

Investigating Potable Water at Doi Tung Schools

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An Interactive Qualifying Project and Interactive Science and Social Project submitted to the faculty of Chulalongkorn University and Worcester Polytechnic Institute.

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Abstract

Water filtration systems were installed at northern Thailand schools to provide the community with safe drinking water. These filtration systems lacked sufficient maintenance, and the community lacked trust in the water quality. Our team assessed the water quality and filtration systems at three schools to analyze methods of improving the filtered water quality. We recommended establishing a mentorship program for the teachers responsible for maintenance and providing testing methods with the goal of improving the sustainability of water filtration systems.

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Executive Summary

Doi Tung, a mountainous region in northern Thailand, is part of an area called the Golden Triangle. This area was once responsible for over 70 percent of the world's opium production (Fuller, 2007). Out of necessity for survival, many people joined the drug trade, which was the highest-earning job available. The Mae Fah Luang Foundation (MFLF) works to create opportunities for the community to "be good" and avoid drug-related activities by offering means to healthcare, a source of income, and education. Our sponsor, Siam Commercial Bank is working in collaboration with the MFLF to enable the community to function completely independent of external help. The Doi Tung schools lacked the knowledge of water quality testing methods and the maintenance of their water filtration systems. The lack of self-sufficiency of the schools required them to heavily rely on the MFLF to repair the system. The goal of our project was to assess water system maintenance at Doi Tung schools and make recommendations for sustainable improvements targeted to the community's needs. Our objectives to achieve this goal were as follows:

(1) Determine the quality of the water at the source and after filtration at each of the three schools;

(2) Evaluate and observe the school community's water system and maintenance practices to determine the strengths and weaknesses of the current system;

(3) Promote the students' confidence in water quality with water testing methods that can be used by the schools;

(4) Encourage schools to maintain their water filtration system independently and sustainably.

We interviewed members of the school community, observed their water usage, tested the water throughout the distribution and filtration system, and surveyed the teachers for feedback on proposed recommendations.

We identified three major findings:

(1) The filtered water at the schools was safe to drink.

(2) The school community did not trust the water quality.

(3) The information on maintaining the water filtration systems was not communicated.

The Filtered Water at the Schools Was Safe to Drink:

On-site and laboratory tests of the water samples from each school were conducted to test for bacterial, chemical and physical contamination. Biological contaminants were tested through total organic carbon (TOC), chemical oxygen demand (COD), and bacteria culturing tests. The physical and chemical tests measured total dissolved solids (TDS), alkalinity, and clarity of the water. The results of our analysis of water quality in the three schools: Ban Kha Yaeng, Bamrung 87, and Ban Mae Salap are below.

Ban Kha Yaeng

The school's water quality from source to point of use was within drinking water standards. The water was safe to consume because the TOC levels were below 3 mg/L, the consumable drinking standard. The levels of TDS throughout the entire distribution and filtration systems remained relatively constant, lower than the maximum allowable measurement of 300 ppm. The COD levels at all sample points were within drinking water standards. The pH was an average of 8.3, at the upper level of the acceptable range for drinking water. We plated water samples on bacteria growth medium. Despite the amount of bacteria present in the pre-filtered water samples, the amount of bacterial growth on the point of use plate was very low and not alarming. Our team determined with these tests that the water at the Ban Kha Yaeng school's drinking water was within acceptable drinking water quality standards.

Bamrung 87

Despite having high levels of TOC at the source and pre-filtration, the TOC levels at the point of use were at acceptable drinking levels. The TDS levels increased between the source and filter as well as between the filter and point of use. However, the TDS present at the point of use was nine times less than the maximum allowable standards. The water at Bamrung 87 had a neutral pH, indicating a lack of chemical imbalances in the water. The bacterial growth plates for the source and pre-filtered water were highly contaminated with bacteria. The point of use plate showed an extreme decline in biological contaminants. Our team determined with these tests that the water at the Bamrung 87 school's drinking water was within acceptable drinking water quality standards.

Ban Mae Salap

The source and pre-filtration levels contained the lowest levels of TOC. The filtration system completely eliminated any TOC present. The TDS levels were relatively high in the source water at this school, the filtration systems decreased the TDS by a factor of 50 and did not indicate poor water quality at the point of use. The source and point of use drinking water's COD were an infinitesimally small quantity expressed as 0.0 mg/L. The water was consistently slightly alkaline throughout the system, ending with a pH of 8.08 at the point of use. The presence of bacteria in the plates decreased from the source through the system, however a significant amount of bacteria remained at the point of use. We were unable to characterize the bacteria so we could not conclude if the bacteria was a concern for human health. Our team determined with these tests that the water at the Ban Mae Salap school's drinking water was within acceptable drinking water quality standards.

The School Community Did Not Trust the Water Quality

Our team was informed by Siam Commercial Bank and the Mae Fah Luang Foundation that the school communities in Doi Tung did not trust the water quality. During our site visits, we interviewed students and teachers from each school to understand their concerns about the water's quality. We identified two main categories of issues the community had regarding the quality of the filtered water:

(1) Secondary aesthetics of the filtered water
(2) Environmental factors

Secondary Aesthetics of the Filtered Water

One of the sets of concerns the community had was about the secondary aesthetics of the filtered water. According to the teachers, students, and superintendents at each school, the community valued secondary characteristics of the drinking water and would not consume it if there was a strange odor, color or taste. Our surveys indicated that none of the interviewees have experienced sickness associated with drinking the filtered water; however, they remained skeptical of its quality.

Environmental Factors

Another set of concerns was about environmental factors. Each of the three schools had environmental issues pertaining to human interactions with the environment. The early dry season allowed for stagnant water within the distribution system and exacerbated the abundance of algae. Use of fertilizers and pesticides at agricultural plots contributed to unclean source water, and encouraged the communities' distrust in the water quality.

The Information on Maintaining the Water Filtration Systems Was Not Communicated

The water filtration systems at the schools required maintenance to ensure that the systems are working effectively to filter the water. The Mae Fah Luang Foundation held an orientation for teachers, however, it was ineffective due to various factors. The schools were previously provided with manuals, which have been reported to be challenging to understand. The teachers and schools were unable to be self-sufficient and continue to rely heavily on the MFLF.

Unsustainable Orientation Process

Because the teachers are employed as part of a national educational initiative, the minimum amount of time they must stay in the northern region is only two years, and this duration is rarely exceeded. There was only one orientation event, however, the schools' water systems have been in place for two months to up to three years. With only two teachers at each school going through orientation, the frequency of orientation programs held was not practical or sufficient to keep up with the rapid exchange rate of teachers in and out of the area.

Need for Improved Informational Documents

Our sponsors, Siam Commercial Bank and the Mae Fah Luang Foundation, established a manual for the water systems at each school. These manuals did not provide enough information for users to independently learn about and maintain the systems. SCB and the MFLF worked to refine the manual to be easily understood by individuals who are not familiar with the system. In addition to the manuals, our team found that many of the infographics at the schools were faded or illegible.

Our team provided Siam Commercial Bank and the Mae Fah Luang Foundations with recommendations that would help alleviate problems that we identified with the water filtration systems at the schools.

Providing Testing Methods

Our team recommends three water testing methods that can be used by the Doi Tung schools to reaffirm their confidence in the filtered water. Each school is recommended to record the results for the tests and to ensure that the result falls within drinking water standards. Infographics will be provided to aid in the understanding of the methods.

(1) *The 3-in-1 Water Quality Detector*: tests for total dissolved solids (TDS), total organic carbon (TOC), and chemical oxygen demand (COD).

(2) *The 9-in-1 Water Quality Testing Strips*: tests for total alkalinity, total hardness, copper, nitrate, iron, lead, free chlorine, nitrite, and pH.

(3) *Secchi Disk Turbidity Test:* tests for the clearness and color of water.

Mentorship Program and Motivation for Participation

Our team recommends setting up a semi-structured peer mentorship program with teachers from the Doi Tung schools. This program would help to overcome the loss of knowledge between the teachers due to the frequent faculty change over the short two-year compulsory period. Pairing incumbent and informed teachers with incoming or uninformed teachers in a mentorship program encourages long-term sustainability. Incoming teachers will benefit from having a mentor for an unofficial orientation to their new home in both a social and professional manner. Teachers who have been in the area and have experienced daily life at the schools will be able to give back in the form of advice, information, encouragement, and help for new teachers to adjust to their new environment.

The Manual and Transition Materials

The schools will be provided with a manual from SCB and the MFLF. We recommend two versions of the manual, paper and online. This paper copy is accessible if there is no computer. An online copy of the manual can include supplementary videos that demonstrate procedures and can be easily updated. The manual will include information on the filtration systems, including the purpose of the filter, the method of filtration, and the maintenance required. The manual will include information on simple water testing methods, including the purpose of each testing method, the procedure for each test, what results indicate, and actions to take.

Guidelines for Sustainable Drinking Water in Doi Tung Schools

Our team recommended solutions to make the water filtration systems more sustainable and user-friendly for the students and faculty at three schools in Doi Tung. We used these solutions and information collected from behavioral interviews and technical analysis to create a set of guidelines for other schools in the area. These guidelines were created within the limitations of the community and were refined to meet the needs and preferences of the community.

Water Collection and Algae Prevention

The schools have a problem of insufficient water during the dry season that came earlier than expected. Current water management practices are not sufficient. Our team recommends collecting rainwater during the rainy season for use in times of low water supply. We recommend a linear low-density polyethylene tank. The polyethylene tank is lightweight and provides a sterile containment for the water that is nearly impermeable to sunlight, which will prevent bacteria and algal growth in the water. The ease of transport and prevention of biological contaminants make it a suitable option for use at the Doi Tung schools.

Individual School Recommendations

Most of the common water potability related problems were present at each of the three schools. However, each school had its own specific problems that our team observed and addressed.

Ban Kha Yaeng

Ban Kha Yaeng lacks consistent access to water. Our team suggests that the school collects rainwater during the wet season and store it in polyethylene tanks to be utilized during the dry season. Our team also recommends covering the storage tanks with a dark material to prevent algae growth. Our team encourages teachers to set a good example for the students by drinking the water from the filtration system in place.

Bamrung 87

There are several structural problems with the piping at Bamrung 87. Our team recommends repairing the piping system so that the wastewater is disposed of appropriately. Our team recommends this school to re-design the clean-out portion of the piping with a P trap, so that it is more curved. This will allow sediments to be cleared and removed more efficiently. As opposed to having the pipe go directly through the dam’s wall, our team recommends that the school redesign the beginning of the distribution system with a curved inlet to decrease resistance and increase the flow of water in the system. The lack of maintenance and cleaning of the pipe entrance contributes to unsafe drinking conditions. The school should clean out the system more frequently to eliminate the contamination added to the system pre-filtration. Bamrung 87 does not have access to proper hand soap for the students to use. Our team suggests the school invests in proper hand soap that students can use at all hand-washing stations.

Ban Mae Salap

Ban Mae Salap has over six filtration systems present, and the complexity of the filtration systems makes it difficult for the schools to maintain. Only 40 percent of the water filtered from the reverse osmosis system is potable. The other 60 percent is wastewater from the filtration process, which must be used for other purposes. The surrounding community uses pesticides and fertilizers that may percolate nitrates into the aquifer. This promotes accelerated growth of algae downstream in the system. Also, there was rubber and dirt around the pipes, the post-RO waste tank, and the post-RO purified water tank, which caused the water to seem unsanitary.

Our team recommends eliminating redundant filtration systems, including the broken UV filter, to reduce the complexity of maintaining them. Eliminating these systems will also decrease maintenance and repair costs. The team additionally suggests more storage tanks so that 60 percent of the water from the RO system is not being wasted. Covering the storage tanks with a dark material will help prevent further algae growth.

Our team's recommendations aim to improve the confidence and sustainability of the water filtration systems in place at Doi Tung schools. We surveyed teachers to receive feedback on our proposed recommendations since they directly impact the lives of the school community. Most of the teachers agree with our proposed solutions and found the recommendations useful. We also gained suggestions that we used to improve our recommendations. The testing methods, mentorship program, and manual provided to the schools will allow them to become independent from the Mae Fah Luang Foundation and to be self-sustaining. The suggestions provided for the schools establish a foundation for water standards and upkeep regulations that will leave the schools with potable water long-term. Our team's recommendations will leave the faculty and students of Doi Tung with the ability to sustain potable water for themselves.

บทสรุป

กล่าวนำ

ดอยตุง ตั้งอยู่ที่สันเขาของเทือกเขานางนอน และเป็นส่วนหนึ่งของสามเหลี่ยมทองคำ ในอดีตพื้นที่ส่วนนี้เคยเป็นแหล่งผลิตฝิ่นรายใหญ่ ซึ่งคิดเป็นอัตราส่วนร้อยละ 70 ของผู้ผลิตฝิ่นทั่วโลก (Fuller, 2007) ท่ามกลางความเป็นอยู่ที่แร้นแค้นของผู้คนบนดอยตุง ชาวบ้านจึงต้องหาทางรอดด้วยการประกอบอาชีพผิดกฎหมาย มูลนิธิแม่ฟ้าหลวง จึงพัฒนาโครงการทางเลือกเพื่อลดการปลูกพืชเสพติด และแก้ปัญหาความยากจน โดยการสร้างงานและอาชีพที่หลากหลายแก่ชาวบ้าน เพื่อให้ชาวบ้านสามารถพึ่งพาตนเองและพัฒนาชุมชนต่อไป ผู้สนับสนุนหลักของเรา ธนาคารไทยพาณิชย์ ได้ร่วมมือกับมูลนิธิแม่ฟ้าหลวง ในโครงการพัฒนาชุมชนที่ยั่งยืน และเนื่องด้วยโรงเรียนต่างๆบนดอยตุงยังขาดความรู้ในเรื่องการซ่อมบำรุงระบบกรองน้ำ รวมไปถึงการทดสอบคุณภาพน้ำด้วยตนเอง ทางโรงเรียนจึงยังคงพึ่งพามูลนิธิแม่ฟ้าหลวง ด้วยเหตุนี้เป้าหมายของโครงการของเรา จึงเป็นการประเมินระบบน้ำหลังจากการบำรุงรักษา และมอบข้อเสนอแนะเพื่อการพัฒนาที่ยั่งยืนแก่ชุมชน และเพื่อบรรลุเป้าหมาย เราจึงมีวัตถุประสงค์ดังต่อไปนี้:

(1.) ระบุคุณภาพของน้ำ ทั้งบริเวณ แหล่งน้ำ และหลังจากผ่านระบบเครื่องกรองน้ำของทั้งสามโรงเรียน

(2.) สังเกตและประเมินผลระบบน้ำของโรงเรียน รวมไปถึงวิธีการบำรุงรักษาเพื่อกำหนดข้อดีและข้อด้อยของระบบปัจจุบัน

(3.) ส่งเสริมความมั่นใจของนักเรียนในเรื่องของคุณภาพน้ำ ด้วยการนำเสนอวิธีการทดสอบคุณภาพที่โรงเรียนสามารถทำได้ด้วยตนเอง

(4.) สนับสนุนให้โรงเรียนบำรุงรักษาระบบกรองน้ำด้วยตนเอง เพื่อความยั่งยืน

มากไปกว่านั้นเราได้ทำการสัมภาษณ์บุคลากรในโรงเรียน สังเกตพฤติกรรมการใช้น้ำ และทดสอบคุณภาพน้ำ รวมไปถึงทำแบบสำรวจสำหรับบุคลากรภายในโรงเรียน เกี่ยวกับข้อเสนอแนะที่เรามอบให้

พวกเราระบุสิ่งสำคัญที่ค้นพบได้สามประการ

1. น้ำหลังจากผ่านระบบการกรองที่โรงเรียนนั้นสะอาดและปลอดภัยในการบริโภค
2. บุคลากรและนักเรียนในโรงเรียนไม่เชื่อถือในคุณภาพของน้ำดื่ม
3. ข้อมูลด้านการบำรุงรักษาระบบเครื่องกรองน้ำไม่ได้รับการถ่ายทอดต่อ

1. น้ำหลังจากผ่านระบบการกรองที่โรงเรียนนั้นสะอาดและปลอดภัยในการบริโภค

การทดสอบน้ำในพื้นที่และห้องปฏิบัติการในแต่ละโรงเรียนเพื่อทดสอบแบคทีเรีย การปนเปื้อนทางเคมี ทางกายภาพ และทางชีวภาพสามารถตรวจสอบผ่านปริมาณสารคาร์บอนอินทรีย์รวม (TOC) ค่าความต้องการออกซิเจนทางเคมี (COD) และการเพาะเชื้อแบคทีเรีย อีกทั้งทางเคมีและทางกายภาพก็สามารถตรวจสอบผ่านปริมาณของแข็งที่ละลายน้ำทั้งหมด (TDS) สภาพความเป็นด่าง และความบริสุทธิ์ของน้ำ โดยผลการตรวจสอบคุณภาพน้ำของทั้ง 3 โรงเรียนได้แก่ โรงเรียนบ้านขาแหย่งพัฒนา โรงเรียนตชด. บำรุงที่ 87 และ โรงเรียนบ้านแม่สแลป มีดังนี้

1.1 โรงเรียนบ้านขาแหย่งพัฒนา

คุณภาพน้ำดื่มของโรงเรียน จากแหล่งน้ำไปจนถึงจุดจ่ายน้ำดื่มอยู่ในเกณฑ์มาตรฐาน น้ำนี้สามารถบริโภคได้อย่างปลอดภัย เนื่องจากปริมาณสารคาร์บอนอินทรีย์รวม (TOC) ต่ำกว่า 3 มก./ล. ปริมาณ

ของแข็งที่ละลายน้ำทั้งหมด (TDS) ตลอดทั้งระบบยังต่ำกว่า 300 มก./ล. และระดับค่าความต้องการออกซิเจนทางเคมี (COD) ก็อยู่ในเกณฑ์มาตรฐานน้ำดื่ม รวมไปถึง ค่า pH ซึ่งเฉลี่ยอยู่ที่ 8.3 ซึ่งเป็นค่าที่อยู่ในเกณฑ์มาตรฐานของน้ำดื่ม นอกจากนี้ พวกเรายังได้ทำการเพาะเชื้อแบคทีเรียจากตัวอย่างน้ำของโรงเรียน โดยผลลัพธ์ที่แสดงออกมาให้เห็นนั้น แม้ว่าจะมีแบคทีเรียในน้ำที่ยังไม่ผ่านการกรอง แต่เมื่อผ่านระบบเครื่องกรองน้ำแล้วเชื้อแบคทีเรียที่ปรากฏออกมานั้นมีปริมาณน้อยมาก และไม่เป็นอันตราย หลังจากพิจารณาคุณภาพน้ำจากการทดสอบเหล่านี้ แสดงให้เห็นว่าน้ำดื่มของโรงเรียนบ้านขาแหย่งนั้นอยู่ในระดับที่ได้มาตรฐาน

1.2 โรงเรียนตชด. บำรุงพัฒนาที่ 87

แม้ว่าน้ำที่โรงเรียนแห่งนี้ จะมีปริมาณสารคาร์บอนอินทรีย์รวม (TOC) สูงในบริเวณแหล่งน้ำและน้ำบริเวณก่อนเข้าระบบเครื่องกรอง แต่เมื่อผ่านเครื่องกรองน้ำแล้วปริมาณสารคาร์บอนอินทรีย์รวมนั้นอยู่ในเกณ์มาตรฐาน และปริมาณของแข็งที่ละลายน้ำทั้งหมด (TDS) ที่แม้จะเพิ่มขึ้นระหว่างแหล่งน้ำ เครื่องกรองและจุดจ่ายน้ำ ปริมาณของของแข็งที่ละลายน้ำทั้งหมดนั้นก็ยังอยู่ในมาตรฐานน้ำดื่ม และยังต่ำกว่ามาตรฐานสูงสุดที่อนุญาตได้ถึง 9 เท่า ในส่วนของค่า pH นั้นก็มีความเป็นกลาง ซึ่งแสดงถึงความสมดุลของสารเคมีในน้ำ และการเพาะเชื้อแบคทีเรียจากตัวอย่างน้ำก็แสดงให้เห็นถึงการลดลงของการปนเปื้อน ของเชื้อแบคทีเรียจากแหล่งน้ำจนถึงจุดจ่ายน้ำ หลังจากพิจารณาคุณภาพน้ำจากการทดสอบเหล่านี้ แสดงให้เห็นว่าน้ำดื่มของโรงเรียนตชด. บำรุงที่ 87 นั้นอยู่ในระดับที่ได้มาตรฐาน

1.3 โรงเรียนบ้านแม่สแลป

ปริมาณสารคาร์บอนอินทรีย์รวม (TOC) บริเวณแหล่งน้ำและน้ำบริเวณก่อนเข้าระบบเครื่องกรองมีอยู่ในปริมาณที่ต่ำมาก และหลังผ่านระบบเครื่องกรองก็สามารถกำจัดปริมาณสารคาร์บอนอินทรีย์รวม (TOC) ได้อย่างสมบูรณ์ และแม้ว่าปริมาณของแข็งที่ละลายน้ำทั้งหมด (TDS) จะค่อนข้างสูงบริเวณแหล่งน้ำ แต่เมื่อผ่านระบบเครื่องกรองน้ำก็สามารถลดปริมาณของแข็งที่ละลายน้ำทั้งหมด ได้ถึง 50 ซึ่งก็ไม่ได้บ่งชี้ถึงคุณภาพน้ำที่ต่ำ ณ จุดจ่ายน้ำ นอกจากนี้ ค่าความต้องการออกซิเจนทางเคมี (COD) ณ แหล่งน้ำและจุดจ่ายน้ำก็มีปริมาณน้อยมากหรือเทียบเท่ากับ 0.0 มล./ล. ส่วนค่า pH นั้นมีความเป็นด่างตลอดทั้งระบบเครื่องจ่ายน้ำ ซึ่งมีค่าเท่ากับ 8.08 การเพาะเชื้อแบคทีเรียจากตัวอย่างน้ำก็แสดงให้เห็นถึงการลดลงของการปนเปื้อนเชื้อแบคทีเรียจากแหล่งน้ำจนถึงจุดจ่ายน้ำ อย่างไรก็ตามยังคงมีแบคทีเรียจำนวนหนึ่งหลงเหลืออยู่บริเวณจุดจ่ายน้ำ และเราไม่สามารถจำแนกชนิดของแบคทีเรียได้ ดังนั้นเราจึงไม่สามารถระบุได้ว่าแบคทีเรียนี้ส่งผลต่อสุขภาพของมนุษย์หรือไม่ โดยหลังจากพิจารณาคุณภาพน้ำจากการทดสอบเหล่านี้ แสดงให้เห็นว่าน้ำดื่มของโรงเรียนบ้านแม่สแลป นั้นอยู่ในระดับที่ได้มาตรฐาน

2. **บุคลากรและนักเรียนในโรงเรียนไม่เชื่อถือในคุณภาพของน้ำดื่ม**

พวกเราได้รับข้อมูลจากทางธนาคารไทยพาณิชย์ และมูลนิธิแม่ฟ้าหลวงในเรื่องความไม่เชื่อมั่นในคุณภาพน้ำดื่ม พวกเราจึงได้ทำการสัมภาษณ์นักเรียนและคุณครูในแต่ละโรงเรียน เพื่อที่จะได้เข้าใจถึงความกังวลใจในเรื่องของคุณภาพน้ำ หลังจากนั้นเราจึงระบุปัญหาหลักออกมาได้ 2 ประเภทที่มีความเกี่ยวข้องกับคุณภาพน้ำ

- คุณลักษณะภายนอกของน้ำที่ผ่านการกรอง เช่น สี รสชาติ กลิ่น
- ปัจจัยทางสิ่งแวดล้อม

2.1 คุณลักษณะภายนอกของน้ำที่ผ่านการกรอง เช่น สี รสชาติ กลิ่น

คุณลักษณะของน้ำที่ผ่านการกรองเป็นหนึ่งในความกังวลของทางโรงเรียน โดยคุณลักษณะของน้ำดื่มคือสิ่งที่ คุณครู นักเรียน และผู้อำนวยการโรงเรียนให้ความสำคัญเป็นอย่างแรก ซึ่งพวกเขาจะไม่บริโภคหากน้ำมีรสชาติ กลิ่น หรือสีที่แปลกไปจากเดิม จากผลการสำรวจของเราพบว่าไม่มีบุคคลใดในโรงเรียนมีอาการป่วยจากการบริโภคน้ำดื่มที่ผ่านการกรอง อย่างไรก็ตามทางโรงเรียนยังคงมีข้อสงสัยและข้อกังขาในคุณภาพของน้ำ

2.2 ปัจจัยทางสิ่งแวดล้อม

อีกหนึ่งในความกังวลของทางโรงเรียนนั้นคือปัจจัยทางสิ่งแวดล้อม ปัญหาด้านสิ่งแวดล้อมนั้นเกี่ยวข้องกับความสัมพันธ์ระหว่างมนุษย์กับธรรมชาติ ในช่วงต้นฤดูแล้งซึ่งมีปริมาณน้ำที่ไม่เพียงพอ ส่งผลให้ปริมาณน้ำในท่อลำเลียงน้ำมีน้อย จึงเป็นสาเหตุให้เกิดตะไคร่น้ำ รวมไปถึงการใช้ปุ๋ยเคมี และยาฆ่าแมลงในพื้นที่การเกษตรที่มีส่วนทำให้แหล่งน้ำเกิดการปนเปื้อน จึงทำให้ชุมชนไม่ไว้ใจในคุณภาพของน้ำ

3. ข้อมูลด้านการบำรุงรักษาระบบเครื่องกรองน้ำไม่ได้รับการถ่ายทอดต่อ

ระบบกรองน้ำในโรงเรียนจำเป็นต้องมีการบำรุงรักษาเพื่อให้แน่ใจว่าระบบจะทำงานได้อย่างเต็มประสิทธิภาพในการกรองน้ำ มูลนิธิแม่ฟ้าหลวงได้ทำการจัดฝึกอบรมให้แก่คุณครู แต่ไม่ได้ผลตามที่ต้องการเนื่องจากปัจจัยต่าง ๆ ก่อนหน้านี้โรงเรียนได้รับคู่มือเกี่ยวกับระบบน้ำ แต่ด้วยความที่คู่มือนั้นยากต่อการทำความเข้าใจ คุณครูและโรงเรียนจึงไม่สามารถใช้คู่มือนี้ด้วยตนเองได้ และยังคงต้องการความช่วยเหลือจากมูลนิธิแม่ฟ้าหลวง

การฝึกอบรมของเหล่าคุณครู

เนื่องจากอาชีพครูเป็นส่วนหนึ่งขององค์กรทางการศึกษาของภาครัฐ ซึ่งระยะเวลาขั้นต่ำที่เหล่าคุณครูต้องประจำอยู่ที่โรงเรียนคือ 2 ปี อีกทั้งการฝึกอบรมเรื่องระบบน้ำที่จัดขึ้นนั้นมีเพียงครั้งเดียว นอกจากนี้ระบบน้ำที่โรงเรียนนั้นได้ถูกติดตั้งมาเป็นเวลาประมาณ 2 เดือน ถึง 3 ปี และมีคุณครูจำนวนเพียง 2 คน ต่อ 1โรงเรียนเท่านั้นที่ได้เข้ารับการฝึกอบรมที่เคยจัดขึ้น ด้วยเหตุนี้การฝึกอบรมที่เคยจัดขึ้นนั้นจึงไม่มีประสิทธิภาพมากพอที่จะสามารถนำมาใช้งานได้จริง หรือเพียงพอในการรักษาอัตราการเปลี่ยนถ่ายของคุณครูภายนอกและภายในพื้นที่

เอกสารที่ต้องได้รับการปรับปรุง

ธนาคารไทยพาณิชย์ และมูลนิธิแม่ฟ้าหลวงได้ร่วมกันจัดทำคู่มือพื้นฐานของระบบกรองน้ำในแต่ละโรงเรียน โดยคู่มือนี้จะให้ข้อมูลที่เพียงพอสำหรับผู้ใช้ในการเรียนรู้และรักษาระบบกรองน้ำ และคู่มือฉบับนี้ยังจัดทำขึ้นเพื่อให้ผู้อ่านสามารถเรียนรู้และลงมือทำได้ด้วยตนเอง ธนาคารไทยพาณิชย์และมูลนิธิแม่ฟ้าหลวงร่วมมือกันปรับปรุงและแก้ไขคู่มือเพื่อความเข้าใจง่าย โดยเฉพาะกับบุคคลที่ไม่มีพื้นฐานด้านการซ่อมบำรุงระบบน้ำ นอกจากนั้นทีมของเรายังค้นพบว่าแผนภาพในโรงเรียนหลายแห่งมีสีที่ซีดจาง และยากต่อการมองเห็น

ทีมงานของเราได้จัดทำข้อเสนอแนะแก่ธนาคารไทยพาณิชย์ และมูลนิธิแม่ฟ้าหลวงโดยมีจุดประสงค์เพื่อที่จะช่วยบรรเทาปัญหาที่เราได้ค้นพบเกี่ยวกับระบบการกรองน้ำในโรงเรียนดังต่อไปนี้

วิธีการทดสอบคุณภาพน้ำ

พวกเราได้เสนอแนะวิธีการทดสอบคุณภาพน้ำทั้งหมด 3 วิธี ให้แก่ทุกโรงเรียน เพื่อใช้ยืนยันเรื่องความสะอาดของน้ำและเสริมสร้างความมั่นใจในน้ำที่ผ่านระบบกรองก่อนบริโภค และแต่ละโรงเรียนควร

บันทึกผลการทดสอบเอาไว้ อีกทั้งเพื่อให้มั่นใจว่าผลการทดสอบนั้นตรงตามมาตรฐานน้ำดื่ม เราได้เตรียมแผนภูมิภาพเพื่อช่วยให้ผู้อ่านสามารถเข้าใจได้ง่ายยิ่งขึ้น

1. เครื่องตรวจจับคุณภาพน้ำแบบ 3-in-1: การทดสอบปริมาณของแข็งที่ละลายน้ำทั้งหมด (TDS) ปริมาณสารคาร์บอนอินทรีย์รวม (TOC) และค่าความต้องการออกซิเจนทางเคมี (COD)
2. แถบสีทดสอบคุณภาพน้ำ 9-in-1: การทดสอบนี้สามารถตรวจสอบความเป็นด่างโดยรวม ความกระด้าง รวมถึงทองแดง ไนเตรต เหล็ก ตะกั่ว ฟรีคลอรีน ไนไตรท์ และค่า pH
3. การทดสอบความขุ่นของแผ่นดิสก์ Secchi: เป็นการทดสอบความใส และสีของน้ำ

โครงการให้คำปรึกษาและปลูกฝังแรงจูงใจ

พวกเราได้เสนอแนะโครงการให้คำปรึกษาและปลูกฝังแรงจูงใจที่ส่งความรู้จากเพื่อนสู่เพื่อน พี่สู่น้อง แก่บุคลากรบนโรงเรียนดอยตุง โดยโครงการนี้จะช่วยถ่ายทอดความรู้เรื่องระบบน้ำระหว่างคุณครู เนื่องจากมีการโยกย้ายคุณครูเป็นประจำ ซึ่งระยะเวลาในการประจำการในแต่ละโรงเรียนจะมีระยะเวลาไม่เกินสองปี โดยที่โครงการนี้จะให้คุณครูหรือผู้มีความรู้ด้านระบบกรองน้ำเป็นที่ปรึกษาข้อมูลให้แก่คุณครูที่เข้ามาใหม่ หรือไม่ได้รับการอบรมในโครงการ ซึ่งคุณครูที่ย้ายเข้ามาใหม่ก็จะได้รับประโยชน์ และความรู้จากคุณครูผู้ให้คำปรึกษา เพื่อส่งเสริมความยั่งยืนในระยะยาว โดยที่ผู้ให้คำปรึกษาคือผู้มีประสบการณ์จะสามารถให้คำแนะนำข้อมูลต่าง ๆ รวมถึงให้กำลังใจ และช่วยเหลือคุณครูคนใหม่ในการปรับตัวให้เข้ากับสภาพแวดล้อมในโรงเรียน

คู่มือการใช้งาน

ธนาคารไทยพาณิชย์ และมูลนิธิแม่ฟ้าหลวงจะมอบคู่มือด้านระบบกรองน้ำให้แก่โรงเรียน โดยคู่มือนี้มีด้วยกันสองแบบ คือ หนังสือคู่มือแบบกระดาษและคู่มือแบบออนไลน์ หนังสือคู่มือจะสามารถใช้ได้ทันทีแม้ปราศจากอุปกรณ์เทคโนโลยีสารสนเทศ แต่สำหรับคู่มือออนไลน์นั้น จะรวมถึงวิดีโอซึ่งแสดงขั้นตอนการทำงานอย่างละเอียด โดยคู่มือออนไลน์นี้สามารถเพิ่มเติมวิดีโออื่น ๆ เข้าไปได้ง่ายอีกด้วย หนังสือคู่มือการใช้งานนี้จะรวมข้อมูลเกี่ยวกับระบบการกรองและวัตถุประสงค์ของตัวกรอง วิธีการกรองและการบำรุงรักษาที่จำเป็นต่อชีวิตประจำวัน อีกทั้งยังรวมไปถึงข้อมูลเกี่ยวกับวิธีการทดสอบน้ำอย่างง่าย รวมถึงจุดประสงค์ของแต่ละวิธีการทดสอบ ขั้นตอนสำหรับการทดสอบแต่ละครั้ง และผลลัพธ์ที่แสดงออกมา เพื่อนำผลการทดสอบคุณภาพน้ำมาระบุและพัฒนาต่อไป

แนวทางการมีน้ำดื่มสำหรับโรงเรียนบนดอยตุงอย่างยั่งยืน

ทีมงานของเราเสนอแนะวิธีแก้ปัญหาเพื่อให้ระบบกรองน้ำมีความยั่งยืน และเป็นมิตรต่อผู้ใช้สำหรับนักเรียนและคณาจารย์ในโรงเรียนทั้งสามแห่ง โดยเราใช้วิธีแก้ไขปัญหาและข้อมูลที่รวบรวมจากการสัมภาษณ์เชิงพฤติกรรมและการวิเคราะห์ทางเทคนิค เพื่อสร้างแนวทางสำหรับโรงเรียนอื่น ๆ ในพื้นที่ โดยแนวทางเหล่านี้ถูกสร้างขึ้นภายในข้อ จำกัด ของชุมชน และได้รับการขัดเกลาเพื่อตอบสนองต่อความต้องการของชุมชน

การกักเก็บน้ำและป้องกันตะไคร่

เนื่องจากโรงเรียนมีปัญหาน้ำไม่เพียงพอในช่วงฤดูแล้ง ซึ่งเกิดขึ้นเร็วกว่าที่คาดการณ์ไว้ อีกทั้งแนวทางในการจัดการน้ำในปัจจุบันยังไม่เพียงพอ ทีมงานของเราจึงเสนอแนะให้รวบรวมน้ำฝนในช่วงฤดูฝนเพื่อใช้ในฤดูแล้ง รวมถึงเสนอแนะให้ใช้ถังโพลีเอทิลีน (Polyethylene tank) ชนิดความหนาแน่นเชิงเส้นต่ำ โดยถังโพลีเอทิลีนนั้นจะมีน้ำหนักเบา และยังเป็นภาชนะที่ผ่านการฆ่าเชื้อซึ่งเหมาะสำหรับกักเก็บน้ำที่ไม่สามารถสัมผัสกับแสงแดดได้ ในกรณีนี้จะช่วยป้องกันแบคทีเรียและตะไคร่ในน้ำ อีกทั้งยังสะดวกในการขนส่งและป้องกันการปนเปื้อนทางชีวภาพทำให้เป็นตัวเลือกที่เหมาะสม สำหรับโรงเรียนบนดอยตุง

ข้อเสนอแนะสำหรับแต่ละโรงเรียน

ปัญหาทั่วไปที่เกี่ยวข้องกับน้ำบริโภคล้วนพบได้ในโรงเรียนทั้งสามแห่ง แต่อย่างไรก็ตามทั้งสามโรงเรียนนั้นมีปัญหาเฉพาะของตนเองที่พวกเราสังเกตและค้นพบ

โรงเรียนบ้านขาแหย่งพัฒนา

โรงเรียนบ้านขาแหย่งนั้นขาดการเข้าถึงน้ำบริโภคที่สม่ำเสมอ เราจึงเสนอให้โรงเรียนกักเก็บน้ำฝนในช่วงฤดูฝน โดยเก็บไว้ในถังโพลีเอทลีนสำหรับใช้ในช่วงฤดูแล้ง คณะผู้วิจัยยังแนะนำให้คลุมถังเก็บน้ำด้วย วัสดุสีเข้มเพื่อป้องกันการเติบโตของสาหร่ายหรือตะไคร่ และเรายังสนับสนุนให้คุณครูเป็นตัวอย่างที่ดีสำหรับนักเรียน โดยการดื่มน้ำที่ผ่านระบบการกรองที่ติดตั้งภายในโรงเรียนเพื่อลดการซื้อน้ำขวดจากภายนอก

โรงเรียนตำรวจตระเวนชายแดนบำรุงที่ 87

ตชด.87 มีปัญหาเชิงโครงสร้างหลายประการเกี่ยวกับการวางระบบท่อน้ำ คณะผู้วิจัยจึงเสนอให้ซ่อมแซมระบบท่อ เพื่อให้น้ำเสียถูกกำจัดอย่างเหมาะสม และเรายังแนะนำให้โรงเรียนแห่งนี้ออกแบบส่วนท่อที่เชื่อมกับท่อทำความสะอาดซ้ำอีกครั้ง โดยทำให้ท่อโค้งมากขึ้น ซึ่งสิ่งนี้จะช่วยให้การล้างและกำจัดตะกอนมีประสิทธิภาพมากขึ้น ด้วยเหตุนี้เราจึงขอเสนอให้ปรับปรุงท่อที่ยื่นผ่านออกมานอกกำแพงของเขื่อน โดยให้โรงเรียนออกแบบจุดเริ่มต้นของระบบการกระจายน้ำใหม่เพื่อให้ปากทางเข้ามีความโค้ง เพื่อลดความต้านทาน และเพิ่มการไหลของน้ำในระบบให้ดีขึ้น การขาดการบำรุงรักษาและทำความสะอาดทางเข้าท่อก่อให้เกิดปัญหาการมีน้ำดื่มที่ไม่สะอาด โรงเรียนควรทำความสะอาดในส่วนของระบบก่อนเข้าเครื่องกรองให้บ่อยขึ้นเพื่อกำจัดการปนเปื้อน นอกจากนี้โรงเรียนยังควรจัดเตรียมให้มีสบู่ล้างมือที่เหมาะสมสำหรับนักเรียน ดังนั้นทีมของเราจึงขอแนะนำให้โรงเรียนลงทุนในเรื่องของสบู่ล้างมือที่เหมาะสม เพื่อให้นักเรียนสามารถใช้ได้ที่จุดล้างมือทุกแห่ง

โรงเรียนบ้านแม่สแลป

โรงเรียนบ้านแม่สแลปมีระบบการกรองมากกว่าหกระบบ ซึ่งความซับซ้อนของระบบการกรองทำให้ยากต่อการบำรุงรักษา น้ำที่กรองจากระบบ Reverse Osmosis มีเพียง 40 เปอร์เซ็นต์เท่านั้นที่สามารถนำมาใช้งานได้จริง โดยอีก 60 เปอร์เซ็นต์ที่เหลือนั้นเป็นน้ำเสียจากกระบวนการกรอง ซึ่งควรจะต้องนำมาใช้เพื่อวัตถุประสงค์อื่น อีกทั้งชุมชนโดยรอบยังใช้ยาฆ่าแมลง และปุ๋ยที่อาจทำให้ไนเตรทซึมสู่ชั้นใต้ดิน โดยสิ่งนี้จะช่วยเร่งการเติบโตของสาหร่าย หรือตะไคร่ที่อยู่ในน้ำส่วนท้ายของระบบ นอกจากนี้ยังมียางและสิ่งสกปรกรอบๆท่อถังขยะ และถังน้ำบริสุทธิ์หลังระบบ RO ซึ่งทำให้น้ำที่ผ่านการกรองนั้นดูสกปรก

ทีมของเราจึงขอเสนอแนะให้กำจัดระบบการกรองที่ซ้ำซ้อนเหล่านี้ รวมถึงตัวกรอง UV ที่ชำรุด เพื่อลดความซับซ้อนในการบำรุงรักษา และช่วยลดค่าใช้จ่ายในการบำรุงรักษาและซ่อมแซม นอกจากนี้เรายังเสนอให้เพิ่มถังเก็บน้ำ เพื่อให้น้ำจากระบบ RO 60 เปอร์เซ็นต์ที่เหลือนั้นไม่สูญเปล่า และการคลุมถังเก็บน้ำด้วยวัสดุสีเข้มจะช่วยป้องกันและลดจำนวนการเติบโตของสาหร่ายได้ในภายภาคหน้า

ข้อสรุป

ข้อเสนอแนะของเรามีเป้าหมายที่จะช่วยเสริมสร้างความมั่นใจอย่างยั่งยืนให้แก่ ระบบกรองน้ำบริโภคของโรงเรียนบนดอยตุง พวกเราได้สำรวจความคิดเห็นของคุณครูเพื่อเก็บข้อมูลเกี่ยวกับข้อเสนอแนะต่าง ๆ เนื่องจากคุณครูเป็นส่วนสำคัญต่อชุมชนในโรงเรียน ซึ่งคุณครูส่วนใหญ่เห็นด้วยกับวิธีแก้ปัญหาที่พวกเราเสนอ และพบว่าคำแนะนำเหล่านี้สามารถสร้างประโยชน์ให้แก่โรงเรียนได้ นอกจากนี้เรายังได้รับคำแนะนำอื่น ๆ เพื่อนำมาปรับปรุง ซึ่งได้แก่วิธีการทดสอบคุณภาพน้ำ โครงการอบรมคุณครู และคู่มือดูแลรักษา

ระบบน้ำที่จะช่วยให้คุณครูสามารถแก้ไขปัญหาได้ด้วยตนเองเมื่อปราศจากความช่วยเหลือของมูลนิธิแม่ฟ้าหลวง ทั้งนี้ข้อเสนอแนะที่เราให้กับโรงเรียนนั้นจะสร้างรากฐานสำหรับมาตรฐานของน้ำและเกณฑ์การบำรุงรักษาที่จะทำให้โรงเรียนมีน้ำดื่มในระยะยาว พวกเราหวังเป็นอย่างยิ่งว่าข้อเสนอแนะของเราจะทำให้คณาจารย์และนักเรียนบนดอยตุงมีความสามารถในการบำรุงรักษาระบบน้ำบริโภคได้ด้วยตนเองในอนาคต

1.0 Introduction

In order to feel secure at school, students must have reliable access to basic life necessities. Schools in Doi Tung, Thailand lacked access to clean drinking water, forcing them to live beyond their means and buy bottled water. The Mae Fah Luang Foundation (MFLF) installed water filtration systems at the schools with the goal of providing them with a sustainable source of potable water. However, according to the Chief Administrative Officer of the MFLF, the Doi Tung schools lacked the knowledge of water quality testing methods and the maintenance of their water filtration systems (Chan-urai, 2020). The lack of self-sufficiency of the schools required them to heavily rely on the MFLF to repair the systems. This posed a health risk to the students when the system was broken or was in need of maintenance because the schools did not have access to filtered water during system repair. Without access to clean water, the students' educational opportunity was being affected.

Doi Tung, a mountainous region in northern Thailand, is part of an area called the Golden Triangle. This area was once responsible for more than 70 percent of the world's opium production (Fuller, 2007). Out of necessity for survival, many people joined the drug trade, which was the highest-earning job available. The Mae Fah Luang Foundation has a guiding principle, "No one wants to be a bad person, but not everyone has the opportunity to be good," (*Hall of Inspiration,* 2007). The MFLF works in collaboration with our sponsor, Siam Commercial Bank (SCB), to create opportunities for the community to "be good" and avoid drug-related activities by offering means to healthcare, a source of income, and education.

The Mae Fah Luang Foundation emphasizes self-sufficiency and sustainability in their solutions. Their goal is to enable the community to function completely independent of external help. Their work focuses on improving the lives of the younger generations. Safe and reliable educational opportunities promote school attendance (Zhang & Xu, 2016). Education improves access to future opportunities for students. The 2018 World Drug Report highlights that young people in poverty who lack opportunities are easily "coerced into working in drug cultivation, production, trafficking, and local-level dealing" (*World drug report 2018* 2018). The students have a better opportunity to grow up with an improved future, continue to increase the self-sufficiency of the community, and reduce the risk of falling back into a situation of dependency with the regional drug trade.

Our team worked in collaboration with Siam Commercial Bank and the Mae Fah Luang Foundation to improve the sustainability of the water filtration systems at Doi Tung Schools. The goal of our project was to assess water system maintenance at the schools and make recommendations for sustainable improvements targeted to the community's needs.

We accomplished this goal by addressing the following objectives:

(1) Determine the quality of the water at the source and after filtration at each of the three schools;

(2) Evaluate and observe the school community's water system and maintenance practices to determine the strengths and weaknesses of the current system;

(3) Promote confidence in water quality with water testing methods that can be used by the schools;

(4) Encourage schools to sustainably and independently maintain their water filtration systems;

The implementation of our recommendations will support our sponsors mission to further the self-sufficiency and sustainability of the Doi Tung schools. The continued access to clean water at schools will encourage school attendance and thereby promote the educational opportunities available to future generations of Doi Tung. Eventually, breaking the cycle of drug trade encourages the community to continue to have access to education and contribute to a drug-free region.

2.0 Background

In this chapter, we provide a brief overview of the global and local scale of the social problem associated with our project in the Doi Tung region. We review the region's history, geography, and climate. Next, we describe the mission of our sponsors, Siam Commercial Bank and the Mae Fah Luang Foundation. Then, we outline information about the three schools our project focused on. Finally, we outline previously identified problems regarding water quality and contamination at the schools.

2.1 The Importance of Clean Water for Self-Sufficiency

Potable water, or water that is safe to drink, is essential for life. According to the Center for Disease Control, there are 780 million people worldwide without access to potable water sources (Center for Disease Control and Prevention, 2016 a). Unclean water can cause health problems, including gastrointestinal diseases that can be life-threatening, especially in susceptible populations like young children (Neil, Yoder, Hall, & Bowen, 2018). Access to potable water decreases the risk of disease and improves health for the consumers. In addition, access to potable water has a long-term impact on education. A study conducted by the Renmin University in China examined the impact of a water treatment program in a rural area. The study found that the implementation of the water treatment program resulted in students staying in school for an additional year. Prior to the treatment program, girls completed fewer years of school than boys due to the additional responsibility of obtaining clean water for their families. After implementation of the treatment program, the gender gap in education was eliminated, and all students had the same educational opportunities. The earlier children have access to clean water, the more educational benefits they gain (Zhang & Xu, 2016). Access to potable water in communities such as the Doi Tung region contributes to better health and education that enable the youth to pursue further opportunities.

2.2 The Doi Tung Region: History, Geography, Climate, and Demographics

The remoteness of the Doi Tung region and it's placement on the border of Myanmar and Laos contributes to the area's high drug distribution. Despite its location, the Mae Fah Luang Foundation has been working to address these problems in the Doi Tung Development Project. In this development, people are provided with the opportunity to do good as opposed to turning to drug trafficking. The geography, geology, and climate of the area contribute to the establishment of many job opportunities in agriculture. The history and population demographics are also important in understanding the region and its people.

2.2.1 History of the Doi Tung Development Project

As part of the Golden Triangle, the Doi Tung region had a strong reputation as a center for illegal drug production and trafficking. Amidst drought and poverty, the residents of Doi Tung had to find a way to survive. Due to the remote location and the ease of border crossings, most residents survived with illegal occupations, such as opium cultivation and prostitution, leading to poor quality of life (Mae Fah Luang Foundation, 2020).

The Doi Tung Development Project was established by the Princess Mother, Princess Srinagarindra nee Sangwan Talapat in 1988 as one of the flagship projects of the Mae Fah Luang Foundation. The Princess Mother was committed to restoring the area on her first visit, announcing “I will reforest Doi Tung" (Mae Fah Luang Foundation, 2019). The Princess Mother decided to establish the Development Project to improve the lives of the community members (Mogg, 2006). She recognized that the root cause of these problems was due to poverty and lack of opportunities in life (Diskul na Ayudhya, 2020). She had a vision for the Doi Tung people to be self-reliant and live in harmony with the forest (Mae Fah Luang Foundation, 2020).

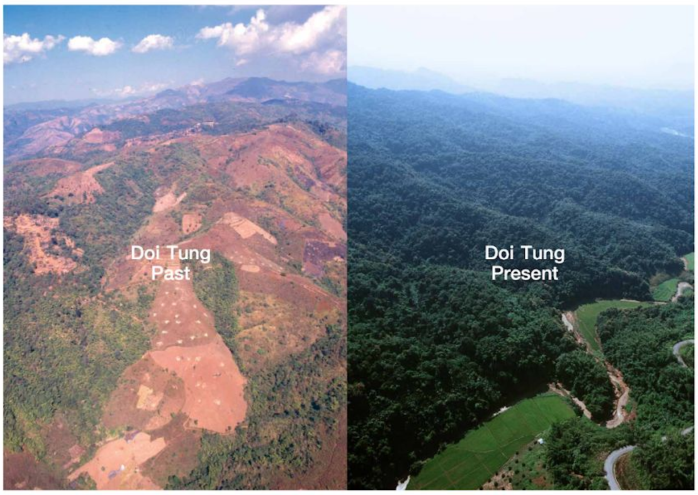

Figure 1. A comparison of the Doi Tung landscape before and after implementation of the Doi Tung Development Project (Mae Fah Luang Foundation, 2017).

The Development Project had a thirty-year time frame. Phase I lasted from 1988 to 1993 and focused on survival. The foundation provided basic life necessities to the people. They tackled immediate health issues through education and prevention. Phase II (1994 - 2002) focused on generating income for the community. For example, forests were replanted with crops to increase agricultural opportunities and restore degraded forest conditions. Along with reforestation, the foundation helped people become self-reliant and further develop the community. Many jobs and careers were created for people with different talents such as coffee and macadamia processing (Mae Fah Luang Foundation, 2020). The foundation enabled the DTDP to move beyond just cultivating crops and implemented the processing steps of the goods on-site to increase the value of their products locally. Phase III’s (2003 to 2017) primary focus was to make the community self-sustaining. The Foundation provided empowerment and education. The ultimate goal was to allow community leaders to handle the administration and management of the community and it’s businesses.

Figure 2. A map of the Chiang Rai Province, highlighting the Doi Tung community.

Through the assistance of the Mae Fah Luang Foundation, the Doi Tung Development Community has been financially self-sustaining since 2001. Tourism, agriculture, horticulture, and handicrafts are the main sources of income (Mae Fah Luang Foundation, 2018). As seen in Figure 1, the previously desolate land on the mountain has been planted with crops like fruit, vegetables, tea, and coffee (Mogg, 2006). The MFLF is still overseeing some projects in the Doi Tung region, with one of their goals being to ensure that the school districts are self-sufficient by 2022 (Diskul na Ayudhya, 2020)

2.2.2 Doi Tung Geography, Geology, and Climate

Geography

Our project focused on the Doi Tung region which is located in Northern Thailand in the province of Chiang Rai, specifically in the Mae Fah Luang district. The district sits on the border of Thailand and Myanmar, with close proximity to the border of Laos in an area called the Golden Triangle. The Doi Tung Development Project gets its name from the 1,389 m high mountain located in the region, highlighted in Figure 2. The Chiang Rai Province covers 11,600 km^2 and sits 580 m above sea level. The development project itself is around 150 km^2, which is approximately the size of Washington, D.C. (Maxwell, 2007).

Geology

The area sits on beds of granite and limestone. Limestone can be used for water treatment to neutralize acidity. The vegetation of deciduous and evergreens can be found seasonally on the granite and limestone bedrocks, but have a tendency to be destroyed and burned by the villagers for agricultural practices such as coffee farming. Coffee plantations cover 15 km^2 of the area, as this is the major export of Doi Tung (Maxwell, 2007). Many people make a living from the coffee industry within Doi Tung. Despite the MFLF's initiative to decrease chemical supplements in agriculture, regional farming practices involve the use of pesticides, fertilizers, and other chemical run-offs which then percolate and contaminate the underground water sources (Phuphanich, 2020).

Climate

Northern Thailand has three different seasons: the cool-dry, the hot-dry, and the rainy season. The dry seasons last from November to May during which there is little to no rainfall, creating a lack of water resources. According to Mae Fah Luang Foundation's Board Member Ms. Puangroi Diskul na Ayudhya, the community has noticed that the dry season has come earlier in the past few years than previous trends, which might be affected by climate change (Diskul na Ayudhya, 2020). The rainy season begins in June and ends in October. The relief from the dryness first comes in April, but it is not until May that the rainfall is consistent. The months of June through September provide the highest amount of rain bringing along monsoons, landslides, and other natural disasters. The average rainfall varies by elevation: the higher the elevation, the higher the rainfall. Where the Doi Tung Community is located, the rainfall is around 1,925 mm (Maxwell, 2007). Water in the dry season has decreased by sixty percent in the past years and schools are now running out of water in January as opposed to in March (Diskul na Ayudhya, 2020). During storms, trees fall on top of power lines and communities are left without power for up to two days until the power can be restored. The chief administrative officer of MFLF noted that all of the water filtration systems run on electricity (Chan-urai, 2020). Additionally, during the rainy season, rainwater collected at the schools may mix with water at the source, changing the chemical composition of the source water. The combination of dissolving ionic pollutants in the water can lower the pH and make the source water more acidic (Ratnayaka, Brandt, & Johnson, 2009). Underground water sources are being polluted with heavy metal run-off (Phuphanich, 2020). Therefore, the water sources are being affected by various factors influenced by the geography, geology, and climate of the region.

2.2.3 Doi Tung Population Demographics

In 2019, the total population of the Chiang Rai Province was 1,298,304 people (Office of Registration Administration, Department of Local Administration, 2019). As recorded by the Department of Provincial Administration, Ministry of Interior of Chaing Rai, from 1979 to 2018 the population increased by 2.78 percent per year. This increase in population is reflected in the Doi Tung community, as seen in Figure 3 (Mae Fah Luang Foundation, 2011))

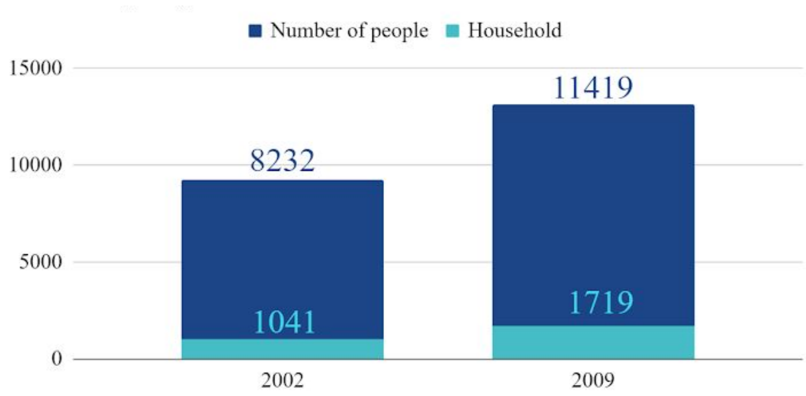

Figure 3. Doi Tung Population Demographics Data (Mae Fah Luang Foundation, 2011).

The residents of Doi Tung live in twenty-nine villages within the district (Mae Fah Luang Foundation, 2018). The residents represent seven different ethnicities consisting of 48 percent Akha, 16 percent Lahu, 17 percent Tai Yai, 9 percent Chinese, 5 percent Lua, 2 percent Thai, and less than 1 percent Lisu (Mae Fah Luang Foundation, 2018). Each ethnic group speaks its own dialect of Thai.

Figure 4. Various ethnic communities found in Doi Tung. (Society and culture. 2015).

2.3 Mission and Goals of Siam Commercial Bank and the Mae Fah Luang Foundation

Our project was sponsored by Siam Commercial Bank (SCB) working in collaboration with the Mae Fah Luang Foundation (MFLF). These two renowned organizations aim to help the Doi Tung schools become self-sufficient. Their goal is to make the maintenance of the water filtration system sustainable and to reaffirm the community's confidence in the filtered water. The Mae Fah Luang Foundation established the Doi Tung Development Project in the 1980's and has been working to improve the quality of life for residents since. Siam Commercial Bank has been working with the MFLF in Doi Tung on various projects. Currently, SCB and the MFLF are working to improve the quality of life for the students in Doi Tung schools. They hope that by supporting these students, the future of the community can continue to improve.

Figure 5. Five practices of corporate social responsibility that SCB utilizes in order to be recognized as the most admired bank.

2.3.1 Siam Commercial Bank

Siam Commercial Bank was the first bank established in Thailand. Their well-recognized and renowned banking networks led them to accumulate over one hundred awards in 2018 alone. SCB's corporate social responsibility motivates the bank to implement long-term solutions and contribute towards their goal of being 'The Most Admired Bank' (Siam Commercial Bank, 2019). Siam Commercial Bank places great importance on sustainable practices and their activities in corporate social responsibility, as seen in Figure 5, aim to improve the quality of life for Thai youths. SCB focuses on assisting younger generations as they will help Thai society progress towards a sustainable future (Phuphanich, 2020). Their sustainable practices are reflected in some of their major projects to improve Thai society, as referenced in Appendix A.

2.3.2 The Mae Fah Luang Foundation

The Mae Fah Luang Foundation was established by the grandmother of King Maha Vajiralongkorn Bodindradebayavarangkun, the late Princess Mother, Princess Srinagarindra. As described on their website, the foundation's vision is to develop communities, society, environment, and cultures in order to create happiness, sustainability, and stability. Princess Srinagarindra's work and dedication to the community inspired the vision for the Mae Fah Luang Foundation. The foundation has two main missions. The first is to help grow "sustainable economic, social, cultural and environmental development" by providing communities with "integrated development cooperation, consultation, and training" (Mae Fah Luang Foundation, 2020). The second is to apply the previously mentioned methods across the entire nation and develop communities outside of Thailand. The Mae Fah Luang Foundation has successfully decreased the drug problems of the region. Since then, on an international level, the UN has become interested in solving the drug problems of other countries by following the model of the Doi Tung Development project. Representatives from the foundation have been invited to participate in various meetings sponsored by organizations working to alleviate the problem of drug addiction both within Thailand and globally. The Mae Fah Luang Foundation is currently using practices established at Doi Tung as a model in other drug-production regions, such as Afghanistan and Indonesia (Diskul na Ayudhya, 2020; Mae Fah Luang Foundation, 2020). The foundation strongly believes that implemented solutions should reflect the people of that area and be sustainable (Diskul na Ayudhya, 2020).

2.3.3 SCB and MFLF's Mission to Aid Thai Youths

In collaboration with Siam Commercial Bank, the Mae Fah Luang Foundation is focusing on self-sufficiency for schools in Doi Tung. The MFLF aims to have the schools functioning independently of the foundation by 2022 (Diskul na Ayudhya, 2020). One important goal is to ensure that the Doi Tung schools have a sustainable source of potable water. The Mae Fah Luang Foundation has installed water filtration systems, however, there is minimal system maintenance and a lack of confidence in the filtered water, among other issues. Through improvements in these areas, SCB and the MFLF hope to provide the schools with sustainable potable water and overall improve the quality of life for individuals in the Doi Tung school communities (Diskul na Ayudhya, 2020; Phuphanich, 2020). Improved conditions at school will encourage Thai youths to continue to attend school.

2.4 Doi Tung Schools: A Study of Three Schools

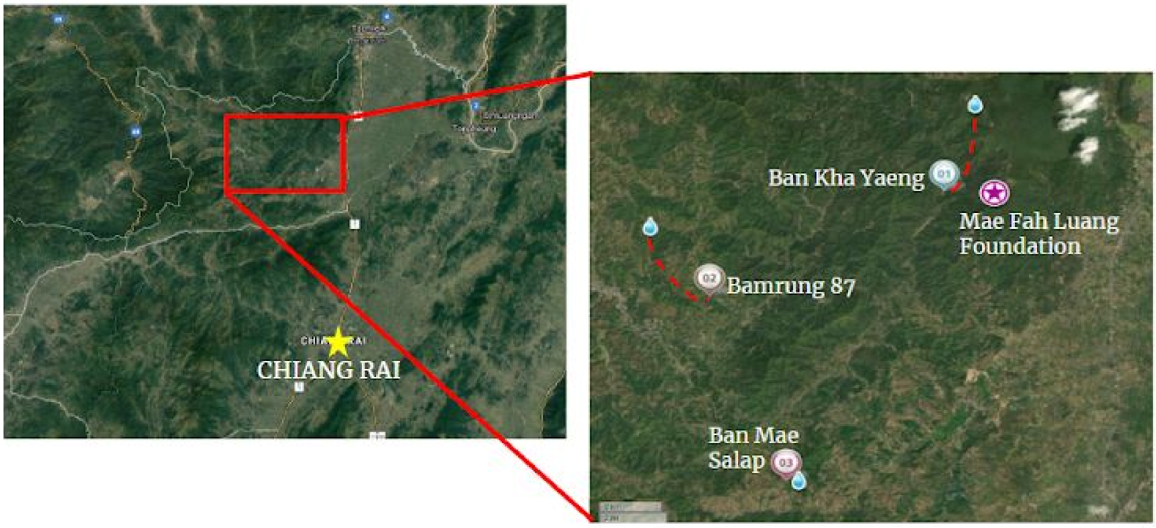

Figure 6. A map of the Doi Tung area, including each of the three schools and their water source locations (water droplets).

Siam Commercial Bank and the Mae Fah Luang Foundation want to establish sustainable sources of water for all of the schools in the Doi Tung region. Our project will focus on three schools: Ban Kha Yaeng, Bumrung 87, and Ban Mae Salap as seen in Figure 6. We will use these schools as case studies to make recommendations for the entire school district. The school district is about 8 kilometers northwest of Chiang Rai, and includes all rural schools surrounding the mountain Doi Tung. Each school has water filtration systems that were donated by various organizations and installed by the MFLF (Diskul na Ayudhya, 2020; Phuphanich, 2020).

Figure 7. A map of the Ban Kha Yaeng school, including storage (red water droplets) and dispenser (blue water droplets).

2.4.1 Ban Kha Yaeng

Ban Kha Yaeng is located at Highway 1338, Mae Fah Luang, Mae Fah Luang District, Chiang Rai 57240. As of 2020, they had 159 students ranging from kindergarten to 6th grade. There were 9 teachers and 1 principal at the school. This school's source of water is mountain water. Additional information on mountain water can be found in Appendix B. The source water is collected into large storage tanks. The water is filtered with sand filtration, manganese, carbon filtration, resin filtration, microfiltration, and ultrafiltration. Further information on the filtration systems can be found in Appendix C. A schematic of the school's system can be found in Figure 7. The filtration systems were installed in November 2019. There are three points of use: a faucet near the cafeteria, a faucet at the back of the school, and a tap attached to two clear storage tanks at the front of the school.

2.4.2 Bumrung 87

Bumrung 87 is located at Thoet Thai, Mae Fah Luang District, Chiang Rai 57240. In 2020, the school had 120 students from kindergarten to 6th grade. There were 12 teachers and 1 principal.

The source of water is from the Klong Plack reservoir 8 km away from the school. Further details on reservoir water can be found in Appendix B. The source water is pumped into six storage tanks before filtration, which may be seen in Figure 8. The water at Bumrung 87 undergoes sand filtration, carbon filtration, microfiltration, and ultraviolet filtration before consumption. Additional information on the filtration systems can be found in Appendix C. The point of use is a metal drinking station near the cafeteria, which cools the water.

Figure 8. A map of the Bamrung 87 school, including storage (red water droplets) and dispenser (blue water droplets).

2.4.3 Ban Mae Salap

Bae Mae Salap is located at 111 m.19, Mae Salong Nai, Mae Fah Luang District Chiang Rai 57110. The school had a total of 177 students in 2020, ranging from kindergarten to 9th grade. There are 17 teachers and 1 principal. The source of water for Ban Mae Salap is underground water, which is pumped and stored into a water tower. Information on underground water can be found in Appendix B. This school has ultrafiltration, ultraviolet, reverse osmosis, microfiltration, sand filtration, carbon filtration, and charcoal filtration systems which are highlighted in Figure 9. More information on the filtration systems can be found in Appendix C. The systems were installed over three years ago by the Mae Fah Luang Foundation. Only 40 percent of the source water was used for consumption, the other 60 percent was wastewater from the reverse osmosis

Figure 9. A map of the Ban Mae Salap school,including storage (red water droplets) and dispenser (blue water droplets).

filtration process and used for other purposes, such as watering the garden. There are three points of use, including two metal drinking stations that cool the water. The third point of use is a set of faucets close to the filtered water storage and have very low pressure.

2.5 Concerns with the Water Filtration Systems

Our sponsors presented us with the opportunity to investigate problems that the schools were facing regarding distrust in water quality and lack of water filtration system management.. The water filtration systems installed at the school are complex and require frequent maintenance (Phuphanich, 2020). In order for the schools to be self-sustaining, they must be able to maintain the systems themselves (Diskul na Ayudhya, 2020). The Mae Fah Luang Foundation held an orientation program for two teachers from each school to learn about basic water system maintenance. However, most teachers at the school lack training and there is still a lack of proper system maintenance.

Another concern is that the young students at the schools do not follow proper sanitation and rules regarding the filtration system in place. These students are inadvertently contaminating the water, through practices like using their hands as opposed to using cups to drink water from an open faucet (Phuphanich, 2020).

2.5.1 Secondary Aesthetics and Skepticism of Water Quality

Aside from the human health issues that accompany some types of water contamination, some water containing discrete amounts of certain chemicals can be harmless, but undesirable. These harmless secondary or “aesthetic” qualities of water can even have a psychological effect on the way people view their drinking water, and the confidence they have in its potability. For example, water with very low levels of sulfur has no adverse health effects when consumed, but may exude a strong, rotten odor. Similarly, while particulate manganese can be harmless at low concentrations, it will produce a pink tint in the water. The presence of unfamiliar colors, odors, and some tastes in water can be enough to convince consumers that safe water is dangerous. Additionally, some of these “flavors” of water can be a direct result of a disinfection method, such as a chlorine aftertaste when hypochlorite is added to remove biological contaminants. In order to effectively create a plan and determine sanitation measures that will result in both safe *and* aesthetically trustworthy water, we will have to gauge the community’s preferences or indifference regarding these unfamiliar characteristics (Dietrich, 2006).

Despite evidence that the drinking water filtration systems are removing contaminants to meet national standards, the students and faculty have doubts about the water quality. In our first meeting with our sponsor, our team was informed that money allocated for students’ lunches was still being spent buying bottled water (Phuphanich, 2020). The school’s fiscal priority of bottled water rather than food for students demonstrates the severity and consequences of their distrust. A study from the Journal of Applied Social Psychology suggests that diverting a group’s attention away from the focus of their distrust, in this case, the filtration system, and toward another variable, such as personal sanitation practices before consuming the water, allows the group’s selective skepticism to diminish (Bratanova, Morrison, Fife-Schaw, Chenoweth, & Mangold, 2013). Convincing the school community members that their drinking water is purified should also motivate the school to redistribute funds back to student lunches.

2.5.2 Water Characteristics, Contaminants and Health Effects

In this section, we discuss important indicators of water quality. We also review various contaminants that can be found in water and the dangers that these contaminants pose to the community.

Total Organic Carbon

Total organic carbon (TOC) is a measurement of all organic molecules, including proteins, sugars, lipids, acids, and dissolved carbon. By gauging all carbon and organic carbon, this measurement also indicates the amount of inorganic carbon present in a water source. Various water bodies have different average levels of TOC that imply a healthy ecosystem. Because TOC is only an indicative characteristic, no certain conclusions about water contaminant types can be made when it is measured. Combustion or oxidation reaction methods are commonly used to detect total organic carbon in water samples (Whitehead, 2020). However, simpler methods are available that could be used by the schools to evaluate carbon levels in the water.

Chemical Oxygen Demand

Waste and organic matter in water can also be evaluated by measuring the chemical oxygen demand or COD of the water. COD works in tandem with TOC, because the chemically reactive oxygen naturally interacts with the organic carbon dissolved in the water. Levels of COD have an inverse relationship with the amount of dissolved oxygen in an aqueous environment (Dissolved oxygen and biochemical oxygen demand.2012). Therefore, elevated chemical oxygen demand indicates less dissolved oxygen in the water, which poses as a threatening characteristic for the ecosystem. High COD in drinking water indicates a range of possible types of pollution present, many of which are often detrimental to human health.

Total Dissolved Solids

The total amount of particulate matter that is soluble in water is indicated by the total dissolved solids, or TDS, in water. This measurement excludes insoluble, suspended particulate matter that eventually settles and is physically separable from the water. Dissolved solids, as opposed to suspended solids, must be removed from the water through chemical means. However, the presence of total dissolved solids in water is a positive indication of clean water. Low TDS levels demonstrate that a water sample is potentially corrosive, with insufficient ions and electrolytes and opportunities for harmful heavy metals to dissolve (Pelican Water Systems, 2019). Alternatively, because of the ambiguity of exactly what TDS measures, very high levels in water are often undesirable for consumption. Similar to TOC and COD, this parameter is only an *indicative* measurement, and does not provide concrete specifications of what chemicals are dissolved in the water.

Contaminants and Health Effects

Parameter	*Description*	Health Effect
Hardness	Hardness is a measure of the amount of calcium carbonate in water. Water with less than 60 mg/L of calcium carbonate is considered soft, 61-120 mg/L is moderately hard, 121-180 mg/L is hard, and above 180 mg/L is deemed very hard. This means that the water contains high concentration of calcium and magnesium ions, and several other dissolved metals (How hard water affects us, 2020).	Hard water can cause many symptoms such as kidney stones, cerebrovascular disease, cancer, etc. Moderate levels of hardness are beneficial to the growth and repair of calcium-based organs and structures such as bones, teeth and nails (Sengupta, 2013).
pH	Normally, the pH of acceptable standard for drinking water is 7. If the pH value is greater than 7, it is considered basic or an alkaline water. However, if the pH value is lower than 7, it is considered acidic.	Alkaline water will have a bitter taste but does not have a negative effect on human health. Acidic water, on the other hand, will have a sour taste and could cause gastrointestinal distress symptoms because it is corrosive (Butler, 2017).
Iron	Iron is a transition metal that can be found in water sources with bacteria. Many simple iron-cation molecules are soluble in water, while iron molecules including polyatomic anions are largely insoluble.	Low iron storage in blood (iron deficiency) can cause or be a symptom of anemia. Consuming too much iron can cause Iron toxicity which leads to cancer and diabetes (Arnasorn, 2017).
Copper	Copper is a reddish ductile metal. It can be found in minerals such as rock and soil. High levels of copper in drinking water can cause bitter and metallic taste.	Copper ions can cause symptoms typical of food poisoning (headache, nausea, vomiting, diarrhea). Long periods of exposure can cause liver damage (Copper in drinking water, 2016).
Lead	Lead is a bluish-white lustrous metal. It is very soft, highly malleable, ductile, and a relatively poor conductor of electricity. Lead can enter water through corrosion of pipes.	The human body will absorb and store lead in bones, blood and tissue. Short period exposure to lead will cause abdominal pain, constipation, fatigue, headache, and soreness in the hands or feet. Long term exposure will cause abdominal pain, depression, memory loss, and nausea or sickness. For children, even a low level of lead in the body can result in behavior and learning problems, slowed development, and anemia (Health problems caused by lead, 2018).
Nitrate and Nitrite	Nitrate and Nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is used mainly in inorganic fertilizers. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity. Nitrite can be formed chemically in distribution pipes by bacteria during stagnation of nitrate-containing	Nitrate compounds occur when nitrate is transformed to nitrite in the digestive system.The nitrite oxidizes the iron in the hemoglobin of the red blood cells to form methemoglobin, which lacks the oxygen-carrying ability of hemoglobin. These reactions can cause many circulatory

	and oxygen-poor drinking water (Nitrate and nitrite in drinking water, 2011).	malfunctions and diseases (Ward et al., 2018).
Free Chlorine	Free chlorine is defined as the concentration of residual chlorine in water present as dissolved chlorine gas, hypochlorous acid, and hypochlorite ions.	Chlorine can combine with other natural compounds to form Trihalomethanes (THMs) which are chlorination byproducts. This reaction triggers the production of free radicals in the body, causing cell damage, and are highly carcinogenic (Abdel-Shafy et al., 2017).

Table 1. Contaminants and Health Effect

2.6 Conclusion

Siam Commercial Bank and the Mae Fah Luang Foundation provided Doi Tung schools with water filtration systems, however, the schools are struggling to maintain the systems and trust the quality of the filtered water. Our team sought to verify the quality of the filtered water at the schools, evaluate the current maintenance practices, and understand community concerns to provide recommendations that would encourage teachers and students in these schools to clean water from these systems.

3.0 Methodology

The goal of our project was to assess water system maintenance at Doi Tung schools and make recommendations for sustainable improvements targeted to the community's needs. Our objectives to achieve this goal were: (1) Determine the quality of the water at the source and after filtration at each of the three schools; (2) Evaluate and observe the school community's water system and maintenance practices to determine the strengths and weaknesses of the current system; (3) Promote the students' confidence in water quality with water testing methods that can be used by the schools; (4) Encourage schools to maintain their water filtration system independently and sustainably. We interviewed members of the school community, observed their water usage, tested the water throughout the distribution and filtration system, and surveyed the teachers for feedback on proposed recommendations.

3.1 Objective 1: Determine the quality of the water at the source and after filtration at each of the three schools.

Our first objective was to determine the quality of the water at the source and after filtration at each of the three schools. The filtration systems at each school were donated and put into place at various times. An image of the filtration system in place at Ban Mae Salap can be seen in Figure 10. Each school had different sources of water and different filtration systems. We conducted a thorough analysis to understand the quality of the water at each site to fully understand the water contamination problems. By measuring the water quality before and after filtration, our team was able to determine the efficacy of each filtration system. The purpose of collecting this data was to gauge the success of the filtration system by monitoring the changes in water quality over time and identifying the components of the system that contribute to elevated contamination levels.

Figure 10. The water filtration systems at Ban Mae Salap including carbon filtration, sand filtration, UF, MF, UV, and RO.

Figure 11. Collecting water sample from the source.

3.1.1 Water Sample Collection

Our team collected water samples from the schools to test the water quality. We collected samples from each school at multiple samples throughout the system. The first set of samples was collected at the source, prior to distribution. An example of a sample collection can be seen in Figure 11. The next set of samples was collected before the water entered the filtration system. Collecting samples around different components throughout the system helped to identify if contamination was introduced during the distribution of the water between the source and the treatment point. The final set of samples were gathered after the filtration treatment of the drinking water at the point of use. This aided our team in evaluating the effectiveness and efficiency of the filtration system at treating the water, as well as to identify any contamination that was introduced during the treatment and distribution process. At each sample location, we collected approximately 30 mL of water in a sterile glass tube to be tested for quality.

3.1.2 Water Sample Testing

Before the first site visit, Siam Commercial Bank informed our team of three primary contaminants in the source water: heavy metals, agricultural runoff, and wastewater. We used this information to select relevant testing methods. On-site, our team used a water quality meter to test the water for total dissolved solids (TDS), total organic carbon (TOC), and the chemical oxygen demand (COD). Distilled water was used to calibrate the meter since it is devoid of dissolved contaminants. At Chulalongkorn University, our team tested the pH of the water to measure acidity and alkalinity and cultured the water samples to test for biological contaminants. A procedure for the biological test can be found in Appendix D. Data from our collected samples allowed us to identify specific areas in the water quality that needed improvement and where contaminants were entering the system. Water quality data was compared to the national standards for drinking water, which can be referenced in Appendix E.

3.2 Objective 2: Evaluate the school community's water system and maintenance practices to determine the strengths and weaknesses of the current system.

Photographs and visual observations helped establish a baseline for the community's ability to make realistic, sustainable changes to the drinking water system. The students and teachers' drinking water preferences and needs were determined at each school through interviews. The team discussed the current practices and maintenance of the water filtration system with the chief administrative officer of the MFLF. We wanted to understand what resources were available for filtration system maintenance. The purpose of this objective was to compile information from the community regarding the water filtration systems to identify areas of improvement.

3.2.1 Recording Observations

The conditions at each school were observed by our project team to identify areas that needed repair and improvement. Our team recorded information about each of the three schools in a datasheet which can be found in Appendix F. Our team gathered information about the demographics of the school, the observable water quality, and information about the water system components. We recorded observations about how the water was being used at each school, sanitation practices, and current educational or instructive material regarding drinking water safety. We smelled and tasted the filtered water at each school as seen in Figure 12. The datasheet organized the information and ensured that there was a complete set of data for each site.

This data sheet can be found in Appendix F. We took pictures of the various system components and the water sources. Photographs were used to document the observations our team made, for additional analysis of the water systems at the schools and as baseline data. The documented data helped identify major problems in the systems. While in Doi Tung, the team worked to determine the severity and origins of contamination in the schools' water distribution and storage.

3.2.2 Understanding Water Usage in the Doi Tung School Communities

The main stakeholders of this project are the students and faculty of the three schools. We wanted to find out what factors other than water quality that influence whether the members of the school communities use the filtered water. We interviewed students and teachers at each school as viewed in Figure 13. The team asked them about how they used the filtered water, their preferences regarding secondary aesthetics, and if they had any health issues due to the water. The student and teacher interviews can be found in Appendix G. The information from these interviews helped us target the specific needs of the students and understand the priorities of the people using the water. We focused our interviews on teachers and students that spoke Thai. Our team interviewed one teacher, one to two students, and the principal, if available, from each school.

Figure 13. Conducting interviews with students at Bamrung 87.

3.2.3 Mae Fah Luang Foundation Interviews

Our team interviewed members of the Mae Fah Luang Foundation, the group responsible for the installation and upkeep of the water filtration systems at the schools. This interview can be seen in Figure 14. Due to their role in the Doi Tung region, our team concluded that the Mae Fah Luang Foundation had the most information about the water sources and filtration systems, including current maintenance practices. We asked them about system repair practices, frequency of upkeep, and commonly faced problems. A detailed list of questions that were asked to individuals responsible for maintenance can be found in Appendix H. Our team used the information from this conversation to identify gaps in the current maintenance program and determined what our observations should focus on.

Figure 14. Conducting interviews with Mae Fah Luang foundation.

3.3 Objective 3: Identify ways to encourage students to drink potable water in schools.

Our third objective focused on ways to encourage students at the school to drink the filtered water. Our team sought to understand the reasons behind the lack of trust in the filtration systems through interviews with both the students and teachers. The team also worked to identify understandable water testing methods that the community could use. The purpose of this objective was to understand why the community did not trust the water quality.

3.3.1 Understanding community doubts about water quality

Despite the previously installed filtration systems' proficiency in removing the contaminants, the school community still doubted the purity and cleanliness of the water. An important aspect of instilling confidence in the water quality was understanding the root cause of the distrust amongst the school community. Our team took time to understand the reasons why the community still did not trust the water being provided for consumption and use. Our team acquired this information through interviews with the students, teachers, and administration as seen in Figure 15. The questions we asked can also be found in Appendix G. The collected information was used to identify the information that needed to be communicated in order to inspire more confidence in the community regarding the drinking water system.

Figure 15. Learning about the water dispenser installed at Bamrung 87.

3.3.2 Identify and Demonstrate Appropriate Water Testing Kit

Our team researched different types of water testing kits for the community to use. The use of test kits will allow the teachers and students to reassure themselves of the water's quality; therefore, instilling further confidence in the filtration system. We selected a test kit for the community based on ease of use, cost, accessibility, and effectiveness. The ability of the teachers and students to test their own water will also allow for easier identification of replacement and repair needs.

3.4 Objective 4: Encourage schools to sustainably and independently maintain their water filtration system.

Our team placed high importance on the school community for they were the main stakeholders of our project. The school community possessed technical, social, and first-hand knowledge that would fortify the decisions that our team made. Their feedback and opinions were invaluable in creating recommendations that would be self-sufficient and sustainable.

3.4.1 Proposing Recommendations and Receiving Feedback from the School Community

Through an educational initiative sponsored by the Thai government, teachers must complete a mandatory two years of work in the rural area. Many teachers transition to new schools elsewhere after these two years, so their knowledge about the drinking water system must be passed on to new teachers as well as students. The teachers and their expertise were utilized to help establish an educational program for students on how to maintain the system for years to come. Our second visit to Doi Tung primarily focused on communicating our recommendations to the three schools as viewed in Figure 16. We understood that the teachers would be heavily influenced by the recommendations we presented to the Mae Fah Luang Foundation, so we determined that their feedback was vital to gauge the realistic success of these recommendations. Our team asked the faculty at each school for feedback on the recommendations through a survey. We presented the faculty with questions to measure how well our recommendations were understood, as well as how effective they believed the recommendations would be. The survey had a scale of 1 to 5, with 1 being 'not very helpful and understandable' and 5 being 'very helpful and understandable'. From this, we learned about the stakeholders' needs and preferences. Our team valued the feedback from the schools' faculty regarding their preferences because we recognized that even if a suggestion of ours is logical, it is imperative that the students and faculty are also personally motivated to engage with these recommendations.

Figure 16. Giving our recommendations at Bamrung 87 school.

3.5 Conclusion

Our team sought to discover and investigate the current problems with the water distribution system at Doi Tung schools. Interviews and observations were conducted to understand the complexities of the issues and how they impacted the schools. We made two trips to Doi Tung to conduct on-site fieldwork. In the next chapter, we describe findings from the results of the data we gathered during our site visits.

4.0 Results and Analysis

Through observations, interviews, and testing, our team evaluated the water quality at the schools and the status of the water filtration system maintenance. We identified three major findings:

1. The filtered water at the schools was safe to drink.
2. The school community did not trust the water quality.
3. The information on maintaining the water filtration systems was not communicated.

4.1 Water Quality Throughout the Filtration and Distribution System

On-site and laboratory tests of the water samples from each school were conducted to test for bacterial, chemical and physical contamination. Biological contaminants were tested through total organic carbon, chemical oxygen demand, and bacteria culturing tests. The physical and chemical tests measured total dissolved solids, alkalinity, and clarity of the water. Each of the tests provided evidence that the water at the point of use at each school was within drinking water standards and presented no concerning qualities. In the following sections, we show the results of our analysis of water quality in the three schools: Ban Kha Yaeng, Bamrung 87, and Ban Mae Salap.

4.1.1 TOC: Total Organic Carbon

The TOC at each school declines from the source to point of use as seen in Figure 17. The total organic carbon in water is a chemical indicator of the presence of waste and organic molecules such as proteins, fats, sugars, and genetic material. TOC levels above the maximum allowable quantity of 3 mg/L constitute water with dangerous amounts of organic matter that can contribute to the spread of pathogens.

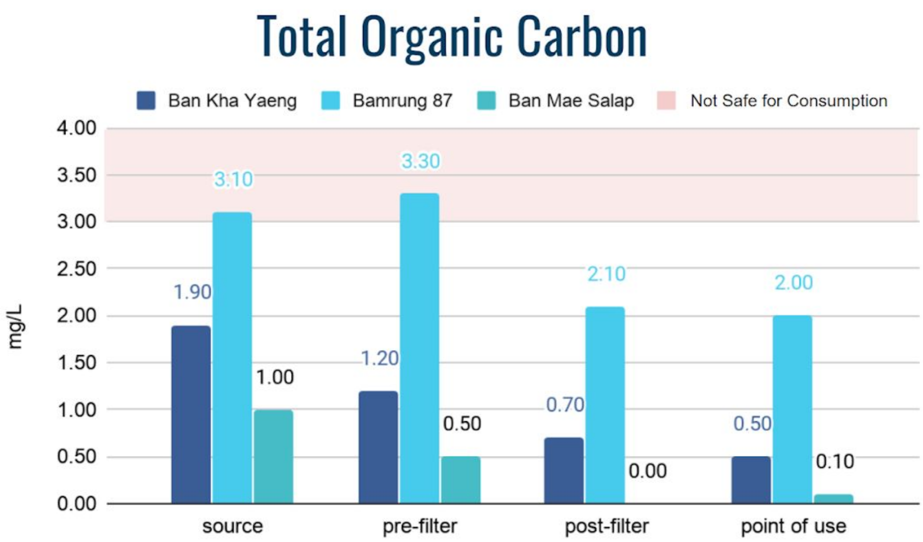

Figure 17. Changes in total organic carbon (TOC) at each point in the drinking water system at three schools. Water that exceeds the standard value of 3 mg/L is not safe for consumption.

Ban Kha Yaeng

In terms of total organic carbon (TOC), Ban Kha Yaeng school's water quality from source to point of use was within drinking water standards, which indicated that the water was safe to consume because the TOC levels were below 3 mg/L. The amount of TOC in the water declined steadily from the source to the point of use, ending up at only 0.5 mg/L. Total organic carbon levels did not indicate poor water quality at the point of use.

Bamrung 87

At the source and pre-filtration drinking water for the Bamrung 87 school, the amount of TOC in the water was too high to be safe for consumption. There was a slight increase in TOC from the water source to the pre-filtration site, attributed to biological contamination inside of the distribution systems. Algal and bacterial growth occurs in the distribution system when the pipes do not have sufficient water flowing through to clean them. TOC levels after filtration and at the point of use were both within drinking water standards, and did not indicate poor water quality at the point of use.

Ban Mae Salap

Of the three schools' water sources, Ban Mae Salap's groundwater contained the lowest levels of TOC. The amount of total organic carbon decreased until the post-filtration samples, where the levels were infinitesimally small, indicating 0.0 mg/L. However, the total organic carbon slightly increased between the filter and point of use, likely due to stagnant water in the distribution system leading to organic growth. Despite the increase of TOC from post-filtration to point of use, the levels of TOC did not indicate poor water quality at the point of use.

4.1.2 TDS: Total Dissolved Solids

The total dissolved solids (TDS) value was measured at the source, pre-filtration, post-filtration, and at the point of use for each of the three schools. A primary method of removing solids from water was to allow the particulate matter to settle in a tank. However, TDS indicates particles that are dissolved in the water and cannot be removed through settling such as heavy metals and soluble particulate matter. While moderate total dissolved solids in water can provide electrolytes and beneficial minerals, levels higher than 300 parts per million (ppm) have ambiguous characteristics and have a higher chance of including denser, dissolved carcinogens. For each school, the TDS values were consistently far below the maximum allowable standard of 300ppm for drinking water. Therefore, the TDS levels did not indicate poor drinking water quality at any of the three schools as seen in Figure 18. However, the levels of TDS and patterns of change in TDS levels can be linked to environmental factors as well as distribution system designs. The TDS levels may have increased from one point to the next due to factors such as coatings on the distribution system piping.

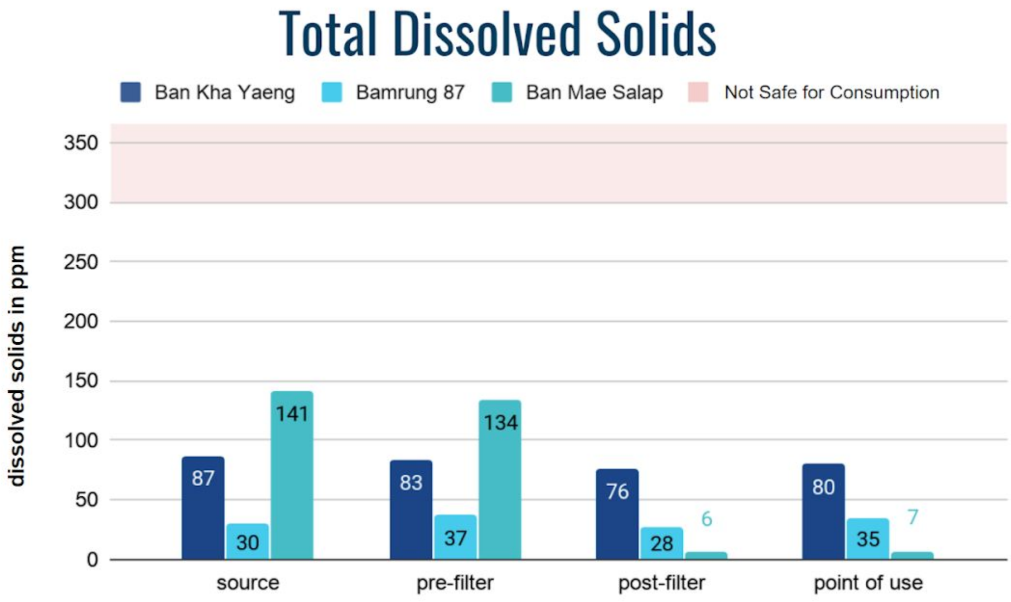

Figure 18. Changes in total dissolved solids (TDS) at each point in the drinking water system at three schools. Water that exceeds the TDS value of 300 ppm is not safe for consumption.

Ban Kha Yaeng

The measurements of total dissolved solids at the Ban Kha Yaeng school remained within 11 ppm of one another at the source, before filtration, after filtration and point of use. TDS levels were nearly four times lower than the maximum allowable measurement of 300 ppm, and therefore it did not indicate poor water quality at the point of use.

Bamrung 87

Within distribution systems between the source and filter as well as between the filter and point of use, the TDS levels increased slightly. This pattern of elevated TDS and where it occurs in the system could indicate that dissolved solids were being introduced into the water through the pipelines. The TDS level at the point of use was nearly nine times less than the maximum allowable standard of 300 ppm, and therefore did not indicate poor water quality.

Ban Mae Salap

The original level of total dissolved solids at the water source of the Ban Mae Salap school was significantly higher than at the other two schools. Ban Mae Salap sources tap water from an underground aquifer, and the sediment within the aquifer likely contributed to these elevated amounts of dissolved solids. Despite the relatively high initial TDS levels in the groundwater, the TDS decreased by a factor of 50 and did not indicate poor water quality at the point of use.

4.1.3 COD: Chemical Oxygen Demand

The chemical oxygen demand (COD) levels were measured at the source, pre-filtration, post-filtration, and at the point of use for each of the three schools. Chemical oxygen demand increases as the amount of available dissolved oxygen in an aquatic ecosystem decreases. Therefore, chemical oxygen demand is an indicator of the environmental health of a water system, demonstrating the impact of human activity and sewage disposal on the water quality. High COD levels in water mostly detrimental to local aquatic species that rely on dissolved oxygen for their oxygen intake. However, long-term exposure to water with COD levels higher than 3 mg/L pose a potential health risk to humans. Each school aligned with the maximum allowable drinking water standard of 3 mg/L, so COD levels did not indicate poor drinking water quality at any of the three schools.

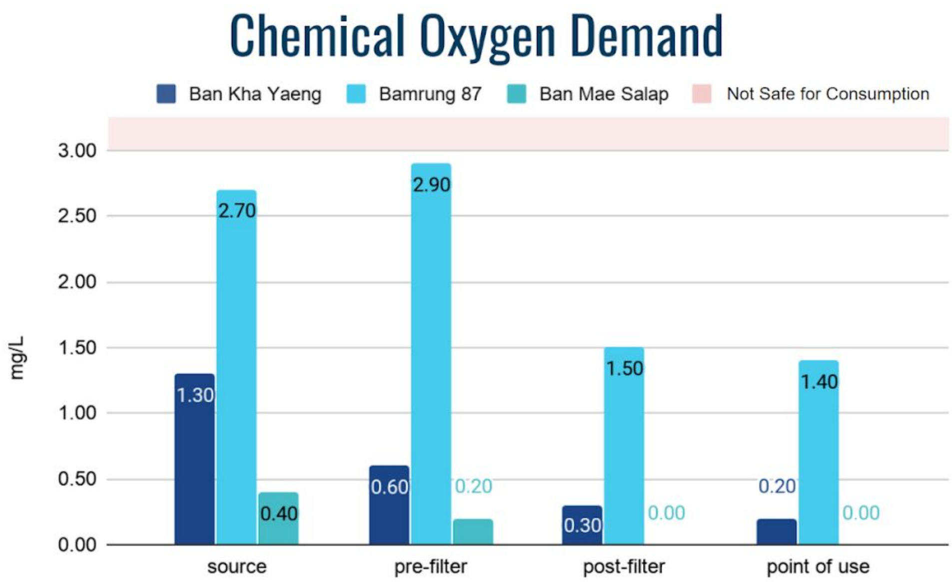

Figure 19. Changes in chemical oxygen demand (COD) at each point in the drinking water system at three schools. Water that exceeds the COD value of 3 mg/L is not safe for consumption.

Ban Kha Yaeng

Chemical oxygen demand of the water at the Ban Kha Yaeng school steadily decreased from source to point of use. The largest drop in COD occurred between the source and pre-filtration point, indicating that the distribution system played a role in sanitizing the water if the pipes are able to self-maintain. Elevated COD from the source to the pre-filter point was likely attributed to algal growth in the distribution system. The chemical oxygen demand at all points, especially the point of use, was far within drinking water standards, and therefore did not indicate poor drinking water quality at the tap.

Bamrung 87

The Bamrung 87 school presented the highest COD levels in the water both before and after filtration as seen in Figure 19. An abundance of nitrate-rich pesticides and fertilizers in the water may have been indirectly causing elevated COD levels through eutrophication or prolific growth of nitrogen-dependent organisms. Although this school had the highest relative chemical oxygen demand in its filtered water, the amount was within standards for drinking water and did not indicate poor water quality at the point of use.

Ban Mae Salap

Chemical oxygen demand in both raw and filtered water at the Ban Mae Salap school did not indicate poor water quality. While the raw water from the aquifer contains a COD level far within drinking water standards, the COD at both points after filtration present an infinitesimally small quantity expressed as 0.0 mg/L.

4.1.4 pH: Acidity and Alkalinity

The pH levels in water measure the levels of dissolved hydronium ions in water, with pH lower than 7.0 indicating acidity and pH higher than 7.0 indicating alkalinity. Slight changes of pH from the source, pre-filter, and point of use may be affected by concentrations of carbon dioxide, dissolved minerals in water and temperature. The pH values of three schools were within an acceptable range of 6.5 to 8.5 which is the standard of drinking water, as seen in Figure 20. Despite the neutral results of the pH test, we could not confirm that there was an absence of chemical contamination in the water; however, this specific test did not indicate any imbalances. We concluded that there are no contaminants that are significantly affecting changes in the pH of water.

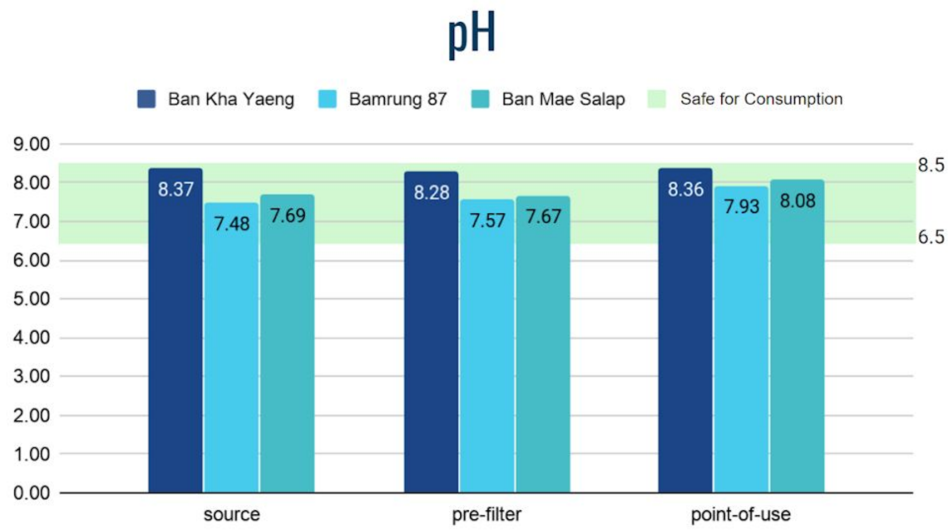

Figure 20. Changes in pH at each point in the drinking water system at three schools. Water below the value of 6.5 or above the value 8.5 is not safe for consumption.

Ban Kha Yaeng

The Ban Kha Yaeng school's raw and drinking water had the highest alkalinity out of the three schools. At each point throughout the system, the pH remained below the upper limit of 8.5, thereby not indicating any concerning chemical imbalances in the water.

Bamrung 87

Water at the Bamrung 87 school had the most neutral pH of the three schools at each point from the water source to the point of use. The pH remained well within standards, and did not indicate any chemical imbalances in the water.

Ban Mae Salap

The pH of the water at the Ban Mae Salap school was consistently slightly alkaline. The pH remained below the maximum alkalinity of 8.5, and did not indicate any chemical imbalances in the water.

4.1.5 The Presence of Bacteria in Water

Bacteria are microorganisms that can be present in drinking water. If the bacteria are pathogenic, they can cause negative health effects when consumed. One such type of bacteria is *E.coli*, which can cause illnesses such as nausea and diarrhea. The tests conducted by our team accounts for the presence of bacteria but cannot determine which type of bacteria is in the water, and if it is disease-causing. Our team's findings show the bacterial contaminants located in the source, pre-filtration, and point of use at the three schools.

Ban Kha Yaeng

Bacterial growth at the source and point of use at the Ban Kha Yaeng school was very limited; however, at the pre-filtration point, there was a high presence of bacteria in the water. This spike in bacteria count indicated that biological contaminants were introduced to the water in the distribution system as viewed in Figure 21. While the amount of bacteria in the point of use water was not alarming, the presence of bacteria indicates biological contamination. Because we were unable to characterize these bacterial species, we could not conclude that the organisms were either beneficial or concerning for human health.

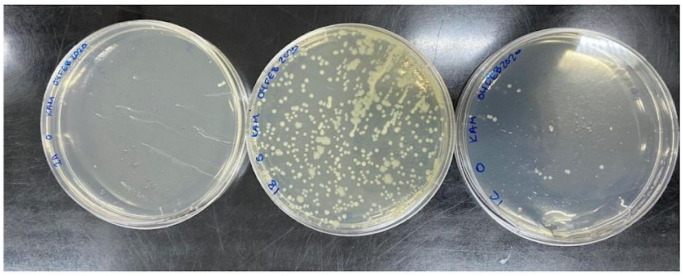

Figure 21. From left to right: Source, pre-filter and point of use bacterial contamination at the Ban Kha Yaeng school. All plates non-diluted, 100 µL water sample incubated at 36°C for 24 hours.

Bamrung 87

While bacterial growth was prolific at the source and pre-filter points at the Bamrung 87 school, minimal bacterial growth arose from the point of use plated sample as seen in Figure 22. This extreme decline in biological contamination was likely due to the appropriately maintained and functioning UV filter in place at the school. Minimal bacterial growth on the point of use plate indicated that the water quality was not poor at the point of use.

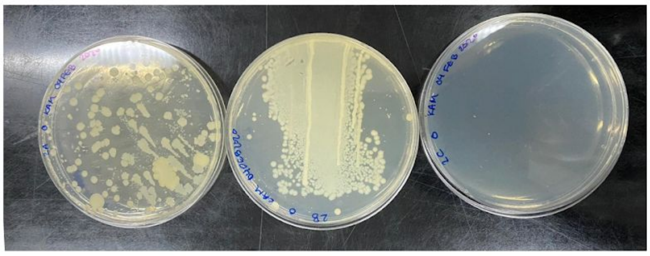

Figure 22. From left to right: Source, pre-filter and point of use bacterial contamination at the Bamrung 87 school. All plates non-diluted, 100 µL water sample incubated at 36°C for 24 hours.

Ban Mae Salap

The presence of bacteria in the Ban Mae Salap school's water slightly decreased from the source through the system, however there remained significant amounts of bacteria at the point of use. This can be seen in Figure 23. School officials reported elevated levels of *E. coli* in the drinking water, but because we were unable to characterize these bacterial species, we could not conclude that the organisms were either beneficial or concerning for human health. The presence of *E. coli* would indicate human or animal waste comes in contact with the source water or distribution system, likely from percolating into the groundwater. Biological contamination at the point of use could be attributed to the lack of maintenance of the UV filter, which had been reported to be non-operational.

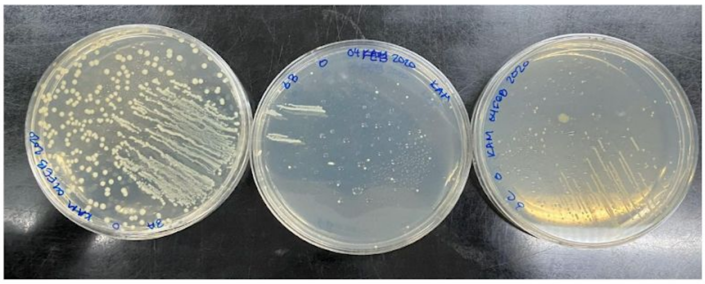

Figure 23. From left to right: Source, pre-filter and point of use bacterial contamination at the Ban Mae Salap school. All plates non-diluted, 100 µL water sample incubated at 36°C for 24 hours.

4.2 Community Skepticism Regarding Water Quality

During our site visits, our team observed and evaluated the water filtration system maintenance and use. We also interviewed community members, including the principle of Ban Kha Yaeng, at least one teacher, and a minimum of two students from each school to understand their concerns about the water's quality. We have identified two main categories of issues the community had regarding the quality of the filtered water. One of the sets of concerns the community had was regarding the secondary aesthetics of the filtered water. Another set of concerns was regarding environmental factors that could not be controlled. Both of these categories of issues contribute to the communities' distrust of the filtered water.

4.2.1 Secondary Aesthetics

According to the teachers, students, and superintendents at each school, the community values secondary characteristics of the drinking water and will not consume it if there is a strange odor, color or taste. At the Bamrung 87 school, the water sourced from the reservoir becomes red during the rainy season and the community members do not trust that it is within drinking water quality standards. According to our surveys, none of the interviewees have experienced or noticed sickness associated with drinking the filtered tap water; however, they remain skeptical of its quality and potential long-term carcinogenic traits or other health effects. This skepticism was also largely rooted in the community's inability to test the water and know exactly what chemical or biological contaminants may be present. Seasonal patterns or instances impacting the secondary aesthetics of the water contributed to the community's long-term distrust in the water's quality, even when the problem had diminished or been eliminated.

4.2.2 Environmental Factors

Each of the three schools have environmental issues or problems pertaining to human interactions with the environment that contribute to unclean water at the source, and thereby contribute to the communities' distrust in the purified water. Algae growth in the distribution system of the Bamrung 87 school and in the storage at Ban Mae Salap are well known to the school communities, who actively try to inhibit the growth. Additionally, at the Bamrung 87 school, a separate but nearby community was known to use water and dispose of wastewater upstream from the dam where the school sources their drinking water. The early dry season exacerbates the abundance of algae because it allowed for water to stagnate within the distribution system, and disabled the pipes' self-cleaning mechanism.

Finally, because the teachers and other faculty live on-site at the schools, there were small agricultural plots to allow for self-sustaining food production. However, a lack of water for irrigation and elongated dry season puts stress on the crops, and the owners of the land tend to supplement the area with pesticides and fertilizers. These chemicals then run off or percolate into water sources, contaminating them with nitrates and straining the filtration systems. This use of chemical supplements and lack of water for irrigation form a cycle that eventually contributed to unclean source water, and encouraged the communities' distrust in the water quality.

4.3 Lack of Knowledge Transfer About Filtration System Maintenance

The water filtration systems at the schools require maintenance to ensure that the systems are working effectively to filter the water. The schools informed us that when there is a buildup of algae in the storage tank, students go into the tank to scrub and rinse the algae and biofilm. This was the only form of sustainable maintenance practice at the school. Filters are not being replaced or cleaned, resulting in buildup of contaminants, as seen in Figure 25. The Mae Fah Luang

Foundation held an orientation for teachers, however, it was ineffective due to various factors. The schools were previously provided with manuals, which have been reported to be challenging to understand. The teachers and schools are unable to be self-sufficient and continue to rely heavily on the MFLF.

4.3.1 Unsustainable Orientation Process

One orientation event has been held by the Mae Fah Luang Foundation to promote teacher education about the water maintenance systems. At this orientation, two teachers from each of the three schools were taught basic water chemistry and maintenance practices relevant to their respective schools. The teachers were assigned to create schematics of the filtration and distribution systems at their schools to be used as references.

Because the teachers are employed as part of a national educational initiative, the minimum amount of time they must stay in the northern region is only two years, and this duration is rarely exceeded. There has been only one orientation event, however, the schools' water systems have been in place for two months to up to three years. With only two teachers at each school going through orientation, the frequency of orientation programs held is not practical or sufficient to keep up with the rapid exchange rate of teachers in and out of the area every two years. The teachers' motivation for working at the schools around Doi Tung is largely because it is part of a government program that rewards them with retirement benefits and pensions later in their careers. Additionally, the teachers lack the motivation to learn about drinking water system maintenance, even if the orientation events were more frequent, nothing is guaranteeing or promoting teacher attendance.

4.3.2 The Need for Improved Informational Documents

Our sponsors, Siam Commercial Bank and the Mae Fah Luang Foundation, established a manual for the water systems at each school. During the orientation process, teachers were provided with these manuals. The manuals reviewed basic information on water chemistry and filtration systems. However, these manuals did not provide enough information for users to independently learn about and maintain the systems. For inexperienced users that lacked prior knowledge, the manual was complex and confusing.

SCB and the MFLF worked to refine the manual. It is now intended to be easily understood so that individuals who are not familiar with the system can learn quickly and adapt to the problems at hand. However, the manual still has some issues and lacks detailed information that is needed to maintain the system.

During the orientation, teachers created schematics and diagrams of their school's filtration and distribution system. The goal was to make a diagram that would make it easy to identify the components of the school's filtration system. These diagrams have been posted near the filtration systems at each school, however, teachers that have not gone through the orientation find it difficult to understand.

In addition to the manuals and the schematics, our team found that many of the infographics targeted toward school children about hand-washing and general sanitation were faded or illegible.

4.4 Conclusion

Through site visits and interviews, our team found three major findings regarding the water filtration systems at the three schools. The water quality at the three schools indicated that the filtered water was safe to drink. However, the community still had distrust in the water quality, because they lacked the ability to test the water themselves and had faced observable contamination issues in the past. In addition, the school communities lacked communication about filtration system maintenance, resulting in improper upkeep of the filters. Based on these findings, our team created a set of recommendations that could alleviate some of the issues the schools are facing.

5.0 Recommendations

Our team recorded observations and conducted interviews on our first site visit to determine recommendations based on the community's preferences and needs. The three schools that were observed shared similar problems maintaining the filtration system and children were not drinking filtered water because they doubted the water quality. The problems faced by these schools overlapped and will be highlighted in this section.

5.1 Providing Testing Methods

Our team observed that students and teachers at the three schools were not drinking filtered water. Teachers and students reported that they noticed an improvement in the water quality after the installation of the filtration systems; however, they could not tell if the water was contaminated by bacteria or chemicals unseen by the human eye. Given the lack of trust in the system, we recommend providing three simple water testing methods that can be used by the Doi Tung schools. A list of water testing methods strengths and weaknesses can be found in Appendix K. These tests will assist the school community to identify microscopic contamination and reaffirm their confidence in the installed filtration system.

5.1.1 The 3-in-1 Water Quality Detector

The 3-in-1 Water Quality Detector, seen in Figure 25, is a water quality tool that accounts for contamination that cannot be observed. It tests for three parameters including total dissolved solids (TDS), total organic carbon (TOC), and chemical oxygen demand (COD). The test requires the device to first be calibrated by distilled water. The school must remove the lid and insert a sample of distilled water into the device. Next, they must press the central button that is in the shape of a raindrop and let the device run through a test. The device must read zero under the three categories TDS, TOC, and COD to be properly calibrated. After the machine is calibrated, the machine can be emptied and filled with a drinking water sample. The central button can be pressed again and the test will begin. The test will run until three numerical values appear on the screen under the categories TDS, TOC, and COD. Each school is recommended to record the results for TDS, TOC, and COD to ensure that it aligns with the drinking water standards provided by the Mae Fah Luang Foundation, as listed in Table 2. The schools are asked to record their findings in their database to keep track of their water quality over time. This test is important for it can account for components that have polluted Doi Tung waters in the past.

Figure 25. The 3-in-1 Water Quality Detector that detects TDS, TOC, and COD in water.

For instance, the COD test can determine if fertilizer and pesticides from the community's agricultural work is contaminating the water. Additionally, the TDS test can account for contamination due to mining in the area. This device will provide the schools with confidence in the water system and promote all to drink from the water filtration systems.

Test:	Drinkable Water:
Total Dissolved Solids (TDS)	Below 300 mg/L
Total Organic Carbon (TOC)	Below 3 mg/L
Chemical Oxygen Demand (COD)	Below 3 mg/L

Table 2. Drinking Water Standards for TDS, TOC, and COD.

5.1.2 The 9-in-1 Water Quality Testing Strips

The 9-in-1 Water Quality Testing Strip is a water quality test that accounts for contamination for nine parameters: total alkalinity, total hardness, copper, nitrate, iron, lead, free chlorine, nitrite, and pH. A single strip in this test kit is sectioned off and comprised of various chemical components that allow water to react and show these varying parameters. In order to perform this test, a paper strip from the test kit must be dipped fully into a glass of drinking water. The strip must then be left in the water for two seconds then removed and shook once to remove excess water. The strip should be allowed to settle so that water can react with the testing strip. The strip will change color as the test begins to take place. Multiple colors will appear and will coordinate with various parameters. The colored strip should be compared to the information on the back of the bottle and check against the standards as noted in Table 3. The results of the strip test can be found in Figure 26. The schools should record the test results in their school's database. An infographic that will be provided to the schools on how to use this test can be found in Appendix L. This test is important because it accounts for microscopic contamination. The schools currently lack confidence in the water, but now have a testing method that can reduce their doubts. Additionally, this test accounts for contamination that has occurred in the past. For instance,

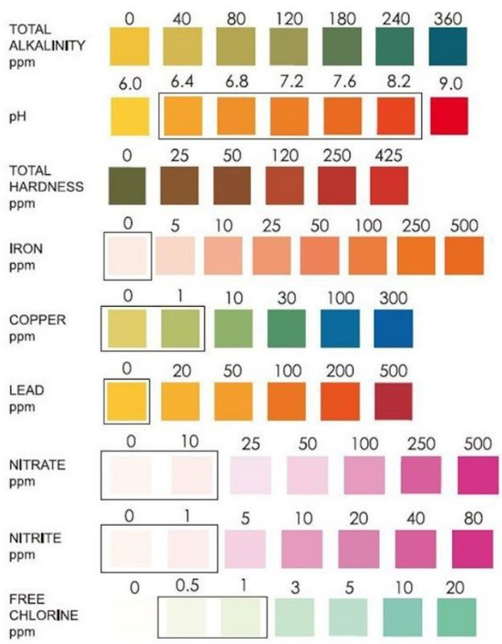

Figure 26. The color key that results of the strip test are compared to in order to identify level of contaminants.

at Bamrung 87 there has been a high presence of nitrate in the water during the rainy season, the water even turns red annually. This test can show that the water is now safe and being filtered as opposed to just looking at the physical properties of the water.

Test:	**Drinkable Standard:**
Total Alkalinity	No more than 8.5
Total Hardness	*Follow the color chart on the bottle
Copper	Below 1.0 mg/dm3
Nitrate	Below 45 mg/dm3
Iron	Below 0.5 mg/dm3
Lead	Below 0.05 mg/dm3
Free Chlorine	Below 0.2 mg/dm3
Nitrite	Below 1.0 mg/dm3
pH	6.5 - 8.5

Table 3. Standards for the 9-in-1 Water Quality Test

5.1.3 Secchi Disk Turbidity Test

The turbidity test is a physical water testing method that looks at the clearness and color of water. It uses the Secchi disk chart which is comprised of black and white circles. The chart consists of five circles labeled A through E. Circle A is filled in fully with a black and white color scheme. The colors fade as you move along the chart to E. Figure 27 shows an image of the Secchi disks chart in detail. In order to begin the test, each school will gather a clean glass of the filtered water and the Secchi disk chart. The tester must then place the glass over the circles while stirring every time it is moved. The water must be stirred so that sediments will not settle at the bottom of the glass while the test is being performed. The tester will then observe the chart through the glass of water and record the results. If circle E can be seen through the glass of water, then it is consumable. If the tester cannot see circle E through the glass, the filtration system must be cleaned or repaired and students and faculty

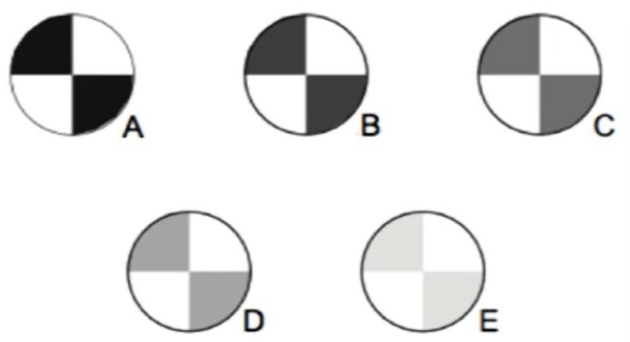

Figure 27. The Secchi Disk Chart.

should not drink the water. This test is a quantitative physical water test that can be done by both the students and faculty. As opposed to just observing the water, this test provides guidelines for what the schools should be looking for. An infographic of this test can be found in Appendix M.

5.2 Mentorship Program for Teachers

Our team recommends setting up a semi-structured peer mentorship program with teachers from the Doi Tung schools. This mentorship program would allow for knowledge about the system's maintenance to be passed on. This would help to overcome the loss of knowledge between the teachers due to the frequent faculty change over the short two-year compulsory period. For this program, mentors would be teachers with knowledge about the filtration system's maintenance and teachers who are nearing the end of their two years at the schools. Mentees would be teachers with little to no knowledge about the system's maintenance and individuals that are at the beginning of their two years at the rural schools. Pairing incumbent and informed teachers with incoming or uninformed teachers in a mentorship program encourages long-term sustainability. The teachers would rely on each other to learn and grow in maintaining the current water filtration system in place. The guidelines for this mentorship program can be found in Appendix N.

5.2.1 Motivation Behind the Program

The teachers have a large personal stake in the filtration system's maintenance. Since the teachers live on the school grounds, their main source of drinking water is the filtered water at the school. Thailand's Ministry of Education guidelines require the teachers to be in the rural mountain region for a mandatory two years. Most teachers come from relatively urban areas and leave their lives behind in the city. Incoming teachers will benefit from having a mentor for an unofficial orientation to their new home in both a social and professional manner. Teachers who have been in the area and have experienced daily life at the schools will be able to give back in the form of advice, information, encouragement, and help for incoming teachers to adjust to their new environment. If successful, this will be a continuous cycle of communication about the system and giving back to others who are beginning their two-year journey away from home.

5.2.2 The Manual and Transition Materials

The schools will be provided with a manual from SCB and the MFLF. There will be two versions of the manual, paper and online. This paper copy is accessible if there is no computer. An online copy of the manual can include supplementary videos that demonstrate procedures such as conducting tests and replacing filtration system components, and can be easily updated as needed. Teachers at the Doi Tung schools will have additional responsibilities due to the filtration system maintenance. Each school will establish two of the teachers as a manager. The manager will have responsibilities that oversee the maintenance of the filtration system. The manual will include information on the filtration systems. It will cover the purpose of each filtration method, the way it filters the water, and the maintenance each system requires. The manual will include information on simple water testing methods. It will cover the purpose of each testing method, the procedure for each test, what the test results indicate, and what actions to take depending on the test results. The transition document guidelines can also be found in Appendix N.

5.3 Guidelines for Sustainable Drinking Water in Doi Tung Schools Based on Three Model Schools.

Our team recommended solutions to make the water filtration systems more sustainable and user-friendly for the students and faculty at three schools in Doi Tung. These guidelines were created within the limitations of the filtration systems and environment to promote sustainable water management standards. Our list of recommendations were refined to meet the needs and preferences of the community. Our team utilized the information collected from behavioral interviews and technical analysis to create a set of guidelines for other schools in the area. Our team outlined which filtration systems should be installed and how filtration systems should be designed for future implementation at other schools. These guidelines can be found in Appendix O.

5.4 Water Collection and Algae Prevention

The schools have a problem of insufficient water during the dry season that came earlier than expected, which may be a result of climate change. The seasons will shift in unfamiliar ways and cause harmful changes to the ecosystem. This problem has a huge impact on people's lives. Even though they already manage their water use, it is not effective enough. Our team recommends having more storage tanks to collect water in the rainy season for use in the dry season. Having a suitable storage tank, such as a linear low density polyethylene tank as seen in Figure 28, will prevent bacteria and algal growth in the water. Algal growth in water can be accelerated due to exposure to sunlight or the presence of other organic matter. In order to prevent the algae blooms in the storage tank, our team recommends buying and setting up a turbid polyethylene tank. The opaque turbid polyethylene tank is easy to transport, and provides a sterile containment for the water that is nearly impermeable to sunlight. The tank is made from silver nano titanium, an opaque material, which protects water from UV light. The inner coating of the tank includes a combative antimicrobial that restrains the growth of bacteria and other microorganisms. Therefore it is suitable for setting up in the Doi Tung schools, which are at a high altitude in a mountainous region.

Figure 28. An image of a polyethylene tank.

5.5 Individual School Recommendations

Most of the common water potability related problems were present at each of the three schools. However, each school had its own specific problems that our team observed and addressed.

Ban Kha Yaeng

Ban Kha Yaeng lacks consistent access to water. The mountain water is reduced due to the lack of rain during the dry season. This problem is exacerbated since students waste the filtered water by playing with it or throwing out half-full cups of water. Additionally, teachers still drink from bottled water, which sets a poor example for the students.

Our team suggests that the school collects rainwater during the wet season and store it as mentioned in Section 5.4 so that it can be utilized during the dry season. We additionally shared our water testing results with the school to show the teachers that the water is being properly filtered and is safe to drink. Our team encourages teachers to set a good example for the students by drinking the water from the filtration system in place. Our team also recommends covering the storage tanks with a dark material to prevent growth of algae in the tank.

Bamrung 87

There are several structural problems at Bamrung 87. Pipes that release wastewater from the cafeteria's dishwashing station are disconnected and are depositing the wastewater near a faucet that students and faculty drink from. The release of wastewater near the point of use poses a threat of contamination to the drinking water and leads to unsanitary conditions. The lack of maintenance and cleaning of the pipe entrance, as seen in Figure 29, additionally contributes to unsafe drinking conditions. The inlet pipes are not being cleaned as frequently needed, leading to decreased effectiveness of the filtration system. Bamrung 87 does not have access to proper hand soap for the students to use. Our team observed that students wash their hands with dish soap. The students lack of hygiene and the unsanitary conditions present at this school pose a threat to the students health.

Our team recommends repairing the piping system in place at Bamrung 87, so that the wastewater is disposed of appropriately. The beginning of the piping system in place at the reservoir has a cleanout component consisting of sharp ninety-degree elbows, as seen in the left side of Figure 29. Our team recommends this school to re-design the clean-out portion of the piping, so that it is more curved, as seen on the left side of Figure 29. By installing a P trap with a clean-out component, sediments can be cleared and removed more efficiently. P traps with clean-outs are curved fittings with a removable hub that allows the pipes to be easily cleared out. This trap will make it easier to clear large sediment clogs. As opposed to having the pipe go directly through the dams wall, our team recommends that the school redesigns the beginning of the distribution system. By designing a curved inlet, as seen in

Appendix P, will decrease the resistance and increase the flow of water in the system. Additionally, changing the pipe entrances to be flush with the dam wall and rounded would reduce water pressure loss due to friction and stagnation. The school should clean out the system more frequently to eliminate the contamination added to the system pre-filtration. Finally, since there is no soap present at the school, our team suggests the school acquires a proper hand soap that students can use at all handwashing stations.

Ban Mae Salap

Ban Mae Salap has over six filtration systems present including UF, UV, RO, MF, carbon filtration, and sand filtration. The complexity of the filtration systems makes it difficult for the schools to maintain them. The UV system in place is broken and creates an additional expense for the school to continuously repair. Water is additionally not being utilized to its fullest extent. Only 40 percent of the water filtered from the reverse osmosis system is potable. The other 60 percent is wastewater from the filtration process, which must be used for other purposes. The surrounding community uses pesticides and fertilizers that may percolate nitrates into the aquifer. This promotes accelerated growth of algae downstream in the system. Also, there was rubber and dirt around the pipes, the post-RO waste tank, and the post-RO purified water tank. These stains affect the water quality and cause it to seem unsanitary.

Our team recommends eliminating redundant filtration systems, including the broken UV filter, to reduce the complexity of maintaining them. Eliminating these systems will also decrease maintenance and repair costs. The team additionally suggests more storage tanks so that 60 percent of the water from the RO system is not being wasted. Covering the storage tanks with a dark material will help prevent further algae growth.

5.6 Conclusions

Our team wanted to receive feedback on our proposed recommendations. Our recommendations would directly impact the lives of the school community, especially the teachers, who would receive an additional burden of water quality testing and participation in a mentorship program. According to surveys given to the teachers at the school, most teachers in Bumrung 87 agree and found the recommendations useful, as seen in Figures 30 and 31. We also gained suggestions that were used to improve upon our recommendations. The feedback questions and responses can be found in Appendix Q.

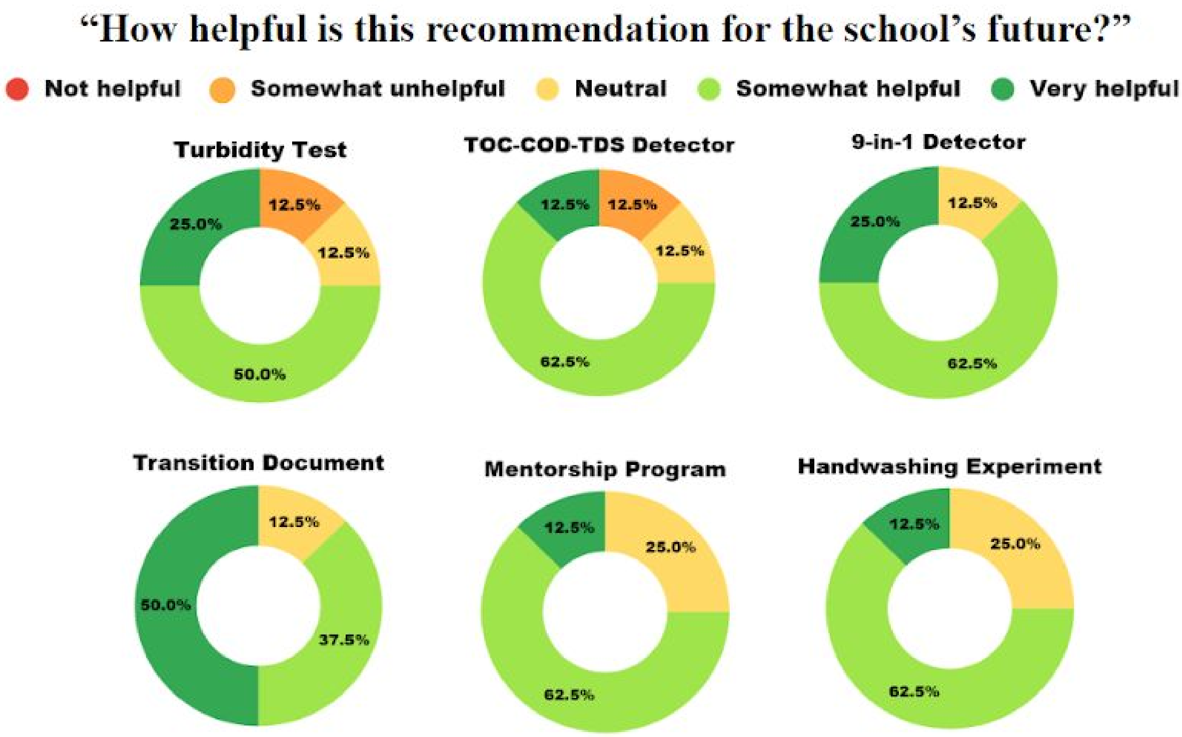

Figure 30. Feedback from 8 faculty participants regarding the level of helpfulness of each recommendation

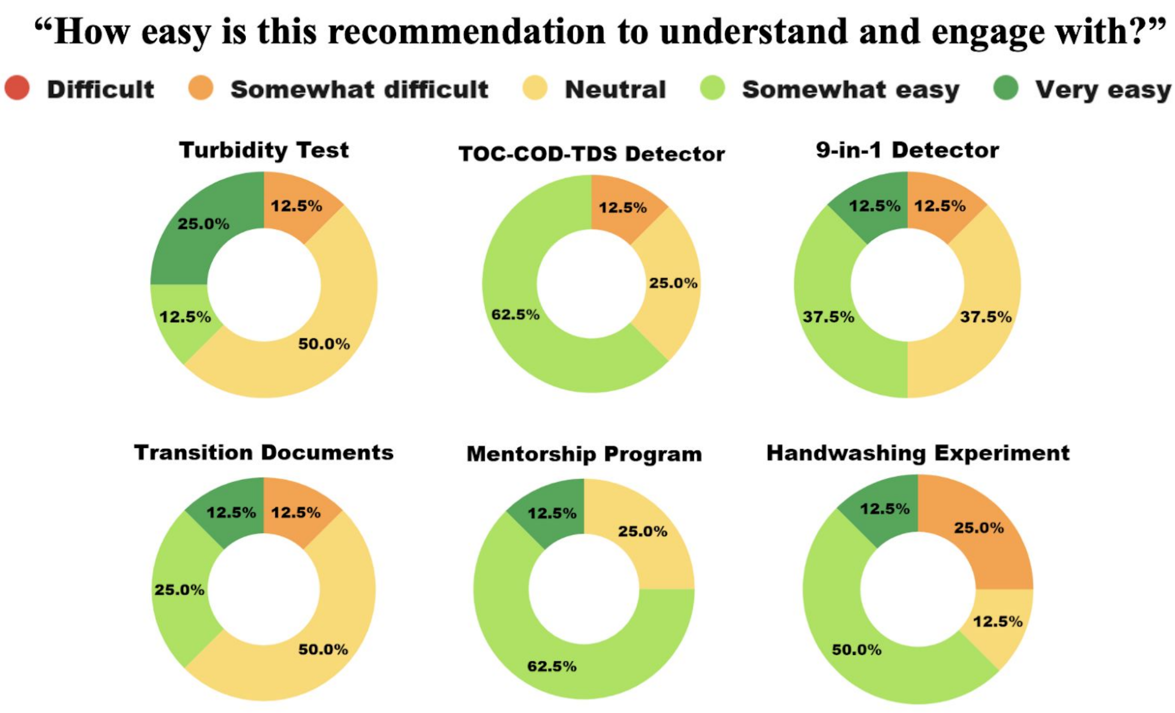

Figure 31. Feedback from 8 faculty participants regarding the ease of understanding or engagement of each recommendation

Our recommendations were made to encourage teachers and students to drink filtered water from the filtration systems in place at Doi Tung schools. The testing methods, mentorship program, and manual provided to the schools will allow them to become independent from the Mae Fah Luang Foundation and to be self-sustaining. The suggestions provided for the schools establish a foundation for water standards and upkeep regulations that will leave the schools with potable water in the long-term. Our team's recommendations will leave the faculty and students of Doi Tung with the ability to sustain potable water for themselves.

Appendices

Appendix A: Siam Commercial Bank

A Brief History

Siam Commercial Bank (SCB) was established on January 30, 1907 and is the first Thai bank. The bank has a multitude of services offered through their extensive banking network along with its technological innovation. Their well-recognized and renowned banking networks has led them to accumulate over one hundred awards in 2018 alone. This success is directly related to their practice in corporate social responsibility. The organization operates as a responsible member of the Thai society. They have a firm commitment in taking their stakeholders into account, in which they place focus on the people as opposed to making profit. The bank's "Corporate Social Responsibility Committee has played a key role in formulating policies, setting operational frameworks, as well as allocating resources and budget for activities to improve the quality of life in the community and society" (Bratanova, Morrison, Fife-Schaw, Chenoweth, & Mangold, 2013). The bank has left a good impression on society by following this standard along with their three major aims of youth development and education, improving the quality of life and community development, and conserving culture and environment.

A Recent Project

A recent project put on by SCB that utilizes sustainable practices is the changing of the EEC strategy to manage water risks. The project's focus laid on the expansion of EEC industries. This project addresses a multitude of problems with water scarcity in Thailand's eastern region, and it notes the demand of water increasing with production capacity. Thus, the project wants to use the powers from both the private and public sectors to support projects that will "increase watershed capacity by over 350 million cubic metres of capacity over the next 10 years" (Siam Commercial Bank, 2019). Despite the project's goal to increase watershed capacity, it realized the threat of water scarcity. The risks of water scarcity is due to the irregular rainfall and abnormal weather cycle in the region. This abnormality in climate could lead to conflicts with the local community that rely heavily on water sources. These conflicts could potentially evolve to accumulate in the future. Therefore, the project called for industries in Thailand to evaluate their current water usage. These industries were tasked to "set targets for improving water efficiency, and forge a positive relationship with the local community who share water resources in an efficient and equal manner" (Aksornkij, 2018). This solution was derived from the possibility of having a severe water shortage in the future. The project wants to reduce potential impacts on costs, develop strong relationships with the local community, and to increase production

Deliverables

SCB has asked for recommendations regarding methods of testing the quality of water at the source and point of use. The recommendations our team propose must allow the schools to test the water themselves at any point in time without having to send samples to a lab. They have additionally asked us to analyze the strengths and weaknesses of the current water management system in place, ways to make the system more sustainable, and communicate these recommendations in a way that is understandable to the community without a technical background. All of SCB's objectives aim to encourage the use of the filtered water systems that were previously installed at the schools that are not being utilized to their full extent.

Appendix B: Water Sources

Mountain Water

Some of the drinking water at the schools originates from a water source at a high altitude in the mountains surrounding Doi Tung. The water quality from this source is relatively clean, but it may become contaminated by substances such as sediments or diseases from local vegetation. Algae, mosses, lichen, and liverworts can adhere to the distribution system and accumulate in the water. Microscopic parasites causing giardia and cryptosporidiosis will reproduce in stagnant water and contaminate the source. These gastrointestinal diseases have symptoms that include weight loss, abdominal cramps, and dehydration. These diseases are not deadly, but can be life threatening to sensitive groups including small children. These diseases could potentially pose a threat to the children at the Ban Kha Yaeng school because mountain water is their main source of water.

Groundwater

Groundwater is found underneath the Earth's surface, contained in sources known as aquifers. Within a groundwater source, water percolates through the soil and moves very slowly around sediments and large rocks. Aquifers can be confined by a layer of bedrock, which is impermeable by water. Unconfined aquifers do not have a layer of bedrock between the water source and the Earth's crust. Both types of aquifers, however, can be accessed by creating wells. Since groundwater exists almost everywhere beneath the surface, it is used as a common drinking water supply throughout the world. Groundwater can become contaminated by nearby industry waste, agriculture, surface water salinity and wastewater systems (Alley, 2009).

Thailand has a groundwater storage of 1,130,000 Mm^3, and the current groundwater abstraction in the whole country is 11,047 Mm^3 per year. Groundwater is used for agriculture (44%), for industry (37%) and lastly for domestic use (19%). Groundwater is mainly used in rural areas as a secondary water source during the two dry seasons. The significant use of groundwater for diverse purposes each year indicates that it is an exhaustible resource and is rapidly being depleted (Fomes & Pirarai, 2014).

Reservoir

Reservoir water is an artificial lake used to store water. Reservoirs are mostly formed by constructing a dam across the river. Reservoirs are built primarily because the water from natural sources varies over the year depending on the season. Therefore, reservoirs are used to store a large volume of water for the dry season and help retain water during the rainy season. Reservoirs can be used for hydroelectric power generation, domestic purpose, and flood control. Sediment and pollutant from agriculture and mining can be found in the reservoir water. Since the reservoir collects all of that substance, it is washed into them. (Nilsson, 2009)

Appendix C: Water Filtration Systems

Water filtration systems are pieces of equipment that eliminate contaminants such as dust, sediment, heavy metals, fluoride, nitrates, and other substances from drinking water. The three Doi Tung Schools have systems that remove such pollutants from the drinking water supply. The three schools have a combination of the following water purification systems: Reverse Osmosis (RO), UltraViolet (UV), Microfiltration (MF) and UltraFiltration (UF). The first and second schools, Baan Kha Yang and Bamrung 87, respectively, have had drinking water filtration systems for around 2-3 months, while the Baan Mae Salap school has been using their filters for 3 years.

Reverse Osmosis

Reverse osmosis filters are highly effective at purifying raw water. These filters remove every type of contamination from the water, including particulate matter, microbes, salts, and metals. Reverse osmosis filters, as the name suggests, use the mechanism opposite to osmosis to filter the water. In osmosis, water moves from an area of low solute concentration to an area of high solute concentration. In reverse osmosis, the contaminated water has high concentrations of solute. Using pressure that is higher than the osmotic pressure, the water is forced through a semipermeable membrane that only allows water to pass (Rao, 2011). The semipermeable membrane has a filtration capacity of 0.0001 microns (1/10 millionth millimeters) which can filter ions and molecules out of solution in the water (TREAT, 2019). The purified water has an extremely low concentration of solute. Although reverse osmosis filters are very effective at water filtration, they do pose some challenges. High amounts of contamination will damage the system. Typical restrictions of the system include that the silt density index (SDI) of the water input should not be greater than 5, the free chlorine should not be more than 0.1 ppm, and turbidity should not exceed 5 nephelometric turbidity units (NTUs). These conditions will result in system clogging and a

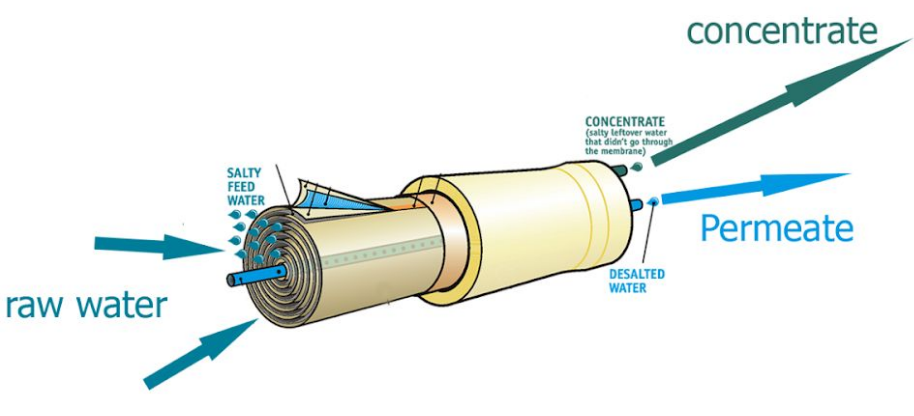

Figure 32. A Reverse Osmosis water filter diagram showing the elimination of pathogens.

decreased service life of the filter membrane (TREAT, 2019). It is not a very efficient method. Only 30 percent to 50 percent of the raw water volume is purified. The remaining 50 percent to 70 percent of the raw water volume is waste. The generated waste, known as Reverse Osmosis Reject, can have extremely high concentrations of salts and metals. This waste is difficult to dispose of safely and can lead to environmental hazards (Rao, 2011).

UltraViolet Water Filter

An ultraviolet (UV) water purifier uses an ultraviolet bulb to filter raw water, eliminating the biological contaminants from water while leaving minerals that are essential to the body such as calcium, magnesium, and fluoride. Electricity is needed to operate the machine. This type of purifier is more suitable for filtering tap water than filtering water from other sources. The advantages of an UV water purifier system is that less water is disposed of in a waste stream. Furthermore, it is more convenient since the filter is easy to find and replace (ESP Water Purification, 2020).

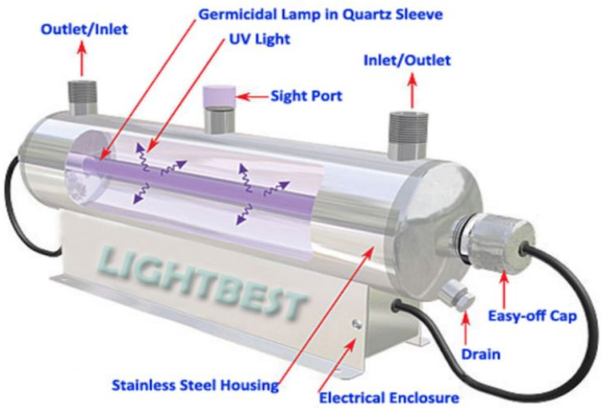

Figure 33. An Ultraviolet water filter showing the components.

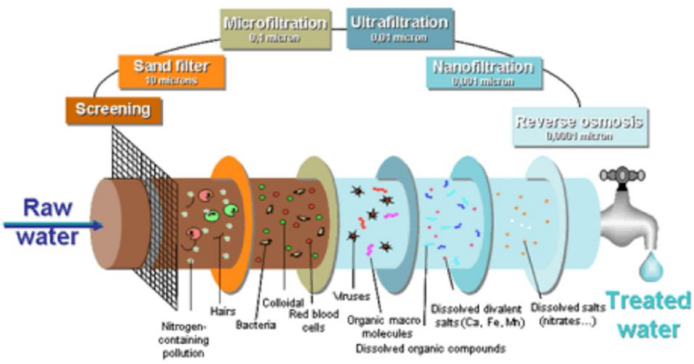

Figure 34. An ultrafiltration system removing contaminants from raw water.

UltraFiltration Water Filter

An Ultrafiltration (UF) water purifier is developed from UV water strainer system. Some systems might not use UV light bulbs but added a filter called Protect bacteria which size is small 0.01 microns so that can kill various germs contaminate from the water. Advantages of the UF water purifier system are that it is easy to change the filter, less time consuming, and can reduce cost on maintenance when compared to the RO system and UV system (Pacific Water Technology, 2019).

Microfiltration Water Filter

Microfiltration system (MF) filters surface water sources into tap water. The quality of the produced water is cleaner than the conventional tap water production system, with the turbidity of water below 0.5 nephelometric turbidity units (NTUs). This system reduces the hassle of people and operators because the production system works continuously and automatically. Water supply systems using MF use only 50-75% of area compared to conventional water supply systems (Water Treatment Specialist, 2014).

Figure 35. A microfiltration system filtering out sediments and solid particles for clean drinking water.

Appendix D: Bacterial Testing Procedure

Making Media and Pouring Plates

1. Weigh ingredients and add to Erlenmeyer flask.
    - 5 g tryptone
    - 2.5 g yeast extract.
    - 2.5 g NaCl
    - 10 g agar
2. Bring up to 500 mL.
3. Autoclave for 1 hour.
4. Let cool for 20-30 mins (until able to comfortably hold).
5. Add approximately 15 mL of media to each plate, for a total of 30 plates.
6. Let cool for 1hr.

Recipe link: doi:10.1101/pdb.rec088203

Serial Dilutions

For each sample:

1. Get two microcentrifuge tubes. Label with sample number, dilution, initials.
    - Ex. 2 10^-1 KAM
2. In each microcentrifuge tube, add 100 uL of distilled water.
3. Use a micropipette to transfer 10 uL of the original sample to the 10^-1 dilution tube.
4. Vortex / shake/ pipette up and down to mix.
5. Use a micropipette to transfer 10uL of the 10^-1 dilution to the 10^-2 dilution tube.
6. Vortex/shake/pipette up and down to mix.

Plating Bacteria

For each sample:

1. Label each plate with the following information: sample number, dilution, date, your initials.
    - Ex. 3 10^0 04FEB2020
2. Gently add 15-20 sterile glass beads to each plate.
3. Pipette 100uL of the corresponding dilution onto the plate.
4. Gently shake the plate, making sure to keep it horizontal.
5. Tap the beads out of the plate.
6. Let the plates dry slightly.
7. Place the plates in a 32C incubator, lid-down.
8. Check the plates after 24 hours to see growth.

Appendix E: Water Quality Standards

The drinking water sources for each of the three schools are contaminated, primarily with chemical pollutants. Surrounding industries as well as weather patterns and a lack of source protection contribute to worsening contamination of the sources.

Local agriculture encourages the use of pesticides and fertilizers, which can run off into the schools' water sources, and can also percolate into the secondary groundwater source. Animal waste and other long-lasting organic matter in the water can also increase the concentration of nitrates. Nitrates in drinking water sources can have carcinogenic and teratogenic effects on a population. Chronic exposure to nitrates can contribute to an individual's likelihood of developing colorectal, bladder and breast cancer. When consumed by pregnant women, nitrates in drinking water can also lead to fatal circulatory imbalances in infants (Corredor, 2016; Maxwell, 2007). Because many nitrate compounds are soluble in water, it is often difficult or expensive to detect and remove these harmful contaminants.

The nearby mining industry contributes to the presence of heavy metals in the water sources. Extraction and refining can release airborne metal particles, and waste from these processes is deposited into the environment, eventually permeating the nearby bodies of water and aquifers.

The presence of *E. coli* in filtered water at the Mae Salab school around Doi Tung indicates the presence of fecal matter in the water source. It also determines that the filtration system in place is insufficient to remove all biological contaminants. Virus transmission between people or from an animal vector to a human population can occur when fecal matter is present in the water, which is signaled by an elevated level of *E. coli* and other symbiotic bacteria. These coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in plant and soil material. A group of bacteria commonly referred to as fecal coliforms act as an indicator for fecal contamination of water. Most Probable Number (MPN) is a method used to estimate the concentration of viable microorganisms in a sample by replicating bacteria in serial dilutions of liquid broth. MPN is most commonly applied for quality testing of water.

Appendix F: School Data Sheet

We plan to record information about each of the Doi Tung schools we will be making recommendations for. Information will be gathered through observations and photographs, along with interviews, if possible.

School Name:

School Location:

School Age/Grade Range:

Number of Students:

Number of Faculty (non-student):

Source of Water:

Water Filtration Systems:

Installed:

Water Source:

Point of Use:

Filtration System:

Storage System:

Contamination Issues:

Physical:

Chemical:

Biological:

Secondary Aesthetics:

Taste:

Smell:

Sight:

Current Maintenance/Repair Procedures:

Ban Kha Yeang

School Name: Ban Kha Yeang

School Location: Highway 1338, Mae Fah Luang, Mae Fah Luang District, Chiang Rai 57240

School Age/Grade Range: Kindergarten to 6th grade, 3-12 years old

Number of Students: 159 students

Number of Faculty (non-student): 9 teachers, 1 principal (total 10)

Source of Water: Mountain water

Water Filtration Systems:

Installed: November 2019
Water Source: Mountain Water
Point of Use:

1. Faucet near cafetaria
2. Faucet at back of the school
3. Two clear storage tanks with tap at front of school

Filtration System: Sand filter, Manganese, Carbon Filter, Resin Filter, MF, UF,
Storage System: Large storage tanks

Contamination Issues:

Physical: clear

Chemical: -

Biological: bacteria

Secondary Aesthetics:

Taste: like ordinary water

Smell: water near kitchen smells

Sight: water looked clear and filtered

Current Maintenance/Repair Procedures:

Bam Rung 87
School Name: Bam Rung 87
School Location: Thoet Thai, Mae Fah Luang District, Chiang Rai 57240
School Age/Grade Range: Kindergarten to 6th grade, 3-12 years old
Number of Students: 120 students
Number of Faculty (non-student): 12 people
Source of Water: reservoir, dam

Water Filtration Systems:
Installed: 3-4 months ago
Water Source: reservoir and dam,
Point of Use: pressure is generally good, drainage was concerning, pipes weren't connected, soap for hand washing was liquid dish soap
Filtration System: Sand and sediment filter, carbon filter, MF filter, UV filter, UV, carbon, and sand filtration
Storage System: six huge ceramic tangs

Contamination Issues:
Physical: slime (bacteria, biofilm) in the PVC piping
Chemical:
- Source quality is influenced by nearby agriculture; fertilizers and pesticides in water

Biological:
- Potential virus transfer through shared cups that are not shared
- Not required to wash hands before eating
- Puppy playing in wastewater then the kids played with the puppy

Secondary Aesthetics:
- tasted normal
- Red coloring from rainwater during the wet season
- Bathrooms were facing a completed collapse
- Plastic smell to the water when first implemented
- Dedicated to teaching the children (medication, teeth brushing)

Current Maintenance/Repair Procedures:
- Manual from the MFLF
- Need to improve the manual, it was lacking in detail
- Need to contact professionals for big problems, small problems like cleaning the filter can be done by the teachers. Students don't clean the system.
- Students clean dishes after they are used

Bae Mae Salap
School Name: Bae Mae Salap
School Age/Grade Range: kindergarten to middle school (9th grade)
Number of Students: 177 students
Number of Faculty (non-student): 17 people
Source of Water: underground water (had two sources before, mountain water)

Water Filtration Systems:
Date Installed: 3-4 years ago UF, UV (doesn't work), RO, MF, sand filtration, carbon filter
Water Source: Groundwater
Point of Use: two metal boxes with four faucets and with UF filters directly behind them, four
other faucets close to the storage that *should* work, but have very low pressure
Filtration System: UF, UV (doesn't work), RO, MF, sand filtration, carbon filter
MF, UF charcoal/carbon++
Storage System: Water tower, RO reject waste, 40% was being used. 60% is being wasted but can be used for various things.

Contamination Issues:
Physical: high TDS, tasted fine, clear; used membranes from the MF system were relatively clean-looking, but a few were mottled brown
Chemical: -
Biological: high in bacteria: over 23 MPN, no specific bacteria names

Secondary Aesthetics:
- Tasted literally ionized from the two metal boxes

Current Maintenance/Repair Procedures:
- They have a group chat going in which they message each other to figure it out
- Manual is present
- Two teachers (one is head of system maintenance since November 2019), two students who know how to clean the system and wash it out
- There were a lot of used filters in the corner of the room, which indicates that they are changed a lot

Appendix G: School Community Interview Questions on User Needs, Maintenance, and Understanding Mistrust of the Water Quality

Doi Tung Community Members associated with the schools will be interviewed to deepen our understanding of the water usage at the schools. Our team will ask questions about the maintenance. The Doi Tung School communities still have a distrust of the quality of the water despite the water filtration systems in place at the schools. We plan on interviewing a set amount of children and teachers at each to gain a better understanding of the mistrust. The answers to these questions will help indicate how to instill more confidence in the system based on the concerns they have. The information from these interviews will also help us make more informed recommendations. We will want to interview an administrator and 1-2 teachers from each school to get a thorough understanding of the needs. We would also like to interview 2-3 students from each school if possible. Personal information like name and age can be omitted if the interviewee prefers to remain anonymous. We will ensure that the information from the interviews remains confidential.

1. Age / Grade:
2. What is your role in the school? (Student, teacher, etc.)
3. What is the water at the schools used for?
4. How many times a day do you [the student] drink water?
5. Do you [the student] have water outside of school / at home?
6. How are the water systems being fixed right now?
7. How often do the systems break?
8. How often do you not have water?
9. How often is the water not clean?
10. Who fixes the water when it is not working properly?
11. Do you know how to fix the water?
12. Do you drink the water from the tap at school? Why or why not?
13. Do you trust the water at the school?
14. Do you drink the bottled water provided by the school? Why or why not?
15. What did you think of the water before the filtration system was put in place?
16. Have you or anyone you know gotten sick from drinking the water at the school since the filtration system has been put in place?
17. How do you drink the water?
18. Do you use a water bottle, cup, or hands?
19. If you use your hands, do you wash your hands before?
20. How do you wash your hands?
21. If not from a bottle or cup, why not?
22. How do you tell if water is safe or not safe to drink?
23. Does the color of the water affect whether or not you'll drink it?

Ban Kha Yeang

Interview 1:

1. What is your name?

Suphit Chaimongkol

2. What is your role in the school? (Student, teacher, etc.)

Principal

3. Do the students/teachers/anyone live here?

All of the teachers live at the schools during the school year. The students do not live at the schools.

4. What is the grade and age range for the school?

The school has kindergarten to elementary school. Elementary school goes until 6th grade. The children are 3-12 years old.

5. What is the water at the schools used for?

The water is used for everything. The students and teachers drink this water, use it for washing dishes and laundry, cooking, and watering the garden.

Before SCB installed the filtration system, they just bought bottled water but the school is now drinking filtered water.

6. How many times a day do the students drink water?

The students drink a lot of water. There is a cold drinking water machine that the students can use and love to drink from.

7. Do the students have water outside of school / at home?

Many families just buy bottled water for drinking, they do not have filtration systems. Some households may take water from resource and boil it as a way to sanitise.

8. What is the source of water?

The school gets the water from mountain water.

9. What filtration systems does the school have?

The principal could not remember the exact names of the filtration system, however there was a diagram with information on the filtration systems posted near the filters.

10. When were systems installed?

The filtration systems were Installed two months ago. Prior to this they had distribution systems but the water was not drinkable.

11. How are the water systems being fixed right now?

The systems were maintained two months ago.

12. How often do the systems break?

Since the systems are so new, they have not broken yet.

13. How often do you not have water?

February through May there is a lack of water annually due to the dry season. This is due to the lack of water at the source. They will still have water but not enough. Usually they have water from 5am to 8am, then again 5pm to 7 or 8 pm during this time period.

14. Who fixes the water filtration systems when it is not working properly?
The schools have to fix the systems themselves. SCB provided lectures and an orientation for the teachers, with a test that involved making the manuals and a diagram for the school.

15. Do you know how to fix the water filtration systems?
The principal does not know how to fix the water himself, but there are two teachers who went to orientation who know how to fix the systems.

16. Do the students like the smell, taste, appearance of the water?
There is a filtration system that has no taste, smell, or color. All of the students like the water from this point of use and drink from it. This point of use is outside, but not far from the main area of the school. There is another point of use near the cafeteria that the students do not like. Right after installation and occasionally now, there is a smell of plastic from the PVC piping.

17. How are the students drinking water? Bottle? Cup? Hands?
Each student has their own reusable water bottle, provided by SCB. However, sometimes when they play sports outside, the students get lazy and use their hands to drink the water instead. They usually use cups and bottles to drink water. The students are taught to wash everything they use: dishes, bottles, cups. Each student has their own bottle.

18. Has any student gotten sick from drinking water?
No one has gotten sick from the drinking water. The children have a high tolerance to any contamination that may be in it, since they have been drinking the water since they were born.

19. What languages do the children know?
The children can speak Thai, but when they speak to each other they use dialect. They can speak a little English, some of the teachers know english and teach it to the students.

20. How does the school know the filtration system is working?
The students and teachers rely on taste, smell, and color of the water to determine if the system is working. The Mae Fah Luang Foundation comes to check on the system occasionally.

21. Do they want a way to test the water themselves?
Yes, right now the principal believes he can rely on physical appearance. However, he is concerned about the presence of chemicals in the water. The problem is not having enough budget to invest into ways to test the water.

22. Do they trust the water?
Slight distrust apart from physical features.

23. Can you tell us about the students hand washing habits?
The principal teaches all the students to wash their hands properly, but they don’t always do it since they are kids.

24. Is the school facing any problems? Are there any areas that need improvement?

In the past, the school had budget issues. The schools are given 3000 baht per month by the government for the children's lunches. In the past, they needed to allocate 1000 baht a month to buy bottled water for the students to drink. Now that the filtration system is installed, the school can keep the funding money for lunches.

Now the students use the water excessively. The students will commonly fill a bottle or cup, sip the water, and throw the rest of the water. They need to learn to conserve water. He would like to educate students to not waste water.

In terms of the water filtration systems, the only thing the principal wants is water testing method so that he can have full trust in the water.

An issue that the principal would like help with is with the trash generated by the school. They currently do not really have access to resources to get rid of the garbage. They compost some and burn some of the trash, but burning causes pollution and they would like to avoid it.

Interview 2:

1. Name

Tiya

2. What is your role in the school?

I am a teacher, and responsible for the administration for the whole school.

3. What ages/grades do you teach? How many students?

I teach grades 4, 5, and 6. There are around 20 students per class and each grade has one class. I teach Thai.

4. Do you and any of the other teachers live at the school?

All of the teachers live at school everyday, except for over summer break.

5. What is the water at the schools used for?

The filtered water from the filtration systems is used for cooking and drinking. The non-filtered water is used for other things like watering the plants.

6. How often do you not have water?

The school does not have problems with water supply. When there is no water left, the school calls the Mae Fah Luang foundation to open water from the tap and let it come to the school.

7. Do you know how to fix the water filtration systems?

I cannot fix the water systems herself, she does not have training. I am waiting for the two teachers who went to the orientation to teach me how to do it.

8. Do you drink the water from the tap at school? Why or why not?

Before installation of the filtration systems, the school bought three packages of bottled water a week. They now only buy one package of bottled water for the use of the teachers. This bottled water is for the teachers. The teachers can get too busy during the day and not have enough time to fill their bottles of water themselves. Therefore, they use bottled water. It can also be dark at night from their rooms to the tap, so it is more convenient to use the bottled water.

9. Do you trust the water at the school?

I trust the *tap in the back of the school more than the one near the cafeteria*. The water from the tap near the cafetaria can smell and have algae at times.
What did you think of the water before the filtration system was put in place?
Tiya and the other teachers did not trust the water from before at all. They would always buy bottled water for drinking.

10. Have you or anyone you know gotten sick from drinking the water at the school?

No one has gotten sick from drinking the water before or after the filtration systems were put in place.

11. How do the students drink the water? Do they use a water bottle, cup, or hands?

The students all have bottles provided by SCB that they use to drink the water. The teachers make sure the kids fill their bottles everyday.

12. Do the students wash their hands?

Only the younger kids (kindergarten) wash hands every time because they are supervised by teachers. The older kids don't usually wash their hands regularly. They want to play and don't really care about hygiene.

13. How do you tell if water is safe to drink?

I use the appearance, smell, and taste of the water.

14. Do you want a way to test the filtered water?

I would like an easy method to test the water.I had learned before in her university but I does not remember the method or how to do it. There's a salesman that sells water purifiers, he tests water and shows the testing method to her. I want to know how to test the water here but it is expensive.

15. Are there currently any problems with the filtered water?

The water from the tap near the cafeteria has a smell. The girl who works in the cafeteria doesn't trust the water and uses the tap at the back of school to get water. She is worried about the smell of the water she uses to cook with.

16. Is there anything you would like to see improved at the school?

No, everything is good.

17. Do you think the students waste water?

When the students are unsupervised then they will waste water. But usually they are good about drinking all of it.

Bumrung 87

Interview 1:

1. What is your name?

Wat

2. What is your role in the school? (Student, teacher, etc.)

Teacher

3. How long have you been at the school?

He has been teaching here for two years.

4. How many students and teachers are at the schools?

There are 120 students and 12 teachers.

5. Do the students/teachers/anyone live here?

The teachers, including her, live at school. She goes home in the summer.

6. What is the grade and age range for the school?

The students range from kindergarten to Grade 6.

7. Do the students have water outside of school / at home?

Around 40% of children live in nearby villages. The source of water for the village is the same as the school, the mountain reservoir water. The students drink directly from the source water without any filtration. The other 60% of students, she does not know anything about where they live, so she does not know.

8. What is the source of water?

Water collected from a dam at the top of the mountain and stored in concrete storage tanks. Another source is the mountain water, which is currently at low levels. During the rainy season, there is a lot of contamination in each tank. The tanks have a drain to remove all the water, which needs to be done to eliminate contamination.

9. When were systems installed?

Three months ago.

10. How often do the systems break?

They have not broken yet, the systems were installed only three months ago.

11. How often do you not have water?

He reported that there is currently not enough water. They do not know exactly why there is not enough water, so they do not know how to fix the problem. It may be due to the dry season. They will buy bottled water with the government lunch budget if there is no water.

12. Who fixes the water filtration systems when it is not working properly?

Wat is responsible for the maintenance and control of the filtration systems. He is one of the two teachers that went to the orientation, there is one other teacher at the school who knows. Wat made the manual that is being used at the schools right now.

13. How are the students drinking water? Bottle? Cup? Hands?

Each child has a water bottle provided by Siam Commercial Bank. There is a spare cup near the drinking water dispenser. The children clean their own cups and bottles during lunch time.

14. Has any student gotten sick from drinking water?

No one has gotten sick from the water before or after the filtration system was put in place.

15. Do you drink the water from the tap at school? Why or why not?

He will only drink the water from the drinking machine, because he knows that there is another filter before it that kills bacteria.

16. Do you trust the water at the school?

He trusts the water is clean because back at home he will drink unfiltered water directly from the source.

17. Do you drink the bottled water provided by the school? Why or why not?

Bottled water is donated to the school, and that is the only reason they have bottled water and will drink it.

18. How does the school know the filtration system is working?

They will only drink the water if it is clear. During the rainy season, the water is red indicating contamination .

19. Do you want a way to test the water themselves?

The water looks clean, but there is no way to know if there are bacteria or chemicals in the water.

20. Can you tell us about the students hand washing habits?

There are signs to tell the kids to wash their hands. The kids are taught to wash their hands,but there is no hand soap available. The only soap at the school is the soap used to wash dishes.

21. Is the school facing any problems? Are there any areas that need improvement?

There are not enough bathrooms at the schools. He would like to see the broken bathrooms repaired.

Interview 2:

1. What is your name?

Sea

2. What is your age and what grade are you in?

12 years old, Grade 5

3. What is your role in the school? (Student, teacher, etc.)

Student

4. What is the water at the schools used for?

She uses the water for drinking and washing the dishes.

5. How many times a day do you drink water?

She drinks the water often, every time she feels thirsty.

6. Do you have water outside of school / at home?

She has water at home, the foundation installed a filtration system at the village she lives in.

7. How often do the systems break? How often do you not have water? How often is the water not clean?

Not often, but at first when the system was installed the water from the filtration system had plastic smell from the pipe and sometimes they have less water flow from the system

8. Who fixes the water when it is not working properly?

The teacher is the one fixing the system.

9. Do you know how to fix the water?

She doesn't know how to fix it.

10. Do you drink the water from the tap at school? Why or why not?

She drinks the water from the filtration system now. At first she didn't drink it since it had a plastic smell.

11. Do you trust the water at the school?

She trusts the water now that there is a filtration system.

12. How are the students drinking water? Bottle? Cup? Hands?

She uses her water bottle to drink water, in the past she drank it from the school cups.

13. Have you or anyone you know gotten sick from drinking the water at the school?

No

14. Are there any other issues that you are facing at the school? Are there any areas that need improvement?

There are not enough bathrooms, and there are not enough bins to throw the garbage out.

Ban Mae Salap

1. What is your name?

Chee

2. What is your role in the school? (Student, teacher, etc.)
   Teacher
3. How many students and teachers are at the schools?
   There are 17 teachers and 177 students.
4. Do the students/teachers/anyone live here?
   All teachers live at school, but students live at home. I go home on the weekends.
5. What is the grade and age range for the school?
   We have kindergarten to up to 9th grade, middle school.
6. What is the water at the schools used for?
   Pumped groundwater is used to shower, wash dishes, wash clothes, and gardening. After filtration is it used for food and drinking.
7. Do the students have water outside of school / at home?
   I buy water and drink it. The students have a water container, they take water from the village water resource, I don't know if these are filtered.
8. What filtration systems does the school have?
   The school uses reverse osmosis.
9. When were systems installed?
   They were installed three to four years ago. The foundation changed filter three to four months ago.
10. How are the water systems being fixed right now?
    I fix the system myself. I wash out the storage tanks. If the filter needs to be changed then I contact the MFLF.
11. How often do the systems break?
    It doesn't break often. There are usually problems with the filter when the filter is not clean enough.
12. How often do you not have water?
    There are two water resources. Right now, the mountain water is not working. So, we are using groundwater. We do not have a problem of running out of water.
13. Who fixes the water filtration systems when it is not working properly? The MFLF comes when I contact them through text about a problem. There is no real schedule.
14. Do you know how to fix the water filtration systems?
    Yes, I have been the head of systems since November 2019. I learned through orientation with the foundation. One other teacher knows how to wash and clean the system and two students know how to wash and clean the systems.
15. Do the students like the smell, taste, appearance of the water?
    Sometimes water has smell, color, and visual contamination.
16. How are the students drinking water? Bottle? Cup? Hands?
    The children were provided with bottled from SCB, but they have been lost. They use their hands. Teachers teach the kids to wash their hands, but many kids don't care to do it.

We also make our own bottled water that the students drink. We sell it for 1 baht per bottle and then reuse the bottles. We plan to sell the filtered water. The teachers drink the bottled water that we will sell to the villagers. We want to make more money and job opportunities for the children.

17. Has any student gotten sick from drinking water?
    No.
18. How does the school know the filtration system is working?
    We can only test by physical appearance. We used to have a water quality kit, but it's now broken.
19. Do they want a way to test the water themselves?
    Yes, we want a water testing method.
20. Do you trust the water?
    My confidence is decreasing over time. But I need to drink it, so others trust the water.
    Can you tell us about the students hand washing habits?
    Is the school facing any problems? Are there any areas that need improvement?

Appendix H: Interview Questions for Mae Fah Luang Foundation

To better understand the history of system use and maintenance, we will be asking a series of relevant questions to the Mae Fah Luang Foundation, who have had experiences with the school water systems in the past. These questions will differ from the common water quality questions addressed to school communities because they will be more focused on technology and behavior rather than community attitudes and preferences.

1. When was the filtration system put in place?
2. When was the last time you monitored the...
    a. Source?
    b. Distribution system?
    c. Storage?
    d. Point of uses/ faucets?
    e. Filtration?
3. When was the last time you made a physical repair on the...
    a. Source?
    b. Distribution system?
    c. Storage?
    d. Point of uses/ faucets?
    e. Filtration?
4. Overall, how often do you monitor any part of the system?

5. Overall, how often do you repair any part of the system?
6. What do you suggest the community do differently to better maintain the system?

1. When was the filtration system put in place?
   It is due to the donor who donated the filtration systems to the schools. For example, some schools got the filtration systems around 2 years ago.
2. When was the last time you monitored the...
   a. Source?
   b. Distribution system?
   c. Storage?
   d. Point of uses/ faucets?
   e. Filtration?
      - They monitored all of them 3 months ago
3. When was the last time you made a physical repair on the...
   a. Source?
   b. Distribution system?
   c. Storage?
   d. Point of uses/ faucets?
   e. Filtration?

   <u>Ban Kha Yeang</u>
      - Changed PVC pipe 3 months ago
      - Changed the storage tank to be opaque color 3 months ago
      - Installed UF system before the point of uses 3 months ago

   <u>Bamrung 87</u>
      - Replaced carbon filtration and MF 3 months ago

   <u>Ban Mae Salap</u>
      - Installed UF systems before the point of uses 3 months ago
4. Overall, how often do you monitor any part of the system?
   Last time was 3 months ago, but not really often, just once in one to two years.
5. Overall, how often do you repair any part of the system?
   Last time was 3 months ago, but not really often.
6. What do you suggest the community do differently to better maintain the system?
   They are recently working on a manual of what and how to maintain the systems before giving it to the schools.

Appendix I: Communication Method

Our team will determine a communication method based on various factors that will be taken into consideration after the team's first site visit. The communication tactic that our team will choose will be based on what is most beneficial for each school's community.

Various communication methods can work for our project. Each method has its own strengths and weaknesses, which we will account for when making the final decision of which method to choose. The various communication methods that our team will investigate include: videos, demonstrations, infographics, and diagrams.

Videos provide an easy to follow method of communication. The video will not include an audio component due to the communication barrier. This way, the video will show how to maintain our solution. Videos can be watched many times, paused, fast-forwarded, and rewinded whenever the user needs, in order to correctly fix and maintain the system. It is a long-lasting solution that can be stored and utilized to maintain the site's water system. However, videos also have their downfalls. A recorded video may be hard to present to the community based on the technology available. The video method is rendered useless if there is no screen to present it on. Additionally, videos can often not load completely and freeze or lag during its presentation. The means of storing the video can also present a challenge. While a USB or a hard drive will play without connection to the internet, it is a physical object that can be lost or misplaced. A video stored in the cloud can be accessed from any device with the internet, but internet connection may not always be reliable. Another problem is that if the information presented in the video is unclear, the team cannot clarify anything that might be misconstrued.

Although videos may be a longer-lasting form of communication, demonstrations pose a more hands-on experience. With a demonstration, the entire community can participate and watch how to maintain the water system. During a live demonstration, individuals will be able to ask clarifying questions. Our team can clarify any confusion while we are on-site. After the demonstration, students and teachers will also have the ability to practice our solution themselves. They can perform the demonstration with our team present and can be guided through the process. It will be a hands-on learning experience for the community. The teachers present at the demonstration will also be able to understand the system maintenance first-hand and be able to teach students further down the line to aid in the upkeep of the system. Demonstrations will be put to good use while visiting the site; however, our team's knowledge of the system will leave the site with us. If a demonstration is given, it must be thorough and easy to follow. All the information that the team possesses should be communicated and practiced by the school community.

Infographics can be printed out and distributed as needed and will be available to place around the community. Therefore, the community including the teachers and the children can access the information. Additionally, advanced technological equipment will not be necessary. Currently, all schools around Doi Tung have received an infographic from our sponsor; however, the infographic is too text-heavy which has led to miscommunication and misunderstanding. Simplified words are needed to overcome the language barrier, but using just a picture to demonstrate may not cover all the information needed to repair and maintain the system fully.

While infographics are text heavy, diagrams are more picture oriented. Diagrams can be a helpful means of communication, especially for young children. These simplified drawings show how the system can be used and maintained. The simplification of the drawings also allows for a wider range of ages to be able to understand. Elementary students that attend the schools in Doi Tung can particularly benefit and understand the use of diagrams. Language does not need to be considered with diagrams as they are wordless and can be understood regardless of the language the user speaks. Since the diagrams are wordless, this presents the issue of information not being understood clearly. Pictures and schematics can lack important information that can not be represented visually. A user may also find it more difficult to follow a diagram than a video or another visual representation.

Appendix J: Data Analysis

Data Interpretation and Analysis

Data provided by SCB and collected by our team was organized into four separate categories: behavioral, technical, environmental and economic. Each school had its own set of data to ensure that the interpretation of one school's data did not directly impact our recommendations for another school. However, the problems identified at one location were generally considered and gave us the foresight to prevent these problems from arising at another location.

Behavioral data included interview responses as well as our observations of how people collected and used water. Interview responses provided insight into the school community members' preferences, attitudes, past experiences with the water, and indicated whether there are data trends relating to the interviewee's demographics or profession. Informal observations related to both the school water systems and direct interaction with the water sources were used to verify and support the interview data. In general, the behavioral data at all three of the schools pointed towards a similar attitude of the students and faculty. They all drink the tap water and have never encountered a sickness resulting from it, however they will drink bottled water when it is more convenient and when the water emits an uncharacteristic odor, taste or color.

Data that our team was provided with and observed about the filtration system, distribution system, and water quality were organized as the technical data. Data relating to the system was derived from our first-hand observations of the filter membranes, pipes, and storage, as well as interview responses relating to the frequency of maintenance. Data collected by a previous MFLF project was incorporated into the analysis, taking into consideration the season in which the data was taken.

We considered environmental limitations, especially pertaining to rainfall and weather patterns to create solutions that can be used by each school year-round. We were able to observe and record the current water levels of the sources. Changes in the natural environment can be both subtle and dramatic; therefore, we took into consideration many community members' understanding of their environment, as well as increasingly frequent weather anomalies. The 2020 dry season arrived early to the Doi Tung region, contributing to the community members' concern about potential upcoming insufficiencies of water.

Through observing our available filter and maintenance labor, we determined the financial limits of the project. Our sponsor's commitment to the community and this project indicated that economic feasibility would not pose an obstacle. However, the longevity of the project's impact is dependent on how easily the community members will be able to test the water and repair the system many years into the future. Because our team was committed to producing durable, long-term results, we considered economic availability for the community members.

Interpretation and Scoring

Each aspect evaluated through observations and interviews will be scored relative to one another to determine its relevance to the problems faced by each school. Then, the character of each response or observation will explain whether the aspect is present or abundant at each school.

Weighing Aspects

Each aspect of the sites' social, technical, environmental and economic features were weighted based on their malleability and relevance to the water filtration problem. Similar to the common approach in environmental analysis, unchanging aspects with maximum influence on water availability and potability, such as rainfall patterns, were weighted much higher than any other aspect. Although technical and environmental limitations presented obstacles that we had no ability to change, behavioral aspects and community preferences were prioritized. Any flexibility to overcome environmental, technical and economic challenges was exercised to meet the community's preferences. Therefore, these aspects were weighed less than behavioral aspects whenever possible.

Scoring Responses

Responses and data were categorized in three different ways: binary, spectral, and numerical. Binary data included any responses that were either affirmative or negative. Spectral data was defined as any data with a qualitative range of possible responses. For example, the water level of a source could be recorded against the average level as "very high, high, average, low, very low." Spectral data was recorded in odd sets to ensure that an average was an option. Finally, the numerical data included contaminant concentrations, water quality information, and weather patterns. We compared this data to recorded national standards and averages, and a percent of deviation was calculated.

Risk Assessment

Based on the resulting weight of each aspect and response, the team created a risk assessment table for each school to understand the consequences of infrequent maintenance, environmental hazards, water source contamination, or any other primary problem. The risk assessment table also included preventative measures to proactively avoid one school's primary problem from resulting at another site.

The data charts below detail and organize the prospective site observations and responses to interview questions for each school. The results are organized into four categories: behavioral, technical, environmental and economic.

Behavioral (Interview results, observation)

Subject	School	Age	Gender	Role in the School?	Encountered sickness?	Do you trust/drink the water?	Complaints or concerns?

A	Ban Kha Yaeng	-	M	Principle	N	Yes, a lot	Smell of plastic in the water due to PVC piping can contribute to distrust; sometimes children use their hands instead of cups
B	Ban Kha Yaeng	-	F	teacher	N	Sometimes, but often drinks bottled water if it is more convenient	Tap near the cafeteria has a smell, and the students can be wasteful of the water
C	Ban Kha Yaeng	-	F	kitchen worker	N	Yes, when the water is clear and has no smell	She would like a way to test the water
D	Ban Kha Yaeng	11	F	student	N	Yes, all the time	The water has had a funny smell in the past, but it's gone now
E	Bamrung 87	-	M	teacher	N	Yes, because back at home he will drink unfiltered water directly from the source	He wants ways to test or know the chemicals and bacteria in water. Also, there are not enough bathrooms at the schools. He would like to see the broken bathrooms repaired.
F	Bamrung 87	12	F	student	N	Yes, because there are water filtration systems	There are not enough bathrooms, and there are not enough bins to throw the garbage out.
G	Bamrung 87	13	F	student	N	Yes, after there are the filtration systems	-
H	Ban Mae Salap	-	M	teacher	N	Yes, but confidence decreasing over time but needs to drink so others trust the water	Sometimes water has smell color and visual contamination. And the problem of children behavior with throwing things away

I	Ban Mae Salap	15	F	student	N	Feel very confident with the current system.	Everything is okay except the smell
J	Ban Mae Salap		M	student	N	Yes	-

Technical (Contamination, System Components, etc.)

School #	Sample Site (Source, distribution, point of use)	Contaminant type	Growth in distribution system	Growth on filter	Tears in filter	Other Component Conditions
1	Surface water	Dissolved solids (heavy metals), turbid	No	No	No	Unused rainwater distribution
2	Surface water (Reservoir)	Algae Bacteria Nitrates	Yes	No	No	Very dirty filter; hadn't been changed in 3 months, pipes are arranged poorly
3	Undergroun d water	Nitrates, organic matter	No	No	No	Redundant system, broken UV filter, low pressure in tap water

Environmental (Seasonal/Weather Observations, Sources)

School #	How much rain per month?	Affect the water source?	Any problem from the system caused by seasonal?	Types water sources and how water transport ?
1	Low amount compared to seasonal average	Dry season comes faster	Lack of water through pipes	Small waterfall, bamboo, metallic and PVC piping
2	" "	Yes, less water through reservoir pipes	Pipes cannot self-maintain, algae clogging system and in storage contributes to community's skepticism	Reservoir, metallic and PVC piping
3	" "	Yes; less rainwater recharge	Lack of water through pipes	Groundwater, PVC piping

Economic (Resource Availability, Cost, Labor)

School #	How much water usage ?	Are they any workers (plumber or volunteer)?	Cost of the labor (if have)	Cost of electricity	Tools and equipments
1	Daily for 17 people; 5 days/week for 176 people	2 teachers maintain the system	Volunteer, student or teacher (unpaid)	Not recorded	Backwash tank
2	Daily for 17 people; 5 days/week for 193 people	2 teachers maintain the system	Volunteer, student or teacher (unpaid)	Not recorded	Broom, brush/sponge

3	Daily for 14 people; 5 days/week for 149 people	2 teachers have knowledge of maintenance; Kids go into the tanks to clean them as a chore	Volunteer, student or teacher (unpaid)	Not recorded	Broom, brush/sponge, several control panels

Appendix K: Water Testing Methods

Various water testing methods can aid in identifying the contaminants present in the schools' water. The methods listed in Table 4 will help our team identify these varying components and help us propose recommendations for the future.

Water Testing Method	Strengths	Weaknesses
pH [1]	Water testing with pH indicators is widely understood by many around the world in terms of toxicity. Additionally, it can be easily measured in the field to make quick decisions.	The setbacks of pH water testing is the use of calibration, or the requirement of routine chemical replacements. Additionally, it does not indicate the stability of the water in acidic or non-acidic conditions. Therefore, our team would have to mitigate acidity risks.
Biological Contaminants [2]	Water testing for biological contaminants utilizes various equipment that is easy to handle. The results are provided quickly and the test provides clean water that will protect human health from these pathogens. This test can detect contaminants that may not be noticeable to the human eye including microbiological pathogens (bacteria, viruses, protozoa, and worms), chemical contaminants (minerals and metals), and physical attributes of the water	The testing equipment for this method can be expensive. It may be hard to use this method in an area that is still developing. Additionally, parts of these testing kits and laboratories are sensitive and must be handled with extreme care. The equipment in the laboratories also requires trained individuals or experts to use.

[1] Degens, B. (2013). Acidic water discharge criteria for saline aquatic ecosystems in the western australian wheatbelt - a technical discussion paper. *Salinity and Land use Impacts Series,* (Report No. SLUI 65), 1-30. This report addresses the dangers of acidic groundwater and proposes various water tests that can help get the water back to baseline levels. The paper acknowledges the hazards of acidic waters and provides characterization methods to determine what risks pertain to each water source. It then suggests a guide for the criteria needed to maintain these acidic waters. One method for testing the acidity of water is using the pH scale. This method has the capability to identify acidity related to dissolved metals such as aluminum and iron. An additional method includes sampling for dissolved metals or the measurement of alkaline materials. With these methods, a net acidity can be developed and used in the analysis. This source can assist our team in testing the water for acidity in the Doi Tung schools.

[2] Stauffer, B., & Spuhler, D. (2019). Water quality testing. Retrieved from https://sswm.info/sswm-solutions-bop-markets/affordable-wash-services-and-products/affordable-water-supply/water-quality-testing
This online source recognizes the social problem of unsanitary drinking water on a global scale. It addresses several basic qualitative observations that can be made to quickly determine if water is consumable. The methods proposed are accessible and efficient. Despite these visual tests, there are still contaminants that are invisible to the human eye. Therefore, water must be tested further with reliable, sensitive methods that can detect biological pathogens. These tests can be done in the field with mobile laboratories or test kits. If these tests are not conducted in the field, samples of water can be collected and then sent to laboratories for testing. This source provides our team with a water testing method that can detect biological contaminants that cannot be seen. It can be utilized as a reference when we perform testing and analysis of the water at the Doi Tung schools.

	(temperature, color, smell, taste, and turbidity).	
Nitrate and Cadmium Levels[3]	Cadmium reduction method is cheap and can be used as a color comparison in the field with samples in any temperature in an easy way because it can convert nitrates to nitrites. These will react with other reagents and can be seen by the naked eye due to it changing to a red color. The nitrate electrode method with a meter is an accurate method. It can be plotted as a standard curve, which can be read easily. The curve is established by using an electric signal in a single mg/L of nitrate.	In the cadmium reduction method, the sample being treated needs to be clear. Nitrate electrodes and meters are expensive and very fragile. These electrodes must be carefully maintained and must be calibrated before each sample runs. This method needed to be done in room temperature, which is not suitable in field work.
Heavy Metals (Iron, Manganese, Lead, Fluoride, and Chloride)[4]	Inductively Coupled Plasma and Mass spectrometry(ICP-MS) is used to determine the presence of dissolved metals in groundwater, surface water and drinking water. The ICP is used to ionize the sample while the MS is used to separate and quantify ions.This equipment reduces testing time and complexity.	In ICP-MS, a rare high purity of reagent should be used. All samples need to be dissolved into liquid. Additionally, the lead sample matrix will suppress the element signal. This reduces the accuracy of the analysis.

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[3] Environmental Protection Agency. (2012). 5.7 nitrates. *Water: Monitoring & assessment* () United States Government. Retrieved from https://archive.epa.gov/water/archive/web/html/vms57.html
Nitrates are an essential nutrient for plants and used as fertilizer in agriculture. However, nitrates runoff into the water and contaminate drinking water. This book section from the Environmental Protection Agency reviews methods to test the nitrate levels in the water. The easiest way to measure nitrate levels is through a cadmium reduction reaction. Cadmium and nitrates react to create a red product, which can be analyzed either through a spectrophotometer or a color comparison. When determining water testing methods in Doi Tung, our team will consider this testing method for nitrates.

[4] Absolute Resource Associates. (2020). Testing for metal contamination in water & solid matrices. Retrieved from https://www.absoluteresourceassociates.com/services/metals.cfm
This online source notes the various metals that exist in our environment. It exemplifies how some metals are harmless while others can become hazardous to human health. Metals such as mercury and lead can be a detriment for humans health and the environment. If these metals or other metallic threats contaminate the water or soil, then various health risks arise. The Absolute Resource Associates' (ARA) laboratory and resources assist many in determining which contaminants are present in their environment. The site lists a variety of methods that can be used to determine if metal pollutants are present. Through the use of mass spectrometry (MS), the Inductively Coupled Plasma (ICP) can be used to determine the metal concentration in the soil or water. Cold vapor atomic absorption (CV-AA) can detect mercury through measuring the absorption of light which has the ability to convert mercury to a gaseous state. Finally, by breaking the chemical bonds of water, one can determine what metals have been dissolved in the water. This resource will assist our team in identifying which contaminants may be present in the water at the Doi Tung schools.

Total suspended solids (TSS)[5]	TSS is the portion of fine particulate matter in water. It measures similarly to turbidity but provides an actual weight for volume (mg/l). TSS is one of the most visible indicators of water quality.	Filtering and weighing water samples is time-consuming and difficult to measure accurately. It is precise and there is potential for error due to the fiber filter.
Biological oxygen demand (BOD)[6]	BOD quantifies the demand for readily available dissolved oxygen in a water source. This value is commonly used to determine the presence of carbonaceous (CBOD) or nitrogenous (NBOD) waste and biological contamination in a water source, and is dependent on temperature, time and the rate of decay of the waste (k). BOD can also be modelled in a first order equation against ultimate BOD (L_0) to find patterns of accumulation or loss of dissolved oxygen.	BOD tests take at least 5 days to complete because the accumulation or decrease of an oxygen demand over 5 days, denoted BOD_5, must be compared to the initial amount, denoted BOD_0. Along with patience, specialized equipment is required to measure initial and final dissolved oxygen.

Table 4. Water Testing Methods

[5] Fondriest. (2020). Turbidity, total suspended solids & water clarity. Retrieved from https://www.fondriest.com/environmental-measurements/parameters/water-quality/turbidity-total-suspended-solids-water-clarity/
This website describes turbidity, total suspended solids, and clarity of water. The turbidity of water can be measured in total suspended solids (TSS) and turbidity units by using turbidity meters and reported in units called a Nephelometric Turbidity Unit (NTU), but this method is difficult to measure accurately, so a new method has been created. However, the most accurate method of determining TSS is by filtering and weighing a water sample even though it is time-consuming. To measure water clarity, the Secchi depth will be used to find the value of water's turbidity based on depth that a black and white Secchi disc can be lowered into a body of water. The instrument is generally used in oceans, lakes and deep, low-flow rivers. However, to determine water in Doi Tung's schools from the sources and the distribution systems, the easiest way is to filter and weigh water samples for finding the TSS value.

[6] Environmental Protection Agency. (2012). 5.2 dissolved oxygen and biochemical oxygen demand. *Water: Monitoring & assessment* () United States Government. Retrieved from https://archive.epa.gov/water/archive/web/html/vms52.html
This website determines two methods that can be used to measure the dissolved oxygen (DO) and biochemical oxygen demand (BOD). If more oxygen is consumed than is produced, DO levels decline and some sensitive animals may move away, weaken, or die. Moreover, the DO levels vary to temperature and altitude. The cold water will hold more oxygen than warm water, and at high altitudes, water will hold less oxygen. For BOD, which is the value that can be affected by microorganisms. The slower, deeper waters might be higher for a given volume of organic and inorganic material than the levels for a similar site in highly aerated waters. For the first method, the Winkler Method will be used by titrating and recording the color of their changing by using a titrant which is a reagent that forms an acid compound. Another method is the meter and probe. This method will use an electronic device that converts signals from a probe that is placed in the water into units of DO in mg/L. Also, it can measure the temperature. However, DO meters are expensive compared to field kits that use the titration method. It has to be maintained carefully since it is more fragile, and repairs to a damaged meter can be costly. Our team will use dissolved oxygen and biochemical oxygen demand value to analyze water quality in Doi Tung.

Appendix L: 9-in-1 Infographic

The following infographic was created to explain the 9-in-1 water testing method that was recommended to the schools. The infographic is intended to be simple and user friendly.

Appendix M: Turbidity Infographic

The following infographic was created to explain the 9-in-1 water testing method that was recommended to the schools. The infographic is intended to be simple and user friendly.

Appendix N: Mentorship Program and Transition Document Guidelines

Teachers in Doi Tung Schools currently lack the proper training regarding the water filtration systems. The orientation led by the Mae Fah Luang Foundation was for two teachers from each school. The orientation reviewed basic water chemistry and a general overview of water filtration systems. It was expected that trained teachers would return to the schools and train the other teachers, however our team has identified that this transfer of knowledge has not occurred.

Teachers are assigned to work in Doi Tung for a period of two years. After the mandatory two year period has passed, the teachers leave Doi Tung to seek teaching opportunities elsewhere in Thailand. This turnover of teachers makes it difficult to have a constant source of knowledge about the filtration systems and their maintenance. A teacher in a managerial position for the water filtration maintenance informed us that he had taken over the position two months ago and had taught himself basic system cleaning based on manuals at the school. The previous individual left the school without training a successor. This creates disjoint in system maintenance and can lead to problems in drinking water supply and reliability. Our team recommends implementing a mentorship program along with a transition manual to facilitate teacher training and prevent gaps in knowledge.

We recommend that there should be two versions of the manual. Each school should have a paper copy of the manual. This paper copy can be easily referenced and transported, and it is accessible if there is no computer access. An online copy of the manual should be provided through the use of a cloud service, such as Dropbox. This online copy of the manual can include supplementary videos that demonstrate procedures such as conducting tests and replacing filtration system components.

Teachers at the Doi Tung will have additional responsibilities compared to typical teachers due to the filtration system maintenance. However, since the teachers are living at the schools and using the water, they have a personal stake in investing in the filtration system. The teachers will not have to spend money and time to get bottled water supply for their use and they will have a reliable and safe source of water.

Each school should establish one of the teachers as a manager. The manager will have responsibilities that oversee the maintenance of the filtration system. These responsibilities include the following:

- Learn about the filtration systems at the school, their function and purpose.
- Know how to conduct water quality checks.
- Ensuring that all water testing is completed according to the schedule.
- Ensuring that the data sheet is kept up to date.
- Performing regular checks of the system.
- Reporting problems to the Mae Fah Luang Foundation or other sources of help.
- Serving as the primary contact at the school regarding issues with the filtration systems.
- Training the next manager at the school prior to leaving.

- Ensuring that the training materials are relevant.
- Updating the responsibilities annually.

All of the teachers at the school should be responsible for the upkeep of the system. The teachers will have responsibilities that help with the maintenance of the filtration system. These responsibilities include the following:

- Know about the filtration systems at the school, their function and purpose.
- Know how to conduct water quality checks.
- Conduct water quality checks according to the schedule.
- Update the data sheet as needed.
- Report problems to the manager of the school.
- Help the manager as needed with the filtration of the system.
- If possible, teach the students about water chemistry and filtration.

1. Defining training requirements and develop programs
    a. Assess job requirements
    b. Design programs accordingly
    c. Training courses, seminars, have a variety of training materials
    d. Information on filtration systems
        i. What do they do?
        ii. What type of maintenance do they need?
    e. Information on tests
        i. What are they testing for?
        ii. What does this tell us?
        iii. What are normal levels?
        iv. When should action be taken?
        v. What action should be taken?
    f. Recording test results

As teachers learn testing methods and about filtration systems, a data sheet should be generated and updated. The data sheet as seen in Figure 36, will track which testing methods or maintenance procedure the teachers have learned. In this way, the teachers can track which techniques they still need to learn. Additionally, the teachers can identify which other teachers can help or aid them with a testing method or protocol.

As teachers who are appointed in the manager role leave the school, they will need to ensure that someone is prepared to replace them. The manager will need to transition the role to a new teacher. Ideally, the existing managers will begin training the new manager 3-6 months prior to one of the managers leaving the school. If this is not possible, then a second manager should be trained as soon as possible after one of the managers has left. The remaining original manager should oversee the training. If no existing managers are available then the teacher stepping into a managerial role should review the training and transition materials provided, which will provide all of the information needed, but lack the personal experiences that past managers have had. The new manager should have been at the school for at least a few months and have a good understanding of the testing methods and filtration systems used at the schools. The new manager should be planning to remain at the school for at least another year after stepping into the manager position.

	Date	Total Hardness (ppm)	Nitrate(ppm)	Free Chlorine (ppm)	pH	Total alkalinity	Iron(ppm)	Lead(ppm)	Copper(ppm)	Nitrite(ppm)
	Standard	100-200, less than 500	10	0.2	6.5-8.5	20-200	0.5	0.05	1.0	1.0
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Figure 36. Routine Checklist for Doi Tung Schools

Appendix O: Filtration Standards for Doi Tung Schools

For additional schools in the region, our team has formulated a standard set of criteria for their filtration systems and maintenance. We have concluded that where other types of membrane-based systems are present, reverse-osmosis filters are redundant. There are other filtration methods that we believe are accessible and effective for the communities.

(1) Sand filters have been in place at many of the schools even before the MFLF's aid, and they are a very inexpensive method of removing suspended solids and biological contaminants. These systems can be constructed on site, and the only form of maintenance required is to gently stir the top-layer of water once or twice per week. However, this system should be used only in the rainy season, because a consistent supply of water is needed for the device to function properly.

(2) Ultra-violet (UV) filtration systems are ideal for eliminating biological contaminants, but can be difficult to maintain and must be maintained properly to operate. Because of the threat of bacterial contamination and the skepticism about water quality that stems from the presence of bacteria, these systems are essential and can be used during any season.

(3) Both ultrafiltration (UF) and microfiltration (MF) devices use membranes to filter particulate matter and chemical contaminants from water. Our team noticed that while microfiltration systems were easier to maintain due to their placement, ultrafiltration systems that could filter our smaller dissolved particles were hidden behind metal water dispensers. Additionally, UF filters were placed immediately before the point of use, ensuring the reduction of any contamination introduced by the distribution system after primary filtration. Our team recommends a general standard that these two filtration devices should be aligned within the system immediately before the point of use, and in a position that is convenient for maintenance.

Our team believes that the transition documents and mentorship program recommended for the three schools that we investigated should additionally be suggested to all of the schools in Doi Tung. These recommendations will assist teachers in having a thorough understanding of how to maintain the filtration systems in place and constitute to the school districts independence from the MFLF.

Appendix P: Pipe Design

The K value of a pipe entrance is a mechanical property that determines the head loss of a pipe structure. Head loss is a realistic pressure loss of fluid moving through a system, and depends on containment material, dimensions and shape. This pressure loss can contribute to lower fluid velocity and momentum moving through the pipe, which can contribute to a lower amount of water reaching the pipe exit, in this case at the schools' filters. At Bamrung 87, the team noticed that the pipe entrance was inward projecting, with the highest K value (0.78) and therefore the highest potential head loss. We suggest that this entrance is re-designed to be chamfered to decrease the K value and head loss.

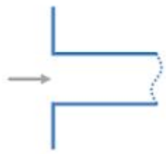
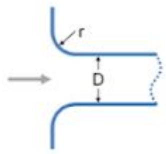
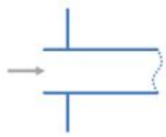
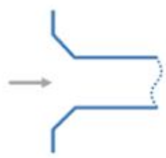
Type	Shape	r/D	K-value
Flush/Square-Edged		0	K = 0.5
Rounded		0.02	K = 0.28
		0.04	K = 0.24
		0.06	K = 0.15
		0.10	K = 0.09
		0.15+	K = 0.04
Inward Projecting/Re-entrant		-	K = 0.78
Chamfered		-	K = 0.25

Figure 36. Different pipe inlet designs; a higher *K* value contributes to greater pressure loss.

Appendix Q: Faculty Feedback on Recommendations

Section 1: Turbidity Test									
Name	**Position**	**How easily understood is this test?**	**Why?**	**How often would you perform this test?**	**Why?**	**How helpful would this test be in determining the water quality?**	**Why?**	**How helpful is the infographic for understanding the test?**	**Why?**
Sasarna Pongluang	teacher	3	-	4	so water quality match the standard	4	-	4	-
May Suwansrinon	teacher	3	-	4	so water quality match the standard	4	to ensure that the water is safe to drink	4	-
Darawan Sabanyha	teacher	3	-	4	so water quality match the standard	4	-	3	-
Piyanuch Sunatho	teacher	4	have no chance to try it yet	5	for good sanitation of every student and the people in the community	3	because it was a proof that this method can be used for testing	4	the current infographic is good but the improvement would made it better
Jongkolni Junthima	principal	5	the picture and manual (from infographic) made it more easily to understand	4	to ensure that the water has no bacteria inside	5	We can test for the water quality standard with the correct method and tool.	5	easy to follow when doing it in real life
Buncha Saemue	teacher	5	infographic was easy to understand	4	for water quality standard	4	has water quality data to proof that the water is clean	4	easy to understand because the picture is easy to follow
Kiettisuk Ridvichai	teacher	3	it can be over and over	5	to know the school water quality	1	need a more trust able tool	4	-

Section 2: 9-in-1 Water Quality Testing Strips

Name	Position	How easily understood is this test?	Why?	How often would you perform this test?	Why?	How helpful would this test be in determining the water quality?	Why?	How helpful is the infographic in understanding the test?	Why?
Sasarna Pongluang	teacher	3	-	4	-	4	-	4	-
May Suwansrinon	teacher	4	-	4	-	4	-	4	-
Darawan Sabanyha	teacher	3	-	4	-	3	-	4	-
Piyanuch Sunatho	teacher	4	color strip is easy to understand	5	to ensure the trust	4	because it is the scientific tools	4	the infographic is easy to understand
Jongkolni Junthima	principal	5	because the manual and the meaning of each parameter is stated there	4	so we can drink good quality water.	5	so we can fully trust the water from the system and we can stop buying the water bottle from the shop	5	specific meaning and the effect of each chemical present inside the water
Buncha Saemue	teacher	4	easy to understand	4	easy to test and can know the result instantly	4	it was a good quality tool	4	easy to understand
Kiettisuk Ridvichai	teacher	3	helpful for drinking water standard manual	5	to ensure the trust	4	trust	4	-

Section 3: TOC/COD/TDS									
Name	Position	How easily understood is this test?	Why?	How often would you perform this test?	Why?	How helpful would this test be in determining the water quality?	Why?	How helpful is the infographic in understanding the test?	Why?
Sasarna Pongluang	teacher	4	-	4	-	4	-	4	-
May	teacher	4	-	4	-	4	-	4	-

Suwansrinon									
Darawan Sabanyha	teacher	3	-	3	-	4	-	4	-
Piyanuch Sunatho	teacher	4	the explanation given is easy to understand	5	to ensure trust	4	trust the testing device	4	the infographic made is easier to understand
Jongkolni Junthima	principal	3	hard to understand because it has no picture	2	the tool is hard to used and has no visual demonstrate for it	2	feel that the device is below standard since the real one hasn't been shown	2	hard to understand, because the working process is not visual demonstrated
Buncha Saemue	teacher	4	understand	2	doesn't need to do the test of frequently if the system still working	4	the device is reliable	4	understood
Kiettisuk Ridvichai	teacher	4	-	3	-	3	-	4	-

Section 4: Mentorship Program						
Name	Position	How many times a week do you associate with other teachers and faculty in a social setting?	How interested are you in learning about the drinking water system maintenance?	How willing are you to learn from peers in a mentorship program as a mentee?	How willing are you to communicate knowledge to peers about the drinking water system maintenance as a mentor?	How effective do you think a mentorship program would be at assisting the transfer of knowledge from one group of teachers to the next?
Sasarna Pongluang	teacher	1-2 days per week	3	3	3	4
May Suwansrinon	teacher	3-4 days per week	4	4	4	4
Darawan Sabanyha	teacher	more than 4 days a week	4	4	4	4
Piyanuch Sunatho	teacher	more than 4 days a week	3	4	4	4
Jongkolni Junthima	principal	more than 4 days a week	5	5	5	5
Buncha Saemue	teacher	3-4 days per week	4	4	4	3

Kiettisuk Ridvichai	teacher	1-2 days per week	3	3	3	4

Section 5: Transition Document										
Name	Position	How often would you update these documents ?	Why?	How helpful would these documents have been when you first arrived?	Why?	How helpful are the guidelines in understand ing?	What should be included in transition documents ?	What can be improved?	How beneficial would the transition materials be for future teachers?	Why?
Sasarna Pongluang	teacher	3	-	3	-	3	-	-	3	-
May Suwansrinon	teacher	4	-	4	-	4	-	-	4	-
Darawan Sabanyha	teacher	3	-	4	-	4	-	-	4	-
Piyanuch Sunatho	teacher	4	this document can be given to other schools which faced the same problems	5	because the past filtration system is not clean and not working effectively	3	how to use the device and how to convert all the data	the way to eliminate to bacteria and heavy metal	4	the next turnover teacher can have an ideal on how to fix the system
Jongkolni Junthima	principal	5	we can learn how to fixed the system ourselves	5	it will be very useful to know all the part in the system and how to fix the system by ourselves	5	how the system work/effec t of contamina nt water/ how to test the water quality	how to filter the water with cheap equipment	5	since the teacher stay in Doi Tung for just a few year this document will be helpful for the future teacher
Buncha Saemue	teacher	3	for future knowledge	4	it good to know the school water system	4	-	-	4	-

Kiettisuk Ridvichai	teacher	3	easy to access	5	good for the future generation	2	video will be better than the paper version	make a video	3	so everyone understand the same concept

Section 6: Hand Washing Experiment												
Name	Position	How easily understood is this experiment?	Why?	How often would you perform this experiment?	Why?	How helpful would this test be in determining the water quality?	Why?	How helpful is the infographic in understanding the experiment?	What can be improved?	How accessible are the materials this experiment requires?	How useful would the student find this experiment in understanding the quality of the water?	Why?
Sasarna Pongluang	teacher	4	-	4	-	4	-	4	-	3	4	-
May Suwansrinon	teacher	4	-	4	-	4	-	4	-	4	4	-
Darawan Sabanyha	teacher	3	-	3	-	4	-	4	-	4	4	-
Piyanuch Sunatho	teacher	4	the tool is easy to find	5	every tools and material is easy to find	4	student will gain more awareness in hygiene	4	more sample should be include	4	4	student get to see with their own eyes
Jongkolni Junthima	principal	5	the student can learn by observing the bread themselves	1	the student get to learn about hygiene when they conduct the experiment in the first	5	student can see the effect of unclean hand	5	use the experiment to test for other thing	5	5	student get to do the experiment

					time							
Buncha Saemue	teacher	4	-	3	-	4	-	4	-	4	4	-
Kiettisuk Ridvichai	teacher	2	-	3	-	2	-	3	-	2	3	-

References

Abdel-Shafy, H. I., Mansour, M. S. M., & Abdel-Shafy, S. H. (2017). Chemical and biological contamination of drinking water as affected by residual chlorine deterioration and storing period: Case study in sinai, egypt. Eqyptian Journal of Chemistry, 60(6), 1067-1076. Retrieved from http://ejchem.journals.ekb.eg/article_3998.html

This journal article details how water storage methods in either open or closed tanks can affect the residual chlorine left in the tanks, which has a preventative effect against coliform bacteria and other biological contamination. In addition to the chlorine, the case study site in Sinai, Egypt, also had UV filters for disinfection after the assessment was conducted. Biological contamination is a problem at the schools in Doi Tung, and chlorine is one of the most widely available chemical disinfectants used for drinking water around the world. Additionally, free chlorine is one of the parameters measured by the 9-in-1 water quality test strips and its health effects are relevant. The article also concluded that open tanks should be avoided, not only due to exposure but also because the chlorine concentration was degraded quicker in an open tank, which is an important consideration when we are making maintenance recommendations.

Aksornkij, A. (2018). Changing EEC strategy to manage water risks. Retrieved from https://www.scbeic.com/en/detail/product/4782

This source encompasses a recent project that our sponsor partook in. The project is comprised of the expansion of Eastern Economic Corridor (EEC) industries in order to conserve water in regions of Thailand, particularly in El Nino. The strategy devised from this project was to receive the help of both the public and private sectors to develop supporting projects that will increase watershed capacity by over 350 million cubic meters. The project encourages industries to evaluate their current water requirements and develop a relationship with the local community so that water sources will be used in an efficient and balanced manner. The goal is to avoid the risk of water scarcity due to the irregular amounts of rainfall that the community receives. An additional aim is to eliminate potential conflicts between the two parties that utilize the same source. This project was enacted by our sponsor and corresponds to our project. The source takes a location in Thailand and addresses the problems arising in their water usage which corresponds with our project goal.

Arnasorn, A. (2017, June 4,). The dark side of iron. Retrieved from https://www.healthline.com/nutrition/why-too-much-iron-is-harmful

From this source, Ph.D. Atili Arnasorn describes the characteristic of iron and the effect of iron levels within the body. This includes iron toxicity and iron deficiency. Iron toxicity can be caused by taking iron in a high dose over a long period of time. An overload of iron can lead to cancers in both animals and humans. On the opposite side, low iron storage in the blood (iron deficiency) can cause or be a symptom of anemia. Since iron is one of the parameters of the 9-in-1 Detector, knowing the side effect of excessive or insufficient iron can explain the importance of the community's knowledge about this parameter.

Bratanova, B., Morrison, G., Fife-Schaw, C., Chenoweth, J., & Mangold, M. (2013). Restoring drinking water acceptance following a waterborne disease outbreak: The role of trust, risk perception, and communication. Journal of Applied Social Psychology, 43(9), 1761-1770. doi:https://doi.org/10.1111/jasp.12113

This online source details how to reaffirm confidence in the quality of drinking water after a recent waterborne disease outbreak. The source provides research that shows the correlation between risk perception, acceptance, and trust. They performed an analysis to determine if acceptance can be given without trust and understanding of the water risks based on the association model. They researched to see if trust influences the perception of risk and acceptance of water standards through utilizing the causal chain model. Their research resulted in placing support for the causal chain as opposed to the association chain. Thus, trust influences the perception of water risks and acceptance. The three are strongly correlated and cannot be distinguished from one another in the analysis. The study also showed that communication with the public had increased the trust and acceptance of the water post the disease outbreak. This source will aid our team in reaffirming confidence in the current water filtration systems within Doi Tung.

Butler, N. (2017, December 6,). Alkaline water: Health benefits and risks. Medical News Today Retrieved from https://www.medicalnewstoday.com/articles/313681

This article of the Medical News Today journal specifies the potential health advantages as well as the drawbacks of consuming alkaline water, which is any water with a pH above 7.0. It is believed that alkaline water may be linked to an increased rate of absorption of calcium in bones, thereby reducing an individual's chance of developing osteoporosis. In the field of oncology as well as digestive health, additional research would be needed to support claims that alkaline water can be used as treatments for cancer or acid reflux. On the contrary, very alkaline water with a pH above 10.0 can be corrosive to internal organs. This information is important for our understanding of the effects of alkalinity and pH changes on drinking water, which is measured by the 9-in-1 water quality meter.

Chan-urai, P. (2020). In Condon J., Jamal-Eddine S., Jenthamnukul P., Mahurkar K., Morton S., Sathirachawal J., . . . Tanaworaphun T.(Eds.), Interview with water filtration system manager. Doi Tung, Chiang Rai:

Chan-urai is a water filtration system maintenance employee of the Mae Fah Luang

Foundation. In our meeting with him, he informed our team that the contamination that we should be testing for specifically include pH, TDS, TOC, and COD. He requested that our team find viable testing methods for each and list recommendations on how the system can become more sustainable with the changing contamination based on the season. He explained the sources present at each school and their problems. The groundwater source was high in hardness and rust, and the surface water source had no hardness but contained organic substances. These substances made the water smell and change color. Chan-urai continued explaining his concern about the current filtration systems in place. He believes that carbon filters need to be changed more frequently. Additionally, the ultraviolet system (UV) has too short of a lifespan and does not successfully eliminate bacteria present in the water. Ultra-filtration (UF) has no wastewater; however, the more it is used the less water comes out of the system. Finally, he shared his concerns about the piping system present and how it now contains slime and bacteria. Our conversation with Chan-urai proved to be vital in identifying current problems in the filtration system.

Copper in drinking water. (2016). Retrieved from https://ww2.health.wa.gov.au/Articles/A_E/Copper-in-drinking-water

This website describes the characteristics of copper in drinking water, how the copper gets in the water and the side effects of copper when ingested. Copper is a reddish ductile metal that exists in the environment as rock and soil. At a low level, copper is naturally present in surface and groundwater. Long term exposure to copper through water consumption can cause liver damage. Short term exposure to a large concentration of copper ions can cause symptoms typical of food poisoning including headache, nausea, vomiting, and diarrhea. This information will help the community to understand the 9 in 1 detector and the consequences of an indication of high copper in the water.

Dietrich, A. (2006). Aesthetic issues for drinking water. Journal of Water and Health, 1(11-16) doi:10.2166/wh.2005.034

This source details the psychological effects that aesthetic or secondary water characteristics can have on how people view the safety of their water, despite any actual contamination. Although the source primarily focuses on Americans and European groups, the author explains how different regional groups can have thresholds of detection that are lower or higher for certain chemicals based on how long the chemicals have been present in the water. While we may detect secondary chemicals at unpleasant, but not harmful levels in the water at the schools around Doi Tung, we also need to consider the threshold of detection of the community members, and be sure that we are creating recommendations based on their preferences, along with their health.

Diskul na Ayudhya, P. (2020). In Condon J., Jamal-Eddine S., Jenthamnukul P., Mahurkar K., Morton S., Sathirachawal J., . . . Tanaworaphun T.(Eds.), Meeting with board member of the mae fah luang foundation. Doi Tung, Chiang Rai:

Dissolved oxygen and biochemical oxygen demand. (2012). Retrieved from https://archive.epa.gov/water/archive/web/html/vms52.html

This website determines two methods that can be used to measure the dissolved oxygen (DO) and biochemical oxygen demand (BOD). If more oxygen is consumed than is produced, DO levels decline and some sensitive animals may move away, weaken, or die. Moreover, the DO levels vary to temperature and altitude. The cold water will hold more oxygen than warm water, and at high altitude, water will hold less oxygen. For BOD, which is the value that can be affected by microorganisms. The slower, deeper waters might be higher for a given volume of organic and inorganic material than the levels for a similar site in highly aerated waters. For the first method, the Winkler Method will be used by titrating and recording the color of their changing by using a titrant which is a reagent that forms an acid compound. Another method is meter and probe. This method will use an electronic device that converts signals from a probe that is placed in the water into units of DO in mg/L. Also, it can measure temperature. However, DO meters are expensive compared to field kits that use the titration method. It has to be maintained carefully since it is more fragile, and repairs to a damaged meter can be costly. Our team will use dissolved oxygen and biochemical oxygen demand value to analyze water quality in Doi Tung.

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Mae Fah Luang Foundation. (2011). ภาพรวมพัฒนาการของประชากรบนดอยตุง - overview of population development in doi tung. Retrieved from http://www.tescogis.com/doitung/detail.php?WP=qmSZAJ0kM190p2y3rTIjoz1Cq5OZhJ3tM3y0MJyerUWjMJ10q3AZLJ1gMlM0BJxjrQSjG22Dq7yZ4T1xM2y0qTyhrTSjqT1hq29ZL20zMmS0G2zDrYyj4T13q29ZnT1GM2I0M2yurSNo7o3Q

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Mogg, R. (2006, March). Reclaiming the golden triangle: Under a successful two-pronged strategy targeting thailand's thriving drug trade across the infamous golden triangle, sustainable agriculture is successfully supplanting poppy growing by providing alternative profit and a better lifestyle for farmers in the rugged region. Ecos, 129, 8+. Retrieved from http://www.ecosmagazine.com/?act=view_file&file_id=EC129p8.pdf

The Golden Triangle region encompasses borders of northern Thailand, southern Laos, and southern Myanmar. This region had a strong reputation as canter for illegal drug production. In Doi Tung, slash-and-burn cultivation had ruined the topsoil. Forests had been cleared to make space for opium poppy farms. In 1982, the Princess Mother decided to establish the Development Project to improve the lives of the villagers. The Doi Tung foundation helped reduce the opium farming in the region by providing the farmers with alternative crops that provided a steady source of income. The land use in the Doi Tung region needs to be considered since it will impact the quality of the water and any

contamination that is present.

Nitrate and nitrite in drinking-water. (2011). ().World Health Organization. Retrieved from https://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf

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Pelican Water Systems. (2019). Total dissolved solids (TDS) - good or bad? . Retrieved from https://www.pelicanwater.com/blog/total-dissolved-solids-tds-good-or-bad/

The web page published by Pelican Water Systems describes the disadvantages and benefits of certain levels of total dissolved solids in drinking water. Both extremely high and low levels of TDS are potentially unhealthy for consumption; low levels may be “over-hydrating,” while high levels may indicate the presence of heavy metals or particulates. The source describes the measurement of TDS to be a relatively ambiguous measurement, because it does not specify the type of solids found in the water. The information presented on this web page facilitates our data analysis in terms of the measurements of TDS in the schools’ drinking water.

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Sengupta, P. (2013). Potential health impacts of hard water. International Journal of Preventative Medicine, 4(8), 866-875. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3775162/

This peer-reviewed article from the International Journal of Preventative Medicine illustrated the long-term effects of consuming hard water. The article argues that this particular type of alkalinity can lead to cancer and cardiovascular disease. However, external influences such as socioeconomics and genetic predispositions that may also impact these outcomes are unspecified or admitted to be unclear. The findings of this research are relevant to our understanding of the results of the 9-in-1 water quality meter, which gauges water hardness.

Ward, M. H., Jones, R. R., Brender, J. D., deKok, T. M., Weyer, P. J., Nolan, B. T., . . . van Breda, S. G. (2018). Drinking water nitrate and human health: An updated review. International Journal of Environmental Research and Public Health, 15(7), 1557. doi:10.3390/ijerph15071557

This article addresses the health issues associated with nitrate contamination in drinking water. When nitrates are consumed through water, the compounds are converted into teratogens and carcinogens, which cause cancers and birth-defects. Nitrates are commonly found in fertilizers, therefore there is a higher risk of nitrate run-off into water sources in areas with agricultural crops. Agriculture is a common source of income for the residents of Doi Tung. Our sponsor, Siam Commercial Bank, has informed us that the use of fertilizers has contaminated the water at Doi Tung with nitrates. Our team will need to ensure that the water at Doi Tung meets drinking water standards for nitrates, and understand the severity of the presence of nitrates in the drinking water source.

Whitehead, P. (2020). Total organic carbon (TOC) and its measurement. Retrieved from https://www.elgalabwater.com/blog/total-organic-carbon-toc

An informational source published by Dr. Paul Whitehead describes the chemistry behind total organic carbon in water, as well as its relationship with other characteristics of drinking water. Total organic carbon in water indicates the presence of organic matter and waste present that may pose as a health hazard to consumers. However, TOC tests are often used in tandem with other detection methods because they cannot accurately specify contaminants in the water. The information presented on this webpage facilitates our data analysis in terms of the measurements of TOC in the schools' drinking water.

Zhang, J., & Xu, L. C. (2016). The long-run effects of treated water on education: The rural drinking water program in china. Journal of Development Economics, 122, 1-15. doi:10.1016/j.jdeveco.2016.04.004

This study was conducted to determine the effects of a water treatment program on education. The area affected by the water treatment program was rural, and after implementation of the program, the entire area had access to potable water. The study

looked at the changes in education after the implementation of the program. Students went to school for an average of one year more than they did prior to the program. In addition, girls benefited from the program more than boys, because boys had an education advantage prior to the implementation of the water treatment. This study reinforces the fact that access to water increases educational opportunities for all students and is beneficial to the development of a community.

References

Abdel-Shafy, H. I., Mansour, M. S. M., & Abdel-Shafy, S. H. (2017). Chemical and biological contamination of drinking water as affected by residual chlorine deterioration and storing period: Case study in sinai, egypt. *Eqyptian Journal of Chemistry, 60*(6), 1067-1076. Retrieved from http://ejchem.journals.ekb.eg/article_3998.html

This journal article details how water storage methods in either open or closed tanks can affect the residual chlorine left in the tanks, which has a preventative effect against coliform bacteria and other biological contamination. In addition to the chlorine, the case study site in Sinai, Egypt, also had UV filters for disinfection after the assessment was conducted. Biological contamination is a problem at the schools in Doi Tung, and chlorine is one of the most widely available chemical disinfectants used for drinking water around the world. Additionally, free chlorine is one of the parameters measured by the 9-in-1 water quality test strips and its health effects are relevant. The article also concluded that open tanks should be avoided, not only due to exposure but also because the chlorine concentration was degraded quicker in an open tank, which is an important consideration when we are making maintenance recommendations.

Aksornkij, A. (2018). Changing EEC strategy to manage water risks. Retrieved from https://www.scbeic.com/en/detail/product/4782

This source encompasses a recent project that our sponsor partook in. The project is comprised of the expansion of Eastern Economic Corridor (EEC) industries in order to conserve water in regions of Thailand, particularly in El Nino. The strategy devised from this project was to receive the help of both the public and private sectors to develop supporting projects that will increase watershed capacity by over 350 million cubic meters. The project encourages industries to evaluate their current water requirements and develop a relationship with the local community so that water sources will be used in an efficient and balanced manner. The goal is to avoid the risk of water scarcity due to the irregular amounts of rainfall that the community receives. An additional aim is to eliminate potential conflicts between the two parties that utilize the same source. This project was enacted by our sponsor and corresponds to our project. The source takes a location in Thailand and addresses the problems arising in their water usage which corresponds with our project goal.

Arnasorn, A. (2017, June 4,). The dark side of iron. Retrieved from https://www.healthline.com/nutrition/why-too-much-iron-is-harmful

From this source, Ph.D. Atili Arnasorn describes the characteristic of iron and the effect of iron levels within the body. This includes iron toxicity and iron deficiency. Iron toxicity can be caused by taking iron in a high dose over a long period of time. An overload of iron can lead to cancers in both animals and humans. On the opposite side, low iron storage in the blood (iron deficiency) can cause or be a symptom of anemia. Since iron is one of the parameters of the 9-in-1 Detector, knowing the side effect of excessive or insufficient iron can explain the importance of the community’s knowledge about this parameter.

Bratanova, B., Morrison, G., Fife-Schaw, C., Chenoweth, J., & Mangold, M. (2013).

Restoring drinking water acceptance following a waterborne disease outbreak: The role of trust, risk perception, and communication. *Journal of Applied Social Psychology, 43*(9), 1761-1770. doi:https://doi.org/10.1111/jasp.12113

This online source details how to reaffirm confidence in the quality of drinking water after a recent waterborne disease outbreak. The source provides research that shows the correlation between risk perception, acceptance, and trust. They performed an analysis to determine if acceptance can be given without trust and understanding of the water risks based on the association model. They researched to see if trust influences the perception of risk and acceptance of water standards through utilizing the causal chain model. Their research resulted in placing support for the causal chain as opposed to the association chain. Thus, trust influences the perception of water risks and acceptance. The three are strongly correlated and cannot be distinguished from one another in the analysis. The study also showed that communication with the public had increased the trust and acceptance of the water post the disease outbreak. This source will aid our team in reaffirming confidence in the current water filtration systems within Doi Tung.

Butler, N. (2017, December 6,). Alkaline water: Health benefits and risks. *Medical News Today* Retrieved from https://www.medicalnewstoday.com/articles/313681

This article of the Medical News Today journal specifies the potential health advantages as well as the drawbacks of consuming alkaline water, which is any water with a pH above 7.0. It is believed that alkaline water may be linked to an increased rate of absorption of calcium in bones, thereby reducing an individual's chance of developing osteoporosis. In the field of oncology as well as digestive health, additional research would be needed to support claims that alkaline water can be used as treatments for cancer or acid reflux. On the contrary, very alkaline water with a pH above 10.0 can be corrosive to internal organs.

This information is important for our understanding of the effects of alkalinity and pH changes on drinking water, which is measured by the 9-in-1 water quality meter.

Chan-urai, P. (2020). In Condon J., Jamal-Eddine S., Jenthamnukul P., Mahurkar K., Morton S., Sathirachawal J., . . . Tanaworaphun T.(Eds.), *Interview with water filtration system manager*. Doi Tung, Chiang Rai:

Chan-urai is a water filtration system maintenance employee of the Mae Fah Luang Foundation. In our meeting with him, he informed our team that the contamination that we should be testing for specifically include pH, TDS, TOC, and COD. He requested that our team find viable testing methods for each and list recommendations on how the system can become more sustainable with the changing contamination based on the season. He explained the sources present at each school and their problems. The groundwater source was high in hardness and rust, and the surface water source had no hardness but contained organic substances. These substances made the water smell and change color. Chan-urai continued explaining his concern about the current filtration systems in place. He believes that carbon filters need to be changed more frequently. Additionally, the ultraviolet system (UV) has too short of a lifespan and does not successfully eliminate bacteria present in the water. Ultra-filtration (UF) has no wastewater; however, the more it is used the less water comes out of the system. Finally, he shared his concerns about the piping system present and how it now contains slime and bacteria. Our conversation with Chan-urai proved to be vital in identifying current problems in the filtration system.

Copper in drinking water. (2016). Retrieved from https://ww2.health.wa.gov.au/Articles/A_E/Copper-in-drinking-water

This website describes the characteristics of copper in drinking water, how the copper gets in the water and the side effects of copper when ingested. Copper is a reddish ductile metal that exists in the environment as rock and soil. At a low level, copper is naturally present in surface and groundwater. Long term exposure to copper through water consumption can cause liver damage. Short term exposure to a large concentration of copper ions can cause symptoms typical of food poisoning including headache, nausea, vomiting, and diarrhea. This information will help the community to understand the 9 in 1 detector and the consequences of an indication of high copper in the water.

Dietrich, A. (2006). Aesthetic issues for drinking water. *Journal of Water and Health, 1*(11-16) doi:10.2166/wh.2005.034

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*. Bangkok:

Sengupta, P. (2013). Potential health impacts of hard water. *International Journal of Preventative Medicine, 4*(8), 866-875. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3775162/

This peer-reviewed article from the International Journal of Preventative Medicine illustrated the long-term effects of consuming hard water. The article argues that this particular type of alkalinity can lead to cancer and cardiovascular disease. However, external influences such as socioeconomics and genetic predispositions that may also impact these outcomes are unspecified or admitted to be unclear. The findings of this research are relevant to our understanding of the results of the 9-in-1 water quality meter, which gauges water hardness.

Ward, M. H., Jones, R. R., Brender, J. D., deKok, T. M., Weyer, P. J., Nolan, B. T., . . . van Breda, S. G. (2018). Drinking water nitrate and human health: An updated review. *International Journal of Environmental Research and Public Health, 15*(7), 1557. doi:10.3390/ijerph15071557

This article addresses the health issues associated with nitrate contamination in drinking water. When nitrates are consumed through water, the compounds are converted into teratogens and carcinogens, which cause cancers and birth-defects. Nitrates are commonly found in fertilizers, therefore there is a higher risk of nitrate run-off into water sources in areas with agricultural crops. Agriculture is a common source of income for the residents of Doi Tung. Our sponsor, Siam Commercial Bank, has informed us that the use of fertilizers has contaminated the water at Doi Tung with nitrates. Our team will need to ensure that the water at Doi Tung meets drinking water standards for nitrates, and understand the severity of the presence of nitrates in the drinking water source.

Whitehead, P. (2020). Total organic carbon (TOC) and its measurement. Retrieved from https://www.elgalabwater.com/blog/total-organic-carbon-toc

An informational source published by Dr. Paul Whitehead describes the chemistry behind total organic carbon in water, as well as its relationship with other characteristics of drinking water. Total organic carbon in water indicates the presence of organic matter and waste present that may pose as a health hazard to consumers. However, TOC tests are often used in tandem with other detection methods because they cannot accurately specify contaminants in the water. The information presented on this webpage facilitates our data analysis in terms of the measurements of TOC in the schools’ drinking water.

Zhang, J., & Xu, L. C. (2016). The long-run effects of treated water on education: The rural drinking water program in china. *Journal of Development Economics, 122*, 1-15. doi:10.1016/j.jdeveco.2016.04.004

This study was conducted to determine the effects of a water treatment program on education. The area affected by the water treatment program was rural, and after implementation of the program, the entire area had access to potable water. The study looked at the changes in education after the implementation of the program. Students went to school for an average of one year more than they did prior to the program. In addition, girls benefited from the program more than boys, because boys had an education advantage prior to the implementation of the water treatment. This study reinforces the fact that access to water increases educational opportunities for all students and is beneficial to the development of a community.