Developing and Initiating a Strategy for Sustainable Wastewater Management in Nakhon Si Thammarat, Thailand

By Sawin Areepipatkul, Marc Gelin, Nathan Longnecker, Phornphit Manageracharath, Laura Pumphrey, Corre Steele and Nontach Thanawatyanyong

44-GFP-1303

Development and Initiation of Sustainable Wastewater Management in Nakhon Si Thammarat, Thailand

An Interactive Qualifying Project Report submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science in cooperation with Chulalongkorn University

Submitted by:
Sawin Areepipatkul
Marc Gelin
Nathan Longnecker
Phornphit Manageracharath
Laura Pumphrey
Corre Steele
Nontach Thanawatyanyong

Submitted to:
Teerayuth Kukangwan, PDA

Project Advisors:
Professor Gary Pollice, WPI
Professor Creighton Peet, WPI
Professor Patchanita Thamyongkit, Chulalongkorn University

Abstract

The village of Tha Phae discharges its wastewater without treatment. We developed a plan for the Population and Community Development Association that can lead to the adoption of an improved wastewater management system, starting with an educational awareness program. We initiated the awareness program by creating lesson plans and testing them in schools near Tha Phae. We provided our sponsor with recommendations to follow our plan of action that can lead to a community-based wastewater management system in Tha Phae.

Acknowledgements

Our team would like to express our sincere gratitude to the following people and institutions for their support throughout our project process:

- The Population and Community Development Association in Bangkok and Nakhon Si Thammarat for sponsoring our project and providing invaluable support and information.
- The Science Center for Education, and in particular Ms. Peeda Chitnuyanont for her guidance and for allowing us the space to run our exhibit in the center.
- The Wat Tha Muang School and the Wat Bot School for allowing us to pilot our lesson at their schools and for providing us valuable information and feedback.
- Our advisors, Professors Siripastr Jayanta, Creighton Peet, Gary Pollice, and Patchanita Thayongkit for their constant guidance and support to ensure the success of our project.
- Rick Vaz and Seth Tuler for their hard work directing the project center to ensure that our project went as smoothly as possible.
- Laura Hanlan, research librarian for the Worcester Polytechnic Institute Gordon Library, for her aid in identifying research tools and helpful information.
- Chulalongkorn University and Worcester Polytehnic Institute for enabling this project experience of working in a cross-cultural project team.
- The Bachelor of Science in Applied Chemistry (BSAC) department for providing workspace for our project team.

Authorship

	Primary Author(s)	Primary Editor(s)
Title Page	Corre	Corre
Abstract	Corre/Nathan	Corre/Nathan
Acknowledgements	Laura	Marc/Nathan
Authorship	Marc	All
Executive Summary	Laura/Marc/Nathan	Corre/Laura/Marc/Nathan
Introduction	Corre/Nathan	Corre/Laura/Marc/Nathan
Background	All	All
Methods	Bom/Laura/Marc/Nathan/Pinn/Prod	All
Results and Analysis	Corre/Laura/Pinn	All
Conclusions and Recommendations	Corre/Laura/Nathan	All
References	All	All
Appendices	All	All

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Executive Summary

Water pollution can cause a multitude of problems for ecosystems and human populations. Excess nutrients from biological waste can lead to an increase in biological oxygen demand, which can lead to the death of aquatic organisms. Sewage discharge can also cause water pollution and often carries pathogenic bacteria that have the potential to adversely affect human populations.

The community of Tha Phae allows this wastewater, including sewage and household wastewater, to flow into the nearby canal without treatment. This situation has a high risk of adverse ecological and human health effects. To mitigate the effects of water pollution in rural communities such as Tha Phae, a number of wastewater management systems have been developed and deployed successfully in other countries and villages.

Community-based management has been shown to be an extremely effective method for implementing and sustaining projects within rural communities. Community-based projects that give the community ownership of all phases of a project are more effective and more successful after they are left to the responsibility of the community. Our sponsor, the Population and Community Development Association (PDA) has successfully employed community-based management programs throughout Thailand.

Goal, Objectives, and Methods

The goal of this project was to **recommend steps the PDA could take that can lead to the adoption of an improved wastewater management system in Tha Phae**. We developed the following objectives that helped us reach this goal:

Our first objective was to **determine the opinions and problems associated with the current wastewater management system**. We needed to determine the readiness of the community to accept a new wastewater management system before we could propose a system and expect it to be accepted. Additionally, we needed to determine what problems are associated with the current system to ensure that those problems would be adequately addressed in a proposed improved system.

Our second objective was to **identify the steps required to provide Tha Phae with an improved wastewater management system**. We needed to identify a plan for Tha Phae that would lead to an improved wastewater management system. Our sponsor requested that the plan also incorporate an incentive program to ensure that the community would adopt the improved wastewater management system.

Our third objective was to **determine a method for building awareness within the community of problems associated with the current wastewater management system**. We arrived at this objective because our analysis indicated that there was a lack of concern in the community about the possible negative effects of poor wastewater management.

Our fourth objective was to **determine the effectiveness of the awareness program and revise the program**. We wanted to make sure that the first step that we have identified for our sponsor would be as effective as possible.

Findings

Following our initial site assessment and interviews we determined that **an improved system would not be accepted at the moment.** For a new system to be successful, the community would need to support the change and be willing to maintain it. The community does not see any major problems with the current system, so they probably would not support a change. Therefore, we determined that **a plan of action for Tha Phae was needed**.

After identifying the need for a more comprehensive plan for Tha Phae, we **identified the steps required to provide Tha Phae with an improved wastewater management system**. We defined the following five steps as a practical way to introduce an improved waste management system in Tha Phae:

1. Raise awareness of the problems with the current wastewater management system.
2. Test the water quality of wells in Tha Phae for pathogens.
3. Analyze epidemiological data from Tha Phae for sicknesses commonly caused by a close proximity to or contact with wastewater.
4. Identify and propose wastewater management programs.
5. Provide resources to sustain the system that the community has selected.

We determined that **designing an education program for the schools would be the most effective way for us to raise awareness** about wastewater pollution in Tha Phae. We designed activities about turbidity and pH, and how to treat water to make it safe to use. When we conducted our pilot tests at the Science Center for Education, we found that the **children understood the concepts presented in the activities that we had designed**.

We adapted the exhibit that we used at the Science Centre for Education to make lesson plans, and then tested those lesson plans in two schools near Tha Phae. These lessons taught about wastewater awareness, turbidity, and pH. We found that **both a small class and a large class were able to understand the basics concepts** behind each lesson, but the lessons were more effective in the smaller class because the pedagogical techniques we used required students to be close to the action. We lacked the resources necessary to keep the larger group engaged in the lesson, so **the smaller group was better able to understand the connection the lesson had to their daily lives**. After testing the lessons in the schools in Tha Phae, we revised them based on student and teacher feedback. We provided the final lessons to the PDA so that they can continue to teach them in future years and in other schools.

Conclusions

In completing our project, we developed a plan for Tha Phae that can lead to the adoption of an improved wastewater management system. We initiated the first step of raising awareness, and left the remainder of the steps as recommendations for the PDA that can lead to an improved wastewater management system in Tha Phae. Once those steps have been carried out, Tha Phae could be used as an example best-practice community for other communities to follow and adopt similar improved wastewater management systems.

Recommendations

We recommend that the PDA:

- Assist the schools around Tha Phae in implementing the education curriculum that we designed.
- Test the well water in Tha Phae for pathogenic bacteria.
- Obtain epidemiological data for Tha Phae and analyze it to determine the presence of health problems that could be caused by wastewater.
- Propose wastewater management solutions to the community of Tha Phae.
- Help community implement and sustain their chosen wastewater management solution.

1. Introduction

Water pollution can have devastating impacts on surrounding communities and ecosystems. Many signs of water pollution are hidden from view, often causing the problem to be ignored until it has progressed to an advanced stage, at which point recovery can be difficult or impossible (Smol, 2009). Dumping untreated waste into rivers, lakes and oceans causes widespread damage around the world. Over the course of the 20th century, 123 aquatic species became extinct because of water pollution in North America alone (Ricciardi, 1999). Water pollution also causes many health problems for humans and contributes to the spread of illnesses such as dysentery, salmonellosis, cryptosporidium, and hepatitis (Cheung, 1990; Infoplease, 2013).

In Thailand, water pollution is primarily caused by wastewater discharge and is one of the most pressing environmental issues (Simachaya, 2009). The village of Tha Phae, located in sub district Pak Phun, in the Mueang Nakhon Si Thammarat district of the Nakhon Si Thammarat province of Thailand, generates wastewater when cleaning and processing fish, which mixes with sewage and other wastewater from the village. Ideally, there would be a system in place that could handle all of the wastewater and treat it appropriately. Instead, the untreated waste flows through trenches along the streets of the village and empties directly into a canal.

Organic waste such as that produced in Tha Phae contributes to water pollution: fish waste can contribute to high biological oxygen demand (BOD), heavy metal contamination, excess nutrients and the spread of fish-borne pathogens; and untreated sewage can also carry diseases such as Salmoella, Shigella, Yersinia, Brucella, and Staphilococcus (Hooda, 2000; Defra, 2009; Sen, 2005; Dumontet, Dinel, & Baloda, 1999). To mitigate water pollution from organic waste, waste can be treated or recycled through various systems including slow-sand filtering, composting, growing aquatic plants, and biogas production (Polprasert, 2007; Dumontet, Dinel, & Baloda, 1999). Systems such as these are most sustainable when the community supports the installation of the system and is fully involved with all steps of the process (Pomeroy, 1995).

Our sponsor, the Population and Community Development Association (PDA), believed that Tha Phae needed a new wastewater management system. However, our preliminary findings indicated that while an improved wastewater management system would benefit Tha Phae, the residents would likely not be willing to expend the effort and resources required to adopt a new system. Therefore, we identified an opportunity for new work—raising awareness of the need for an improved wastewater management system in the community so that the environment and the community's health would not suffer.

Our goal was to recommend steps the PDA could take that can lead to the adoption of an improved wastewater management system in Tha Phae. To achieve this goal, we identified and completed four objectives:

1. Determine the opinions and problems associated with the current wastewater management system in Tha Phae,
2. Identify the steps required to provide Tha Phae with an improved wastewater management system,
3. Determine a method for raising awareness within the community of problems associated with the current wastewater management system, and
4. Determine the effectiveness of the awareness program and revise the program.

By following through with the awareness program that we initiated and the rest of the steps we provided, the PDA can introduce a wastewater management system in Tha Phae. The steps can be adapted, as necessary, to improve wastewater management in similar communities around Thailand.

2. Background and Literature Review

The residents of Tha Phae currently dispose of their wastewater in a nearby canal without any treatment. Our sponsor, the PDA, believes that this is inappropriate but does not know the negative impacts of the current system or what possible improvements can be made. This chapter discusses some of the problems that could be caused by the pollution from the current waste disposal method, introduces several waste management systems that could potentially work in Tha Phae, and presents a method for implementing sustainable projects in communities.

2.1 Negative Impacts of Water Pollution

Dumping waste into water bodies can cause a multitude of problems. The impact of a specific type of waste depends on the attributes of the waste and receiving water body. In this section we examine a few ways that water pollution can affect a community and the environment to emphasize the importance of protecting the waterways by reducing water pollution.

2.1.1 Biochemical Oxygen Demand (BOD)

In any water body that contains biological waste, a biochemical oxygen demand (BOD) exists (Defra, 2009). BOD is a measure of the amount of oxygen used by aerobic microorganisms when breaking down organic material. When the BOD is high enough, it can reduce the biologically available oxygen (BAO) to the point that the level of dissolved oxygen in the water cans no longer support aquatic life (Hooda, 2000).

2.1.2 Nitrogen and Phosphorous

Water contaminants can increase the nitrogen and phosphorous levels in water. High nitrate and phosphate levels can lead to increased algae growth and increased oxygen consumption, reducing the BAO in the water (Gonzalez, 1996; Hill, 1991). Excessive algae growth can cause algal blooms, which consume dissolved oxygen and block sunlight from reaching the bottom of the pond, river, or lake. This process is eutrophication, where excess nitrates and phosphorous in the ecosystem lead to an increase of algae growth reducing the BAO and killing aquatic organisms.

2.1.3 pH

Water that contains many contaminants may have its pH value altered. Extreme high or low pH values can cause damage to aquatic life and increase the toxicity of some pollutants, such as ammonium-N (Morrison, Fatoki, Persson, & Ekberg, 2001; Holmes, 1996). Ammonium-N is common in surface runoff and sewage. In basic water, ammonium-N breaks down into ammonia, which is extremely toxic to aquatic life in high concentrations. Acidic water can decrease the solubility of some elements that are essential for cellular function in animals such as selenium. It can also increase the solubility of toxic heavy metals such as cadmium and mercury that can cause reduced growth and development of children, cancer, and organ damage (Physicians for Social Responsibility, 2014).

2.1.4 Turbidity

Wastewater that contains insoluble materials will introduce turbidity to the water body. Turbidity is a measure of the haziness of the water caused by the number of suspended solid particles in the water (Gonzalez, 1996). If water has high turbidity levels, the particles in the water can block sunlight and affect organisms living on the bottom of the river, lake or ocean. The lack of sunlight can cause plants and algae to die and remove a food source for fish and other animals higher on the food chain.

2.1.5 Pathogens

Wastewater pollution can affect population in different ways depending largely on the pathogens present, the environment in which they are spread, and the immunity of the people (Shuval, 1989). Thousands of pathogens can be found in human and animal wastes presenting significant health risks when these wastes lack proper treatment protocols, especially in countries with high prevalence of diarrheal diseases and intestinal parasites (WHO, 1989). Swimming and bathing in these polluted waters allow these pathogens to transfer into a person through their mouth or skin.

The risks of wastewater-associated diseases are increased in crowded communities and areas with unsafe sanitation, both of which can facilitate the spread of these diseases (WHO, 1989). Epidemiological studies have been performed in communities that come in contact with wastewater, and have identified numerous diseases resulting from these conditions. Most commonly, pathogens that are ingested from wastewater are bacteria, viruses, protozoa and helminthes (WHO, 1989; Ewemeje, 2014). Depending on the type of pathogen, an infection can be caused by as little as a singular organism entering the body. Wastewater from human wastes often contains bacteria such as E. coli, Listeria, Salmonella, Leptospirosis, Biyrio, and Campylobacter that cause infections such as diarrhea, dysentery, or skin and tissue infections. Ingestion of wastewater can also cause many microbial intestinal infections including cholera, typhoid fever and bacillary dysentery. Viruses are also often found in human wastes, and pose a risk of infection even though they cannot multiply without a host. Microbial pathogens have been found to cause chronic diseases such as degenerative heart disease and stomach ulcers. Helminthes can also be passed through untreated wastewater and include organisms such as roundworms, tapeworms and pinworms.

2.1.6 Reduced Quality of Life

Polluted water areas contribute to a lower quality of life. On the Chesapeake Bay, for example, real estate values increased in areas with decreased levels of water pollution (Leggett, 2000). Areas that had higher water pollution had a corresponding drop in property values, indicating that areas that suffer from water pollution are less pleasant and desired locations to live. Polluted areas may suffer from unpleasant odors, murky water, algal blooms, and death of aquatic life, among other negative impacts.

2.2 Testing for Pathogenic Bacteria

To determine whether pathogenic bacteria are present, it is easiest to test for indicator organisms such as E. coli (El-Lathy, El-Taweel, El-Sonosy, Samhan, & Moussa, 2009). If E. coli is present, then that means that there is a high risk that other pathogenic bacteria are also present. Testing for indicator organisms is a simpler and less expensive method of estimating the risk of pathogenic microorganisms being present in a water source. This will not produce an exact quantification of the level of microorganisms present, but it will estimate the risk of contamination due to pathogenic bacteria.

2.3 Possible Wastewater Management Systems

Conventional waste treatment systems are often not feasible in solving the sanitation and water pollution problems in developing countries (Polprasert, 2007). Therefore, alternative wastewater treatment systems that have natural sources of energy input, recycle waste, or do not require full time staff have been developed (Mihelcic, 2009, Polprasert, 2007). For any system to be successfully implemented and maintained it must be economically affordable, environmentally sustainable, and socially acceptable (Pongrai, 2012). These requirements change for different communities based on factors such as local culture, layout of the community, economic affluence, characteristics of waste produced, climate, and environment. It is essential to carefully evaluate which wastewater management system is most appropriate for a particular community (Massoud, 2009). This section discusses several alternative wastewater management systems. Appendix B – Table of Alternate Wastewater Management Systems compares the advantages and disadvantages of each system in a table.

2.3.1 Filter Pipe Openings

Communities can use filters to cover the openings of pipes that collect wastewater. This would prevent solid waste from entering the pipes, thereby reducing the chance of clogging in trenches that transport the wastewater. Fewer clogs in the trenches would reduce the amount of stagnant water, removing a potential mosquito breeding ground.

While the cost of this system is minimal, this system requires each household to maintain their filter. The filters would need to be cleaned whenever they get clogged, which could be frequent, depending on the amount of solid waste and leaves being flushed towards the pipes. If the community keeps the filters properly maintained, it should allow the wastewater to flow freely through the trenches and reduce the frequency that the trench would need to be flushed by the government. This is not a complete waste management system, but is a small improvement that could be implemented temporarily while a more comprehensive change is being implemented.

2.3.2 Anaerobic digestion

Tha Phae could also use an anaerobic digester to process their waste. The digester would increase the quality of the effluent flowing into the canal and produce methane gas that the community could sell or use for fuel.

An anaerobic digester is a tank that uses bacteria to facilitate the biological decomposition of wastewater without oxygen (American Biogas Council, 2014). The digestion process creates ammonia, methane, and carbon dioxide. There are a number of different types of anaerobic digesters that vary in size and design; some are better for mostly solid effluent, while others work well with very dilute effluent. There are many types of anaerobic digesters and an expert is required to determine which type of anaerobic digester would be most appropriate for a community.

Anaerobic digesters often have ammonia remaining in their effluent (Polprasert, 2007). Depending on the level of ammonia left in the effluent, a second system for treating the water could be necessary to make the water safe enough to deposit into water ways.

Anaerobic digesters have high construction costs, and maintenance can also be expensive. Additionally, someone would need to be trained to take care of the digester. Care would primarily involve ensuring that the digester maintains a desired temperature and does not clog (Balsam, 2006).

2.3.3 Land treatment of wastewater

Wastewater can be distributed over land, acting as a fertilizer due to the nutrients in the effluent (Sperling, 1996). The soil and roots filter the wastewater as it penetrates the ground. This treatment method could allow the community members to sell their wastewater for profit.

However, before wastewater can safely be used as fertilizer, it must be tested to ensure that it is not harmful. Wastewater could contain pathogenic organisms or toxins, which could be harmful to plants, humans caring for the plants, or humans eating the plants. If the wastewater is not safe enough, it could be treated to make it suitable for distribution and then used as fertilizer.

2.3.4 Septic Tanks

Septic tanks are a low-cost, low-maintenance method of dealing with sewage (NESC, 2014). A septic tank is a storage container for sewage. They are usually stored underground, and in areas with plenty of open space they are often combined with a leach field that allows used wastewater to be dispersed in the environment naturally.

For septic tanks to be adopted in a community, each household or set of households would need a location that the tank could be installed. The size of the tank would vary based on the size of the home, but would typically only require a few cubic meters of space (Engineering ToolBox, 2014). If the tank were to be combined with a leach field, then a flat, open grassy area would also be required (NESC, 2014). The size of the grassy area would vary based on the amount of waste being produced.

Septic tanks are relatively cheap to install and maintain (NESC, 2014). Households would periodically need to hire a service to pump the tank and take away the sludge. However, the household owner would not need to be involved in maintenance aside from hiring a service to pump the tank.

2.3.5 Slow Sand Filtration

A slow sand filter is an open container filled halfway with sand and gravel. On top is a thick layer of fine sand that is supported by a layer of gravel. At the bottom, drains allow filtered water out of the container. Wastewater is collected on top and trickles through the sand. As the water is filtered, contaminants build up in the sand (Huisman, 1974, Lahlou, 2000). This causes the filter to remove smaller particles, but also decreases the rate in which the water passes through the sand (Huisman, 1974). The sand filter needs to be cleaned periodically to prevent clogging (WHO, 2013). The required frequency of the cleaning depends on how fine the sand is. If it is coarse, the entire filter will need to be replaced periodically because particles from the wastewater will infiltrate through the whole pile of sand. Fine sand keeps all particles on the top layer so just the top layer will need to be removed and disposed of periodically. Slow sand filters are easy to maintain, can filter out many organic and inorganic wastes, and have little to no power or chemical requirements (Lahlou, 2000). However, sand filters require a large area in which to be built and high turbidity effluent can cause it to clog rapidly (WHO, 2013).

2.4 Current Wastewater Management in Thailand

As of 2012 only one fifth of the wastewater generated in Thailand was treated (Pongrai, 2012). The Thai central government has several agencies concerned with wastewater regulation, such as the Pollution Control Department and National Environment Board (Pollution Control Department, 2013). These agencies have defined water quality guidelines for different types of water such as drinking water, ground water, effluent, water for fresh water animals, and coastal water. However, these agencies are not responsible for the actual maintenance of waste treatment plants (Simachaya, 2009). At the industrial level, producers are responsible for treating their own waste. For domestic waste, the central government designs and builds treatment plants and then transfers the management over to the local governing authorities (LGAs), often without a long-term management plan.

These wastewater treatment plants typically fail to operate effectively since the LGAs are not prepared for the responsibility of operating them and lack a sense of ownership over them (Simachaya, 2009). Because the LGAs are not involved in developing the wastewater management systems, they are not invested in the local treatment plants. Additionally, LGAs often lack the training and resources required to maintain the plants.

The central government has provided for funding by introducing the "polluter pays" principle, allowing the LGAs to charge tariffs to fund the treatment plants (Pollution Control Department, 2013). As of 2009, only three of the ninety-five wastewater treatment plants had implemented tariffs (Simachaya, 2009). LGAs avoid imposing tariffs due to local politics, the lack of collection systems and the clients' unwillingness to pay to use treatment facilities. Polprasert (2007) argues that even without the current collection issues, tariffs collected may not be enough to support a wastewater treatment facility in a developing country.

2.5 Community-Based Management

Complete community involvement and ownership in all phases of any project can ensure the success of that project after it is left to the responsibility of the community (Pomeroy, 1995). This involvement relies heavily on the inclusion of the community members at the very beginning of the project process. Community management is more effective when the community itself is responsible for the project, not the local government or other authority. Therefore, in Thailand where the governing office holders are local but not usually influential, the community can remain the main stakeholder and decision maker in the project. Additionally, when a project incorporates individual systems for each family this will promote ownership as that family is responsible for their own installation and maintenance.

Community management means something slightly different for each community, depending on their internal structure and eagerness to support a project (Mihelcic, 2009). Success has been seen in projects where the community leadership maintains participation, the needs of the community are considered in all decisions and the community understands the necessity for the project. When this participatory approach is properly managed, it often acts as a facilitator for future community development with broader implications.

2.6 Tha Phae

Our project site is located in Tha Phae village located in sub-district Pak Phun of the Mueang Nakhon Si Thammarat district of the Nakhon Si Thammarat province, Thailand. Tha Phae is a Thai-Muslim community that is approximately 80% Muslim and 20% Buddhist (Tha Phae community members, personal communication, January 27, 2014).

The community consists of 60 households, 30 of which process fish for a living (Tha Phae community members, personal communication, January 27, 2014). A few community members fish and eat fish from the canal. Those who process fish purchase frozen fish from a market, remove the innards, and then sell this processed fish locally within the city district. Some parts of the innards are useful for making special dishes. For example, the fish kidneys are a main ingredient in making fish kidney soup. The remaining innards are taken away by a third party to an aquaculture farm nearby and used to feed the fish.

The community members use almost every part of the fish and leave only blood as waste (Tha Phae community members, personal communication, January 27, 2014). According to the Islamic religion, the community members cannot consume the blood of the fish. Therefore, all the blood is disposed of along with the water used to thaw, clean, and cook the fish.

Tha Phae contains three trenches built by the government to carry the village's wastewater into the canal (Tha Phae community members, personal communication, January 27, 2014). Community members in both sections of the community dump their wastewater into a pipe connected from their house to the government trench, which leads directly to the canal.

Each house dumps wastewater from fish processing, wastewater from household activities, and sewage into the canal (Tha Phae community members, personal communication, January 27, 2014). Community members are not the only ones polluting the canal with wastewater. Nearby there are commercial buildings that also discharge wastewater into the canal.

2.7 Summary

Dumping untreated organic wastes into rivers, lakes and oceans causes widespread damage around the world. Water pollution from organic waste comes in many forms and can be the root of many serious health problems. The risks associated with dumping organic wastewater into waterways apply to the situation in Tha Phae due to their current waste management practices. A variety of appropriate wastewater management systems have been developed that address these risks. Community based management of these systems can help insure their success.

3. Methodology

The goal of this project is to **recommend steps for the PDA to take that could lead to the adoption of an improved wastewater management system in Tha Phae**. We developed the following objectives that helped us reach this goal:

1. Determine the opinions and problems associated with the current wastewater management system in Tha Phae.
2. Identify the steps required to provide Tha Phae with an improved wastewater management system incorporating an incentive program.
3. Determine a method for raising awareness within the community of problems associated with the current wastewater management system.
4. Determine the effectiveness of the awareness program and revise the program.

3.1 Objective #1

Our first objective was to **determine the opinions and problems associated with the current wastewater management system**. It was necessary to assess the readiness of the community to accept a new wastewater management system before we could propose an improved system that would be accepted. We needed to determine what issues are associated with the current system to ensure that those issues would be adequately addressed in our proposed system. To accomplish this objective we interviewed community members and surveyed the site.

3.1.1 Interviews

We conducted semi-structured interviews with eleven households to determine the community's opinions of the current wastewater management system. We interviewed nine out of the thirty fish-processing households, and two of the remaining thirty households. The households were chosen by our sponsor the Population and Community Development Association who aimed to represent the different views of the community. See Appendix C – Interview Protocol for Tha Phae Residents for the interview protocol for Tha Phae.

One of our eleven interviews is shown in Figure 1: Interviewing locals. The interviews aimed to help us understand the community's view of the wastewater problem that the PDA had identified. We asked about the amounts and types of waste that were produced, the methods used to eliminate the waste, and whether they considered the current system problematic.

Figure 1: Interviewing locals

3.1.2 Site Survey

We conducted a site survey in Tha Phae to determine the potential problems associated with the current system. This entailed mapping the layout of the village while augmenting the map with pictures. While mapping, we tracked the path that the wastewater follows as it flows from houses around the village to the canal. We noted the sources of wastewater that fed into the wastewater trenches and types of coverings used over the trenches. We also observed the rate of water flow in the trenches and in the canal at both high and low tide.

3.2 Objective #2

Our second objective was to **identify the steps required to provide Tha Phae with an improved wastewater management system**. It was necessary to identify a plan for Tha Phae that would lead to an improved wastewater management system. The plan incorporated an incentive program as to ensure that the community would adopt the improved wastewater management system. To accomplish this objective we conducted a SWOT analysis of the data we had collected and consulted with our sponsor.

3.2.1 SWOT Analysis

We conducted a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of our findings from objective one to determine the potential approaches for introducing an improved wastewater management system in Tha Phae. We identified controllable and uncontrollable factors around Tha Phae and organized them into categories based on their advantages and disadvantages. We categorized each factor as a strength, weakness, opportunity, or threat. We analyzed the four categories to develop specific strategies that leverage the strengths and opportunities to overcome the weaknesses and threats.

3.2.2 Sponsor Consultation

We consulted with our sponsor to determine the best approach to encourage the adoption of an improved wastewater management system in Tha Phae. One of our meetings is shown in Figure 2: Consulting with PDA in Nakhon Si Thammarat. The PDA was a valuable source of knowledge because they have extensive experience with community development programs. Our sponsor suggested we incorporate an incentive program with our recommended wastewater solutions as a way to maximize the participation of the community in any waste management improvement. We discussed the need to raise awareness within the community, inquired about the feasibility of our potential plan, and brainstormed methods for incorporating incentive programs into the plan.

Figure 2: Consulting with PDA in Nakhon Si Thammarat

3.3 Objective #3

Our third objective was to **determine a method for raising awareness within the community of problems associated with the current wastewater management system**. This was necessary because our analysis indicated that there was a lack of concern in the community about the possible negative effects of poor wastewater management treatment. To complete this objective we researched previous methods for raising awareness, interviewed an education professional, designed turbidity and pH activities, tested the activities at an exhibit in the Science Center for Education (SCE), wrote lesson plans that incorporated those activities, and created a website to host the lesson plans and activities that we had created.

3.3.1 Research Previous Awareness Campaigns

To promote awareness within Tha Phae, we consulted previous work to determine the most appropriate programs to be installed. We reviewed our SWOT analysis for strategies to raise awareness and referenced previous Interactive Qualifying Projects (IQP) focused on raising awareness. The main IQP we drew from was "Promoting a Lead Free Community: An Educational Program for Schools in Thailand" (Hayes *et al.,* 2013). We adapted their methods of developing an effective program and evaluated their findings to develop our education program for Tha Phae.

3.3.2 Interviews with Science Museum Educator

We conducted two informal interviews with Ms. Peeda Chitnuyanont, an educator at the SCE. The purpose of the interviews was to gain insight on how to enhance an education program so that it would be captivating for the students and promote awareness about wastewater pollution most effectively. In both interviews, we asked her for ideas on activities to incorporate into our lessons, and for feedback on our existing lesson plans. Refer to Appendix D – Agenda for Meeting with Ms. Chitnuyanont.

3.3.3 Pilot Test at the Science Center for Education

To evaluate the feasibility and educational value of the experiments that we were incorporating into our lesson plans, we asked children to test two of our experiments. The SCE provided us with the space for our team to hold an exhibit. We held the exhibit for four hours and encouraged children who were visiting the SCE to participate in our activity. The experiments introduced how water quality is affected by pH and turbidity.

We used posters to advertise the exhibit and guide the students through each of the activities. At the beginning of the exhibit, we told the children that they were water doctors and that they had to help cure the contaminated water. We provided them with workbooks to record their progress through the exhibit as they cured their patient: a cup of contaminated water.

At the first station, students cured a cup of turbid water. They used simple filters to improve the quality of the water. We constructed the filters ahead of time using sand and cotton, so that the children only had to pour their water through the filters to cure it.

At the second station, students cured a cup of acidic or basic water. We provided them with homemade cabbage paper strips to determine whether the cup was acidic or basic. The students then cured the water by neutralizing the solution by adding acid or base. Our procedure for creating cabbage paper strips is included with the lesson plans in Appendix E – Lesson Plans.

After they cured the water at each station, we gave them a candy as a prize. We also provided a handout for parents that contained information about our exhibit and about wastewater pollution. To support the exhibit and provide the children with follow-up activities, we created a website to host instructions about how to do the activities at home. We provided the link to the website on the workbooks, parents' handouts, and posters. English version of the website can be viewed here: https://sites.google.com/site/pollutionedueng.

PH Experiment

One of the activities that we had children test at the SCE was a pH experiment. The purpose of the pH experiment was to educate the children that clear water is not always safe and may still be harmful to aquatic life. We made pH testing strips using red cabbage and filter paper. We distributed cups of water solutions that either contained lime juice (acid) or baking soda (base). We instructed the children that their cup of water was not safe for fish to live in, and they needed to neutralize it to make it safe. The children then used the pH testing strips and a pH scale displayed on our poster to determine whether their cup of water was acidic or basic, and attempted to neutralize their cup by adding either an acidic or basic solution. Figure 3: Child and parent doing pH experiment depicts Phornphit helping one of the children with the pH activity.

Figure 3: Child and parent doing pH experiment

Turbidity Experiment

The second activity at the SCE was a turbidity experiment. The purpose of the turbidity experiment was to teach that water that appears dirty may be cleaned using simple methods. We made filters using empty water bottles, cloth, cotton balls, and coarse sand. We gave children cups of water mixed with dirt and instructed them to pour the turbid water into one of the filters. Figure

4: A group of children testing the water bottle filters shows a group of students at this station. They watched the filter remove the turbidity and clearer water come out at the end. Both the turbidity experiment and the pH experiment were designed to teach the children that they could make a difference in improving water quality.

Figure 4: A group of children testing the water bottle filters

Survey

We surveyed the children after they completed the exhibit to determine how much they enjoyed the activities and to evaluate the educational value of the experiments. We wanted to ensure that the activities were fun for the children so that they would be engaged when these activities are implemented in classrooms. To evaluate how much the children learned, we asked questions about whether they felt comfortable touching or drinking the water after its neutralized or filtered. We used candy prizes as an incentive to encourage children to complete the survey. Figure 5: A mother helps her son fill out a survey shows a mother helping her child fill out the survey. See Appendix F – Survey for Science Center for Education for the survey questions used at the SCE.

Figure 5: A mother helps her son fill out a survey

3.3.4 Design Lesson Plans for Tha Phae

We created lesson plans for the teachers of Tha Phae that incorporated the activities that we tested at the Science Center for Education. The purpose of these lesson plans was to educate the children of Tha Phae about the dangers of wastewater, and to provoke students to think how clean water can become polluted and how to clean it up. We combined the results of our survey and observations from the SCE to evaluate the educational value and effectiveness of the activities. We used our results from our evaluation and consultation with Ms. Chitnuyanont to determine how to improve the activities and incorporate them into our lesson plans. Once we had created the lesson plans, we uploaded them to our website so that anyone can access them.

3.4 Objective #4

Our fourth objective was to **determine the effectiveness of the awareness program and revise the program**. This was necessary to ensure that the first step that we set forth for our sponsor would be as effective as possible. To accomplish this, we conducted a pilot lesson in two schools in Tha Phae using the lesson plans from objective #3, obtained teacher feedback, surveyed the students about the lesson, and finally revised the lesson plans.

3.4.1 Tha Phae Pilot Lesson

We tested our lesson plans by teaching a combined three-lesson class over two hours in two separate schools in Pak Phun. The purpose of teaching the lessons was to determine the effectiveness of the lessons so that they could be evaluated and revised.

Wastewater Awareness

The purpose of the first activity was to get the students thinking about wastewater and to teach them that pollutants are not always visible in wastewater. We asked the students to brainstorm what wastewater their community produces using a drawing of a house near a canal, as shown in Figure 6: House and canal brainstorming aid. We asked the students what goes into the canal from the house. To make the activity more fun and engaging, we gave the students rubber chickens and had them pass the toys around while we played music. When we stopped playing music, the students that were holding the rubber chickens had to come up and write an answer on the paper. This was a fun way of getting them thinking about water pollution and what waste they deposit into the canal.

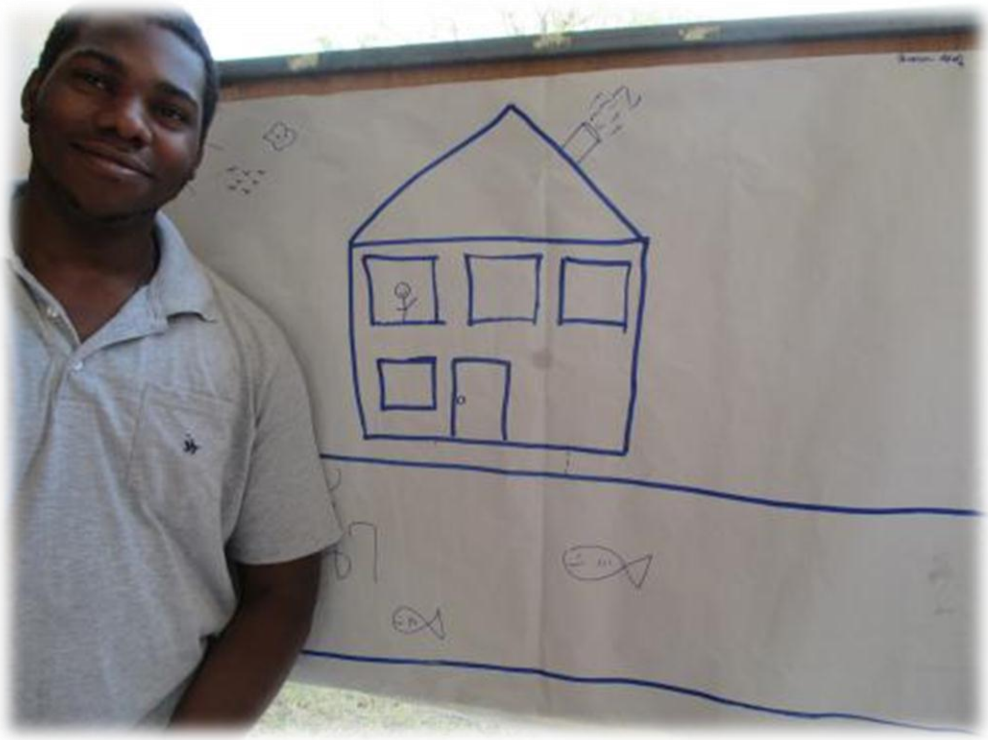

Figure 6: House and canal brainstorming aid

Water Quality: Turbidity

The purpose of the turbidity activity was to teach the students that they could make a difference in the quality of water. At the beginning of the lesson, we distributed a workbook similar to the one used in the SCE. The workbooks were intended to ensure that the students paid attention to the turbidity and pH lessons because they had to record their findings from the experiments. The workbooks also contained a link to our website so that the students could find information about how to do these experiments at home.

During the lesson, we explained how turbid water can block sunlight and affect aquatic life. We demonstrated how a filter works by pouring cloudy water through a filter that we had constructed, and showed them how it had reduced the turbidity of the water, but did not make it entirely clear. We then challenged the students to build a better filter. We split the students up into groups of around five, and gave them materials to construct their filters with. Figure 7: A group of students discussing the best filter design shows a group discussing the best filter design. Once they had constructed their filters, a representative from each group explained how they chose their design, and then tested how well their filter worked. The group with the clearest filtered water received a prize. This lesson was intended to teach the students that they have control over the quality of their wastewater.

Figure 7: A group of students discussing the best filter design

Water Quality: pH

The purpose of the pH experiment was to teach the kids that clear water is not always safe. To initiate the pH experiment, we showed the students two cups of clear water, one acidic solution with vinegar, the other basic with baking soda solution. We asked the students if anyone thought they were safe to drink. We poured the solutions together, creating a vigorous bubbling effect. This was done to show the students that there are things in the water that they cannot see that can potentially harm them, so clear water is not necessarily safe to drink.

We divided the students into groups of five, and provided each group with a cup of water, an acidic solution, a basic solution, and a supply of our homemade cabbage paper. We taught the students the pH of many household items and how to use cabbage paper to identify an acid or base and how to neutralize those solutions. We allowed them to experiment with the cabbage paper to see how the acid and base changed the color of the paper. We told them that fish cannot live in water that is too acidic or basic, and if many household items are dumped into the canal then they could make the waterway unsafe for fish. Figure 8: A student using cabbage paper to determine the pH of a solution shows a student examining the cabbage paper after dipping one end in acidic solution and the other end in basic solution.

Figure 8: A student using cabbage paper to determine the pH of a solution

Next, we told them to add either acid or base to make the water unsafe for drinking. Each group then switched cups with another group. We challenged each group to determine whether their new cup was acidic or basic, and then to neutralize it. This lesson was intended to teach the students that clear water is not always safe for people or animals to swim in or drink from.

At the end of the lessons, we provided the students with a parents' handout to take home. The parents' handout informed the parents about what the kids learned that day, provided a short summary of the dangers of wastewater, and also contained a link to our website.

3.4.2 Teachers' comments

Before going to Tha Phae to carry out the lesson plans, we sent the teachers of both schools pre surveys for information about their teaching style, the student's general behavior and their attention span, and the techniques they used to hold their students attention. The information obtained helped shaped the lessons that we prepared for the students. After we completed the lessons, we asked the teachers for feedback about the lessons. These discussions assessed the teachers' opinions about the effectiveness of the lessons, their confidence in giving the lessons on their own, and whether they thought there should be any modifications to the lesson plans. Refer to Appendix G – Pre Lesson Questions for Teachers for the teachers' pre survey and Appendix H – Feedback Questions for Teachers for questions soliciting teacher feedback after the lessons.

3.4.3 Pre and Post Surveys

We surveyed the students to evaluate the effectiveness of our lessons. We distributed a pre-survey before the lesson to establish the students' prior level of knowledge about wastewater. After the lesson, we distributed a post survey to determine what new information the students retained. Figure 9: A student filling out the survey after the lesson shows a student filling out one of our surveys. We compared the two surveys to determine the effectiveness of the lesson. Both the pre-survey and the post survey are available in Appendix I – Pre and Post Survey for Schools in Pak Phun.

Figure 9: A student filling out the survey after the lesson

3.4.4 Lesson Plan Revision

We used the information that we gathered from the pilot lesson, surveys, and teacher feedback to revise the lesson plans. We used anecdotal data from instructing the pilot lesson to gain a general understanding of how much fun and how instructive the lessons were. We analyzed the teachers' feedback to determine how the lessons could be improved and the likelihood that the lessons would be adopted within the school system. We also analyzed the survey results to obtain quantitative data about the effectiveness of the lesson. We used the results of our analysis to identify necessary improvements to the lessons and revised our lesson plans accordingly.

4. Results and Analysis

During our initial visit to Tha Phae, we identified the main problems the community faced with regard to their current wastewater management system. We found that the problem was more complex than we had originally thought. In this chapter we will discuss our initial findings around which we structured our last three objectives. We then go into detail on how we determined the steps necessary to lead towards an improved wastewater management system in Tha Phae. Lastly we describe our initiation of the first step to raise awareness in local schools about wastewater pollution, including the information gained from our pilot lessons.

4.1 Problems and Opinions Associated with the Current System

Our first objective was to determine the problems and opinions associated with the current wastewater management system in Tha Phae. We interviewed residents of Tha Phae about the current system and their opinions regarding it. We also observed and assessed the current system ourselves. We determined that the current wastewater management system needs improvement but many residents do not see a need to improve. Without the support of the community a new system would most likely be unsuccessful.

4.1.1 The Current System Needs Improvement

Tha Phae's wastewater management system should be improved because there are environmental and health risks associated with the current wastewater management system. The canal that all of Tha Phae's wastewater is dumped into is visibly polluted (see Figure 10: Polluted canal in Tha Phae). When we asked whether the community members thought the canal was polluted, several community members informed us that there are times when large numbers of fish in the canal die. This suggests that the level of pollution of the canal is environmentally problematic. However, we do not know the extent to which Tha Phae's wastewater affects the canal compared to other sources. Several community members informed us that nearby commercial buildings also dispose of their waste in the same canal. It is likely that pollution from those sources causes more harm than the wastewater from Tha Phae, so it is possible that an improved system in Tha Phae would not significantly improve the quality of the canal.

Figure 10: Polluted canal in Tha Phae

Nevertheless, the system needs improvement because there are a couple ways that the current system could be adversely affecting human health. While the community does not directly interact with the wastewater in the trenches or the canal, the wastewater could still cause sickness in the community by spreading contamination through animals or well water.

We observed that the trenches that carry wastewater through the community are an ideal breeding place for mosquitoes and flies that can spread diseases such as dengue fever and malaria. Many trenches are uncovered and contain stagnant water that insects could use for breeding. One of our interviews revealed that there has been an outbreak of dengue fever in Tha Phae, suggesting that this is a valid concern.

Larger animals can also spread illnesses that they receive from the canal. The community keeps many animals such as cats, ducks, and chickens that interact with the trenches and canal. During our site survey, we witnessed a duck drinking from the trenches (Figure 11: Duck drinking from a trench). Sewage and other organic wastes often contain many pathogens that can infect or be carried by the animals. Because of the close living quarters in Tha Phae, disease could easily spread to affect other animals and humans.

Figure 11: Duck drinking from a trench

In addition to spreading through animals, pathogens could also spread through groundwater. Pathogens from wastewater could seep out of the trenches or the canal and contaminate groundwater and wells. Interviewees confirmed that all households use well water for everyday tasks such as laundry, bathing, and processing fish. If the well water were contaminated, it would provide a high risk infection vector for pathogens because of the frequent contact that the community has with the well water. The community does not consume well water, so while pathogens still pose a risk to human health, other pollutants are not as large a concern.

From our interviews, we discovered that there is an annual flood in November and December that lasts a couple of weeks. During this flood, the canal overflows and covers the lower part of the village in water. During the flood the water level rises above the concrete canal bottom, and the water seeps into the ground. If the floodwater carries any pathogens, those pathogens could spread to the groundwater and contaminate the wells.

4.1.2 The Community is Unaware of Problems with the Current System

Families are unconcerned about the potential negative impacts of the current waste management system. Of the eleven families interviewed, five did not think there was an existing problem with the fish waste disposal system. Of those who did think there was a problem, only three saw a problem with the smell coming from the trenches. They did not believe that the existing wastewater management system impacted their health. Even with the knowledge that wastewater was being dumped into the canal, four of the families we interviewed believed that the canal was clean and two of the families stated that they eat fish that they get from the canal. This evidence indicates that there is a lack of awareness in the community about the risks associated with their current system.

4.1.3 The Community Depends on Local Government

Evidence from our interviews indicated that the community does not take initiative in caring for their current wastewater management system and depends on the government to solve problems. The largest concern the community has with the trenches is the odor that comes from the uncovered sections of the trenches. When the odor gets too strong, the community asks the government to clean the trenches for them. The government cleans the trenches by flushing them out with water. When we asked the community members about how they thought the current system should be improved, six out of eleven households responded that they would like the local government to clean the trenches more often. None of the interviewees suggested that the community members should take action to improve their system themselves. This demonstrates that the community either does not realize that they can make a difference in the quality of their wastewater management system or that they do not want to take action to improve it. The community is not proactive about improving their wastewater management system.

4.1.4 An Improved System Would Not Be Successful

For an improved system to be successful, the community would have to support the change and be willing to maintain it. Our findings indicate that the community does not see any major problems with the current system, so they probably would not support a change. Our findings also indicated that the community is currently inactive about improving their wastewater management system, because the residents of Tha Phae depend on the government to fix their waste management system. Because the community does not recognize the problem and does not take action to improve the situation, we determined that an improved system would not be successful at this time.

4.1.5 A Plan of Action is Necessary

Because we determined that an improved system would not successful, we identified the need for a plan of action that could lead to the success of an improved system in Tha Phae. Our previous research had indicated that community-based management is an extremely effective method for ensuring the success of projects like this, so we determined that our plan of action would need to incorporate community involvement. To successfully implement an improved system through community-based management, the community would need to recognize and take ownership of the problem so that they could take responsibility for implementation and maintenance. Therefore, we determined that a plan of action for Tha Phae was necessary, and modified our second objective to be identifying that plan.

4.2 Steps Leading Towards an Improved System

Our second objective was to identify the steps required to address the problems that we identified within Tha Phae. We determined that the following five steps would be a practical way for the PDA to introduce a sustainable waste management system in Tha Phae:

1. Raise awareness of the problems with the current wastewater management system.
2. Test the water quality of wells in Tha Phae for pathogens.
3. Analyze epidemiological data from Tha Phae for sicknesses commonly caused by a close proximity to or contact with wastewater.
4. Identify and propose wastewater management programs.
5. Provide resources to sustain the system the community has selected.

We identified these by performing a strengths, weaknesses, opportunities and threats (SWOT) analysis and adapting ideas from the PDA's typical approach to introducing new programs to a community.

In the SWOT analysis we organized the results and analysis from our observations and interviews of the community into the four categories. Abbreviated results are listed in Figure 12: SWOT matrix excerpt.

Strengths

1. The community values education: most people are educated through 12th grade
2. The community has minimal interaction with the canal

Weaknesses

1. Wastewater pollutes the canal
2. Trenches hold stagnant water
3. Pipes and trenches may contaminate wells
4. Community does not see a problem with the current system apart from the smell
5. The community is not proactive and depends on government services

Opportunities

1. Community has a good relationship with PDA
2. Potential to gain revenue from reusing waste
3. Water quality tests could be used for evidence
4. Epidemiological data could be used for evidence
5. PDA has connections with nearby schools

Threats

1. A flood occurs every year for about 15 days
2. Nearby commericial buildings dispose of waste into the canal
3. The PDA does not want to interfere with the local government

Figure 12: SWOT matrix excerpt

We then analyzed these four categories to develop specific strategies to overcome the weaknesses and threats and optimize the opportunities and strengths. The steps were developed to be possible for the PDA to follow and so they modeled similar strategies the PDA has previously established.

4.2.1 Step 1 – Raise Awareness

We found that a new wastewater management system would not be likely to be successful because most of the people are not aware of the problems associated with the current system (weakness 4). Even if they were aware of a problem, they would not change the current system because they are too dependent on the government to provide such services (weakness 5). To address these weaknesses, we determined that an appropriate first step was to raise awareness about the negative impacts of water pollution on human health.

This is a common first step in the PDA's approach when introducing a new program to a community. After gaining the community's trust, they work to make sure that the residents understand the problems. If residents do not, then the PDA's first priority is to educate them so that they will support a proposed change.

4.2.2 Step 2 – Test the Water Quality of Wells

The residents of Tha Phae use well water for most daily activities such as showering, doing laundry and fish processing. They do not use this well water to drink. One of the problems with the current wastewater management system is that it is possible for pathogens from wastewater to contaminate wells by spreading through groundwater (weakness 3). This weakness can be turned into an opportunity by testing well water for pathogens (opportunity 3). If the tests show that the wells are contaminated, then that is hard data that can be used to motivate the community to improve their current system (combating weaknesses 4 and 5).

The test results would also provide information that could be factored into the design for a new system. If the tests show that the well water is safe, the current method of transporting waste can be used without contaminating ground water. However, if the wells are contaminated, a new system should to be designed in such a way as to minimize groundwater contamination.

Instead of testing for multiple pathogens, it is sufficient to test for the presence of E. coli because it is an indicator organism. If E. coli is present in the wells, then that means that there is a high risk of other pathogenic bacteria also being present in the wells.

The water in nine wells should be tested for E. coli once a month over the course of a year. This is based off of recommended sampling intervals in "The Science of Water" (Spellman, 2008). The wells to be sampled should be chosen such that there are three wells near the canal, three near the government trenches, and three from elsewhere in the community, far from the wells and canal, to serve as control samples. The control samples will provide information about the level of pathogenic bacteria naturally occurring in the groundwater, and may be compared with the levels in the samples near the government trenches and canal to determine whether contaminant seepage is occurring. Particular attention should be paid to the months November and December, when flooding occurs in the community, because the increased volume of water flowing through the canal could cause changes in the composition of the groundwater.

4.2.3 Step 3 – Analyze Epidemiological Data

Our investigation indicated that the community thinks they are generally healthy and that the current wastewater management system is not causing any health problems (weakness 4). One of the reasons we determined that the current system needs to be replaced is that it has the potential to adversely affect human health. Therefore, epidemiological data should be analyzed for diseases typically caused by a close proximity to or contact with wastewater (opportunity 4). The results of this analysis can potentially be used to show the community the problems with the current system and help to motivate them to improve it (minimizing weaknesses 4 and 5).

4.2.4 Step 4 – Propose New Programs

Once the community is convinced that their current wastewater management system needs improvement, the next step is to give them a way to improve it (diminish weaknesses 1, 2 & 3). The improved system should either filter the wastewater or recycle it so that it is not polluting the canal. Several new programs that incorporate incentives should be proposed so that the community can choose the one or multiple solutions that they prefer.

Having the community choose the new system gets them invested in it. One way the PDA ensures sustainability of their programs is by giving the community ownership of the program through community-based management. The community choosing which system to implement is the first step in giving them ownership.

Another technique the PDA has used to ensure the effectiveness of its programs is giving the community incentives to adopt the program. The incentive can be a monetary reward for adopting the program or the PDA doing something for the community. The community should select the selected improvements so that they have full support for all changes. To encourage these improvements, the PDA should provide incentives to the community. This can include subsidizing costs of implementation or training, or providing information about how their quality of life would be improved with the proposed improvements.

4.2.5 Step 5 – Sustain the Chosen System

To ensure that the system is properly implemented and maintained over time, the PDA will need to provide education and institutional support. Educating the community on the proper usage and maintenance of their system will help to ensure the system's sustainability over time. The PDA is well positioned to do this because of its good relationship with the community of Tha Phae and its experience in sustaining programs (opportunity 1).

4.3 Raising Awareness through Education

Our third objective was to determine a method for raising awareness in the community of the problems associated with the current wastewater management system. To achieve this objective we developed a school curriculum about wastewater pollution and treatment and uploaded our curriculum to a supporting website that we created. We decided to raise awareness through schools based on the results of our SWOT analysis and the success of other projects that used this approach. We developed the lesson plans after talking to a professional educator and testing out the activities in the lesson plans to determine how to make them most effective. We developed the website along with the lesson plans as a resource for teachers to use while preparing to teach and to provide at home activities that reinforce what was learned at school.

4.3.1 A School Program is an Appropriate Way to Raise Awareness

Based on our SWOT analysis mentioned in section 4.2 Steps Leading Towards an Improved System4.2 Steps Leading Towards an Improved System, we determined that the community values education, as many children will continue their education past high school (strength 1). In addition, the PDA has a working relationship with the schools in Tha Phae, which provided our team with the opportunity to establish an educational program to promote awareness (opportunity 5). Educational programs developed by previous Interactive Qualifying Projects were found to promote sustainability within a community, as the children can pass the information on to their families encouraging them to accept behavioral changes. "Promoting a Lead Free Community: An Educational Program for Schools in Thailand" developed an educational program in Thailand to promote the awareness of the dangers of lead (Hayes *et al.*, 2013). They successfully educated students about the important exposure prevention methods and empowered them to protect themselves against lead. Based on the previous project's success and our analysis of the SWOT matrix, we determined that designing a curriculum for the schools in Pak Phun would be the most effective way for us to raise awareness.

4.3.2 Qualities of Effective Lessons

We consulted with Ms. Peeda Chitnuyanont, an educator at the Science Center for Education, and "Promoting a Lead Free Community" to learn how to enhance our education program (Hayes *et al.*, 2013). Based on this consultation and research we identified the following qualities of an effective lesson:

- Lessons should be **fun** so that students want to pay attention.
- Lessons should be full of **activities** and **hands-on** learning instead of just lectures.

- Lessons should have a **common theme** tying everything together. For instance, the previous IQP "Promoting a Lead-Free Community" integrated stories about lead boy and lead girl throughout their program (Hayes *et al.*, 2013).
- Each lesson should have one **take away message** that is repeated constantly. Each lesson is likely to present more information than a student can absorb all at once, so it is important to identify exactly what is most important and emphasize that throughout the class.
- Lessons should incorporate **group work**. This encourages critical thinking and discussion that facilitates better understanding of the topic.
- Students enjoy and are motivated by **competitions** that are integrated into the lesson plan.
- **Handouts** are important to keeps students engaged in a lesson. Handouts also help the students retain the information after the lesson because the student takes something home.
- **Rewards** for performing well in the lesson are a great way to provide incentive for the students to remain motivated throughout the lesson.

After identifying these specific qualities that increase the effectiveness of a lesson, we worked to incorporate them into our lesson plan for Tha Phae where appropriate.

4.3.3 Our Experiments Target the Younger Age Group

To test the effectiveness of the turbidity and pH activities as described in Section 3.4.1 Tha Phae Pilot Lesson, we ran an exhibit at the SCE where children could participate in the activities and then fill out an optional survey. Over sixty children came through our exhibit at the SCE and forty-nine of these, aged six to seventeen years old, filled out the survey questionnaire. There were 32 children in the older age range of 14 to 17 year olds, and 17 children in the younger age range of 6 to 11 year olds (there were no 12 or 13 year olds who completed our survey). On the survey we asked them to rank how much they enjoyed the experiments with a scale of 1 meaning not fun at all to 4 meaning a lot of fun. The turbidity experiment averaged 3.5 out of 4 and the pH experiment averaged 3.4 out of 4 for all surveys completed, indicating that all of the children enjoyed the experiments. However, when comparing age groups, the younger age group tended to enjoy the experiments more than the older age group. This is demonstrated in Figure 13: Averaged level of fun for each age group at the SCE, which shows the difference in the averaged level of fun the two experiments on the y-axis, compared between the two age groups.

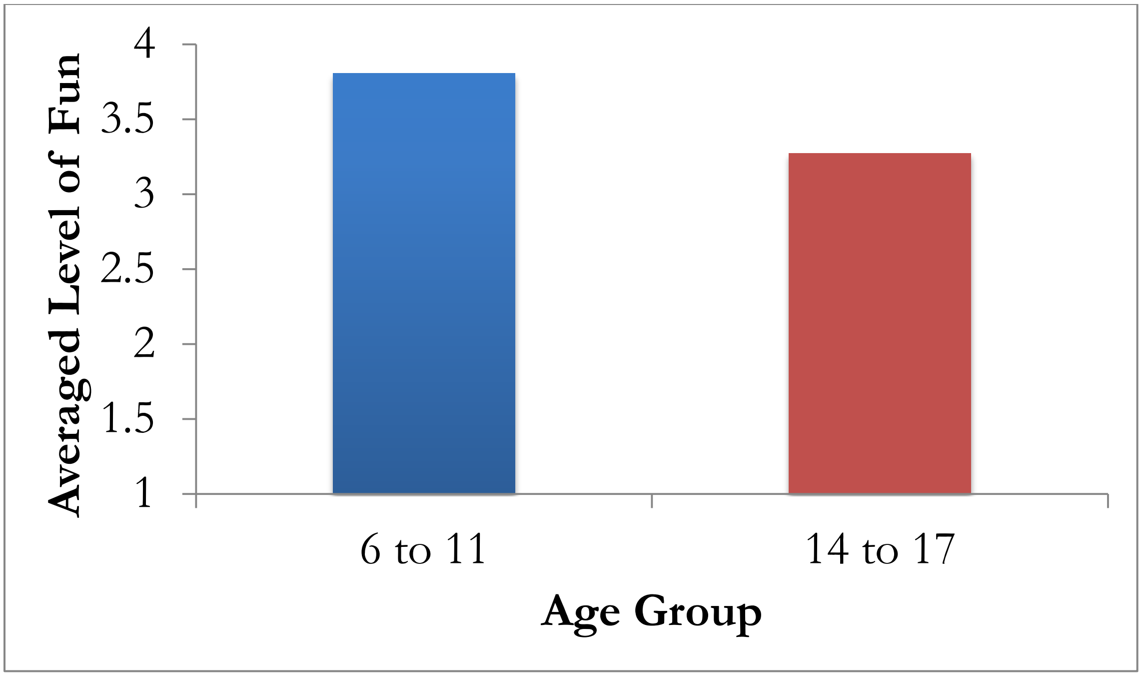

Figure 13: Averaged level of fun for each age group at the SCE

4.3.4 Children Understood Concepts Presented in Activities

Water quality experiments were new to the younger age group, and they expanded upon the knowledge of the older age group. The younger children understood the pH experiment best, commenting that they understood the difference between acid and base. They were able to grasp the general concepts of pH, such as learning that "lime juice is acid, soap is basic" and how to "change turbid water to clear water." Higher levels of thinking were apparent in the older age group, as they commented that they learned that "a simple filtration apparatus can be easily made" and "clear water does not mean we can drink it." This showed us that both age groups understood the concepts of the activities.

4.4 Effectiveness of the Awareness Program

Our fourth objective was to determine the effectiveness of the awareness program and revise the program based on our findings. We took our findings from the SCE and applied them to conduct pilot lessons for classes that children from Tha Phae attend. We held a pilot lesson at two schools, the Wat Tha Muang School and the Wat Bot School. For our pilot lesson we taught 4, 5 and 6th grades together. At the Wat Tha Muang School there were 27 students for the lesson, and there were 91 students for the lesson at the Wat Bot School. This allowed us to determine whether the amount of students affect the quality of the lesson, and the effectiveness at communicating the main takeaway idea that clear water is not always safe. For each pilot lesson, we combined our three lesson plans into one two-hour class. The detailed lesson plans can be found in Appendix E – Lesson Plans.

Before and after we conducted each pilot lesson, we had the students complete surveys for us to determine how much they learned about water pollution and wastewater from the lesson and whether they applied that knowledge to their daily life. We also had the teachers complete a pre lesson survey and gathered their feedback after the lesson to further modify our lesson plan.

4.4.1 Children Understand the Basic Concepts of the Lesson

Through the analysis of the student surveys and our observations of the class, we found that the children understood the basic concepts behind each of the three lessons. The first activity was about wastewater awareness. It allowed the students to brainstorm about waste being disposed of at their house that can affect the water quality of nearby bodies of water. The students brainstormed wastes and wrote them on a large piece of paper that had a drawing of a house and a canal on it. At the end of the lesson, the paper appeared crowded and demonstrated to the students the amount of wastes that are dumped into the canal. The paper at the end of the lesson is shown below in Figure 14: Result of brainstorming of wastewater at Wat Tha Muang School.

Figure 14: Result of brainstorming of wastewater at Wat Tha Muang School

We adapted the second and third activities from the exhibit at the SCE. We split the students into groups of 5 to 7. In the second activity about turbidity, the students competed to create the best water bottle filter using materials that could be found in their houses. The teachers judged which group had the clearest water after filtering, and that group received a prize. Figure 15: Water bottle filters created by students at the Wat Bat School shows completed filters that the students created at the Wat Bat School.

Figure 15: Water bottle filters created by students at the Wat Bat School

The third activity was about pH and taught the kids how to measure the pH of a solution using red cabbage filter paper and taught them how to neutralize acidic and basic solutions. Each group “poisoned” neutral water with an acid or base and passed this on to another group to “heal” by adding the correct acidic or basic solution. Figure 16: The change in understanding of pH concepts before and after the lesson below shows the percentage of students who answered correctly for the question in the student surveys “how do you make an acidic solution neutral?” This graph illustrates how well the students understood of the concept of pH before and after the lesson. The small school is shown as blue and the large school is red. This shows that they increased their knowledge of the concepts of pH by 29% and 22% for the large and small school respectively. While this is not the optimal increase to 100% understanding of the concepts, it shows that more than half of the students from both schools were able to understand the concepts behind the lessons. We expect that our revisions from this pilot lesson will increase the percentage of understanding on all of these topics introduced.

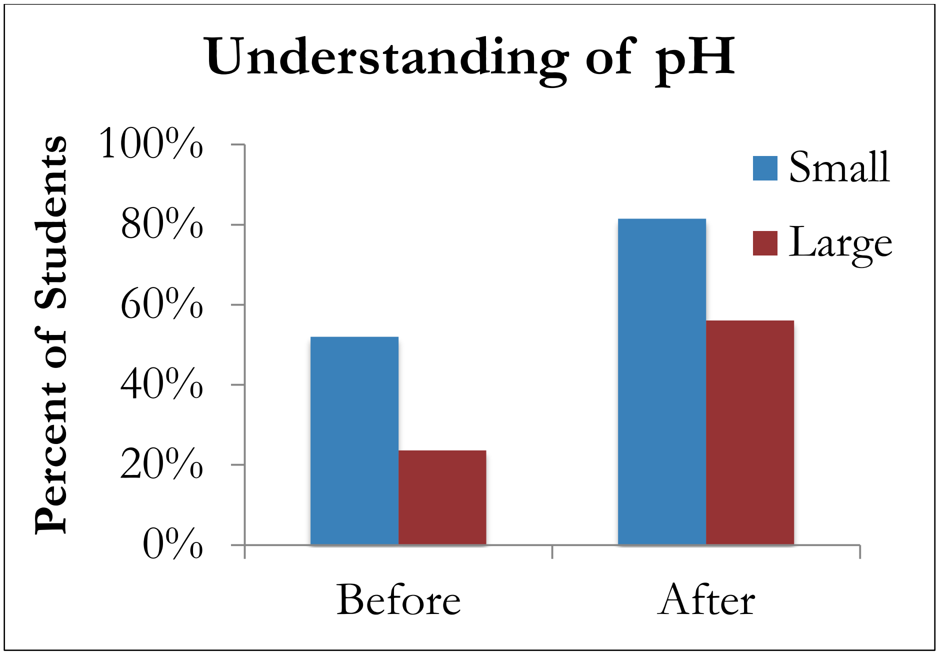

Figure 16: The change in understanding of pH concepts before and after the lesson

4.4.2 Smaller Groups Understand Connection to Daily Life

When comparing the pilot lesson from the large school (Wat Bot) and the small school (Wat Tha Muang), we were able to determine that the techniques we used in our lesson plan were most effective for teaching the smaller school. We found this by determining whether the students understood the connection between the experiments and their daily life.

Figure 17: Percent of students who think the canal is safe to swim in, before and after the lesson below shows the results from the question in the surveys "Is the canal near your home safe to swim in?" The way they answered this question shows whether they made the connection between the risks of water pollution that were taught in the pilot lesson and the water quality of the canal near their home.

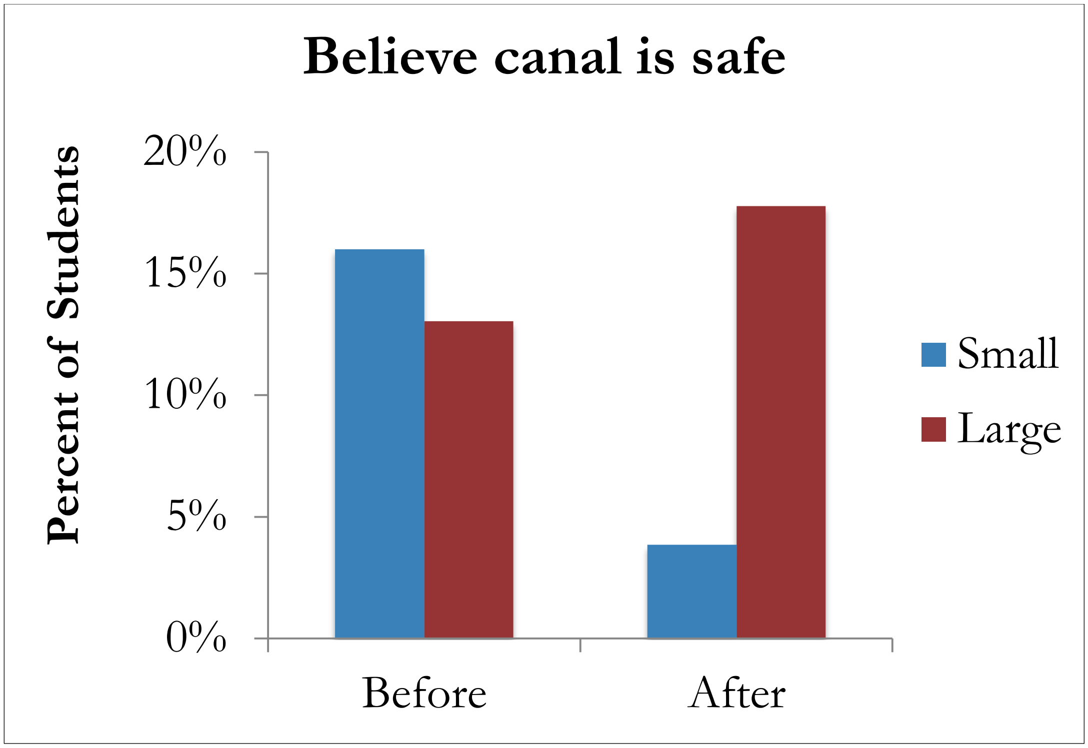

Figure 17: Percent of students who think the canal is safe to swim in, before and after the lesson

We found that the small school recognized the danger of the water pollution near their home more after the lesson. The lesson in the smaller school allowed the students to connect the main takeaway idea to their daily life. At the large school there was an increase in the students that believed the canal was safe. This increase indicates that while they were still able to grasp the basic concepts of the lesson plan; the main takeaway idea was lost in the large school. These larger schools require different pedagogical techniques to engage all of the students in the activities, so that they can also connect the lesson to their daily life.

4.5 Summary

Through site observations and interviews, our team was able to establish that there was a lack of knowledge of the dangers of their current system for wastewater management. After identifying the need for a more comprehensive plan for Tha Phae, we determined the steps to recommend for the PDA to take leading to an improved system that could then be fully integrated into the daily life in Tha Phae. We analyzed the threats and weaknesses that need to be overcome in the community to create these next steps for the PDA.

To initiate the first steps in our recommendations to the PDA, our team worked to create an awareness program that would allow the community to understand why improvements to their current system are necessary. Through the incorporation of this education into local schools, we believe it will allow for long-term awareness in the community about the dangers of wastewater, which is vital to the continued maintenance and success of an improved system.

To produce a lesson plan that would accomplish these goals, we worked at the SCE and two schools in Tha Phae to gather feedback from the students and teachers about the activities we planned. We created a curriculum that teaches about pollution, water quality and wastewater management. After testing these lessons in the SCE exhibit and the schools in Tha Phae, we revised them based on student and teacher feedback.

5. Conclusions and Recommendations

While working in Tha Phae, the PDA identified that there could be problems due to the waste management system, particularly the wastes produced from fish processing. After our site observations and interviews, we identified that an even larger problem was present within the community. While the fish waste was being disposed of in higher volumes than the past, it was also mixed with human waste and all other wastewater from the community. Not only was their management system questionable, but the people of Tha Phae also showed little concern about the health risks that could be caused by their current system. Their lack of concern appeared to be linked to their reliance on the government for all maintenance of their current system. Because the community did not see the need for a new system, we determined that a new system would not be successful now and that a plan of action was necessary that would lead to an improved system.

We identified the following five step plan by using the results of a SWOT analysis to adapt the PDA's typical approach to introducing a new program to a community:

1. Raise awareness of the problems with the current wastewater management system.
2. Test the water quality of wells in Tha Phae for pathogens.
3. Analyze epidemiological data from Tha Phae for sicknesses commonly caused by a close proximity to or contact with wastewater.
4. Identify and propose wastewater management programs.
5. Provide resources to sustain the system that the community has selected.

After identifying that the next step for Tha Phae was to raise awareness, we determined that the most effective way to achieve this is through education in primary schools using lessons that incorporate hands-on activities. We created lesson plans that emphasized the theme that clear water is not always safe to use. In order to determine the initial effectiveness of the activities, we first tested them at an exhibit at the Science Center for Education in Bangkok and determined that they best targeted the younger age group of 6 to 11 years old. Through interviews with an education professional and our experience from our exhibit, we determined some best practices for effective lesson plans. We used these findings to modify the activities from the SCE and incorporate them into lesson plans that we created to be used in the schools in Pak Phun.

Through pilot lessons at Wat Bot School and Wat Tha Muang School, we determined that the students were able to understand the basic concepts presented in the lessons: awareness of wastewater, how to build a simple filtration device, and how to test the pH level of a solution. We determined that our lesson plans were most suitable for smaller classrooms because our lesson plans required students to be actively engaged all of the time, and we did not have enough teachers to adequately engage all of the students at the larger school. Surveys showed that students at the smaller school were better able to understand the connection to their daily life. This message was lost in the larger schools, likely because of our difficulty in engaging all of the students, so alternative pedagogical techniques must be applied for those settings. We used pre- and post- surveys to gather these data, and used them to revise our original lesson plans to be more effective at raising awareness of the dangers of wastewater pollution. These lessons, along with supporting materials, are available on the website we created.

5.1 Recommendations

We developed five steps that can be used to implement a wastewater management system in Tha Phae. We initiated the first step of beginning to raise awareness of the problems of pollution from wastewater, and we recommend that the PDA finish the process that we have identified. This section lays out the steps that we recommend the PDA take to encourage adoption of a waste management system in Tha Phae that will reduce odor, health risks, and pollution in the canal.

Our vision is that this series of steps may be adapted for use in other communities around Thailand to promote awareness and proactivity to take ownership of their own wastewater management and to guide the PDA in implementing an appropriate wastewater management system for those communities.

5.1.1 Implement and Sustain the Education Plan

We recommend that the PDA use the lesson plans we designed in monthly programs with the schools around Tha Phae. We recommend this because the education curriculum will raise awareness of the dangers of wastewater and provoke the community to question the safety of their current wastewater management system. By educating children, we are educating tomorrow's decision makers and leaders of the community.

We piloted our lesson plans with 4th, 5th and 6th graders at two schools in Tha Phae. Some PDA employees were present during the pilot lessons and helped to facilitate the lesson. They perform programs at each of the schools they are associated with in Pak Phun, once a month. Due to the difficulty of getting these activities inserted into the curriculum of these schools, we identified that the most realistic approach is for the PDA to insert each of the three lessons we are providing into separate one hour classes with small groups over the course of three months. This will allow the subject of wastewater pollution to return to the student's attention multiple times, and for there to be more time to explain the main takeaway lesson behind each experiment.

In the case that this cannot be inserted into the PDA's monthly activities, it could be an additional program that can be organized by the PDA to be done after school. Parents could be encouraged to attend as well, learning alongside their children the basics of wastewater management. Additionally, if the PDA feels it is necessary, a professional educator could be introduced in order to deliver the lesson during the school day or after school.

We also created the *pollutionedu* website (https://sites.google.com/site/pollutionedueng) as a resource for teaching about pollution from wastewater. We recommend that the PDA maintain the website for their own use and so that others can use it and the education curriculum could have a lasting and possibly broader impact. All revisions to the lesson plans should be updated on the website, and all feedback from teachers and students can be used to further edit the lesson plans. Additional resources could be added to expand the website and revise the curriculum based on teacher feedback. This website can also help the PDA expand this awareness program to other areas in Nakhon Si Thammarat.

5.1.2 Conduct Water Quality Tests

We recommend that the PDA test the well water in Tha Phae for pathogenic bacteria. Well water is widely used in Tha Phae for everyday tasks such as showering, laundry, and processing fish. Since well water is so widely used, it should be tested for pathogenic bacteria which can have huge impacts on human health. Water quality tests should be performed to determine whether wastewater in the trenches or canal is contaminating the well water.

If the tests indicate that pathogenic bacteria are present, it would provide the PDA with strong evidence that a better wastewater management system is necessary in Tha Phae because the most likely source of pathogenic bacteria in the wells is contaminant seepage from wastewater. PDA can use this evidence to advise the community of Tha Phae that their well water is not as clean as they believe, and that a better wastewater management system is necessary.

5.1.3 Analyze Health Data from Tha Phae

We recommend that the PDA obtain epidemiological data about Tha Phae and analyze it to determine health problems in Tha Phae that could be caused by wastewater. This analysis will provide the PDA with additional data that can be used to educate the community of Tha Phae about the unseen negative effects that their current system has had on their health. We recommend that the PDA submit a request for access to the national health database for information about the village of Tha Phae.

Once the PDA has obtained access to the epidemiological data for Tha Phae, we recommend that they look for occurrences of sicknesses that can be caused by proximity to wastewater such as diarrhea, dysentery, cholera, typhoid fever, degenerative heart disease, and stomach ulcers. We recommend that the PDA contact a health professional to help them analyze the epidemiological data to determine which diseases are most indicative of the health threats in Tha Phae.

Based on the frequencies of wastewater borne diseases, the PDA will be able to determine the types of health risks that are present in Tha Phae. They can use this information to provide the community of Tha Phae with evidence that there is a need for an improved wastewater management system. They can also take this information into account when determining which wastewater management system would be best for Tha Phae.

5.1.4 Propose Wastewater Management Programs

We recommend that the PDA propose one or more wastewater management solutions to the community of Tha Phae. Once the community of Tha Phae has recognized the need for an improved wastewater management system, we recommend that the PDA select one or more wastewater management solutions to propose to the community. The solutions that we have identified as candidates include pipe filters, slow-sand filtration, anaerobic digestion, land disposal, and storage tanks. These systems are discussed in section 2.3 Possible Wastewater Management Systems. Additionally, Appendix B – Table of Alternate Wastewater Management Systems contains a table that displays and compares the various systems we recommend be considered.

These systems are not mutually exclusive. For instance, it may make sense to use septic tanks for sewage and slow sand filters for other waste. Also it may be appropriate for different parts of Tha Phae to use different systems. No one system will necessarily be sufficient.

To increase sustainability, community members should be invested in the program. They should choose it and they should invest resources into it. PDA can ease the process by recommending systems, providing contacts to companies that can build a new system, providing training on how to use and maintain the systems, and subsidizing the installation cost of systems but should not take over responsibility.

Incentives

For the residents of Tha Phae, the main motivator for improving their system should be increasing their quality of life and helping the environment. However, the PDA could also offer a few small incentives to help convince the community to change. For instance, after half of the houses no longer pollute the canal the PDA could hold a fair or clean up the garbage around Tha Phae. The PDA could also tell Tha Phae that if they treat their wastewater, they could be the best practice community that PDA would use as an example for other communities to model.

Ways to Propose New Systems

There are a few ways that the PDA could propose new wastewater management systems to the community. Ideally the PDA will find a similar village that has already adopted the new system. Then they can take a group of leaders from Tha Phae to see the system and how it could improve Tha Phae. In the absence of an example community, the PDA should take a different approach.

If a system can be adopted one household at a time, we recommend that the PDA identify several early adopters in the community and approach them with the proposal. Once a few people have used the new system and shown that it works, other people may be more likely to switch. The PDA should then approach the rest of the village with the new system.

However, not all systems can be adopted a household at a time. If a system requires a large infrastructure or must process a large amount of waste to be feasible, then the entire community will have to switch systems at the same time. In this case we recommend that the PDA suggest the systems to individuals and small groups to plant the idea and then hold a meeting with as many people as possible to agree to a plan and figure out how to implement the system.

Wastewater Treatment Companies

We recommend that the PDA provide Tha Phae with contacts to wastewater treatment companies that can build the selected system. We have found several wastewater treatment companies that we are providing as resources for the PDA. One of the companies is Bangkok Watertech Co., Ltd. which has been in the business for more than 20 years. All employees have been in wastewater treatment industry for 2-10 years and are ready to provide reports regarding the treatment process and any analytic information every month. They provide consultations and design, construct and install wastewater treatment equipment. The company has been approved and accepted by both government and private sectors.

Another company the PDA could contact is Hydrotek Public Company Limited. It has been in the wastewater management industry for over 30 years and is expert at satisfying customers with a wide range of services.

5.1.5 Sustain the Selected Wastewater Management Solution

We recommend that the PDA help the community implement and sustain their chosen wastewater management solution. Once the community has identified a system that they would like to implement, we recommend that the PDA provide them with support in implementing and sustaining that system.

The type of support that the community needs from the PDA will vary depending on the specific system implemented. The types of support may include monetary support in constructing or maintaining the system and providing training for members of the community to ensure that the system is used and maintained appropriately.

Once Tha Phae has successfully adopted an improved wastewater management system, the PDA can use the community as an example of a best-practice community to help convince other communities in the region to adopt improved wastewater management systems as well.

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Appendix A – Sponsor Description

The Population and Community Development Association (PDA) was founded in 1974 by Mechai Viravaidya and was originally known as the Community-Based Family Planning Service (CBFPS) (Mukerjee, 2005; PDA, 2012a). The organization's initial goal was to complement the Royal Thai Government in promoting family planning in Thailand, especially in areas where knowledge and access to services were scarce (PDA, 2012a). Since then, the organization has expanded so its goal is to reduce poverty and create a sustainable future for communities by working directly with people most in need such as people affected by HIV/AIDS and the rural poor.

In the early 1970's, Viravaidya identified a direct correlation between population growth and poverty. At the time, Thailand had a population growth rate of 3.2%, which is equivalent to 7 children per family (Walker, 2010). Birth control drugs were only available through health care professionals, so they were only used by around 20% of the population. Viravaidya had previously served as secretary-general of a government organization that promoted family planning, and recognized that the most feasible method to aid the development of Thailand was to promote population control to reduce poverty (Mukerjee, 2005).

Viravaidya founded the PDA to continue the mission of promoting family planning, emphasizing a "participatory, community-based approach" (PDA, 2012a, para. 1). Mukerjee explained why this approach is the most effective:

> Villagers can develop a sense of pride in the project that represents their own achievements and so will gain maximum benefit from it. This will help them to maintain the project activities even after PDA leaves and thus to achieve self-sustainability in the long run. (2005, p. 104)

The PDA used their community-based approach to gather and educate respected members of rural and urban regions, sharing and providing information on family planning. Their approach included distributing affordable oral contraceptives and condoms directly to the communities. Volunteers of the PDA's family planning program made a strong impression by using new approaches instead of the previous clinic-based system. They handed out condom key chains at official dinners, had monks bless contraceptives with holy water, held condom blowing competitions in schools, sold t-shirts with funny and amusing logos, and started the Cops and Rubbers project by supplying the police with condoms to be handed out to pedestrians in the center of Bangkok. This community-based network has led to the decrease of Thailand overall growth rate from 3.2% in 1970 to 1.3% in 1991 and finally 0.5% in 2005, thus, the average children per family fell from 7 to less than 2 (Walker, 2010).

Since its founding, the PDA has expanded its scope and grown to be "the leading and most diversified Non-Governmental Organization or NGO in Thailand" (PDA, 2012a, para. 3). The PDA has expanded its network into many other programs including HIV/AIDS education and prevention, water resource development and sanitation, income-generation, environmental conservation, promotion of small scale rural enterprise programs, gender equality, youth development, and democracy promotion (PDA, 2012a). The PDA has utilized its 18 regional development centers and branch offices, 800 staff members, and 12,000 volunteers help these programs reach a third of Thailand (Skoll Foundation, 2008).

Viravaidya established the structure of PDA so that it would mimic the sustainable nature of the systems it implements (PDA, 2012b). From the start, he recognized the fickleness of traditional NGO funding due to the variations in donations from year to year. To ensure a consistent source of funds, he started a company in 1975 to supply funding for the PDA whenever donations dwindled. The original business has branched into sixteen companies that have supplied up to 70% of PDA's financial needs in a year. Because of the success of this method of funding, the PDA also offers training to other NGO's on achieving financial sustainability by "engaging in profitable business" (para. 3).

Appendix B – Table of Alternate Wastewater Management Systems

System	Filters	Slow Sand Filters	Anaerobic digestion	Land disposal	Septic tanks
Advantages	- Keep solid waste from entering trenches with fishy water	- Low maintenance low cost - Scum can be sold Treats wastewater	- Produces methane gas - Short retention time - Insensitive to load fluctuations - Low area demand	- Wastewater can be sold to farmers	- Reduced smell - Reduced health risk
Disadvantages	- Are a small solution that does not address the whole problem	- High area demand - Algae and high turbidity may clog filters	- Difficult to start up - Ammonium in the effluent - High cost of packing media and support system	- High area demand - Workers exposed to wastewater - May contaminate groundwater and crops	- Would only treat sewage
Requirements	- Households must install and clean filters	- Top layer of sand must be scraped off - High area demand	- Low area demand	- Farmers must be willing to buy wastewater - Tanks to store wastewater	- Low area demand
Costs	- Minimal installation costs	- Moderate installation costs and low maintenance costs	- High installation and maintenance costs	- Installation of tanks - Transportation of wastewater	- Low installation and maintenance costs
Training	Minimal	Low	Required	None	Minimal

Appendix C – Interview Protocol for Tha Phae Residents

The following was the structure for interviews with household leaders in Pak Phun. There was always a minimum of one Thai student present to conduct the interview. Written notes were taken to record the interviews.

Due to the culture of the village, structured interviews behind closed doors were not possible. Therefore, interviews were conducted by approaching community members as they went about their daily tasks. An effort was made to recite the consent script as closely as possible before addressing the questions in the interview protocol.

Consent Script

My name is ____ and I am a student from the Chulalongkorn University and this is my partner who is from a university in the United States. We would like to invite you to talk with us about the waste management and water usage in your household. The interview should only take 15 to 20 minutes. We are part of a seven-person research team that is sponsored by the Population and Community Development Association to develop a waste management solution for your community.

The purpose of this interview is to learn about how you manage your wastewater and obtain your input on what you would like to see changed with regard to wastewater management in Pak Phun. The information gathered in this study will be anonymous; no names or other identifying information will be recorded.

At the end of the study, our research will be published.

This study is completely voluntary. You do not have to answer any questions you do not want to and may choose to stop participating in the study at any time.

Do you agree to take part in our study? Do you have any questions before we begin?

Interview Protocol

How many fish do you process every day?

How do you deal with the waste from processing fish?

Do you think there is a problem with the current fish waste disposal method?

If so, what is wrong with it?

Do you use or go in the canal for any activities?

Do you think the canal is dirty?

What other kinds of waste are produced in your house?

What other kinds of waste are produced in Pak Phun?

Do you think there is a problem with the current waste disposal method for these other wastes?

If so, what is wrong with it?

If not mentioned: How is sewage disposed of?

Do you have any ideas for better ways to deal with waste?

Is there anything that we have not talked about that you want to bring to our attention?

Appendix D – Agenda for Meeting with Ms. Chitnuyanont

IQP-SSP 3 Meeting with Khun Peeda at Science Center
1:30/2:00 pm Tuesday, February 11th, 2014

Chair: Phornphit Manageracharath
Secretary: Nontach Thanawatyanyong
Translator: Sawin Areepipatkul
Participants: Khun Peeda, Ajarn Patchanita Thayongkit, Ajarn Gary Pollice, Sawin Areepipatkul, Marc Gelin, Nathan Longnecker, Phornphit Manageracharath, Laura Pumphrey, Corre Steele, & Nontach Thanawatyanyong

- Introduction
- Explain our project
    - We are working with the PDA (explain what the PDA foundation is)
    - Our goal is to create an education system to promote proactivity within Tha Phae to understand and address potential issues from wastewater
    - We are creating three lesson plans
    - We would like to present some of the lessons at the science center to collect a wider variety of data on how well different methods of teaching the material work
- Show her the three lessons we have planned to do at the Science Center for Education
- We would like to come in this Saturday or Sunday
    - Discuss possible times that would work
    - Preferably 10 kids - 30 kids (can be split up into different sessions)
        - Flexible, depending on their structure

Questions:

- Do we need to provide all materials for experiments?
- What ages would you expect?
- Any suggestions on what teaching methods work well? Especially for fifth graders?

Appendix E – Lesson Plans

What is Wastewater?

Overview

Students will learn about how pollution affects water quality. The students will brainstorm wastes from their house that can pollute canals and rivers. The answers can be wastes that either affects water quality or not. By the end of the lesson, students will be able to identify wastes that affect water quality but may not be visible.

Teachers' Notes

Water pollution can have devastating impacts on surrounding communities and ecosystems. Many of the signs of water pollution are hidden from view, often causing the problem to be ignored until it has progressed to an advanced stage, at which point recovery can be difficult or impossible (Smol, 2009). Dumping unregulated waste into rivers, lakes and oceans causes widespread damage around the world. This damage includes damaging the environment of aquatic animals, causing endangerment and extinction of those animals (Ricciardi, 1999). Water pollution can be the cause of many health problems for humans and can contribute to the spread of illnesses such as dysentery, salmonellosis, cryptosporidium, and hepatitis (Cheung, 1990; Infoplease, 2013). In Thailand, water pollution is primarily caused by wastewater discharge and is currently one of Thailand's most serious environmental issues (Simachaya, 2009). It is important to raise awareness of what a specific community is improperly disposing and how that can negatively affect their health and environment. This can encourage a proactive mindset within the community about in limiting those dangerous wastes or looking for another disposal method.

Materials

- Large piece of paper or whiteboard/blackboard
- Marker(s)
- One or two rubber toys (depending on number of kids)
- Music

Teaching Points

- Make sure each group of students have all the required materials before starting.
- Ensure that all groups can see all demonstrations so that they remain engaged in the activity.
- Allow the students to discuss, disagree, and make mistakes while brainstorming.

Procedure (Approximate time, 1 hour)

1. On a large piece of paper or board, draw out two lines to represent a canal or river and a house above the river.
2. Ask the students what goes into the canal from the house.
3. To select which students will answer, play a game. Hand out the rubber toys and tell the students to pass them around while you play music. When you stop the music, the students must stop passing the toys around. The students that are holding the rubber toys must come forward and write an answer on the paper. Repeat until the paper is crowded with many answers, visually showing the students how much waste is being dumped into the canal.

Suggest the following wastes if the students need help brainstorming:

- Soap and shampoos
- Detergents
- Human wastes
- Cooking water
- Waste from other buildings:
    - Schools
    - Hospitals
    - Businesses
    - Markets

4. After the students have listed everything on the paper, go through each of the wastes and ask whether you can see them once they have been mixed into the water, and whether they can still affect the water even if they are not visible. Circle the ones that can change the quality of the water without being visible.
5. Split the students into groups of 5 or 6 and have them brainstorm what happens to the canal when all of these wastes are dumped into it.
6. After about 5 minutes, have a representative from each group present their group brainstorming. Make appropriate corrections to their ideas when needed.

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Cloudy to Clear: Filtering Dirty Water

Overview

Students will learn about how pollution affects water quality, in particular turbidity or the cloudiness of water. The students will compete to construct a simple water bottle filter with household materials to filter the solids out of cloudy water. At the end of the lesson the students should be able to build a simple filter at home and understand which materials make an effective filter.

Teachers' Notes

The impact of a specific waste depends on the attributes of the waste that affect the water quality of the receiving waterway. Wastewater that contains insoluble materials will introduce turbidity to the water body. Turbidity is a measure of the cloudiness of the water caused by the number of suspended solid particles in the water (Gonzalez, 1996). If water has high turbidity levels, the particles in the water will block sunlight and affect organisms living on the bottom of the river, lake or ocean. The lack of sunlight can cause plants and algae to die and remove a food source for fish and other animals higher on the food chain.

The water bottle filter created in this lesson is used to simulate a slow sand filter. A slow sand filter is a container filled halfway with a large layer of fine sand on a layer of gravel with drains at the bottom of the container. Wastewater is collected on top and trickles through the sand. As the water is filtered the contaminants build up in the sand (Huisman, 1974; Lahlou, 2000). Fine sand keeps all particles on the top layer so just the top layer will need to be removed and disposed of periodically. These filters have been constructed around the world as a low-cost method to filter suspended solids and pathogens out of polluted water.

Materials

- Cups
- Empty 1.5 liter water bottles, cut in half
- Rubber bands
- Sand
- Cotton balls
- 6 cm by 6 cm squares of cloth
- Prizes (Candy or toys)
- Workbook provided

Teaching Points

- Make sure each group of students have all the required materials before starting.
- Ensure that all groups can see all demonstrations so that they remain engaged in the activity.
- Instruct and guide them through each steps, but not thoroughly since we are going to let them makes some certain mistakes so they can learn to correct them.
- Allow the students to discuss, disagree, and make mistakes in their filter design.

Procedures (Approximate time, 1 hour)

1. Prepare a not-so-effective water bottle filter beforehand that leaves water still turbid when it filters through. Prepare this by cutting a water bottle in half and cover the mouth of the top

half of the water bottle with a piece of cloth and secure it with an elastic band. Invert the top half into the bottom half and fill it halfway with only cotton balls. Saturate the filter with clean water. Cover the filter portion with paper so that the students cannot see the cotton balls.

2. Show the students a bottle or container of dirty water consisting of dirt, soil, leaves or materials of your choice and ask if anyone would drink it. Ask why they would not and why they think cloudy water is bad.
    - Tell them about how sunlight cannot pass through the water if the water is too cloudy. Without sunlight, the plants would not be able to live, and without plants for food, fish and other aquatic life would not survive.
3. Then pour the cloudy water with the water bottle filter prepared beforehand and show them that the filtered water is still cloudy. This will show the children that this filter is not efficient, and challenge them to create a better filter than you created.
4. Split the students up in groups of 5-6 and challenge them to create a filter that would yield clearer water than the one you showed.
5. Each group will be provided with their own materials to build the filter.
6. Allow the students 5-10 minutes to construct the filter
7. Once they have finished constructing the filter, instruct them to saturate the filter with clean water
8. Have each group come in front of the class and explain why they decided on each layer of the filter
9. Have each group pour dirty water through their filter to see how effective their filter is
10. After all groups have tested their filters, award the group that created the best filter that makes the water the clearest.
11. To test the students understanding, ask for their opinion of the best filter materials
12. Have the students record through drawing and writing in their workbook on what the best filter would be according to what filter won the competition

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Why Can Clear Water Be Unsafe?

Overview

Students will learn about acids and bases, the pH scale, how to neutralize acidic or basic solutions. They will learn about the basic properties of household materials and how they can endanger aquatic life if dumped into the water. By the end of the lesson, the students should understand that even clear water may not be safe to use.

Teachers' Notes

The impact of a specific waste depends on the attributes of the waste that affect the water quality of the receiving waterway. Water that contains many contaminants may have its pH value altered. pH values below 5 and above 8 can cause damage to aquatic life (Morrison *et al.,* 2001; Holmes, 1996). The pH level can be impacted by untreated household wastewater and sewage water, which then can cause serious water pollution. High pH levels are toxic to fish and increase the toxicity of ammonia, while low pH levels decrease the solubility of some essential elements and increase the solubility of toxic metals. Therefore, it is important to monitor the pH levels to ensure the safety of humans and animals.

Litmus paper is often used as an indicator of the pH of a liquid and can be easily simulated by using red cabbage juice. Red cabbage contains a pigment called anthocyanin which gives the cabbage its red-purple color. Anthocyanin is a natural pH indicator with a neutral pH of 7 that changes color when exposed to acids and bases. When filter paper is soaked in cabbage juice, it acts similar to litmus paper. Acidic solutions will turn the cabbage paper red, neutral will leave it purple, and basic solutions will make it blue. Most household materials are basic, and will turn the strip a darker blue.

Materials

Red cabbage filter paper (see Instructions for Cabbage Filter Paper below)
Cups
Straws
Acid solutions: Lime juice, Vinegar, Soda
Basic solutions: Baking soda solution, Soap, Detergent, Shampoos
Prizes (candy or toys)
Student Workbooks

Teaching Points

- Make sure each group of students have all the required materials before starting.
- Ensure that all groups can see all demonstrations so that they remain engaged in the activity
- Instruct and guide them through each steps, but not thoroughly since we are going to let them makes some certain mistakes so they can learn to correct them.
- Allow the students to discuss, disagree, and make mistakes in their experiment.
- Make sure the final cups of water are neutral before disposing of them.

Instructions for Cabbage Filter Paper

Procedures (estimated time of activity) (½ hour)

1. Hold up a cup of baking soda dissolved in water and a cup of vinegar. Both cups should appear to be clear water. Ask if anyone would want to drink them. After getting answers,

pour the vinegar into the baking soda and have the kids watch the reaction that will form. The solution should begin bubbling. Explain how even if the water is clear it might not be safe to drink.

2. Explain the basics of acid and base, how acids are sour and bases are bitter and how to neutralize both.
3. Tell the students how the cabbage paper is made and color changes that can be seen when exposed to acid and base. Tell them how fish are not able to live in water with a pH value of lower than 5 or higher than 8.
4. Have them guess if soap and detergent are acidic or basic. Explain that if these wastes are dumped down the drain without being neutralized, the water in the canal could turn more and more basic, and the fishes and other aquatic organisms will die.
5. Explain the demonstration to the students. Explain how one cup was baking soda (a base) and one cup was vinegar (an acid) and that the reaction that was formed was the reaction between acid and base. Demonstrate this by dipping the cabbage paper in each and showing them how the color changes for acids and bases.
6. Split the students up in groups of 5-6 and give them a cup of water, an acidic solution and a basic solution. Instruct them to add either acid or base to the cup of water to "poison" the water.
7. Have the groups switch their cups of water with other groups and instruct the groups to identify whether the water is acidic or basic by using the cabbage paper. They will be acting as water doctors, working to diagnose whether the water is acidic or basic.
8. Instruct the groups to now neutralize the solution so that the cabbage paper stays purple when dipped in the water. Here they are acting as water doctors to treat their illness of either being acidic or basic.
9. Test each group's solution after they have neutralized it to see whether the water is really neutral by using the cabbage paper.
10. Repeat steps 7 to 9 again if you would like to reinforce the lesson on how to neutralize acids and bases.
11. Throughout the entire lesson, emphasize the takeaway message: Even if the water is clear, it does not mean that it is safe.

Expected Questions

Can I determine acids and bases by tasting it?
No, because some acids and bases are too strong and can harm you. It is best to determine the pH by using an indicator like the cabbage paper.

If soda is an acid, why is it not sour?
Not all acids are sour. The sour taste of many acids is due to citric acid, which is not present in every acidic solution.

Can I drink the water after it is neutralized?
No, there may be bacteria or pathogens in the water that could make you sick. This is another reason why clear water is not always safe to use.

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Appendix F – Survey for Science Center for Education

After children participated in the experiments at our exhibit in the National Science Center for Education, we asked them to fill out a survey. The original survey was in Thai and this is the English translation.

Science Center for Education
Survey

Thank you for participating in our activity at the Science Education Center. We would appreciate if you took our survey. All answers will be kept anonymous and answering them is completely voluntary.

1. How old are you?
2. How much fun was the filtering experiment? (Circle one)

   a. Not fun at all   b. A bit fun   c. Fun   d. Super fun

3. How much fun was the pH experiment? (Circle one)

   a. Not fun at all   b. A bit fun   c. Fun   d. Super fun

4. Which of the following would make the experiments more fun? (Circle all that apply)

   a. More experiments   b. Fewer experiments   c. Longer time   d. Shorter time

5. What did you learn from these experiments?
6. How clean do you think the cup of water was at the beginning? (Circle all that apply)

   a. I wouldn't touch it   b. I'd put my feet in it   c. I'd swim in it   d. I'd drink it

7. How clean do you think the cup of water was after the filtering station? (Circle all that apply)

   a. I wouldn't touch it   b. I'd put my feet in it   c. I'd swim in it   d. I'd drink it

8. Could fish live in the water that you treated? (Circle one)

   a. No   b. Yes, but the fish would become sick   c. Yes

Appendix G – Pre Lesson Questions for Teachers

What methods do you normally use to teach the students?

Presentation
Handouts
Pictures
Group work
Hands on learning
Other (explain)

How long can you hold the attention of the students during a lesson?

What helps to hold their attention for longer?

Have the students learned about water pollution before?

Have they learned about filtering dirty water?

Where does the wastewater from the school go?

Is there any form of treatment before disposal?

How do the students go home after school? (walking home, public transport, parents picking them up)

If we were to hold an after school activity to promote water pollution awareness within the community, do you think the students would want to stay for an extra hour?

Do you think the parents will come and take part?

Other comment on successful and fun lessons plans?

Appendix H – Feedback Questions for Teachers

The following was the structure for discussion with the teachers of the fourth, fifth, and sixth grade at the schools in which we conducted lessons. Discussions were conducted after the lessons were given to the students. There was always a minimum of one Thai student present to conduct the discussion. Written notes were taken to record the discussion.

Discussion Protocol

1. Did you think they had fun?
    a. Too much fun?
2. Would you feel comfortable teaching these lessons if we gave you the lesson guide?
3. Have you done lessons/experiments similar to this one?
    a. If, so what?
4. What could be done to improve the lessons to allow better understanding of wastewater pollution?

Appendix I – Pre and Post Survey for Schools in Pak Phun

The following survey was administered to all students who participated in our trial lesson in the two schools in Tha Phae. They answered the questions before and after the lesson so that we could deduce how much they learned from the lesson.

If water is clear, is it safe to use?

Yes, for drinking
Yes, for showering
No, it's not safe

How do change an acidic liquid into a neutral liquid?

Add acid
Add base
Add water
I don't know

Can polluted water make you sick?

Yes or No

What causes water pollution? (Circle all that apply)

Playing in water
Water from laundry
Water from the toilet
Fish living in water

Is the canal near your home safe to swim in?

Yes or No

Where does the wastewater in your home go? (Circle all that apply)

Underground
Pipes
Canal
Ocean

Do you think treating your wastewater is important?

Yes or No

Are you interested in learning about how water becomes polluted?

Yes or No

Appendix J – Summative Teamwork Assessment

This entire project experience has allowed each of us to discover our own strengths and identified areas of improvements. Through our weekly discussion, we were able to reflect critically on our progress as a team throughout the project. We quickly discovered that the division of work was most successful when it was done according to everyone's strengths. When the divided tasks were clearly defined and appropriate the improvement in the quality of that portion of the project was noticeable.

One challenge that we faced as a team regarded the decision making process. As a team we needed to define when team decisions became individual decisions. Quickly we realized that it was not possible to approve every decision by all seven team members. Therefore to improve our efficiency, we discussed what decisions actually should be approved by the entire team. For example, the wording of a sentence in the report can be determined individually, however multiple team members should determine a change in the goal of a lesson plan. Initially this resulted in gaps in information, so we established the practice of checking in with each other to discuss our progress and changes made to our sections. From this we could reevaluate and reprioritize the divisions of work.

Working in a cross-cultural and cross-functional team has provided us with a new challenge every day. Due to the need for both Thai and English, there were defined areas that certain team members focused. Both areas were equally important for the success of the project. This cross-cultural aspect of our team allowed us to complete a broad range of tasks that each group could never have accomplished alone.