Improving Water Quality in the Villages of Himachal Pradesh

Revising Monitoring and Treatment Techniques

An Interactive Qualifying Project
submitted to the Faculty of
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in partial fulfilment of the requirements for the
degree of Bachelor of Science

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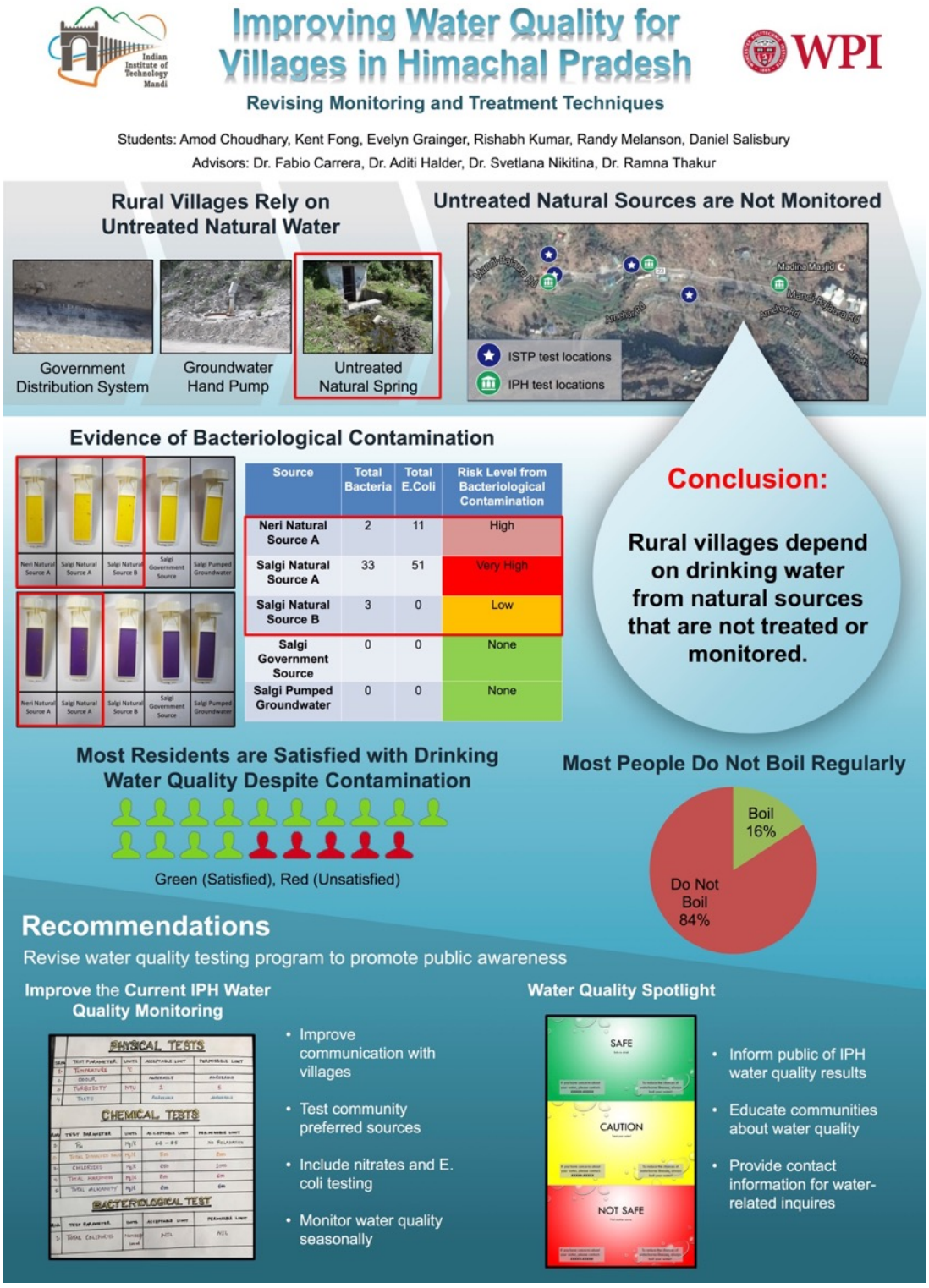
Abstract

The goal of our project was to assess the quality, monitoring, and treatment methods of drinking water in rural villages of Himachal Pradesh. To realize this goal we assessed local perceptions and behaviors regarding drinking water. Next, we investigated the relationship between local water quality and public health. Finally, we measured the levels of water contamination. The major finding was bacteriological contamination in untreated natural water sources. This project resulted in recommendations to improve the current water quality-testing program to promote public awareness regarding the safety of untreated natural water sources.

Executive Summary | Poster



Chapter 1: Introduction

India has significant ground and surface water pollution in both rural and urban areas. Agricultural and industrial chemical runoff in addition to improper sewage treatment are major contributors to this pollution. It is estimated that water contamination causes the death of up to 500,000 children under the age of five annually (Ganapati, 2003). It is necessary to control pollution and to set up a strict water quality monitoring system to reduce the incidence of disease. Developing communities, especially in the rural areas of India, often lack the ability to effectively monitor and maintain good quality drinking water.

There are many rural villages in the Mandi district of Himachal Pradesh that currently lack the infrastructure to monitor and maintain drinking water quality. The Irrigation and Public Health (IPH) department is responsible for testing and monitoring for twelve potential water contaminants annually or biannually. With only one to two yearly tests, it is not feasible to get a clear and consistent view of the overall water quality in these villages.

The rural villages in the area depend on three main sources for drinking water: groundwater from government hand pumps, tap water from the government distribution system, and untreated natural water from springs. Despite public preference for untreated natural sources, the government only treats and monitors hand pumps and the distribution system. Untreated natural sources may contain dangerous contaminants unknown to the residents. Thus, in rural villages, there is a need to monitor untreated natural water sources to determine if public water supplies are safe to drink.

This study is intended to assess water quality treatment and monitoring in rural Himachal Pradesh villages. To accomplish this goal we assessed local perceptions and behaviors regarding drinking water. We then investigated the relationship between local water quality and public health. Finally we quantified the levels of water contamination. By accomplishing these three objectives we provided a more complete water quality assessment of rural villages than is possible through the current practices. From these results we **provided the government with an alternative water quality testing plan, developed a public awareness campaign**, and **compared and designed optimal water treatment methods** that could be implemented in the rural villages.

Chapter 2: Background

Two rural villages of the Mandi district were identified for the purposes of this study: Salgi and Neri. The yellow and purple faucets on Figure 1 represent the locations of Salgi and Neri respectively, while IIT-Mandi South Campus is represented by the blue faucet. The rural villages depend on the government distribution system, ground water, and untreated natural sources for their drinking water. Table 1 provides additional information regarding population size and number of drinking water sources by type.

Figure 1 Map identifying locations of Salgi, Neri, & IIT-Mandi

Village	Approximate Population	Identified Water Sources
Salgi	160	➔ 1 government distribution system from natural spring ➔ 3 ground water hand pumps ➔ 3 unofficial natural sources
Neri	100	➔ 2 natural springs ➔ 1 ground water hand pump ➔ 1 surface water (tributary of Uhl River) ➔ 1 government distribution system

Table 1: Community population & water sources

The map in Figure 2 indicates the locations of the three major types of drinking water sources: government distribution systems, ground water hand pumps, and untreated natural sources in Salgi and Neri.

Figure 2: Map of the variety of drinking water sources available in Salgi (left) and Neri (right)

2.1 Types of Water Contamination

Water contamination for these drinking water sources can be categorized as bacteriological, chemical, or physical. Given that bacterial and chemical contamination are the more dangerous and problematic, we elected to only focus on those.

2.1.1 Bacteriological Contamination

Bacteriological contamination is defined by the number of harmful and benign microorganisms within a water sample. Developing rural communities are especially vulnerable to bacteriological contamination due to improper sanitation and waste management. Bacterial contamination causes a number of gastrointestinal diseases that can cause major public health issues. Many harmful microorganisms originate from human and animal fecal waste. One gram of feces can contain 10 million viruses, 1,000,000 bacteria, 1,000 parasite cysts and 100 parasite eggs that can have detrimental human health impacts if ingested (Mihelcic, 2009). E. coli is a bacterium that is exclusively found in mammal digestive tracts and can be used to indicate the presence of other disease-causing microorganisms. By measuring bacteriological contamination, a history of the water quality can be hypothesized due to the stable nature of bacterial growth. This study measured bacteriological contamination by determining the presence of total bacteria and E. coli in drinking water sources in Salgi and Neri.

2.1.2 Chemical Contamination

This study also quantified chemical contamination. Organic chemicals are often found in water as a result of human activities that include agriculture and industry. Inorganic chemicals are often present in water due to drilling and mining that releases naturally occurring, but toxic, heavy metals. Organic and inorganic chemicals are dangerous to health and result in a multitude of diseases, generally from long-term exposure. When compared to bacteriological contamination, measurements of chemical contamination are vulnerable to periodic spikes due to human activity and cannot be reliably analyzed without long-term monitoring to indicate water quality. As a result, we focused on chemical parameters previously tested by the Irrigation and Public Health (IPH) department to provide a comparison to our results.

2.2 Government Water Quality Monitoring in Mandi District

Water quality standards created by local or national governing bodies regulate the maximum levels of contamination allowed in drinking water sources. In the Mandi region, the IPH department is in charge of monitoring water sources for contamination levels. To measure water quality, the IPH department conducts a chemical analysis twice a year, and a bacterial analysis once a year. This testing includes three sampling sites in Salgi and two sampling sites in Neri seen in Appendix A. The twelve specific contaminants that they measure can be found in Appendix B. The IPH, however, only conducts water quality testing on official government-

operated water sources. Government sources include tanks, distribution systems, and hand pumps but not the untreated natural waters sources.

2.3 Known Water Treatment Techniques in Mandi District

In developing rural areas such as Salgi and Neri, people often collect drinking water from untreated natural water sources. Untreated sources are risky because they frequently contain bacteriological contamination that manifests in gastrointestinal illnesses. To reduce morbidity, the water can be treated at the source or at the point-of-use. In rural developing communities, methods of treatment that purify contaminants at the point-of-use have been proven to be more effective and economically feasible at reducing diarrheal illnesses than the treatment at the water source. In the Mandi District, chlorine, heat, filtration, and neem oil are locally available technologies that disinfect water. Some of these technologies are considered for the water treatment prototype discussed in Chapter 5.

2.3.1 Chlorine

Chlorine is an effective and affordable disinfection method. Chlorination is most effective at treating water sources with a low turbidity and a pH lower than 8. Disinfection by chlorine occurs via primary disinfection and secondary disinfection. The primary disinfection inactivates microbiological activity and the secondary disinfection refers to the residual chlorine that remains in treated water. Residual chlorine is preferable to protect against future contamination.

2.3.2 Heat

Heat is another effective disinfection method and it does not require the use of chemicals such as bleach that can leave an undesirable taste. Boiling water destroys all types of microorganisms by raising the water temperature to 100°C. This approach ensures that the water is safe but requires enough energy to heat the water. Additionally, it does not prevent future biological growth.

Water has to reach only 70°C to kill most microorganisms. The point at which bacteria die is called the pasteurization temperature. Devices have been created that help indicate when water has reached the pasteurization temperature. These devices have solidified wax situated at the top end of a tube. Once water has reached 70°C, the wax melts and fall to the bottom of the tube, indicating water has been pasteurized. A water pasteurization indicator is considered for a water treatment design in Chapter 5.

2.3.3 Filtration

Filtration is a method that can be used to reduce turbidity and bacteriological contamination. Through the method of slow-sand filtration, a non-uniform bed of sand filters out

the majority of bacteria. Within the filter, a biological layer called the Schmutzdecke forms, acting as a mechanism to degrade organic matter. A slow sand filter can be constructed at the home level as an effective means of water treatment. In Salgi and Neri, the government employs this method for the water that feed the distribution system. To improve the effectiveness of a slow sand filter, activated charcoal can be added as an additional layer that is able to remove chlorine, sediments, volatile organic compounds and odor from water.

2.3.4 Neem Oil

Neem oil has also been tested as a method of water treatment. The oil has been shown to significantly reduce the number of total coliforms within a water sample. It reduces the number of coliforms by disrupting the cell membrane of bacterial contaminants. However, neem oil does not effectively remove all coliforms. As a result, neem products cannot be used as a sole means for bacterial disinfection (Mathews, 2009). The bitter taste of neem makes it an undesirable method of water treatment.

Chapter 3: Methodology

Three objectives were identified in order to complete an assessment of drinking water quality in Salgi and Neri. The three primary objectives investigate the perceptions and behaviors regarding water quality, the water-health relationship in the villages, and the water quality of the various sources. The objectives and methodologies can be found in Figure 3.

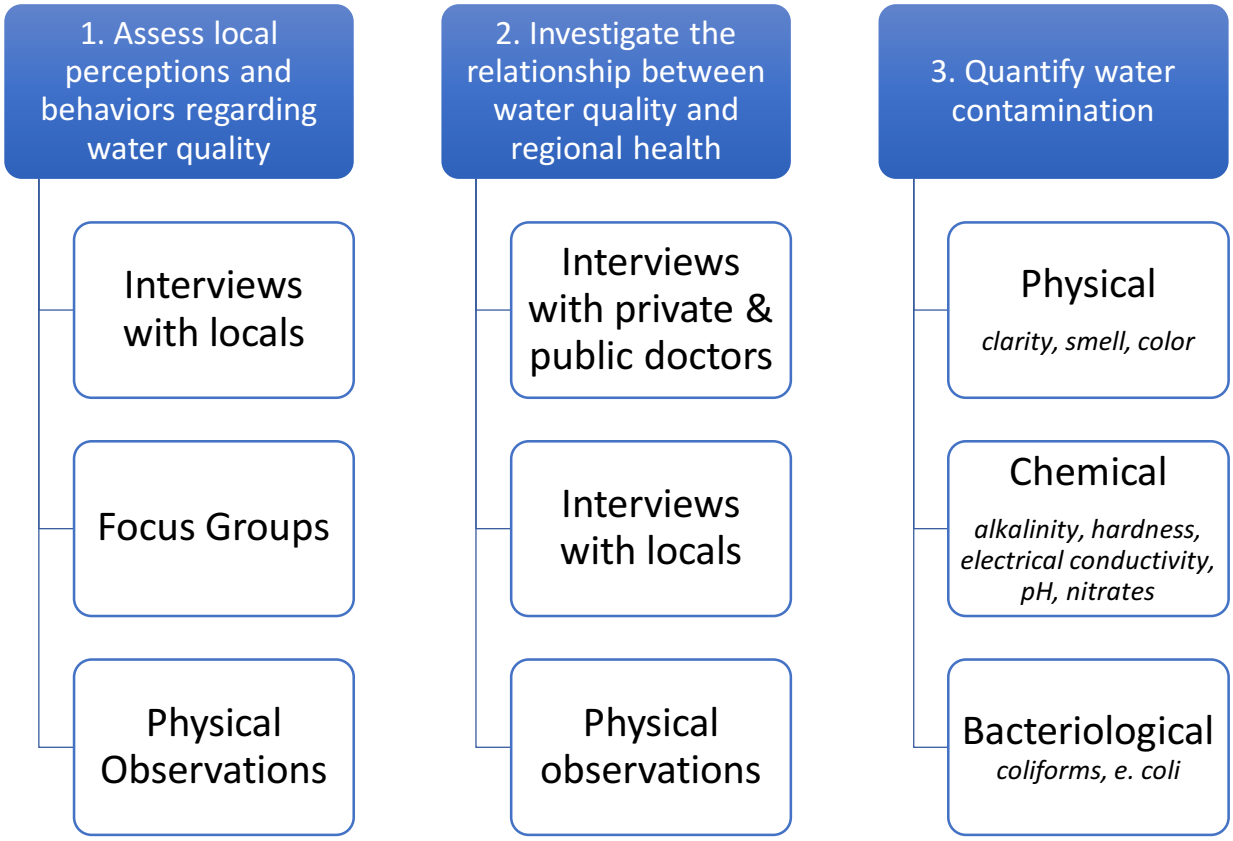


Figure 3: Objectives and Methodologies

3.1 Assessing Local Perceptions and Behaviors Regarding Drinking Water Quality

Local **perceptions of drinking water quality can help reveal behaviors that may be affecting water quality**. To assess the perceptions and behaviors of the villages, we conducted interviews, a men's focus group, surveys with local schools, and recorded observations of how people interacted with their water sources.

3.1.1 Assessing the Government Approach to Water Quality Monitoring

The IPH department is responsible for the development, operation, and maintenance of drinking water supply schemes. We interviewed Mr. Hemraj Thakur, senior chemist, and Miss

Aprajita, consultant chemist, at the IPH department to learn more about the government's involvement in protecting water quality. The interview questions can be found in Appendix C and the results of the interview can be found in Appendix D.

3.1.2 Perceptions of Water Quality in Rural Villages

Surveys and physical observations were conducted at nineteen homes in the rural villages of Salgi and Neri. The locations of the household interviews in Salgi and Neri can be seen in Appendix E. Figure 4 outlines the objectives and types of questions asked within the household interviews. Physical observations provided supplementary information to our interviews. All interview questions asked within the household and their resulting can be found in Appendix F and the physical observations sheet can be found in Appendix G. Results from both interviews and physical observations can be found in Appendix H. A men's focus group was held in Salgi. The focus group questions and responses can be found in Appendix I and J, respectively. Additionally, an interview was held with faculty and students at the Kamand and Neri government schools. School interview questions and results can be found in Appendix K and L, respectively.

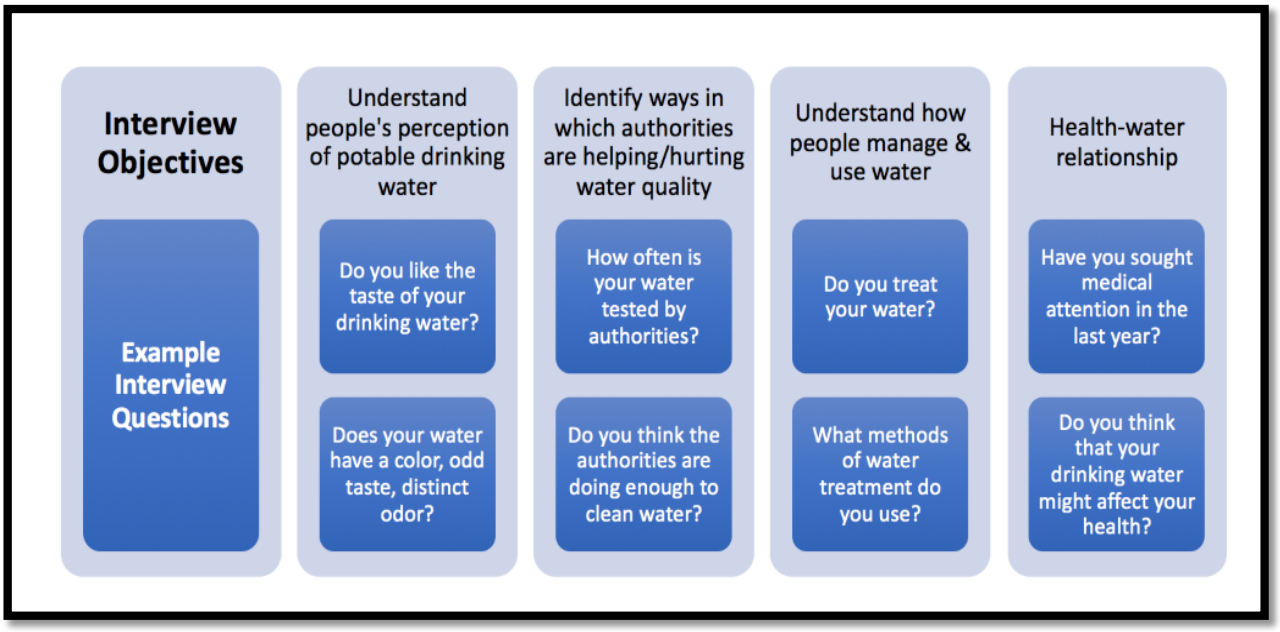


Figure 4: Interview objectives and example questions used to achieve the objectives of each interview

3.2 Investigating the Relationship Between Water Quality and Health

To understand the relationship between water quality and local health we interviewed doctors at three medical clinics: a private medical doctor in Salgi, a doctor at IIT-Mandi Medical Unit, and a few medical doctors and lab technicians at the Community Health Center in Kataula. The medical doctor in Salgi provided information about the frequency of waterborne diseases in the immediate area. Dr. Neha Sood at the IIT-Mandi Medical Unit provided insight into regional health concerns. In addition, the doctors and lab technicians at the Community Health Center in Kataula shared information about the frequency of waterborne diseases and explained the existing public awareness campaigns that prevent these diseases. Interview questions for medical officials can be found in Appendix M. From these interviews, we gathered a holistic perspective on how water quality may be impacting regional health and the measures currently being taken to prevent these diseases. Results of these interviews can be found in Appendix N.

3.3 Assessing Water Contamination

Drinking water from a variety of different sources was collected and tested for overall quality. Our testing included existing sampling sites from the government testing program and also expanded to include untreated natural sources. Figure 5 shows a map of the sampling locations for chemical and bacterial testing.

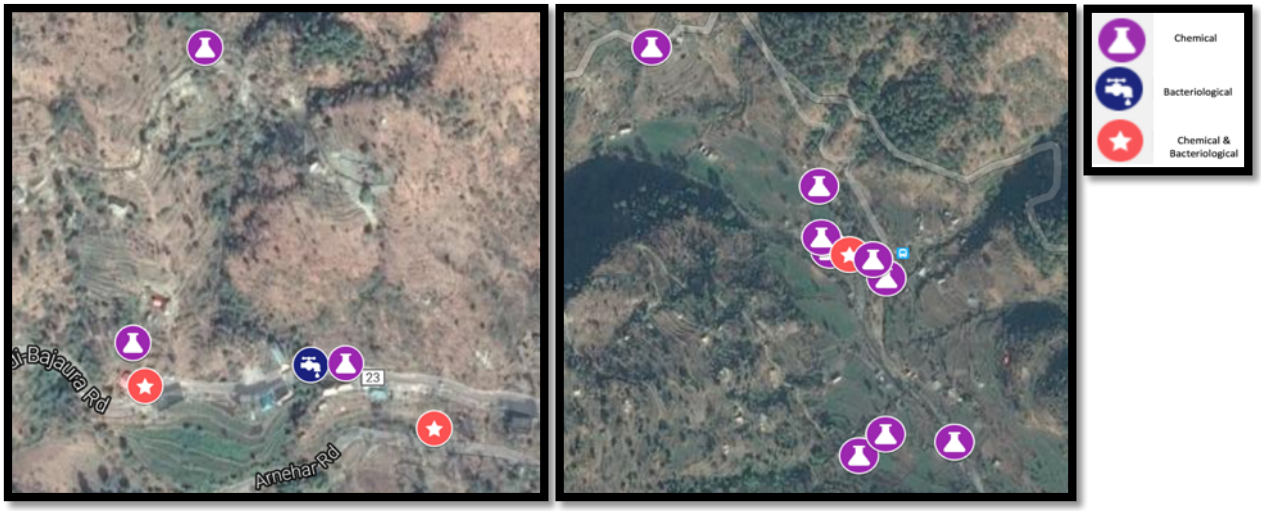


Figure 5: Chemical and bacteriological testing locations for Salgi (left) and Neri (right)

To quantify water chemical contamination our study analyzed existing government data and tested nineteen sources pre and post rain for four different chemical parameters. Tests were conducted within the IIT-Mandi Kamand chemistry lab. The standard methods for water quality

testing were followed for alkalinity and hardness via titration. pH and electrical conductivity were measured using probes. The procedures for each of these tests can be found in Appendix O.

Bacteriological contamination was assess based on Bactaslyde Microbe Detection (BMD) devices. The BMD devices measured total bacterial colonies and E. coli colonies. The total bacteria test was measured by red dots on a yellow medium while E. coli was measured by yellow or clear dots on a purple medium. Counting the colonies on each medium allowed bacteriological contamination to be quantified. An example of the BMD devices can be seen in Figure 6. The six water quality tests conducted and information about each test can be found in Table 2.

Figure 6: (Top) Total Bacteria indicator (Bottom) Total E. coli indicator

Water Quality Parameters	
Alkalinity **Rationale:** Indicates the ability of water to buffer pH changes **Limit:** 600 mg/L **Health Impact:** Reduce stomach acid which reduces the ability for the stomach to prevent harmful pathogens from entering bloodstream, can degrade pipes leading to metal contamination	**Hardness** **Rationale:** Measurement of magnesium, calcium, and other dissolved ions concentrations **Limit:** 600 mg/L as $CaCO_3$ **Health Impact**: No known health impacts unless water is soft & causes degradation of pipes leading to metal contamination
pH **Rationale:** Indicates how acidic or basic water is, can be indicator of large chemical contamination **Limit:** 6.5-8.5 **Health Impact:** N/A, indicator of other contamination	**Electrical Conductivity** **Rationale:** Large increases or decreases can be indicative of contamination **Limit:** 800 mg/L **Health Impact:** N/A, Indicator of other contamination
Total Bacteria **Rationale:** An indicator for potentially harmful bacterial contamination **Limit:** N/A **Health Impact:** Potential gastroenteritis, cholera, typhoid, vomiting depending on type of bacteria	**E. Coli** **Rationale:** An indicator for fecal contamination that carries harmful bacteria **Limit:** 0 **Health Impact:** Potential gastroenteritis, cholera, typhoid, vomiting, diarrhea

Table 2: Water Quality Parameters

Chapter 4: Results

The results of our seven-week study indicate a **community dependence on sources of drinking water that are not treated or monitored**. This conclusion is based upon the following findings:

1. Villages depend on untreated natural water sources
2. The government fails to monitor untreated natural water sources
3. Natural water sources have significant levels of bacteriological contamination
4. Residents lack regular household water treatment methods

4.1 Villages Depend on Untreated Natural Water

74% of residents interviewed in Salgi and Neri rely on untreated natural water sources for their drinking water. 92% of village members in Salgi and 100% of village members in Neri liked the taste of their drinking water. In addition, the majority of residents positively ranked water quality, as seen in Figure 7. Most villagers from Salgi and Neri have depended on untreated natural water and have been satisfied with these sources since birth. These conditions make them reluctant to alter water sources.

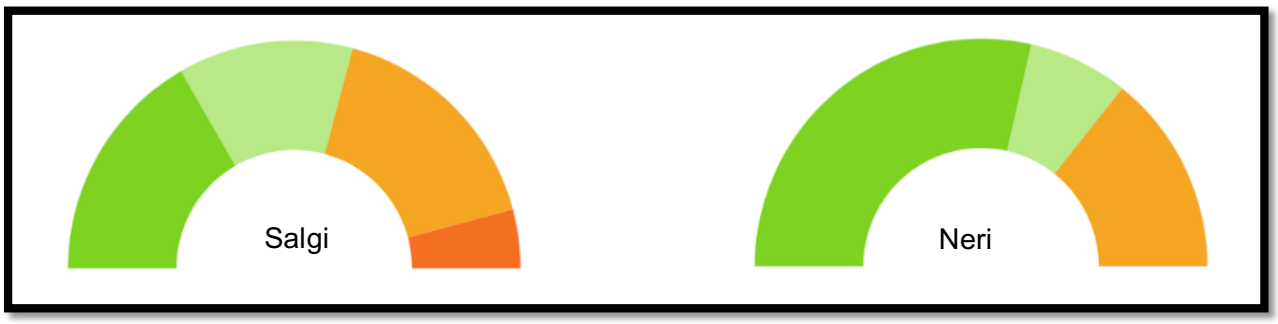


Figure 7: When asked to rank their drinking water on a scale of 1-5, with 5 being the best, most village members ranked their water a 4 or above

4.2 The Government Fails to Monitor Untreated Natural Water Sources

Upon surveying villagers and comparing the results to government data, it is clear that the IPH department is not monitoring an important source of drinking water, the untreated natural sources. Government data suggests that drinking water quality for Salgi and Neri is of good quality, but it fails to monitor untreated natural sources. This gives an **incomplete and inaccurate representation of water quality in Salgi and Neri**.

4.3 Natural Sources Have Significant Levels of Bacteriological Contamination

Bacteriological testing for E. coli and total bacteria indicated **harmful contamination for natural water sources** in Salgi and Neri. While the study was limited to five coliform and five E. coli tests, the results show an alarming and significant difference between the levels contamination in natural sources from the levels of contamination in government distribution and government groundwater sources.

4.3.1 Total Bacteria Test Results Indicate Bacteriological Contamination

Total bacteria tests indicate low bacterial contamination in Neri Natural Source A and Salgi Natural Source B, and high total bacterial contamination in Salgi Natural Source A. The distribution and hand pump sources, however, did not show any bacterial contamination. Figure 9 depicts the results of the total bacteria tests, with colonies indicated by red dots on the yellow testing medium.

4.3.2 E. Coli Test Results Indicate Bacteriological Contamination

E. coli appeared only in natural water sources. Similar to the total bacteria test, the E. coli test yielded no contamination for the government or groundwater sources. Salgi Natural Source B had no E. coli contamination, but the other two natural sources had high levels of contamination. The results of the bacteriological tests and the corresponding health risks for each source are shown in Figure 9 and

Figure 9: Results of total bacteria test (top) results of E. coli test (bottom) with positive tests indicated by red box

Table 3 respectively.

Source	Total Bacteria (# colonies)	Total E. Coli (# colonies)	Risk Level from Bacteriological Contamination
Neri Natural Source A	2	11	High
Salgi Natural Source A	33	51	Very High
Salgi Natural Source B	3	0	Low
Salgi Government Source	0	0	None
Salgi Pumped Groundwater	0	0	None

Table 3: Bacterial Contamination and Corresponding Risk Level

4.3.3 Chemical Tests Suggest Possible Nitrate or Iron Contamination

Chemical testing results indicated **soft water and potential iron and nitrate contamination**. All drinking water sources were soft to slightly hard with values ranging from 16 to 46 ppm. Table 4 shows levels of hardness as ranked by the World Health Organization. Soft water can be corrosive to metal pipes and storage containers. Many of the pipes observed in the villages that contained running water were brown and rusted on the inside. When compared to alkalinity, the hardness was much higher which indicated possible contamination of nitrates from human waste and fertilizers or iron from rusty pipes. This hypothesis is also supported by the high readings for conductivity. Conductivity is usually twice the magnitude of hardness, but was found to be 6.8 times the hardness. This again points to contamination from nitrates or iron. These tests show **possible chemical contamination but the primary health concern still lies in bacteriological contamination**. The results chemical testing can be found in Appendix P.

Water Hardness	
Calcium carbonate (ppm)	**Designation**
0-43	Soft
43-150	Slightly Hard
150-300	Moderately Hard
300-450	Hard
450	Very Hard

Table 4: *Water Hardness levels by ppm of calcium carbonate (WHO)*

4.4 Residents Lack Regular Household Water Treatment Methods

While both chemical and bacteriological water quality tests have indicated that some contamination exists in natural sources, villagers in both Salgi and Neri infrequently treat their water. As

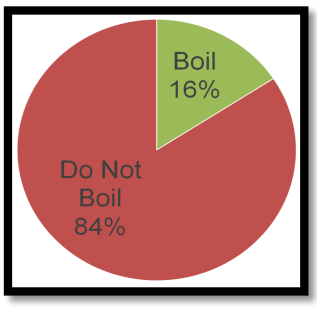


Figure: 10: Majority of villagers do not boil water regularly

shown in Figure 10, **the majority of villagers do not regularly boil**. However, more than 75% of the villagers have reported boiling water for various reasons within the last year. This suggests that the **village residents have the technical capacity to regularly boil drinking water but choose not to**.

4.4.1 Medical Officials Encourage Boiling Water

All medical officials interviewed in this study believed a **relationship between water quality and public health is evident**. Although none of the medical officials reported any cases of cholera, they reported many cases of typhoid, gastroenteritis, vomiting, and diarrhea. If a patient were suffering from a waterborne illness, the doctors recommend boiling water to reduce the bacteriological contamination of drinking water. Although each medical official cautioned against drawing a clear and definitive relationship between water quality and health, they indicated an observable increase in water-related illnesses during the rainy season that may be attributed to the decrease in water quality.

4.4.2 Local and National Government Encourage Water Treatment

Interviews with the Kataula Government Medical Office and the Department of Mass Education indicated how the government encourages regular water treatment. An awareness campaign called *Integrated Diarrhea Control Fortnight* (IDCF) is run during July when waterborne illnesses peak. This campaign focuses on methods of improving water quality through practices such as boiling water, using chlorine tablets, and washing hands and storage containers. Teachers and students were also knowledgeable about proper hygiene and water treatment techniques. It is evident that there is a strong campaign for proper water management, but the village surveys indicated an apparent lack of water treatment. It can be concluded that the **lack of treatment is not from insufficient education but rather from lack of awareness about water contamination in untreated natural sources**.

Chapter 5: Conclusions & Recommendations

From the results, it is evident that improvements must be made to the current **water quality testing program** to **promote public awareness** regarding the safety of untreated natural water sources. The following recommendations will improve upon current water quality monitoring and treatment:

1. Revise drinking water testing scheme for the Irrigation and Public Health (IPH) department
2. Improve the effectiveness of communication of water quality results to villagers

While these recommendations are based on data for Salgi and Neri, the recommendations can be extrapolated to improve the drinking water quality of other rural

villages in Himachal Pradesh. A letter to the IPH department that provided our recommendations can be found in Appendix Q.

5.1 The IPH Department Should Identify and Monitor Drinking Water Sources Most Commonly Used by Residents

From our results in Chapter 4.1 and Chapter 4.2 that indicated village dependence on untreated, unmonitored natural sources, **we recommend that the IPH department communicate with villages to identify and monitor the water sources which are most commonly used.** To identify the water sources that a village relies on, we recommend using similar metrics such as the household surveys used in this study or alternatively by collaborating with the panchayats of each rural village. Although identifying the proper water sources to monitor will be time consuming, it will allow the water quality tests to get a more accurate representation of the drinking water in the villages.

Since Chapter 4.3 indicated high bacteriological contamination within natural sources, we suggest that **the IPH department should also expand testing parameters to include E. coli and nitrates**. Currently the IPH department tests for total coliform but E. coli is a more meaningful indicator for bacterial contamination. Testing for nitrates will also help indicate possible sources of contamination. Identifying the source of contamination will allow villages to improve drinking water quality.

Currently the IPH department tests water sources annually or biannually, but bacteriological contamination can vary greatly with seasonal shifts. Thus, it is recommended that **drinking water sources should be tested and monitored seasonally**.

5.2 The IPH Department Should Communicate Water Quality Results to Villagers

Results indicated a disconnect between local perceptions of positive water quality and potential contamination in untreated natural water sources. As a result, we recommend that **the IPH should work with the local panchayat to publish results of water quality data**. Many residents are knowledgeable about boiling water but do not practice this treatment method because the water is perceived to be safe.

To help better inform the public about their drinking water quality, it is suggested that the IPH department collaborate with local panchayats to implement and upkeep the IIT-WPI designed Water Quality Stoplight. The Water Quality Stoplight, seen in Figure 11, is a sign designed to be located next to drinking water sources that will publish IPH department water quality data using a three-color system. This design will

Figure 11: Water Quality Stoplight sign prototype

include the most recent and future dates of the IPH department tests. Based on the most previous test, the sign will display a color that indicates the overall water quality. The sign will be one of three colors: green for safe, yellow for caution, and red for unsafe. Beside this sign will be a legend that reminds community members to properly treat water. This design will effectively improve communication of water quality results conducted by the IPH department while also reminding villagers of the importance of water treatment.

5.3 The IPH or IIT Should Monitor Pipes and Water Storage Units

The chemical tests of drinking water sources in Salgi and Neri show evidence of soft water. Soft water is generally safe but can be corrosive to pipes and hand pumps. Based on the physical observation in the villages, many of the pipes were rusted which may have resulted from the water hardness. A degraded pipe can be viewed in Figure 12. A further study should **investigate if pipes are corroding faster than expected** due to this chemical property of the water.

Physical observations showed that villagers stored water in recycled chemical barrels. **Testing for heavy metals should be conducted** on these barrels to ensure safety. To eliminate the need for testing, the local panchayat should ensure that no residents are using these barrels to store water. Figure 11 shows an image of a barrel that one resident was using to store drinking water.

Figure 12: Corroding pipe (top) and chemical container being used for water storage

5.4 A Household Water Treatment Device Should be Implemented for Residents Relying on Untreated Water

If communities still rely on untreated natural water sources after implementation of the Water Quality Stoplight there should be an **investigation into a household water treatment device**. Potential water treatment devices for the household level include: water pasteurization indicator (WPI) using local materials, solar filtration (SOFI) prototype, and chlorine tablets. A preliminary design and decision matrix of these technologies is can be seen in Table 5.

Drinking Water Treatment Method	Water Pasteurization using WPI Prototype	SOFI Water Treatment	Chlorination
Description	Small plastic tubing with local wax on the interior, weighted on one end to be placed in water to indicate when water has reached pasteurization point	3 part system (1) a black holding compartment for solar treatment (2) plastic container with sand, gravel, and activated charcoal filter, (3) clay pot holding container	Tablets that are designed to be used per specified number of liters
Cost	~$2 for WPI Energy for boiling depends on heating source	~$15 for initial ~$1.50 every 3-4 weeks for activated carbon replacements	Free at government hospital
Time for Treatment	10 minutes + cooling time	1/2 day	30 minutes
Difficulty to Properly Treat	Low: need to know how to properly use indicator	Medium/Hard: need to know how to clean/change multiple layers, valve and maintenance	Medium: need to use proper amount of chemical per volume of water
Taste	No change in taste	No change in taste	Changes the taste of water sources

Table 5: Decision matrix for future investigation into at home treatment methods

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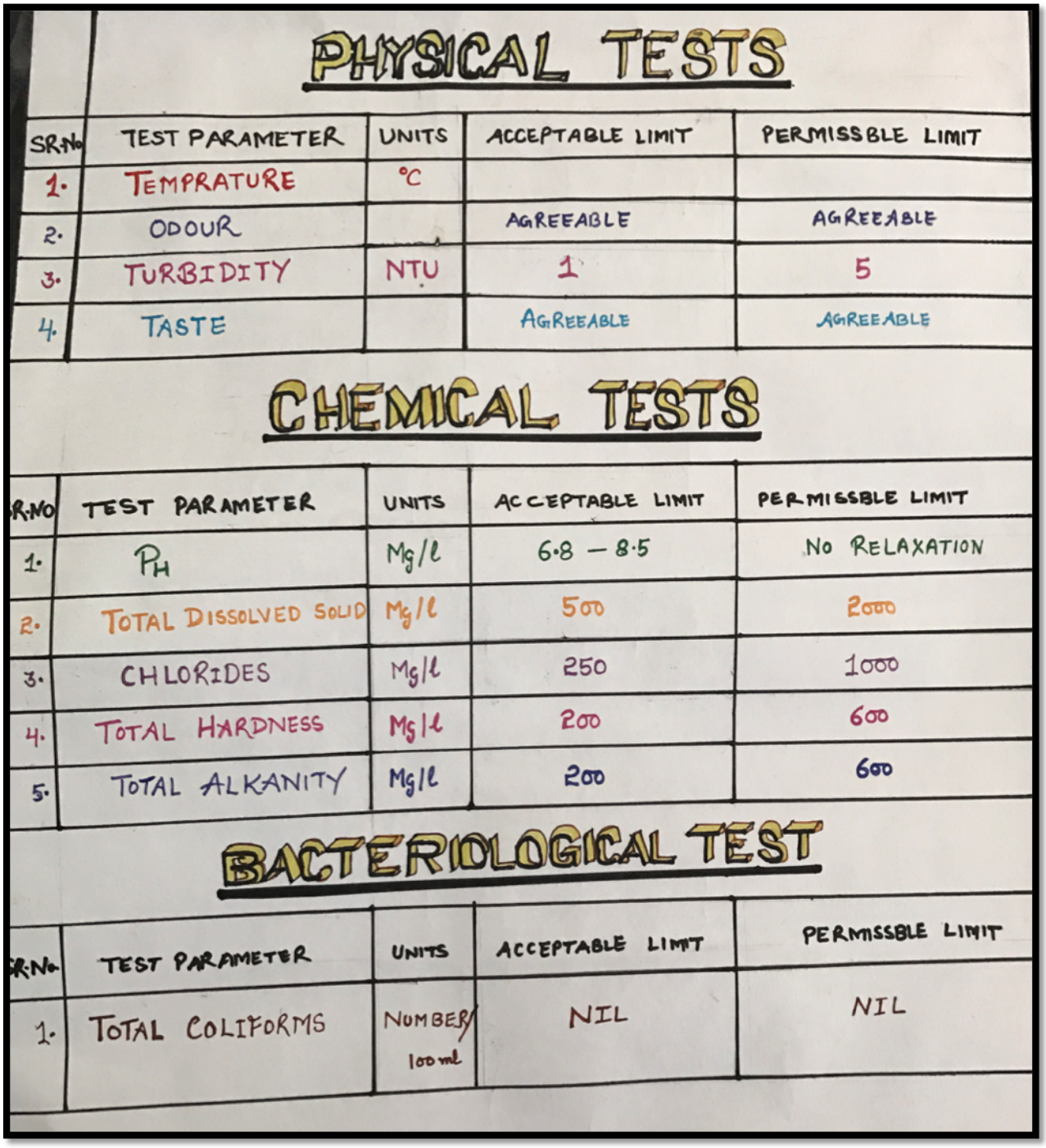
Appendix A: Map of Neri & Salgi Government Sampling Sites

Testing locations in Salig (left) and Neri (right) indicated by orange circles

Appendix B: Irrigation and Public Health Department Testing Parameters



PHYSICAL TESTS

SR.No	TEST PARAMETER	UNITS	ACCEPTABLE LIMIT	PERMISSBLE LIMIT
1.	TEMPRATURE	°C		
2.	ODOUR		AGREEABLE	AGREEABLE
3.	TURBIDITY	NTU	1	5
4.	TASTE		AGREEABLE	AGREEABLE

CHEMICAL TESTS

R.NO	TEST PARAMETER	UNITS	ACCEPTABLE LIMIT	PERMISSBLE LIMIT
1.	PH	Mg/l	6.8 – 8.5	No RELAXATION
2.	TOTAL DISSOLVED SOLID	Mg/l	500	2000
3.	CHLORIDES	Mg/l	250	1000
4.	TOTAL HARDNESS	Mg/l	200	600
5.	TOTAL ALKANITY	Mg/l	200	600

BACTERIOLOGICAL TEST

SR.No	TEST PARAMETER	UNITS	ACCEPTABLE LIMIT	PERMISSBLE LIMIT
1.	TOTAL COLIFORMS	NUMBER/ 100 ml	NIL	NIL

Physical, chemical, and bacteriological tests conducted by the IPH department with permissible limits

Appendix C: Irrigation and Public Health Department Interview Questions

IPH Testing Operations

1. What bacteriological, chemical and physical tests do you conduct to measure the quality of drinking water?
2. Which locations do you collect samples from, and how do you identify those locations to test?
3. How often do you get the samples from these areas to be tested?
4. How often workers in IPH are given training?
5. What action do you take when you find contaminants in water in a large amount?
6. Do you think there should be more infrastructure to test water?
7. Where do they update the data after testing?
8. Does rainfall impact the sampling of water for testing?

Water Sources

9. Which source of water people prefer generally?
10. Have you banned any natural source because bacterial contamination?
11. Have you banned any source because of chemical contamination?
12. How do you generally treat the tank water?
13. Has arsenic been detected in water?
14. Do people generally like the taste of groundwater, surface water and natural sources or do they tend to prefer one source over another?

Water Management

15. How often is maintenance of storage tank done?
16. What type of filter do government use to filter water at mass level?

Public Health

17. Has there been any outbreak of any waterborne diseases such as cholera or typhoid?

Public Awareness

18. Do you organize any awareness campaign for people?

Appendix D: Irrigation and Public Health Department Interview Results

IPH Testing Operations

1. What bacteriological, chemical and physical tests do you conduct to measure the quality of drinking water?
    - Physical tests includes
        i. Color, taste, Odour, Turbidity, temperature
    a. Chemical tests includes :
        i. Total dissolved solids, pH, Chloride, Alkalinity, Total Hardness, Residual Chlorine
    a. Bacteriological test includes:
        i. Total Coliform test.
2. Which locations do you collect samples from, and how do you identify those locations to test?
    a. Mandi Town and rural areas surrounding Mandi town
    b. But don't always take samples from a fixed location, sometimes take from people's homes
3. How often do you get the samples from these areas to be tested?
    a. On a regular basis in Mandi, less frequently in rural areas
4. How often workers in IPH are given training?
    a. Once per year
5. What action do you take when you find contaminants in water in a large amount?
    a. Shut of the water supply and contact superiors
6. Do you think there should be more infrastructure to test water?
    a. Yes, more advanced bacteriological testing
7. Where do they update the data after testing?
    a. Keep paper records in a log book but also upload to the National Rural Drinking Water Programme website database
8. Does rainfall impact the sampling of water for testing?
    a. Rainfall makes the water more turbid, especially in the rainy season but it doesn't impact sampling

Water Sources

9. Which source of water people prefer generally?
    a. Natural source
10. Have you banned any natural source because bacterial contamination?
    a. Yes, January 2016
11. Have you banned any source because of chemical contamination?
    a. No
12. How do you generally treat the tank water?

a. Chlorination

13. Has arsenic been detected in water?
    a. No
14. Do people generally like the taste of groundwater, surface water and natural sources or do they tend to prefer one source over another?
    a. People prefer the taste of natural sources

Water Management

15. Do people generally treat water at the household level?
    a. No, they don't. If they do, they boil, but not regularly
16. How often is maintenance of storage tank done?
    a. Every four months
17. What type of filter do government use to filter water at mass level?
    a. A three layer filter with sediments and charcoal

Public Health

18. Has there been any outbreak of any waterborne diseases such as cholera or typhoid?
    a. No, not in Mandi

Public Awareness

19. Do you organize any awareness campaign for people?
    a. Yes, during Maha Shivratri Fair

Appendix E: Household Interview Locations

Household interview and physical observation locations in Salig (left) and Neri (right) indicated by red circles

Appendix F: Household Survey Questions

Identification number	
GPS coordinates	
Description of house/location	

Background Info		
#	Question	Response
1	Age	
2	Gender	
3	Location of residence	
4	Family Size	
5	Time residing in community	

Objective 1: *Understand people's perception of potable water*					
#	Question	Yes	No	Unsure/ No Response	Comments
6	Do you like the taste of your drinking water				
7	Does your water have a color, odd taste, or distinct odor				
8	Does taste/ odor of water change seasonally				
9	How would you rank your water quality on a scale from 1 to 5				

Objective 2: *Identify ways in which the authorities are helping/hurting the water quality*					
#	Question	Yes	No	Unsure/ No Response	Comments
10	How often is your water tested by authorities				
11	What types of water tests are currently being done				
12	Do you thing the authorities are doing enough to clean water				
13	Have you contacted the authorities in regard to poor water quality				
14	What, if any, actions would you hope to have done for safer drinking water				

Objective 3: *Understand how people manage and use water, water handling practices*						
#	Question	*Circle appropriate answer*				
15	Where do you get your drinking water from?	Surface	Ground	Storage Tank	Distribution system	
16	Do you treat water before drinking, cooking, or bathing	Yes	No	Unsure/No Response	*Comments*	
17	What types of treatements do you do	(A) Filter	(B) Boil	(C) Chlorine/ Iodine	(D) Indigenous	(E) None
17 A	What kind of filter do you use					
17 A	Do you clean your water filter					
17 A	How often do you clean your water filter					
17 B	For how long do you boil your water					
17 B	Where do you get the energy source for boiling water					
17 C	What dosage do you use					
17 C	Where do you purchase the chemical(s) from					
17 D	What is the indigenous method					
17 D	Where do you get the plant/other material from for treating the water					
17 D	How long have you/ your family been using this method					
17 E	Have you considered treating your water					

#	Question	Yes	No	Unsure/ No Response	Comments
18	Do you store water?				
19	Do you clean your water storage container				
19 A	How often do you clean your water storage container				

Health					
#	Question	Yes	No	Unsure/ No Response	Comments
20	Have you sought medical attention in the past year				
20 A	For what reasons have you sought medical attention				
20 AA	Do you think that your drinking water might affect your health				

Appendix G: Physical Observation Sheet

Physical Observation Sheet	
Identification number	
GPS coordinates	
Description of house/location	

At each home interviewed try to obtain pictures of:		
Photo	Yes	No
Water source		
Water storage container		
Water treatment method		

Source					
Type/description of water source					
Type/description of piping					
Does source appear contaminated (by what)	Yes:			No:	
Ranking of observable water cleanliness	1	2	3	4	5
Proximity to wastewater/latrines					
Proximity to livestock					
Potential additional evident contmainants					

Storage Methods					
Is there an evident storage container	Yes:			No:	
Approximate size of storage container	Sm household	Lg household	Sm Community	Lg Community	Other
Material of water storage container	Plastic	Concrete	*Other:*		

Ranking of observable cleanliness of water storage container	1	2	3	4	5

Treatment Methods Observations	
Treatment Type	
Observations	

Health	
Are there any noticiable health concerns (protruded stomach, discolored teeth)	

Appendix H: Household Interview and Physical Observation Results

Full Results can be found at:

https://docs.google.com/spreadsheets/d/1pqQcLXpg1AhaM6fkl_dGHg5ByYpkuHOxFVm5u6_WHrw/edit?usp=sharing

Salgi Results

	Background Info												sample ofrom lady @ half way mark 31 47' 14" 76 59' 42
	Identification number	**S-A1**	**S-A2**	**S-A3**	**S-A4**	**S-A5**	**S-B1**	**S-B2**	**S-C1**	**S-C2**	**S-C3**	**S-D1**	**S-D2**
	GPS Coordinates	31.7839, 79.9989			31.78397, 76.998	31.788, 76.997	31.473, 76.5957	31.784167, 76.998889				31.785833, 76.9886111	31.787222, 76.995
	Description of house/ location	storefront near water pump on left side of road	shop on right side with tables	small blue house on left side of road	Yellow shop	hill past the panchayat, blue, with small latrines in front	First house on right of town center hand pump	Neighbor of B1	Tap HOH1 house on hill	shop near doctor	house next to house on hill	SA kent rishu girl house top	deep in hills
1	Age (estimated)	50	45	35	20	40	45	60				~30	29
2	Gender	Male	Male	Female (but male came to complete the interview)	Male	Male	Female	Male	Female				female
3	Location of residence	Salgi	Salgi	Salgi	Salgi	Salgi	Salgi	Salgi	Salgi	Salgi		female topot concrete waster	salgi
4	Family Size			4	6	12	8	9		5	12	4	4
5	Time residing in community			from birth	from birth	from birth	12 years	40 years		16 years	20 years	from birth	from birth
	Additional Comments	first interview conducted in this community, found the government worker who collected samples for us to interview	Name of interviewed: Netear						percieveds that community primarily drinks from the tank	well bore, base turns yellow 10+ days		a different lady sat in on interview and talked a lot during it	
	Objective 1: *Understand*												
6	Do you like the taste of your drinking water	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No (of distribution)	yes	yes
7	Does your water have a color, odd taste, or distinct odor	Yes, rainy season muddy	No	Yes	No	No	Yes, yellow color	Yes, during rainy season	No	Yes	Yes, salty	no, muddy	no
8	Does taste/ odor of water change seasonally	Yes, seasonally	No	Yes	No	Yes, rainy season	Yes, rainy season	Yes, rainy season	Yes, heavy rain causes it to be muddy	Yes	Yes, rainy season turns yellow	no, whole year	mud in rainy season
9	How would you rank your water quality on a scale from 1 to 5	5	5	5	5	4	3	4	4	3.5	3	2	3
	Additional Comments	"People have the perception that natural					"When water is yellow, 90% unfit" then	"during summer, supply tank		Believes there are some impurities in		muddy water	
	Objective 2: *Identify ways in which the authorities are helping/hurting the water quality*												
10	How often is your water tested by authorities	when requested	when requested	daily	monthly		N/A	N/A	2-3 times per month at the tank	unsure	once every ten days and when tastes bad	no	no
11	What types of water tests are currently being done	government has not disclosed this to them	unknown	unknown	Unsure		N/A, but tanks and natural resources are monitored	N/A	unsure	unsure	unsure		
12	Do you thing the authorities are doing enough to clean water		there are things being done but the government could be doing more	Yes	No, there are shortages		No	N/A	**Yes**		no		no
13	Have you contacted the authorities in regard to poor water quality	Yes	No	**No**	Yes, there was a broken pipeline 3 years ago		Yes, when the water is colored yellow. It was sampled but nothing was done	No, they drink water from natural source	**No**	Yes	yes	no, just never ask	no
14	What, if any, actions would you hope to have done	filtration for the large source	Nothing to suggest	clean water tank regularly, not sure how	No		Reduce the color of water	supply water should be improved	clean water free of germs	proper maintenance of the tank	clean source better, tank gets polluted	yes, want something done, not sure	yes
	Additional Comments	Government does not share results either,		sometimes a shortage of		this house uses a private source, their government	handpump maintained regularly and	Supply of water should be increased.		the government cleans the tank	Gurus use natural sources are polluted		they want house to house pipe lines,
	Objective 3: *Understand how people manage and use water, water handling practices*												
15	Where do you get your drinking water from?	surface, ground, storage tank,	storage tank (natural source, from	Ground, storage tank, distribution	Natural source (Ground but not for drinking)	Natural source (appeared to be a spring?)	Ground, Storage tank, Distribution	storage tank, natural stream, distribution	government distribution system	natural source, distribution system,	distribution system ONLY	surface, natural source	surface, natural source
16	Do you treat water	No	Seasonally	sometimes	No	No	Yes	No	No	no	no	yes	no
17	What types of treatements do you do	Boil	Boil (rainy season only)	boil (only under govt recommendation)	None	None	Filter, Boil	Boil	Boil (when ill)	boil if sick, silk cloth seiving method when muddy	boil if sick	boil for bathing	boil, for bathing to get it hot
17 A	What kind of filter do you use				N/A	N/A	Buy a filter from Mandi with two layer structure and filter stone within						
17 A	Do you clean your water filter				N/A	N/A	Yes						
17 A	How often do you clean your water filter				N/A	N/A	2-3 days, change 2-3 months						

Appendix I: Salgi Men's Focus Group Questions

Introduction:

- We are students from IIT Mandi and WPI, completing a seven week assessment of water quality in the community as well as some other nearby communities.
- The reason we are having these focus groups is to find out more about the community's perception of water quality
- To learn about water quality we hope that you can share your honest opinions and thoughts.
- Ask if anyone has any objections to the conversation being recorded

Collect Demographic Information:

- Name (optional)
- Gender
- Age
- Occupation
- Family size?
- Residence location/Community they are from
    - If not from Salgi, may need to ask them to not participate in the focus group
- Primary water source

Engagement Questions:

1. What is the water source that the community depends on the most?
    a. Where is it located?
    a. What is the quality of it?
    a. How is the quality of it maintained?
1. What water source in the community is known to be of the poorest quality?
    a. Why is it believed to have the poorest quality of water?
    a. What might be sources of contamination?
    a. Have there been any efforts to improve that source?
        i. If so, who has taken action to improve the source?
    a. What sources are used in replacement of that source?
    a. Do you believe that everyone in the community has access to a good quality water source?

Exploration Questions:

1. What, if any, is the biggest source of water contamination in the community?
    a. Agriculture? Pesticides? Fecal contamination from wastewater? Other domestic contamination? Metal pipes/pump?
    a. Are different sources susceptible to different types of contamination?
1. How do you think the quality of water in the community impacts health?

1. When, if at all, was the last outbreak of typhoid, cholera, or other waterborne diseases?
    a. What source was it believed to be caused by?
    a. How did people respond to the outbreak in regards to managing their water?
1. Are there certain actions you take to improve the quality of your drinking water?
    a. Boiling, sieving, filter, etc.?
1. If you or an external party were to take action to improve the quality of drinking water, what would you want to see done?
    a. What time/financial capacity would you invest into these actions?

Exit Question:

1. Is there anything else you would like to say about the water quality of the community?

Methods of Guiding Conversation

- *If conversation dies down or if participants aren't fully answering, use phrases like:*
    - Can you talk about that more
    - Help me understand what you mean
    - Can you provide an example
- *If one person is dominating the conversation, use phrases like:*
    - Thank you. What do other people think?
    - Let's have some other comments

Appendix J: Salgi Men's Focus Group Results

Engagement Questions:

1. What is the water source that the community depends on the most? Natural source provided by government
    a. Where is it located? Top of mountain
    a. What is the quality of it? good
    a. How is the quality of it maintained? Unsure, clean once or twice a year
1. What water source in the community is known to be of the poorest quality? Don't think water quality is poor
    a. Why is it believed to have the poorest quality of water?
    a. What might be sources of contamination? rainy , mud
    a. Have there been any efforts to improve that source? Called iph
        i. If so, who has taken action to improve the source?
    a. What sources are used in replacement of that source? Hand pump during rainy season
    a. Do you believe that everyone in the community has access to a good quality water source? yes

Exploration Questions:

1. What, if any, is the biggest source of water contamination in the community?
    a. Agriculture? Pesticides? Fecal contamination from wastewater? Other domestic contamination? Metal pipes/pump?
    a. Are different sources susceptible to different types of contamination? Closed tank has rocky water
1. How do you think the quality of water in the community impacts health? No health effects
1. When, if at all, was the last outbreak of typhoid, cholera, or other waterborne diseases? n/a
    a. What source was it believed to be caused by?
    a. How did people respond to the outbreak in regards to managing their water?
1. Are there certain actions you take to improve the quality of your drinking water?
    a. Boiling, sieving, filter, etc.? don't use filtration methods, use sedimentation sometimes
1. If you or an external party were to take action to improve the quality of drinking water, what would you want to see done? Had a broken tank that villagers repaired themselves
    a. What time/financial capacity would you invest into these actions?

Exit Question:

1. Is there anything else you would like to say about the water quality of the community? Iph should maintain tank properly, more supply.

Appendix K: Interview Questions for Government Schools

Introduction:

- We are students from IIT Mandi and WPI, completing a seven week assessment of water quality in the community as well as some other nearby communities.
- We would like to find out more about the community's (school) perception of water quality & what the students already know about water quality
- To learn about water quality we hope that you can share your honest opinions and thoughts.
- Ask if anyone has any objections to the conversation being recorded

Collect Demographic Information:

- Name (optional)
- School location
- School size?
- Primary water source of school

School Water Source

- What is the water source that the school depends on the most? (distribution, gov st...)
- Where is it located?
- What is the quality of it?
- Is it filtered?
- How is the quality of it maintained?

Existing Education/Knowledge

- Are students educated on water quality in school?
- Do they know the importance of good water quality?
- Do they know the outcomes of poor water quality?
- Do they practice maintain good water quality habits in school?
- Have there been any programs to educate students on water quality?
    - If so, when? What did they include? Were they sponsored by any organization?
- What do you find is the best way to engage students in a topic?
- What are the technical capabilities of the school?
- If have a video, would we be able to display it?
- If we ask students to draw/color would we need to supply those materials?
- How long do students tend to pay attention to a single topic?

Students Impacted by Water Quality

- Do you think the quality of water in the community (school) impacts health?

- Do you think the water quality of students home is different (better or worse) than water quality of the school?
- Do you think students have access to equal levels of water quality within their homes?
- Do students miss school often?
- What causes this? (water, flu?)
- When, if at all, was the last outbreak of typhoid, cholera, or other waterborne diseases?
- What source was it believed to be caused by?
- How did people respond to the outbreak in regards to managing their water?

School Water Treatment

- Are there certain actions the school takes to improve the quality of drinking water?
- Boiling, sieving, filter, etc.?
- If you or an external party were to take action to improve the quality of drinking water, what would you want to see done?
- What time/financial capacity would you invest into these actions?

Conclusion

- Is there anything else you would like to say about the water quality of the school or education of water quality?

Appendix L: Government School Interview Results

Interview & Student Survey at Kamand Sen. Secondary School

Grade Level	Number of Students
6th	18
7th	9
8th	24
Absent students	3

Towns Represented: Kamand, Neri, Salgi, Tikiri, Kahra, Bassar, Deuhki

6th-8th Grade Interview Findings

- The school offers filtered water through an Aquaguard filter and the government sourced water commonly referred to as tank water, students drink both
- The school cleans the tank every 15 days (this was later found to be incorrect; the school has it cleaned once per month)
- The tank water is of good quality according to the students
- Chlorine is added to the unfiltered tank water
- 47/48 students claim they boil their water prior to drinking it
- They have a strong grasp on the ideas of waterborne illnesses and the effects of drinking unsafe water
- In general they claim to wash their hands frequently
- The teachers tell them to wash their hands and in the last month the teachers have reminded them once to boil their water when at home
- Roughly half of the students use the government source at home; the other half use natural sources. There were a few outliers who used a variety of sources
- They stated that the community water can cause stomach pain, vomiting, and fever if untreated
- They also claim that they feel that the water quality is about the same as it is at their homes
- Last year 7 students in these grades missed school for sickness

Grade Level	Number of Students
9th	31
10th	15
Absent students	6

Towns Represented: Kamand, Salgi, Neri, Bassar, and Nandli

9th-10th Grade Interview Findings

- They generally drink from the Aquagaurd filtered water at the school but occasionally use the tank when there is a shortage of water
- They have a good understanding of waterborne illnesses and the importance of water quality
- When asked all of them claimed to wash their hands
- Techers encourage them to boil water while at home and only between 8 and 10 do not boil their water while at home
- They claim that none of them have missed school in the last year but 7 of them have been to the doctor in that time
- The claimed the water quality is about the same at home and at school
- They also stated that the tanks are cleaned twice per month (later found to be incorrect it is once per month

Interview with principal, Mr. H. R. Thakur

- The school primarily uses Aquaguard filtered water but also has the direct government sourced water
- The filter is cleaned twice per year
- When students visit the health center on the school grounds the staff encourage the students to boil the water and wash their hands
- The school executes maintenance on the filters and tanks
- The tanks are cleaned once per month, on the second Saturday of every month
- The principal feels that the water quality at the school is good
- He also feels that the students would benefit a water quality awareness program
- He feels the students do not truly understand safe water habits
- He has the teachers tell the students to boil their water during the rainy season

Appendix M: Interview Questions for Medical Officials

Katoula Community Health Center Interview Questions

Water/Health

- What is the number of people the clinic serves?
- What is the number of patients seen for diarrhea and/or vomiting?
- What is the number of patients seen for typhoid/cholera/other major illnesses that are waterborne?
- What do you think the relationship between water and health is?
- When a patient comes in with a waterborne illness, what is the common treatment?

Vulnerability

- Are there certain populations you think are more susceptible to waterborne diseases?
- Are there communities you see more often for treatment?
- Do you think the quality of people's health is at all related to their economic status?

Water Treatment

- What methods of water treatment do you think are most effective
- Are there any methods that are used that are ineffective or harmful at treating water?
- What types of sources of water do you think are safest for people to drink, especially without home-treatment?

Education

- Are there any existing programs for educating the population about waterborne illnesses or the treatment of water to prevent them?
    - If so, do these programs target certain populations?

IIT-Mandi Medical Office Interview Questions

Introduction

-IIT/WPI students conducting an assessment of water quality
-Primarily focusing on two rural communities but would like to better understand the relationship between health and water quality

Health

1. Approximately how many students do you treat per year
2. Are there certain months in which you treat more patients?
   a. If so, which months? Why do you see more in these months?

Water Quality

1. Which source do you prefer for drinking water
2. How would you rate the drinking water in IIT Region on the scale of 1-5.
3. Do you think drinking water quality is a problem on campus?
4. Do patients complain about drinking water?
    a. is there a certain demographic of patients that complain more about water quality

Water Quality-Health Relationship

1. Do you believe there is a strong correlation between poor water quality and waterborne diseases?
2. On an annual basis, how many cases of these diseases do you have per year?
    a. typhoid
    b. diarrhea
    c. cholera
    d. jaundice
    e. viral fever
    f. dysentery
    g. others

2a. What is the likelihood of these cases being caused by something other than water quality problems?

    a. such as food? communicable disease? etc.?

2b. Is the prevalence of any of these diseases dependent on the season, climate and weather?

    a. Which season has the highest number of cases?

3. Has there been any serious case caused by water borne disease that patient has been transferred to Mandi.

Methods of Treating/Improving Water Quality

4. Do you suggest them to boil water before drinking?
4. Do you think enough steps are taken to provide potable drinking water?

<u>Salgi Private Doctor</u>

Objective: Determine if waterborne/ water related diseases are a local issue

1. What types of diseases are prevalent in local populations?
2. Might any of these diseases be attributed to the consumption of unclean water?
3. Do you have the number of cases in the last year?
4. Do you think diseases relating to water quality are preventable for local communities?
5. How might you recommend alleviating the rate of morbidity?
6. Do you think poor water quality is a high priority issue for the region?

Appendix N: Medical Official Interview Results

Katoula Community Health Center Interview Questions

Water/Health

- What is the number of people the clinic serves?
  - 10,000 people
- What is the number of patients seen for diarrhea and/or vomiting?
  - Given data for 2016
- What is the number of patients seen for typhoid/cholera/other major illnesses that are waterborne?
  - No outbreaks of cholera
  - Typhoid is seasonal, seen in rainy season more commonly, no number given
  - Lab technician reported that 3-4 patients are tested for typhoid per day but only 1-2 tests are positive at the most
    - Sees Jan-March an increase in typhoid cases
- What do you think the relationship between water and health is?
  - Summer quality of water is poor
  - You can not directly say that there is a relationship but you can observe changes in the weather and water that may be impacting health
- When a patient comes in with a waterborne illness, what is the common treatment?
  - Anti-diarrheal, oral rehydration salts

Vulnerability

- Are there certain populations you think are more susceptible to waterborne diseases?
  - Socioeconomic areas that are slums are more vulnerable, believe it is related to a lack of knowledge of personal hygiene
- Are there communities you see more often for treatment?
  - No

Water Treatment

- What methods of water treatment do you think are most effective?
  - Boiling
    - Encourage people to boil all year long but many people don't
    - Unsure about why people don't boil regularly
    - Use natural sources that need to be tested more frequently
    - Raised the concern that people use natural sources that are not monitored or treated
  - But also encourage people to treat with chlorine
- Are there any methods that are used that are ineffective or harmful at treating water?

    - Not mentioned
    - Brought up the idea of insects in natural water sources that clean water
- What types of sources of water do you think are safest for people to drink, especially without home-treatment?
    - Natural sources are not maintained
    - Natural sources need to be cleaned
    - Government sources are maintained and cleaned

Education

- Are there any existing programs for educating the population about waterborne illnesses or the treatment of water to prevent them?
    - Have IDCF campaign that gives out oral rehydration slats during the rainy season when outbreaks are high
    - Handwashing techniques
    - Posters
    - Distribute chlorine tablets
    - Have found that the number of cases is reduced when they have the program

- If so, do these programs target certain populations?
    - Programs in school
    - IDCF targets the whole village level
    - At village level have ASHA Program

Appendix O: Laboratory Procedures

Hardness Testing: Total Hardness

50 mL of deionozed water sample was added to a conical flask. Then 5 mL of ammonia buffer and 15 drops of a 0.0314 M $MgCl_2$ solution were added to the sample in the flask. Next, a small amount of the Erichrome Black indicator powder was added to produce a red-purple color. The solution was then titrated against 0.01066 M EDTA until the color changed to from purple to blue. The total volume of the EDTA used to change the color was noted. This same procedure was followed for a water sample and the volume of EDTA required for deionized water was subtracted from the normal samples. This test was done in triplicate

Example calculation: (mL EDTA- mL EDTA for DI water)*8.54466= ppm Ca^{2+} and Mg^{2+}

Alkalinity testing:

100 mL of the water sample was added to a conical flask. A few drops of phenolphthalein to were added to the sample. If the sample turned pink, then the solution was titrated against 0.02 N H_2SO_4 until the color faded to clear. Next, a few drops of bromocresol green was added until the solution turned blue. The sample was titrated against 0.02 N H_2SO_4 until the blue color turned yellow. The total volume of H_2SO_4 was recorded. This test was done in triplicate.

Example calculation: ml H_2SO_4*10= ppm $CaCO_3$

pH Testing:

The probe was calibrated using a pH 7.0 buffer. The probe was then used to measure the pH of each water sample taking caution not to touch the sides of the glass beaker. This test was done in triplicate.

Electrical Conductivity Testing:

The probe was calibrated using deionized water to read as close to zero as possible. The probe was then used to measure the electrical conductivity of each water sample taking caution not to touch the sides of the glass beaker. This test was done in triplicate.

Bacteriological Testing Procedures:

The Bactaslyde Microbe Detection (BMD) devices were opened using gloves to avoid any potential contamination. The plastic containers were filled with the water sample and the BMD devices were dipped in the container for 25 seconds. The water was removed from the container and the media was allowed to incubate at room temperature (22°C) for 24 hours. The samples were carefully inspected for the presence of E. Coli colonies on the purple side of the media slide and total bacteria on the yellow side of the media. The level of contamination was determined based on the diagram below.

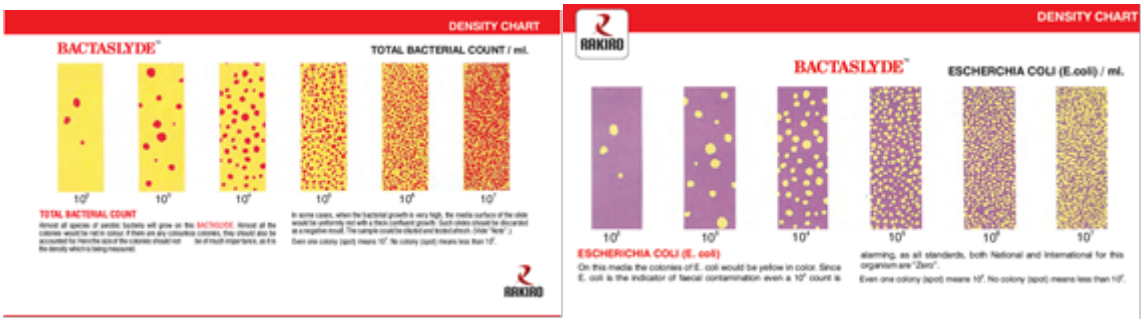


Diagram to determine total bacteria (left) and E. coli (right) contamination levels.

Appendix P: Chemical Test Results

Hardness Data

Hardness data for samples based on location and date in units ppm Ca2+ and Mg2+

Hardness						
Sample	3-Apr	4-Apr	6-Apr	7-Apr	10-Apr	12-Apr
NERI DATA						
Sample						
A		17.66				21.36
B		27.63				19.08
C		33.89				20.22
D		17.66				25.06
E		29.91				30.76
F		94.28				29.34
G		25.63				60.10
H		16.52				24.49
I		22.22				39.87
J		24.49				37.17
SALGI DATA						
Sample						
Pump COV	30.48		33.32	30.76		
Pan OW	40.16		45.57	47.00		
Gov CST	18.23		19.37	18.80		
Nat BH2	26.77		26.20	26.77		
Pump OV			43.29	44.72		
IIT DATA						
Sample						
Sample F					24.21	
Sample A					29.62	
Sample D					50.70	
Sample E					26.20	

Alkalinity Data

Alkalinity data for samples based on location and date in units ppm CaCO3

Alkalinity						
Sample	3-Apr	4-Apr	6-Apr	7-Apr	10-Apr	12-Apr
NERI DATA						
Sample						
A		7.33				9.67
B		8.00				7.33
C		11.33				5.67
D		8.00				7.67
E		12.67				7.33
F		19.00				7.33
G		9.00				17.67
H		8.00				7.33
I		9.33				11.00
J		8.00				11.67
SALGI DATA						
Sample						
Pump COV	10.67		13.33	12.00		
Pan OW	14.00		16.33	16.33		
Gov CST	5.67		7.33	8.00		
Nat BH2	8.00		7.33	8.00		
Pump OV			16.00	16.33		
IIT DATA						
Sample						
Sample F					8.67	
Sample A					10.33	
Sample D					23.67	
Sample E					9.67	

Electrical Conductivity Data

Electrical conductivity data for samples based on location and date in units of us/cm

Electrical Conductivity						
Sample	3-Apr	4-Apr	6-Apr	7-Apr	10-Apr	12-Apr
NERI DATA						
Sample						
A						138.37
B						121.90
C						113.83
D						152.33
E						173.87
F						172.70
G						512.10
H						127.07
I						187.93
J						188.17
SALGI DATA						
Sample						
Pump COV				237.17		
Pan OW				314.27		
Gov CST				140.50		
Nat BH2				166.77		
Pump OV				262.92		
IIT DATA						
Sample						
Sample F					156.83	
Sample A					224.43	
Sample D					440.40	
Sample E					156.47	

pH Data

pH data for samples based on location and date

pH						
Sample	3-Apr	4-Apr	6-Apr	7-Apr	10-Apr	12-Apr
NERI DATA						
Sample						
A						8.01
B						7.78
C						7.65
D						7.49
E						7.24
F						7.66
G						8.05
H						7.98
I						8.31
J						8.32
SALGI DATA						
Sample						
Pump COV			7.17	7.25		
Pan OW			6.70	6.79		
Gov CST			7.74	7.65		
Nat BH2			7.53	7.67		
Pump OV			7.18	7.13		
IIT DATA						
Sample						
Sample F					6.69	
Sample A					6.61	
Sample D					7.56	
Sample E					8.08	

Appendix Q: Letter to the IPH Department

Dear Honorable Irrigation and Public Health Minister Smt. Vidya Stokes,

We are a team of undergraduate students from IIT-Mandi and Worcester Polytechnic Institute (USA) who have recently completed a seven-week social and scientific study regarding drinking water quality in rural villages. We have developed recommendations for your department to help improve the quality of drinking water available. We hope that through your consideration and potential implementation of these recommendations water quality can be improved in the region.

From the findings of our study, **we recommend that your department consider revising or expanding water quality testing locations in rural villages to ensure that sampled water is from sources of high community dependence.** We found that most residents preferred untreated natural spring water and exhibited a general misconception regarding the cleanliness of these sources. Many people will be reluctant to drink from other sources than natural spring water due to generational use and the misperception that untreated water is safe to consume. By testing these natural sources and conveying the results of these tests, we believe that over time a societal change to using government treated sources will be achieved.

To promote societal change, we believe there needs to be better communication of water quality results to the general public. **We recommend that your department communicate water quality results to villagers through the implementation our Water Quality Stoplight.** The Water Quality Stoplight is a sign designed to be located next to each sampling site and is intended to easily communicate the results of water quality testing. The sign uses a three-color metric to indicate good, fair, and poor drinking water quality. In addition the previous testing date and future testing date would be published.

Finally, to improve the quality of results communicated to the public and to ensure public health through the safety of drinking water quality, **we recommend that your department expand testing to include E. coli, nitrates, and heavy metals.** From our chemical testing, we found that there was a discrepancy between the alkalinity and hardness results. These results suggest that additional ions may be present in the water. Due to the agricultural nature of the region we believe that these ions may be nitrates that further exacerbate bacteriological contamination. Additionally, since drinking water was determined to be soft, it is possible that water is corroding pipes faster than it should. More frequent maintenance and monitoring for heavy metals such as iron would be a step the department can take to further protect public health.

For more information regarding our study please visit our website:
www.sites.google.com/site/in17water/.
If you have any additional questions or concerns regarding the study please do not hesitate to reach out to us at in17.water@gmail.com

Sincerely,
Amod Kumar Choudhary, Kent Fong,
Evelyn Grainger, Rishabh Kumar,
Randy Melanson & Daniel Salisbury