carbon

The characterization of activated carbon revealed favorable results on surface functional groups and total surface area. This instigated the need to investigate its ability to adsorb heavy metals, such as arsenic, from drinking water. Heavy metals must be addressed because they are considered a major source of water contamination in poor communities.

The rise of global industrialization has resulted in the generation of heavy metal wastewater, specifically zinc, cadmium, arsenic, lead, copper, and nickel. Plants and factories in countries that do not possess strict environmental regulations unscrupulously pollute nearby rivers and waterways, and the contaminants often find their way to the water sources of poor rural communities. Traditional chemical precipitation processes used to remove these heavy metals would not be feasible to be performed by communities with little resources or laboratory expertise. Thus, activated carbon from natural materials offers an alternative solution to this problem.

In one example, performed by Ahmedna et al (2004), lead, copper, and zinc were removed from wastewater using steam and phosphoric acid activated nutshell carbons (derived from walnuts, pecans, and almonds). Their findings show that activated carbon generated from these nutshells performed better than activated carbon filters (made from coal) in removing the aforementioned heavy metals.[xiv]

In a separate study performed by Manju et al (1998), copper-impregnated coconut husk carbons were used to remove arsenic from wastewater. It was discovered that activated carbon was able to successfully remove arsenic in a dose dependent manner. Moreover, they were able to show that the adsorbent may be re-used after treatment with hydrogen peroxide in a nitric acid solution.[xv]

Another study performed by Kadirvelu et al (2002) involved activated carbon produced from waste parthenium to aid in the removal of nickel (II) from aqueous solution. The results showed that Ni (II) was successfully removed using the activated carbon from the parthenium weeds, especially at increased pH levels. In addition, the activated carbon could be regenerated upon its treatment with hydrochloric acid.[xvi]

These three studies demonstrate that activated carbon from various natural sources has the potential to remove heavy metals from water. It is important to note that the technology to generate this activated carbon is viable for poor communities because it is does not require sophisticated equipment, and these communities are often rich in the raw materials required to make them. However, future research in this area is still needed to examine activated carbon generation from the perspective of these poor communities.

5. Using Service Learning for Solutions

To this end of generating cost-effective water-purifying solutions for poor, rural communities, a service learning project was created, comprised of a collaboration between chemical engineering students at Manhattan College in the United States and De La Salle University in the Philippines. This project utilized the aforementioned solutions to address this specific need for a water purification system in Nagcarlan. In particular, the solution formulated by the student team centers around a personal water filter comprised of activated carbon derived from coconut shell, housed in a bamboo shell. The most important characteristics of both these materials are that they are abundant in the Philippines, biodegradable and the product of recycling waste products, reusing a material that would otherwise be thrown away, therefore imparting minimal effects to the environment.

Service learning is a teaching method employing the knowledge students have acquired in the classroom to meet the needs of a less-developed community. From a pedagogical perspective, it addresses many components in a student's education, resulting in opportunities for personal growth. Most undergraduate engineering programs focus on teaching the rudiments of their particular discipline, ultimately incorporating this collection of knowledge into a capstone course. A majority of these programs fail to underscore an engineer's duty to serve society. Engineering education should not only train a student in the technical aspects of the practice, but also encourage him or her to use these skills to serve society.

Service learning also helps build problem solving and critical thinking capabilities, it can help to enhancing a student's ability to work in multidisciplinary teams, and service learning can provide practice in managing a project from conception to final goal. Furthermore, it helps to better understand cultural differences, develop communication and interpersonal skills, and encourage lifelong learning.[xvii] In this context, however, service learning has the advantage of maintaining a sustained supply of engineers eager to solve real-world problems. More specifically, engineering educators can always apply the technological aptitude, innovation, and creativity of their students to problems of social significance, ultimately helping a disadvantaged sector of society.

6. Sustainability and Replication

6.1 Community Outreach Program

The Chemical Engineering Department of De La Salle University started its outreach program in Nagcarlan in May 2008 with an initial assessment of the water resources of Nagcarlan. The assessment consisted of an actual visit to the water sources/springs, as well as a group discussion with the Mayor and his staff. The discussion was facilitated by Department of Science and Technology Assistant Secretary Maria Lourdes Orijola. It was agreed that in order to have a sustainable supply of clean water, a comprehensive and integrated environmental management system (EMS) for the town should be set up. The planned EMS for Nagcarlan consists of not only assessing the water resources, but includes air quality management and solid wastes management as well.

The first phase of the project, environmental education, was conducted in November 2009. More than one hundred participants attended this whole day activity. Officials from the 52 barangays of the town came to learn from the lectures. Youth representatives and women also joined in, taught by volunteer faculty members about the following topics: the 3Rs of solid waste management (reduce, reuse and recycle), the use of biofuels, and the leachate problem of landfills. As a result of the first phase, a waste audit of the town was conducted.

Figure 2: Manhattan College and De La Salle University groups in Laguna, Philippines in December 2009.

During the second stage, the use of waste coconut shell was identified as potentially recyclable. It was agreed to be used for activated carbon manufacture. The ITDI (Industrial Technology Development Institute) proven process for activated carbon manufacture was used in the project. The third phase was a consultative meeting with the townspeople to discuss two projects. One project is addressing climate change and the other project is on the development of personal water purifier.

In the fall of 2009, the group from Manhattan College, with a group from De la Salle University (shown below in Figure 2), visited and presented their project in the Philippines.

6.2 Removal of Heavy Metals with Activated Carbon

The proposed service learning project for the development of a personal water purifier is currently focused on the barangays (Filipino division for town) in Nagcarlan. However, if a program's outcome proves successful, then a replication to other towns and nations would be the next step towards solving the global problem of unavailability of potable drinking water. As mentioned earlier, several million Filipinos do not have access to safe drinking water, making it essential to implement similar programs in other poor communities throughout the Philippines. Similarly, the proposed solution can be extended to other nations stricken with water quality issues, such as India, by utilizing indigenous, natural resources, exemplified by the use of Philippine's natural resources of coconut shells and bamboo.

Figure 3: Community Outreach Program with the people of Nagcarlan.

In conclusion, finding effective solutions for clean drinking water may be a challenging undertaking. However, the proposed service learning project and the community outreach program to sustain water resources for the poor communities in the Philippines shows initiative at tackling this drinking water crisis.

End Notes

[i] UNICEF & WHO, 2008

[ii] UNDP, 2006

[iii] Angara, 2010

[iv] UNICEF, 2009

[v] Orijola, 2009

[vi] Orijola, 2009

[vii] Rajala, 2003

[viii] Sato, 2002

[ix] Blume, 2004

[x] Luby, 2008

[xi] Keonig, 1967

[xii] Hu 1999; Gratuito, 2008

[xiii] Yang, 2006

[xiv] Ahmedna et al, 2004

[xv] Manju et al, 1998

[xvi] Kadirvelu et al, 2002

[xvii] Eyler, 1999

Bibliography

Ahmedna, M. et.al., "The Use of Nutshell Carbons in Drinking Water Filters for Removal of Trace Metals", *Water Research*, Vol. 38, pp.1062-1068, 2004.

Angara, E. J. (2010, March 16). Harvesting rainwater. *Business Mirror*. Retrieved June 4, 2010, from http://businessmirror.com.ph/index.php?option=com_content&view=article&id=23014:harvesting-rainwater-&catid=28:opinion&Itemid=64

Blume, T., and Neis, U., "Improved Wastewater Disinfection by Ultrasonic Pre-Treatment", *Ultrasonics Sonochemistry*, 11:333-336 (2004)

Gratuito, M.K.B. et. al., "Production of Activated Carbon from Coconut Shell: Optimization Using Response Surface Methodology", *Bioresource Tech.*, 99:4887-4895 (2008)

Hu, Z., and Srinivasan, M.P., "Preparation of High Surface Area Activated Carbons from Coconut Shell", *Microporous and Mesoporous Materials*, 27:11-18 (1999)

Kadirvelu,K. et al., "Activated carbon prepared from biomass as adsorbent: elimination of Ni(II) from aqueous solution", *Bioresource Technology*, Vol. 81, pp.87-90, 2002.

Kinetz, E. (2009, December 7). Tata Group launches water purifier for the masses. *Washington Post*. Retrieved December 15, 2009, from http://www.washingtonpost.com/wp-dyn/content/article/2009/12/07/AR2009120701004.html

Koenig, L., "The Cost of Water Treatment by Coagulation, Sedimentation, and Rapid Sand Filtration", *J. Am. Water Works Assoc.*, 59:290-336 (1967)

Luby et. al., "Difficulties in Bringing Point of Use Water Treatment to Scale in Rural Guatemala", *Am. J. Trop. Med. Hyg.*, 78:382-387 (2008)

Manju, G.N., et. al., "Evaluation of Coconut Husk Carbon for the Removal of Arsenic from Water", *Water Research*, Vol. 32, pp. 3062-3070, 1998.

Orijola, M. (2009). *Water condition in Nagcarlan*. Taguig, Philippines: Department of Science and Technology.

Rajala, R.L., et. al., "Removal of Microbes from Municipal Wastewater Effluent by Rapid Sand Filtration and Subsequent UV Irradiation", *Water Sci Technol.*, 47:157-62 (2003)

Sato et. al., "Performance of Nanofiltration for Arsenic Removal", *Water Research*, 36:3371-3377 (2002)

United Nations Development Programme. (2006). *Human development report 2006*. Retrieved June 3, 2010, from http://hdr.undp.org/en/media/HDR06-complete.pdf

UNICEF. (2009). *UN, RP and Spain launch Joint Programme on water services for poor Filipinos*. Retrieved December 15, 2009, from http://www.unicef.org/philippines/8891_10480.html

World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply and Sanitation (JMP). (2008). *Progress on drinking water and sanitation: Special focus on sanitation.* Retrieved June 3, 2010, from http://www.who.int/water_sanitation_health/monitoring/jmp_report_7_10_lores.pdf

Yang, J. *Solving Global Water Crisis – New Paradigms in Wastewater and Water Treatment*. Sacramento, CA: Earth Ecosciences Publishing Company 2006