# Evaluation of the Safe Water System in Jolivert Haiti by Bacteriological Testing and Public Health Survey

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## Abstract

The Centers for Disease Control and Prevention's (CDC) Safe Water System (SWS) is intended for use in developing countries and comprises three key elements: locally produced hypochlorite solution, safe storage of drinking water in the household, and community education about safe drinking water.

In Haiti, only half of the 8 million inhabitants have access to safe water. Therefore, a SWS was implemented in Jolivert, a village in the Northwest of the country, in January 2002. The pilot project now reaches 200 households in the area. In order to provide a framework for project expansion, the pilot project was evaluated by: 1) a health survey conducted in 56 households using the system and 64 non-using households, 2) bacteriological tests of water from each water source and from each household drinking water in the health survey, and 3) chlorine residual tests in each household with the system.

From a health perspective, the use of the SWS reduces diarrhea incidence by 40 percent. If there is chlorine residual in the drinking water, diarrhea incidences are reduced by 60 percent. However, it does not reduce diarrhea incidences for children under five years old, which is the main target age-category population. It is hypothesized that this age group is exposed to waterborne disease via other mechanisms than drinking water. The use of the system reduces the number of total coliform colonies by a factor of ten and the number of *E.coli* colonies by a factor of twenty. Moreover, if the water presents chlorine residual (indicating safe use of the system), the presence of total coliform units is lowered by a factor close to one hundred, and the tests show no presence of *E.coli*.

The results show that the project is successful and should be expanded. However, logistic issues need to be resolved. First, a correct pricing needs to be chosen to ensure the project's sustainability. Second, the hypochlorite solution has to be easily available in remote regions. Third, schools should play a role in the expansion of the project as promoters and educators. Lastly, further research is recommended to determine why a health benefit was not seen for children under five years old.

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# Chapter 1: Why a Safe Water System in Haiti?

## 1.1 Historical Background

Columbus discovered the island of Hispaniola (currently the Dominican Republic and Haiti) in 1492 (IBP, 1999). In 1697, the Spaniards ceded a third of the island to the French. From 1697 to 1791, the French imported slaves from Africa for labor in the agricultural production. The first slave rebellion occurred in 1791, as civil war between the blacks from the North of the island and the mulattos from the South began. Five years later, Toussaint L'Ouverture took the lead of the Northern party and calmed the nation. In 1801, in response to the slave rebellion, Napoleon Bonaparte sent an army of 34,000 men to assure French control over Haiti, but he did not succeed. However, L'Ouverture was captured and deported to France where he died a year later. In 1804, Jean-Jacques Dessalines proclaimed the independence of the Republic of Haiti. This date marks the first slave nation of Central America to become independent. In 1820, General Boyer obtained official independence for a payment of 150 million French Francs to France.

Haiti thus became only the second nation in the Western hemisphere to gain freedom from domination by Europe (IBP, 1999). The United States of America was the first. However, the United States very quickly joined the community of nations and began trade and other economic relationships with the countries of the hemisphere and the world. Haiti, on the other hand, was treated as an outcast nation and was shunned both politically and economically by other countries, which were afraid that Haiti might export its slave revolution.

After independence, however, the political situation was no better. From 1843 to 1915, there were no fewer than twenty-two different leaders of Haiti's government (IBP, 1999). The conflicts between whites, mulattos, and blacks increased until the United States felt they had to intervene and invaded Haiti in 1915. The US presence was not welcomed and they were finally forced to leave in 1934.

Rebellions and coup d'états continued until 1957, when François Duvalier, known as "Papa Doc," came to power and created a relatively stable government, but one ruled with terror (IBP, 1999). He changed the constitution and proclaimed himself governor for life in 1964. The dictator died in 1971, but his son, Jean-Claude Duvalier ("Baby Doc"), took over. In 1986, the Duvalier regime finally collapsed.

In 1990, Jean-Bertrand Aristide was democratically elected to govern the country (IBP, 1999). Not long after, a military coup overthrew the governance of Aristide. This caused the Organization of American States to impose an embargo of three years. It was only in 1994 that Aristide went back to Haiti, helped by the United States Army and United Nations troops. Rene Preval was then elected in 1995, and Aristide was reelected in 2000 and is currently President of Haiti.

Due to the country's history of political and economical instability, few international monetary aid agencies have been willing to invest in Haiti. Access to safe water, power, health care, decent roads, public transportation, and other basic necessities that are taken for granted in most large cities in this hemisphere are severely limited in Haiti's largest cities, and non-existent in smaller cities and rural areas. The vacuum created by this lack of infrastructure is partially filled by large non-governmental organizations (NGOs) in larger cites and towns, and churches and smaller NGOs in small towns and rural areas.

## 1.2 Water in Haiti

Lack of safe water is near the top of the list among Haiti's many needs, however, it is a worldwide problem as well. William Cosgrove, Vice-President of the World Water Council, reports that 7 million people die each year due to water-borne diseases (Kempf, 2003). This number includes 2 million children. He estimates that 30 percent of the world lacks access to clean water and forecasts an increase to 50 percent by 2025. On the other hand, Le Monde states that the population of developed countries over-consumes water by a factor of seven. He considers this situation as a crime against humanity.

The World Water Council ranks Haiti 147$^{th}$ of 147 studied countries in terms of water poverty (WWC, 2002). The countries were evaluated from five water perspectives: resource, access, capacity, use, and environmental impact. Each water perspective was worth 20 points. Haiti's total score on the evaluation was only 35 points. As a comparison, the Dominican Republic (located on the same island as Haiti) ranked 64$^{th}$. A study from the World Health Organization indicates that the access to safe drinking water in Haiti decreased from 65% to 49% from 1982 to 1999 for the urban areas, whereas it increased from 33% to 45% in the rural areas for the same time period (WHO, 2001).

Haiti's population is approximately 8 million (World Bank, 2002). The country has an area of 27,750 $km^2$, of which about 190 $km^2$ is water. Also, 98% of its forests have been cleared for agriculture and the use of wood as fuel. This results in extensive soil erosion and reduction of the topsoil. However, agriculture still remains the second major economic activity of the country, the first one being services (IBP, 1999). Nearly 40 percent of Haiti's population is concentrated in its cities. Although its per capita GNP is only about $520, approximately 1 percent of the population holds half of the total income. At the end of 2001, inflation was 15 percent.

Unsafe drinking water is a major cause of illness and can be lethal for children. In Haiti, this is reflected in only 45 and 54 years of life expectancy and 118 and 103 per thousands births infant mortality rates for the Haitian males and females respectively (Figure 1.1) (WHO, 2003). It is interesting to notice that more male children die before the age of 5 years than female children.

**Males** **Females**

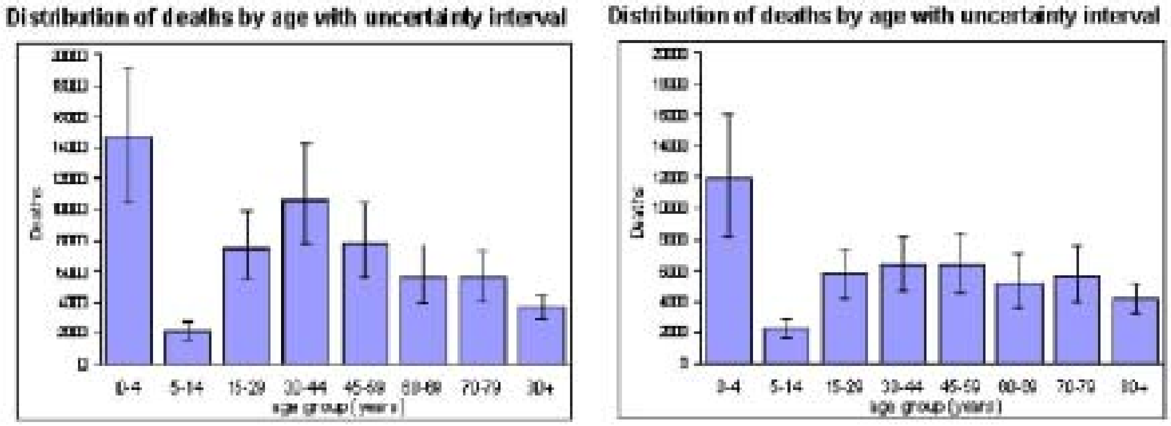



**Figure 1.1: Distribution of deaths of males and females by age category for Haiti (WHO, 2003)**

Combined with its political instability, Haiti's lack of resources prevents the creation of large-scale infrastructure for providing safe drinking water. Therefore, point-of-use systems have been implemented at small scale throughout the country at a local level.

## 1.3 What is a Safe Water System?

In reaction to the cholera epidemic that strangled South America in1992, the Center for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO) developed a point-of-use treatment of water called the Safe Water System (SWS) (CDC, 2002). The SWS is a low cost solution using simple technology that provides clean drinking water, which has been shown to drastically reduce the incidence of waterborne diseases. The SWS is a combination of: 1) treatment with a locally produced sodium hypochlorite disinfectant, 2) safe storage of the drinking water in adapted containers, and 3) community education.

In the SWS program, the water is treated in the household with a sodium hypochlorite solution, which is comparable to weak household chlorine bleach (CDC, 2002). Chlorine in water of pH around 7 is found in the form of HOCl and $OCl^-$ (Brière, 2001). These compounds act as oxidants to react and inactivate bacteria. A simple electrolysis process transforms saline water into hypochlorite solution, and is easily produced in developing countries. The hypochlorite solution is then sold to costumers at a price that is high enough to recover part of the investment, but that is within the population's ability to pay. The price can be determined by investigating how much families currently spend to purchase fuel to boil water, or to pay for the clinic visits and to buy antibiotics to cure waterborne diseases.

Another important dimension of the SWS is safe water storage (CDC, 2002). In fact, significant contamination of water results from contaminated hands or utensils touching the water after it is in the home. Also, if the storage container is uncovered, insects and other particles may fall in the water and contaminate it. For these reasons, the CDC recommends providing a container for the safe storage of water. The CDC recommends that the container meet the following six main criteria:

1. An appropriate size (10-30L) so that it is easy to lift and carry,
2. A construction of a robust, light, and translucent material that resists oxidation and solar light,
3. An opening, with a robust lid, that is large enough to facilitate filling and cleaning, but small enough to prevent even children from dipping out water out with a cup,
4. A durable spigot that is easy to close and enables a flow of one liter per 15 seconds,
5. A permanent label with instructions about the methodology to treat the water, and about the usage and cleaning of the recipient, and
6. A certificate from the local Ministry of Health that ensures the container conforms to national standards.

The third essential component for a successful SWS is education. The best way to ensure correct and continued usage of the system is to help people understand how contaminated water may create health problems and how the SWS reduces the risk of contracting waterborne diseases. Also, the correct use of the SWS should be thoroughly explained.

This behavior modification education can be done by different means at different levels. It can be at an interpersonal level such as community meetings, door-to-door visits, informational pamphlets, scholar information, or health information in clinics. It can also be done at a local level by storytelling or public announcements, or at a mass media level such as radio or television. Finally, the information can be distributed as printed material such as posters, newsletters, or brochures.

CDC Safe Water Systems have seen successes all over the world (CDC, 2002). Projects in Bolivia, Ecuador, Peru, Ivory Caost, Guinea-Bissau, Kenya, Madagascar, Rwanda, Tanzania, Uganda, Zambia, Pakistan, India, Nepal, and other countries have been implemented following the CDC SWS manual guidelines. The manual is available in English, French, and Spanish on-line at www.cdc.gov/safewater.

## 1.4 Implementing the Safe Water System in Jolivert

Missions of Love Incorporated (MOL) is a not-for-profit evangelical Christian Mission (MOL, 2003). Its president, Dr. Robert Johnson ("Dr. Bob"), and his wife Betty Johnson, a nurse and also a director of MOL, have been working in Northern Haiti for the past fifteen years helping to build churches associated with clinics and providing medical care for Haitians. Four years ago, MOL decided to build their own clinic, and now are providing health care for thousands of Haitians each year in the Jolivert, Haiti, area. Through their work in Haiti, Dr. Bob and others who have worked at the clinic have become aware of how many health problems originate from waterborne diseases such as typhoid fever and diarrhea.

William Gallo, who has worked with water projects throughout Haiti for more than five years, was invited by MOL to start an in-home water purification program in Jolivert and the surrounding communities, which would be based at the clinic. The clinic is an ideal place to gather information on the current water problems and facilitate communication and educational activities associated with the project. Furthermore, the clinic is able to provide the minimal amount of electrical power needed for the production of the hypochlorite solution.

Jolivert is a village located on the shore of the Trois-Rivieres River, in the northwest Haiti (Figure 1.2). The river provides a large amount of water low in suspended sediments. This optimizes the electrolysis process. The weekly production of chlorine solution could easily supply 2000 families. Since Jolivert has only about 300 households, the targeted area reaches many surrounding villages from Bassin Bleu (about 2 miles north of Jolivert) to Frage (about 2 miles south of Jolivert). A map in Appendix I shows the local area.


**Figure 1.2: Map of Haiti**

**(World Bank, 2002)**

The SWS started the Jolivert Safe Water for Families Project (SWF) in January 2002 with a preliminary study of the local population. After locating a Haitian supplier for buckets to adapt as SWS containers, and importing bottles in which to store the hypochlorite solution and other materials needed in order to start the project, a pilot project was implemented with 200 participating households in December 2002.

The project is run with local personnel.  Christophe Velcine, who works as a laboratory technician at the clinic, directs the project.  He completes the administrative and material management work.  Elédère Odin is the SWS full-time technician who prepares and sells the hypochlorite solution.  He also visits the homes and ensures the transmission and understanding of educational information throughout the community.

In April 2002, an initial meeting was held by Dr. Bob Johnson and Bill Gallo with community leaders to explain the project.  In September 2002, Christophe and Elédère explained the use of the buckets and associated health issues with the first twenty people to receive systems.  The program was underway.  Then, Christophe and Elédère conducted a series of meetings and distributed the remainder of the 200 special buckets that were to be used for the pilot project.  Elédère then began visits to the households to verify that the system is used properly and that users are aware of the health implications of unsafe water.  Information concerning the Safe Water System was also included in the clinic's newsletter.  Some schools from Bassin Bleu have shown interest in the SWS.  The use of the SWS in schools would serve a useful educational purpose, but have limited health consequences since many of the children do not drink treated water in their home.

The locally generated hypochlorite solution is called Dlowòks.  A highly concentrated chlorine solution is currently used in Haiti and is called Klowòks, which is a calcium hypochlorite solution.  "Dlo" means water is Creole.  Dlowòks therefore suggests clean water through using a chlorine solution.

The special containers used in the pilot project are adapted from buckets that are similar to the ones Haitians normally use.  They are standard plastic 5-gallon (20-liter) buckets, as commonly sold in the United States and other countries.  They meet many of the six CDC criteria, but not all:

1. They are of a reasonable size to carry.  They also have a handle, even though most people carry the buckets on their head.

2. They are robust and light; however, they are not translucent, but opaque.
3. The opening is very large (~45cm of diameter). It eases the cleaning process, but does not prevent people from taking water from the top with a cup.
4. The bucket is equipped with a durable spigot, but if the lid is completely closed, suction prevents water from flowing from the spigot. To solve this problem, the user either does not close the lid tightly or the technician drills a small hole into the lid to allow for the passage of air.
5. The buckets have a sticker attached to them explaining how the system is used.
6. While there is not yet specific approval from the Haitian Ministry of Healthfor these units, the CDC is investigating starting a country-wide program that will gain MOH approval for the SWS process.

As can be seen, except for the color and the size of the opening, the bucket's characteristics respond to the CDC requirements. Another issue is that the lid, however, needs holes drilled that will let the air enter. The bucket and chlorine bottle used in Jolivert for the Safe Water System are presented on Figure 1.3.

**Figure 1.3: Jolivert SWS material**

## 1.5 Jolivert's Sources of Drinking Water

As mentioned earlier, Jolivert and the nearby communities are located along the Trois-Rivieres River. The main road between Port-de-Paix and Port-au-Prince borders the river and most homes in the area are located near the road and river. It is no surprise that the river constitutes the main source of water for the population.

Most people harvest their drinking water from what they call "sous dlo", the Creole word for "spring water." This choice of wording shows that the Haitian people differentiate groundwater and surface water. However, the "sous dlo" is not a groundwater spring, but only river water filtered by the soil. People dig a small hole in a dry spot in the riverbed and wait until it fills with water (Figure 1.4). They then harvest it with a bowl or a glass to fill their buckets. As they harvest the water, they are careful not to drop anything into the "sous dlo" to avoid clouding the water. A hole that has been previously dug may be reused by emptying the water and removing a layer of soil from the bottom. That way, they remove the sediments that settled at the bottom in which bacteria may have grown.

**Figure 1.4: Woman harvesting water from a "sous dlo"**

Groundwater sources, true springs, are also available for drinking water. The clinic sends people to get spring water, even though it takes about 20 minutes longer than collecting it from the river. Three groundwater sources were mentioned during the surveys: De Riyon, La Boule, and Tiboukan. De Riyon is located near La Hatte, about a 20-minute walk from the clinic, but on the other side of the river. La Boule is on Jolivert's side of the river, but is in the hills, above La Boule district, about a 30-minute walk from the clinic. Tiboukan is just north of Bassin Bleu, but we did not have the chance to visit it. The spring De Riyon (Figure 1.5) is capped and the water flows from a steel pipe that facilitates collecting it. As showed on Figure 1.5, the access for De Riyon spring is not safe. The rocky wall is slippery due to the fresh groundwater flowing on it that encourages the growth of vegetation. The darker shades of the rock on the photo indicate the presence of vegetation. Transporting a 20-liter bucket or two across this surface can be dangerous.

**Figure 1.5: Groundwater source De Riyon**

Sido, the clinic employee responsible for collecting the clinic's water at the De Riyon spring, crosses the river, fills two 20 liter buckets and then returns to the other shore. Even when it is at a low, the river is about one meter deep. The easiest way to transport the buckets is to let them submerge in the river to reduce the weight. However, this raises the possibility of the river water mixing with the bucket water. This undermines the purpose of collecting the water from the spring in the first place. This particular example suggests that if Sido did not fully understand why he should collect water from a spring, others may not be aware of the health benefits of using the spring water as well.

Another reason why people may not use groundwater sources is their location. It is probable that people harvest their drinking water from the "sous" only because it is the nearest source of water from their homes.

To date, MOL and Bill Gallo have worked with the Jolivert community to set up a pilot SWS program, and have hired two local coordinators for the project. The following chapters assess the evaluation of the pilot project in order to provide a framework for the project expansion. Chapter 2 discusses the survey results, Chapter 3 evaluates the hypochlorite solution produced by the Jolivert SWS technician, Chapter 4 presents the bacteriological testing from the drinking water sources and household drinking water sampling, and Chapter 5 suggests different alternatives for the project's expansion.

# Chapter 2:  Survey, Methodology and Results

The first objective of this research was to evaluate the pilot SWS project in Jolivert. Therefore, a survey was developed and administered to households that use the system and households that do not use the system in order to compare the health of the two populations.  For all the households, information about the number of people with diarrhea, the demography of the household, their usage of water, and simple sanitary issues were obtained.  Also, for the users of the SWS, information specific to their use of the system was also obtained.  Lastly, microbiological samples were collected in each home to compare water quality in the two groups.  These results are presented in Chapter 4.

This chapter first presents the surveyed population and describes how the households were chosen.  Then, the difficulties encountered are discussed, and what should be done in the future to obtain more complete survey results.  Then, methods used to effectively collect and manage the data are discussed.  Lastly, the results of the survey are presented.

## 2.1 Description of the Population Surveyed

The surveyed population was to include 60 households that use the system (30% of total system users) and 60 that do not use the system.  Thirty percent of the households from each of the ten communities included in the pilot project were randomly selected in order to obtain representative results of the overall pilot population.  For each household that had the system, a household nearby that did not have it and looked the same was selected during the survey process.  This process was to obtain surveys from households with and without the system with similar characteristics such as their distance from the clinic, the source of water they use, and their socio-economic status.

However, the sample sizes and the randomly chosen people changed slightly during the survey process because people were not present when we visited the randomly selected home or they had given their buckets to one of their relatives. The response rate is very close to 100%, since only one person out of 120 refused to answer the survey. Also, seven households completed the survey but did not have water in their bucket at the time of the visit. The final population sizes that had water available to sample at the time of the visit are then 54 households with the system and 59 without. The number of people who were surveyed but did not have water was 2 (4 percent of the population with the system) with the system and 5 (8 percent of the population without the system) without the system. The number of households visited in each community is presented in Table 1.1:

**Table 1.1: Number of households visited in each community**

| Place | Dist. from clinic (min. walk) | With the system | Without the system |
|---|---|---|---|
| Bassin Bleu | 45 | 5 (+2 w/o water) | 7 |
| Benjamin | 40 | 0 | 1 |
| Brizard Nicole | 20 | 1 | 1 |
| Corosse | 30 | 2 | 2 |
| Fond-du-Roc | 30 | 9 | 9 |
| Frage | 35 | 2 | 2 |
| Jolivert | 10 | 24 | 25 (+3 w/o water) |
| La Boule | 30 | 3 | 3 |
| La Hatte | 15 | 5 | 6 (+1 w/o water) |
| Limite | 35 | 3 | 3 (+1 w/o water) |
| **TOTAL** | | **54 (+2 w/o water)** | **59 (+5 w/o water)** |
| | | **113 (+7 w/o water)** | |

In order to be able to compare categories that have and do not have the system, it was necessary to assure that both populations had the same average socio-economic status. In fact, a method used during the survey to determine the relative wealth of the family was to look at the general characteristics of the house. At the beginning of the survey period, the interviewers ranked the households' socio-economic level from one to three, one corresponding to a households with straw roofing or very old steel roofing, earthen floor and walls, and three being a household with a nice steel roof, and cement floor and walls. In fact, I based my observation criteria on Arun Varghese's thesis. He ranked the quality of housing as follow:

i. "Earthen walls and floor, corrugated iron roof,
ii. Earthen walls, cement floor, corrugated iron roof,
iii. Cement walls, floor, and roof, unpainted, unfinished fittings,
iv. Cement walls, floor, and roof, partially finished fittings,
v. Completely concrete structure with modern fittings". (Varghese, 2002)

Varghese conducted his study in Dumay, which borders Port-au-Prince. Some families had cars and the difference in socio-economic status was more prominent than in Jolivert. In the survey population of this thesis, the only household that showed a different socio-economic status was the home of the mayor of Bassin-Bleu, which had a nice steel fence that delimited the property. But, for the rest of the population, the socio-economic status did not vary a lot. Therefore, after two days of surveying, we stopped evaluating the socio-economic level of the households because we found out that they were almost all in the same category of socio-economic level 2, based on the grading presented above. Also, the subjectivity of the grading involves an uncertainty that is greater than the differences seen in the households' socio-economic status of Jolivert.

Also, in the next chapter where the survey results are presented, we see that the majority of the households have about the same number of rooms and that the percentage of families connected to electricity is nearly zero, except for some families in Bassin Bleu, who are connected to the community generator. The results from these two metrics also elucidate the socio-economic status of the survey participants.

## 2.2 Survey Limitations

There are some limitations in the survey method. Some are inherent in surveying techniques, and others were discovered specific to the community. These limitations include the privacy level of some questions, the perception of children under five years old, the interviewing process, the interviewer's nationality, and the total time of the surveying process.

Questions relating to diarrhea and sanitation sometimes appeared to intimidate the interviewee. These questions concern the private life of the people and some were ashamed about diarrhea or other sanitary practices such as not using soap and not washing hands. Therefore, it is possible that some answers regarding these questions are biased.

Also, some families did not mention children under five in their list of people living in the household. This probably reflects the high infant mortality rates. In fact, we noticed that children under five might not be listed because their lives were so unsure while they were still under five years old. These observations would explain the high presence of coliform colonies in the drinking water of households without the system and that reported no diarrhea incidences in the last week.

Moreover, there are some factors that were not taken into account in this study but that could have influenced the results. Jennifer Davis, in her text called "*Assessing community preferences for development projects: Are willingness-to-pay studies robust to mode effects?*" reports the effect of different interviewing processes (2001). In fact, a face-to-face interview may give different answers than one that was conducted in front of neighbors or other members of the family. As an example, MacRae, in "*Assessing preferences in cost-benefit analysis: Reflections on rural water supply evaluation in Haiti*" (1998), noted that Haitian men were not willing to improve the water supply system because they were afraid that their wives would have too much spare time. Therefore, we can argue that the survey answers depend on which member of the family was interviewed and in what circumstances. Unfortunately, these criteria could not be taken into account in this study.

Furthermore, all the interviews were conducted in teams. Therefore, some people were interviewed alone in front of two interviewers. This situation can be intimidating. A better way would probably have been to assess interviews by only one person. Also, teams of interviewers consisted of one Haitian and one "white." It is possible that the presence of a foreign people influenced the answers and encouraged people to try to get the "right answer" or give a good image in front of the foreign people.

Due to time constraints, it was not possible to assess a complete health, and water and sanitation evaluation survey. The survey was constructed with general questions on the health, water, and sanitation situation of the household, but oriented towards our goal to evaluate the pilot project efficiency from a health perspective. There were no questions related to the willingness-to-pay for different solutions, or development questions about what they think of the SWS as it is now, what they know about it, and how they would like to see it expand.

Despite these limitations, valuable information was collected. In fact, the next section presents informative survey results.

## 2.3 Survey Results

The discussion of survey results is divided into four parts: 1) diarrhea results, 2) demographic, health, and sanitation results, 3) discussion of the drinking water situation in Jolivert, along with its handling and storage, and 4) Safe Water System usage results. The relevant findings are exposed and explained in this section, and a complete copy of the survey questions and answers is included as Appendix III. Furthermore, for some questions, people could give more than one answer, therefore, some categories sum up to more than 100%.

### *2.3.1 Diarrhea Incidence Results*

Since all the analysis refers to diarrhea incidences, it is important to analyze this question first. The following question was asked to each interviewee:

**Question 14: How many people in the family had diarrhea last week, and who?**

The results are presented in Table 2.1 in such a way that we can compare the different age categories of people in relation with the use of the system. This analysis indicates the health benefits that the use of the system can provide.

**Table 2.1: Diarrhea incidences data**

| SWS | People | Less than five years old | | | | From 5 to 16 years old | | | | More than 16 years old | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Female | | Male | | Female | | Male | | Female | | Male | | | |
| Without | Total | 35 | **33%** | 25 | **29%** | 62 | 14% | 70 | 8% | 112 | 19% | 84 | 21% | 388 | **18%** |
| | With diarrhea | 11 | | 7 | | 8 | | 5 | | 21 | | 17 | | 69 | |
| With | Total | 28 | **32%** | 27 | **40%** | 64 | 7% | 40 | 2% | 112 | 6% | 79 | 7% | 350 | **11%** |
| | With diarrhea | 9 | | 11 | | 5 | | 1 | | 7 | | 6 | | 39 | |
| With residual* | Total | 18 | **28%** | 20 | **38%** | 45 | 4% | 26 | 4% | 85 | 1% | 60 | 5% | 255 | **8%** |
| | With diarrhea | 5 | | 8 | | 2 | | 1 | | 1 | | 3 | | 20 | |

* This category includes families with the system and with chlorine residual at the time of the survey

Families with the Safe Water System had 40 percent fewer diarrhea incidences than the population without the system. However, no improvement is seen in the main target population, children under five years old. In fact, boys under five had an even higher rate of diarrhea incidence in the families with the system.

Moreover, the children do not see health benefits even when the system is used correctly, that is to say when there was chlorine residual in the water. The female children present a slight amelioration of four percent less diarrhea incidences, but the male children do not change significantly. On the other hand, if we only look at people of five years old and more, diarrhea incidences are reduced from 15.5 percent of diarrhea incidences without the system to 6.4 percent with the use of the system to finally 3.2 percent with the system and chlorine residual in the water.

However, by breaking the category of children under five into two categories, one for children of zero, one or two years, and the other one for the children of three or four years old, interesting results are found (Figure 2.1).

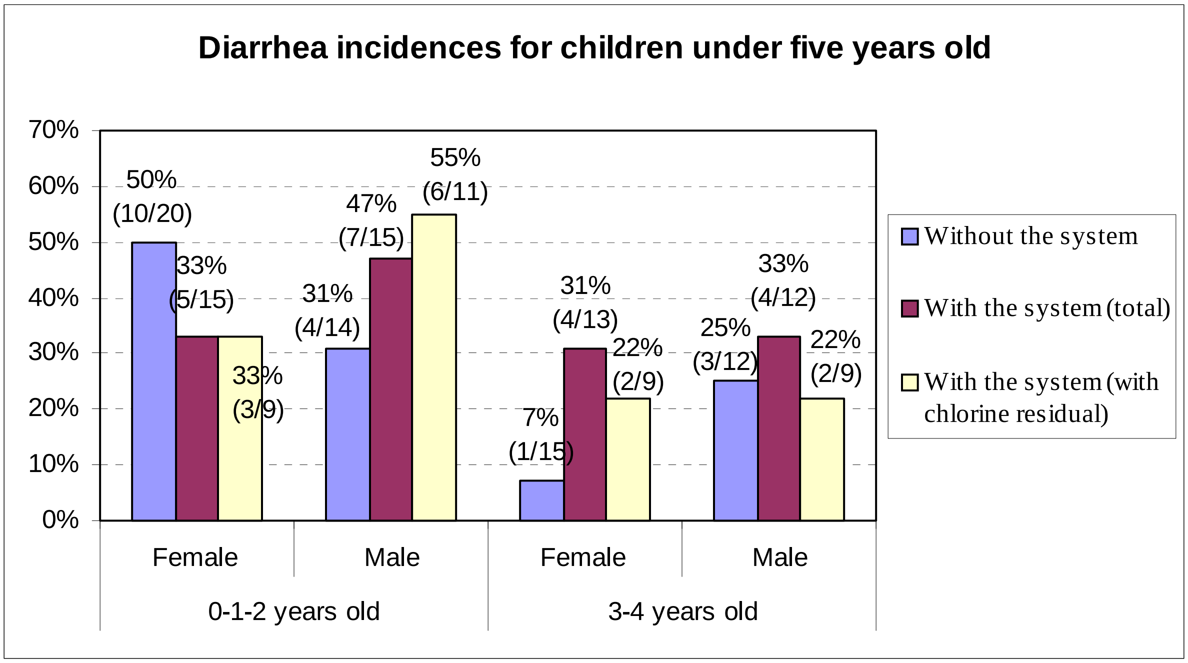



**Figure 2.1: Impact of the SWS on diarrhea incidences for children under five years old**

The main point to see Figure 2.1 is that the safe use of the SWS has a positive impact on girls and boys of three or four years old. In fact, we a reduction in diarrhea incidences of about 30 percent for female and males of three or four years old when there is chlorine residual in the drinking water, respectively going from 31 and 33 percent of diarrhea incidences without chlorine residual to 22 percent with chlorine residual. However, there are more diarrhea incidences in the category of females from three and four years old with the system than for the ones without the system. Also, from the Figure 2.1, we see that girls under three years old have less diarrhea incidences with the system, but have the same diarrhea rate when the drinking water does or does not have chlorine residual. On the other hand the boys from the same age category present higher rates of diarrhea with the use of the SWS and even more when the water has chlorine residual.

The result regarding the children under five years old requires further studies. My hypothesis is that children under five are exposed to bacteriological contamination by other means than water with or without the system. Therefore, a Safe Water System will not prevent them from contracting diarrhea if no sanitary improvement is done.

### *2.3.2 Demographic and Sanitation Results*

Eight relevant questions related to demography and sanitation were included in the survey. These questions are important in the evaluation of the system because they assess the success of the behavior modification component of the system.

**Question 1: List of people living in the household with their respective age.**

A distribution of the total population included in the surveys is presented in Table 2.2:

**Table 2.2: Demographic characteristics of the surveyed population**

| Age (year) | Female | Male |
|---|---|---|
| Under 5 | 62 | 53 |
| 5-16 | 126 | 110 |
| Over 16 | 224 | 163 |
| TOTAL | 412 | 326 |

It seems that the number of children under five is low compared to the other age categories. In fact, some people did not mention their presence in the house until it was specifically asked. Therefore, some may have been omitted. As mentioned previously, this comportment may be a sign that children under five are not considered since their survival is so uncertain. As mentioned previously, the World Health Organization (WHO) evaluates the probability for children dying under the age of five years to 118/1000 for males and 103/1000 for females, compared to 9/1000 and 7/1000 for males and females under five in the United States of America (WHO, 2003).

**Question 18: How many rooms are there in the house?**

This question was asked to have a sense of the family wealth. Figure 2.2 shows that the majority (52 percent) of households have two rooms. The remaining varies from one to eight rooms.

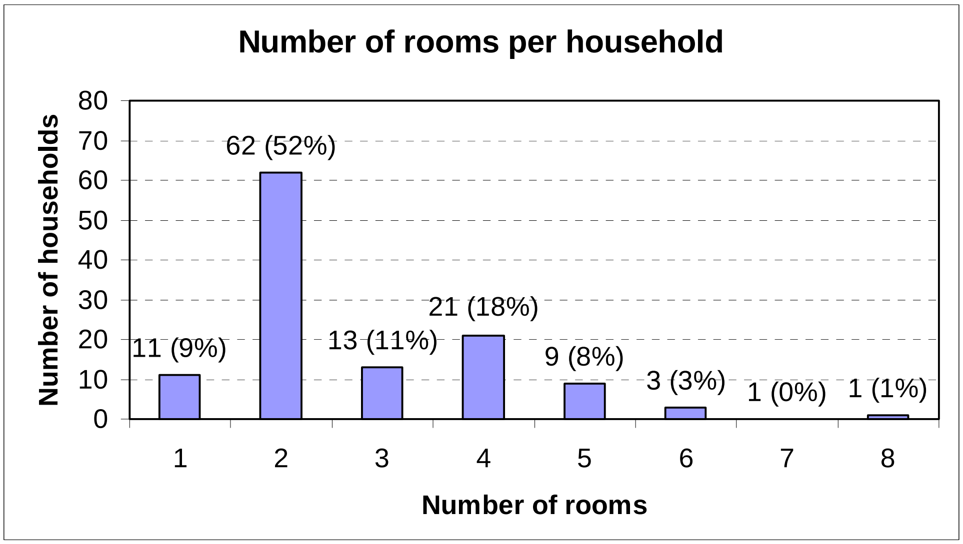



**Figure 2.2: Number of rooms per household**

**Question 24: Do you have electricity?**

This question was also to assess household wealth. Only 10 households out of 120 had electricity (8 percent). The ones with electricity were mainly located in Bassin Bleu or Limite, where a generator provides sometimes electricity to connected households. Also, there was no significant difference in the connection percentages of the people who did or did not have the system, or did or did not have diarrhea. Therefore we can assume that there was no major difference in the wealth of people of the different categories.

**Question 15: Where do people in your family go to the bathroom?**

Having a latrine influences the diarrhea incidences for people with and without the system (Figure 2.3).

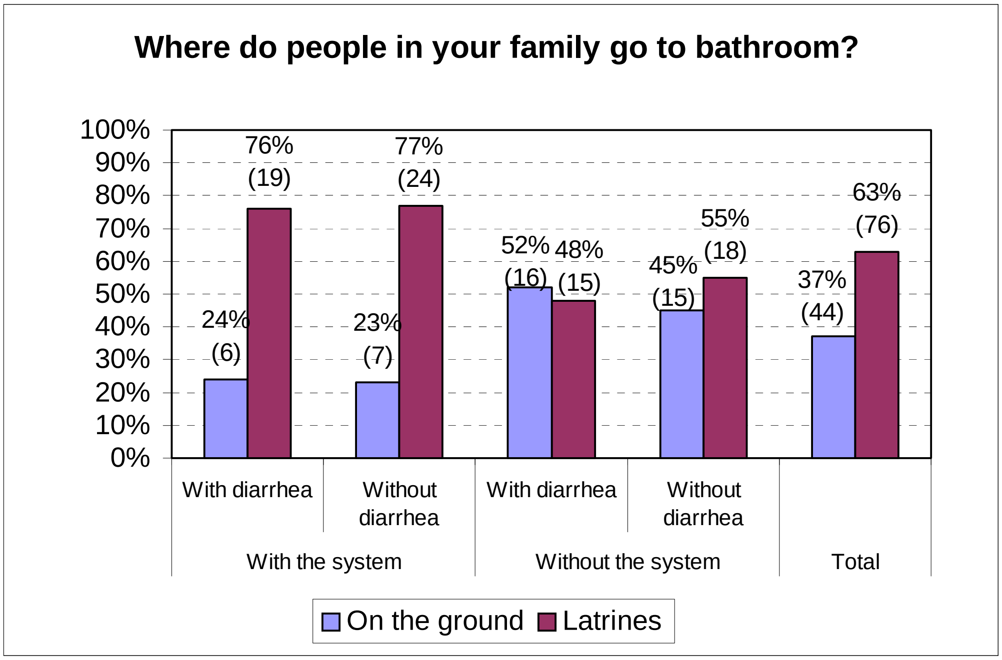



**Figure 2.3: Where do people in your family go to bathroom?**

From the general overview, we can tell that the ones with the system more often have latrines than the others. This can be due either to a preferential selection of the pilot population, or to greater sanitation awareness from the people who possess latrines, bringing them to get involved more quickly in any sanitary project.

Moreover, it is interesting to notice that in the "without" population, more people with latrines did not have diarrhea. This finding is consistent with the hypothesis that adequate sanitation prevents diarrhea, regardless of drinking water practices (Esrey, 1996). On the other hand, for the population with the system, this result is not significant. The ones without diarrhea only have more latrines by one percent than the ones with diarrhea.

**Question 22: When do you wash your hands?**

This question is important because the hands are the number one transporter for waterborne diseases (CDC, 2002). The results concerning the hand washing are presented in Figure 2.4.

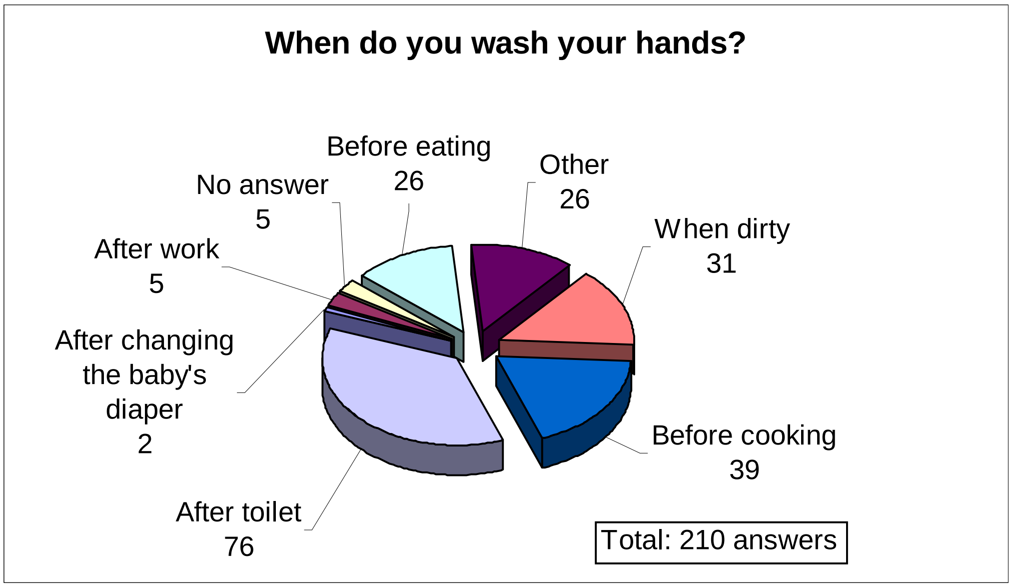



**Figure 2.4: When do you wash your hands?**

The diversity of answers is very interesting. The most popular answer being "after toilet" (76 percent), it shows a good knowledge of sanitary practices. However, vague answers such as "when dirty", or "always" (included in the "other" category) indicate that some people do not associate washing hands with specific actions. This may be because people felt a pressure to answer the question quickly or they because they do not know specifically when they wash their hands.

On average, the people without the system answered this question with more answers than the people with the system. The answers in the latter category summed to 165 percent compared to 185 percent for people without the system. Further research should be done in order to see if having treated safe water creates a false feeling of security and property, and therefore, reduces the number of times people wash their hands. Also, it would be interesting if they wash their hands less often because they pay for the hypochlorite solution and value the safe water more than the ones who do not treat their water.

From the two population categories, two major differences were noticed in the specific times they wash their hands. First, 27 percent of the people without the system reported to wash their hands before eating compared to only 16 percent in the category with the system. Second, 30 and 20 percent, respectively, reported to wash their hands "when dirty". These findings support the argument that people with the system wash their hands less often.

Another way to look at the answers is to compare the results from people with diarrhea with answers from the ones without diarrhea. In this case, the major difference is the people without diarrhea wash their hands more before cooking (39 percent compared to only 25 percent for people with diarrhea). It is therefore possible that diarrhea is transmitted through this practice. However, for the other categories, the results present no significant difference.

**Question 23: Do you have soap right now?**

Contrary to the suggestion of answers to the previous question, results from this question indicates that 86 percent of the people with the system have soap, compared with only 75 percent for the ones without the system (Figure 2.5). This suggests that people with the system may wash their hands with soap more often. However, comparing people who reported cases of diarrhea with people with no diarrhea cases, 80 percent of both categories had soap at the moment of the interview. This means that having soap in the house did not prevent diarrhea. In order to relate with the previous question about how often people wash their hands, it would be interesting to investigate the proportion of people using soap to wash their hands. In fact, it is possible that the soap in the house is only used for showering or cloth cleansing.

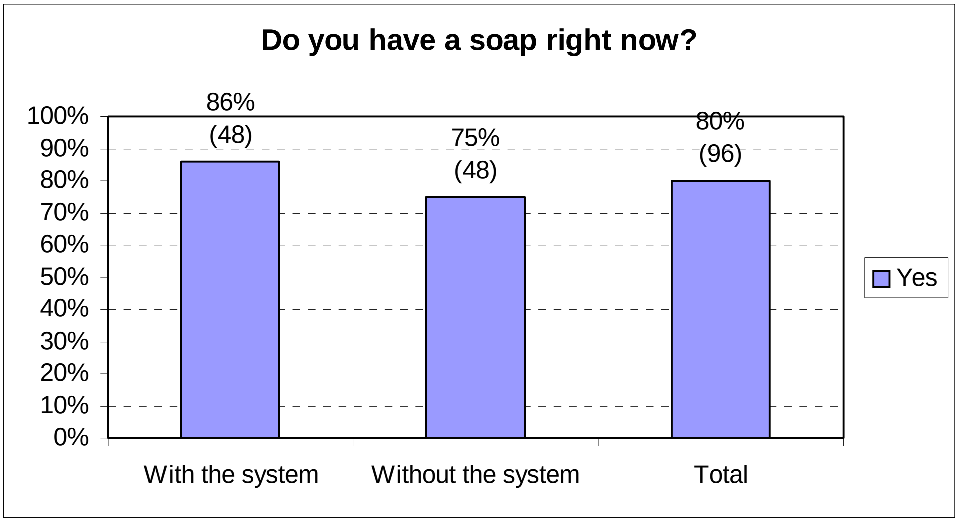



**Figure 2.5: Do you have soap right now?**

**Question 25: Are there flies in the house?**

**Question 26: If so, how many?**

It was not always possible to enter in the house to answer this question. However, from the 100 households (83 percent response rate) that we obtained an answer to this question, 63 (63 percent) had flies in the home. This result is comparable for people with or without the system and with or without diarrhea. Only the sub-category without the system and without diarrhea presented a slightly lower result with 57 percent of households with flies in the home, compared to 65 percent for the other categories.

The answers of question 26 depended on which room we entered. In fact, there were more flies when we entered in the kitchen than when we entered in a bedroom or a living room. However, there were less than 10 flies in 80 percent of the homes where there were flies.

### *2.3.3 Drinking Water Sources, Safety, Storage, and Handling*

Twelve questions in the survey related to the drinking water sources, as well as its safety, storage, and handling. The following section presents the results to these questions and, when relevant, comparing the answers from people who did and did not use the SWS, and people that did or did not have diarrhea.

**Question 2: Where do you get your drinking water?**

Of the total 120 houses visited, 109 (91 percent) take their drinking water from the "sous dlo," which is the hole just beside the river (Figure 2.6). Seven (6 percent) people said their primary source of drinking water was from a groundwater source, and three use ground water as their secondary source of water. Two (2 percent) said their primary source of water was rain. Only two persons (2 percent) reported obtaining water directly from the river.

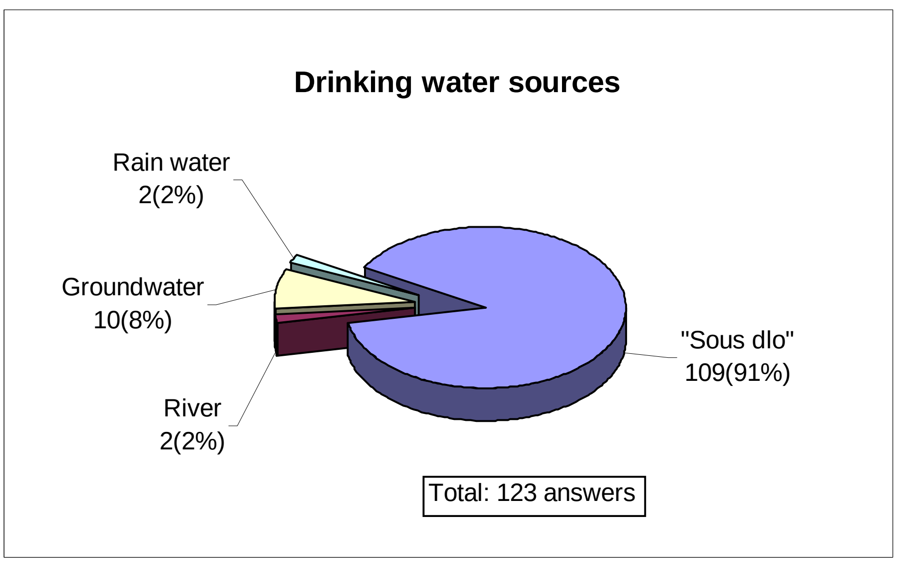



**Figure 2.6: Drinking water sources**

Groundwater is not a major source of drinking water because the springs are not as close to most households as the river. It would be interesting to know if people would be willing to change their drinking water source if they knew one source is of better quality than another source. That way, we could relate how they value their time compared to health benefits.

It is however a little unfortunate to see that only two persons harvest rainwater. This is probably due to the absence of inexpensive cisterns. In fact, most homes already have steel roofs and steel gutters. Many people take their buckets out when it rains to harvest what rainwater they can. However, due to limited storage volumes, most of the rainwater is lost.

**Question 3: Do you think your water is safe to drink?**

From this question, we found that 63 percent of the population (75 households) think the water is good for drinking, 27 percent think it is not good, and 11 percent do not know (Figure 2.7).

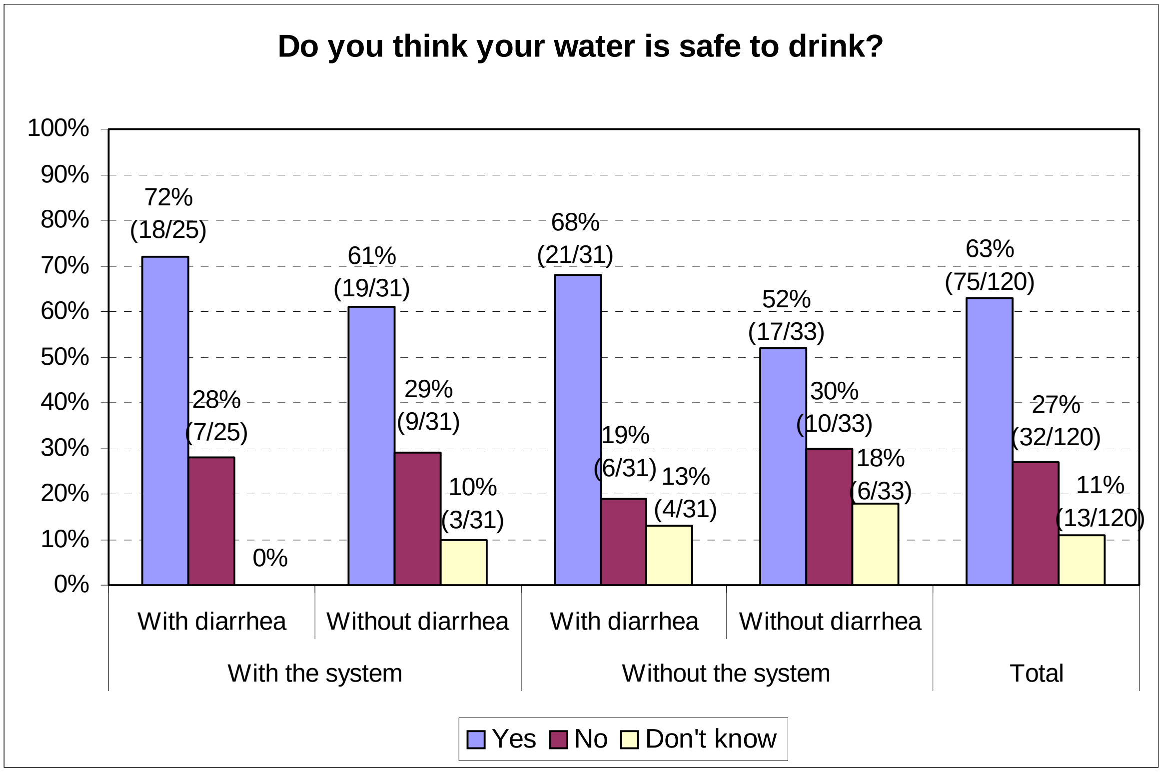



**Figure 2.7: Safety perception of drinking water**

It is important to note that people who did not have diarrhea in the last week have a better sense of the quality of the water. In fact, 30 percent of the people without diarrhea said that the water was not good for drinking compared to only 22 percent for the people with diarrhea. Therefore, a good perception of the quality of water presents health benefits.

However, this question should be reformulated to "Is the water good to drink as it is, without treating it?" In fact, it is difficult to conclude anything from this question because many people who said that the water was good for drinking actually treated it, as seen in the next question.

**Question 4: Do you do something to your water to make it safe?**

Fifty percent of the people who do not have the system stated that they treat their water. Even if some of these answers may not be true, it shows a certain degree of concern and knowledge of the water quality. It is also important to point out that 58 percent of the households without the system and without diarrhea said they treated their drinking water, in opposition to only 42 percent in the group who reported diarrhea incidences.

In fact, of the 33 households without the system and without diarrhea, twelve said they treated their water. Three households out of theses twelve have less than 10 total coliform colony forming units (cfu) per 100mL, two of which had zero *E.coli* cfu/100mL, and the other had one *E.coli* cfu/100mL. For the ones without the system and with diarrhea incidences, fourteen out of 31 reported to treat their drinking water. Two presented water samples with less than ten total coliform cfu/100mL of water, but four had zero *E.coli*. However, three other households had less than 1000 total coliform cfu/100mL, which is much lower than the mean of 3500 cfu/100mL. This could be due to a treatment that was not strong enough, but it reveals that some coliforms have been removed. The different alternatives for treating water were tested and the results are presented in the Chapter 4.

It is interesting to look at the results from the bacteriological testing from the households without the system, and compare the ones that reported to treat their water and those who did not (Table 2.3).

**Table 2.3: Bacteriological results from households without the system reporting to treat or not to treat their water**

| | Total coliform (cfu) | | *E.coli* (cfu) | |
|---|---|---|---|---|
| | With diarrhea | Without diarrhea | With diarrhea | Without diarrhea |
| Said that they treat the drinking water | 5600 | 5520 | 350 | 200 |
| Do not treat the drinking water | 6350 | 9050 | 300 | 250 |

It is interesting to notice that people who treat their water and do not have diarrhea incidences have less *E.coli* cfu in their drinking water than people who do not treat their water. However, when people treat their water but present diarrhea incidences, there are more *E.coli* cfu in their water than for those who do not treat their water. Also, people who treat their water have less total coliforms than those who do not treat their water.

**Question 5: What do you do to make your drinking water safe?**

From Figure 2.8, we see that even though people do not have the system, almost half of the population is treating water before drinking it. Section 3.4 will examine the performance of different treatment technique used as alternatives of the Safe Water System. The most common practice is to use calcium hypochlorite grains, which are commonly sold in local shops and markets.

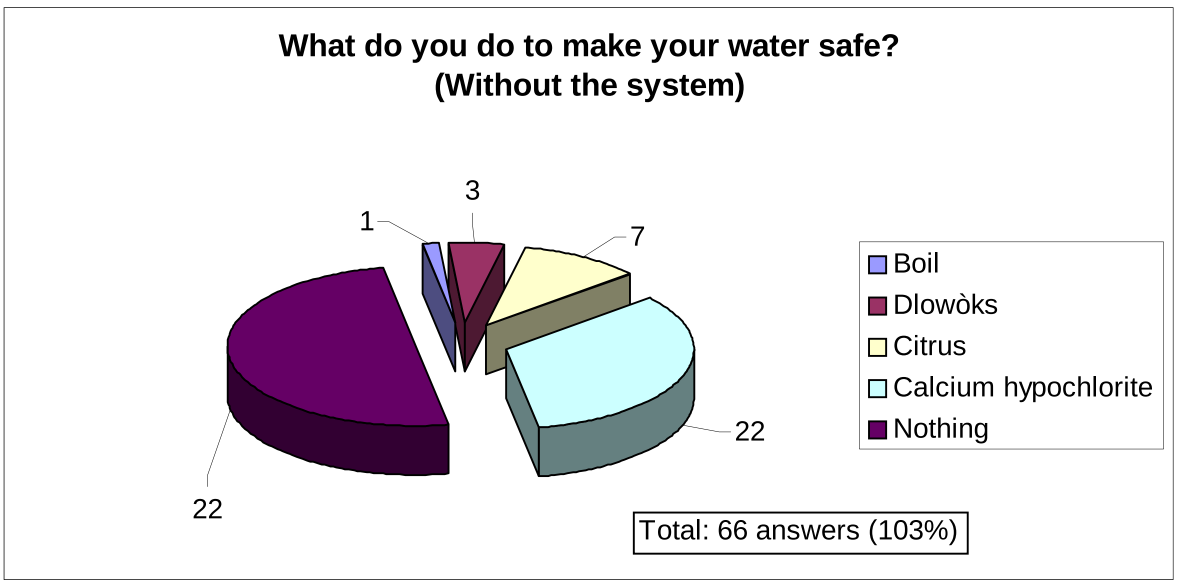
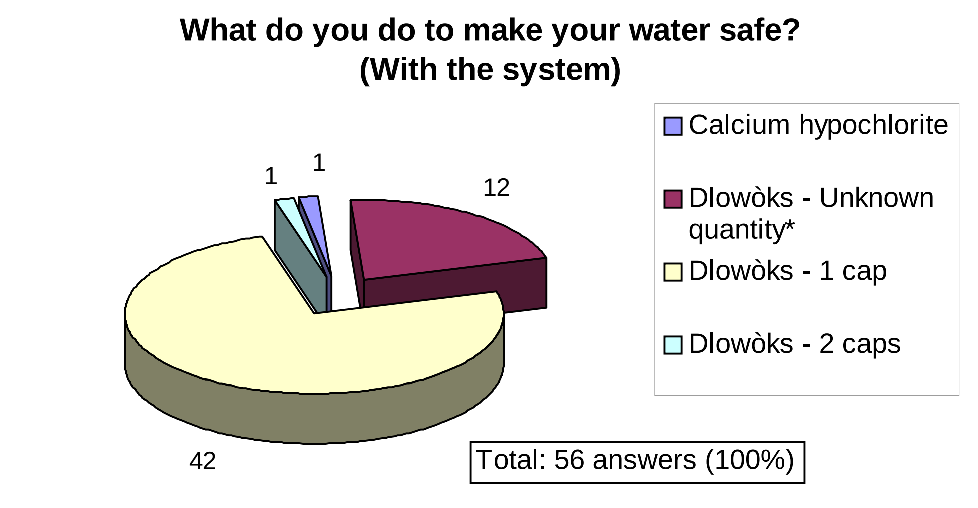



**Figure 2.8: Treating method (without the system)**

Also, it is important to report that 58% of the ones with diarrhea incidences did not treat their water, compared to 45% for the households without diarrhea incidences. This difference reflects that: 1) people get diarrhea less often if they use alternative methods to treat their water and, 2) even if some of these alternative methods are not as effective as Dlowòks, concern about safe drinking water may improve their sanitary practices and indirectly improve their health. For example, adding citrus to water does not kill any bacteria, as will be explained in Section 3.4. However, if such a practice is done with the intention of making the water safe for drinking, it is possible that people from this household are more concerned about health and sanitation and pay more attention to other details that may improve their health condition, such as washing their hands more often, not leaving left-over food anywhere, and other sanitary measures.

For the population with the system, this question was more to get a sense of the use of the system. From Figure 2.9, we can conclude that the majority uses the system correctly, adding one cap of the hypochlorite solution (Dlowòks) bottle in the bucket of water. For the people we know which quantity they use, 95 percent put the correct quantity of Dlowòks in their drinking water. The ones for whom we do not have specifications on the quantity of Dlowòks they add to the water are the ones where the interviewee was not the one taking care of this duty.




* The quantity of Dlowòks added is unknown because the person surveyed was not the one responsible for adding Dlowòks

**Figure 2.9: Treating method (with the system)**

**Question 6: How is drinking water stored in the house?**

From the answers to this question, we found four kinds of containers were mainly used: 1) the bucket, which is a 5 gallon (20 liter) container shaped like the SWS containers, 2) the "kanari", which is a clay pot, 3) the gallon, which is a small plastic container of one gallon (3.8 liter) used by children to harvest water, and 4) the “dwoum”, which is like a cooking pot.

We found that the households using the SWS are using the buckets suggested by the program (100 percent). Only one household still uses a gallon to store drinking water in addition to the SWS bucket. In fact, for this particular case, ten people live in the household. Maybe a twenty-liter bucket is not enough to store the daily drinking water for that many people. Unfortunately, only the bucket water was tested. It would be interesting to know if the water stored in the gallon is also treated with the Dlowòks solution.

On the other hand, people that do not have the system have different methods for storage (Figure 2.10). It is interesting to note that the bucket is commonly used (70 percent) and that the Safe Water System is consistent with this practice. Therefore, it is probable that the implementation of the SWS will be more easily accepted since it does not change the storage recipient type currently used.

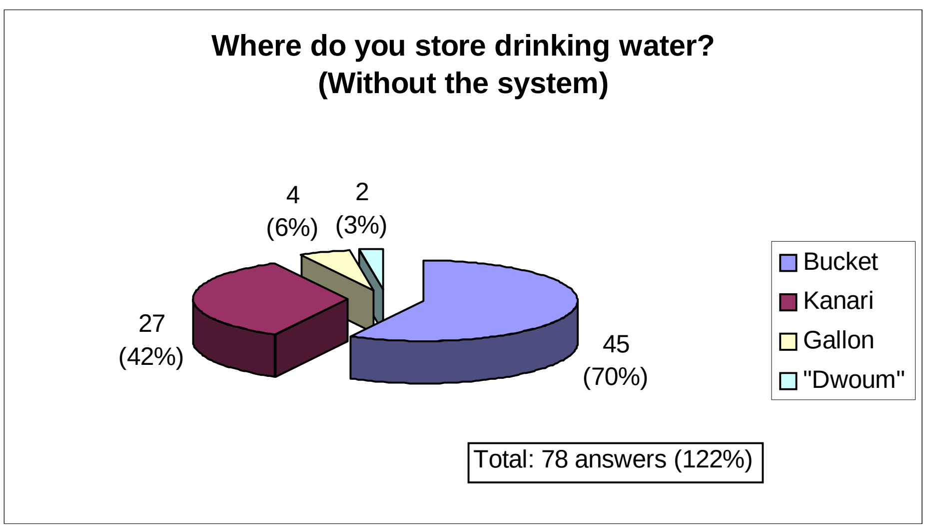



**Figure 2.10: Storage recipients for people without the system**

**Question 7: Is the container covered?**

**Does it have a cloth on top of the lid?**

The answers from this question show that 98 percent of the population covers the drinking water container. Only one household does not cover it. This household is one that does not have the system and presents diarrhea incidences in the family. Also, one other household had the container only half closed. However, this household had the system, and it is possible that the lid was only half closed to let the air enter, due to the suction problem explained earlier.

Also, a common practice is to put a cloth on top of the lid. Nearly 25 percent of the total surveyed population reported to do that. For those who have the system, this proportion increases to 46 percent. Moreover, people with the system and without diarrhea, reported more often (55 percent) putting a cloth on top of the lid than people with the system and with diarrhea (32 percent).

**Question 8: If so, how?**

All households that have the Safe Water System buckets covered them with the associated lid. However, in the population without the system, a variety of answers were mentioned (Figure 2.11). Most people (84 percent) use the container lid to cover it. An interesting fact is that the one using a peel of banana to cover its container shows very high results of total coliforms compared to the other samples done the same day, from the same community.

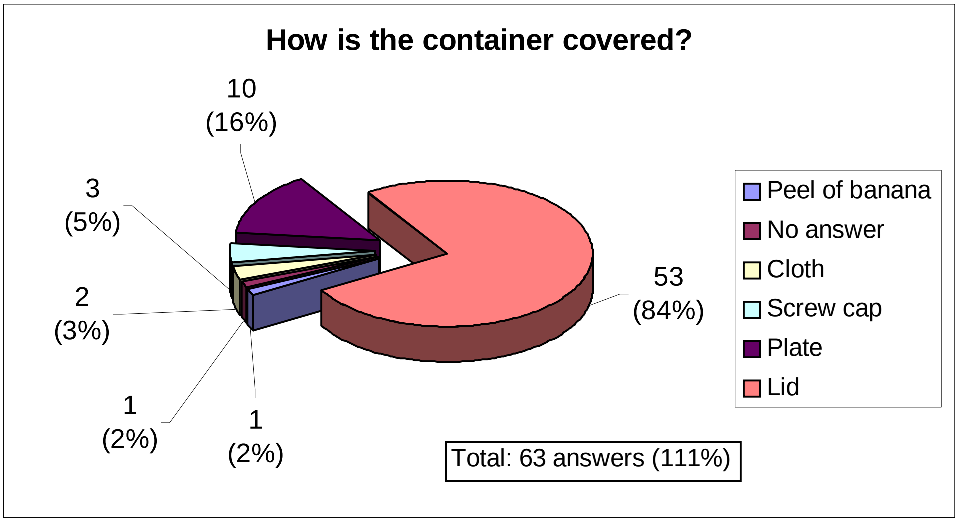



**Figure 2.11: Cover type for drinking water container for people without the system**

**Question 9: Do you use the water in this container for other uses than drinking?**

**Question 10: Besides drinking, what do you use this water for?**

Many households use a specific container to store drinking water and report not doing anything else with that water besides drinking. However, this finding changes proportion whether the household does or does not have the system and whether diarrhea cases were seen in the family or not (Figure 2.12).

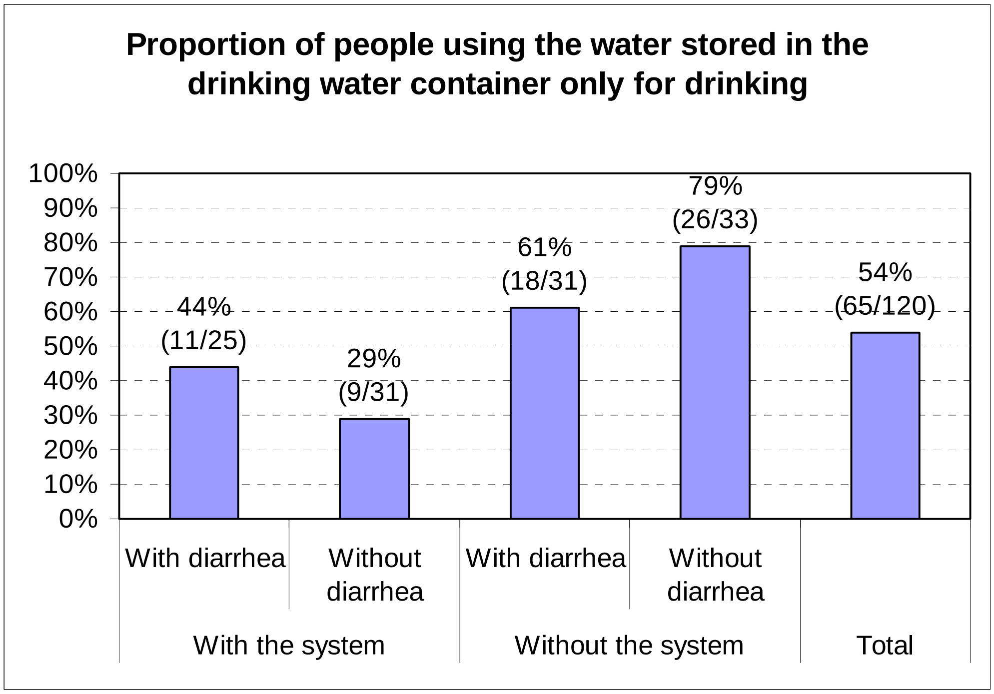



**Figure 2.12: Proportion of people using the water stored in the drinking water container only for drinking**

We notice that the ones with the system use the clean water for more purposes than the ones without the system. On average, only 37 percent of the people with the system use the drinking water only for drinking, compared to 69 percent for those without the system.

Also, in the case of people without the system and without diarrhea, 80 percent use the water only for drinking. This is a significant difference (20%) with the people without the system but with diarrhea where only 60 percent use the water only for drinking. In fact, people without the system have to dip into the container to scoop out water. Thus, when water is used exclusively for drinking, there is less exposure to hands (and bacteria) and there is more attention to keeping the water clean. Therefore, using this water only for drinking can prevent people from contracting diarrhea.

However, the reverse happens in the “with the system” category. The people with the system but without diarrhea use the clean water for more purposes than the ones with diarrhea. In that case, due to the presence of a spigot, the potential contamination due to frequent handling of the water is reduced. Therefore, using clean water for many purposes will help reduce diarrhea incidences.

The rest of the answers are however proportional between the four categories (Figure 2.13). From this figure, we see that the most popular practices are the ones that are being done in the kitchen, such as cooking, cleaning dishes, fruits and vegetables. Bathing is also surprisingly important.

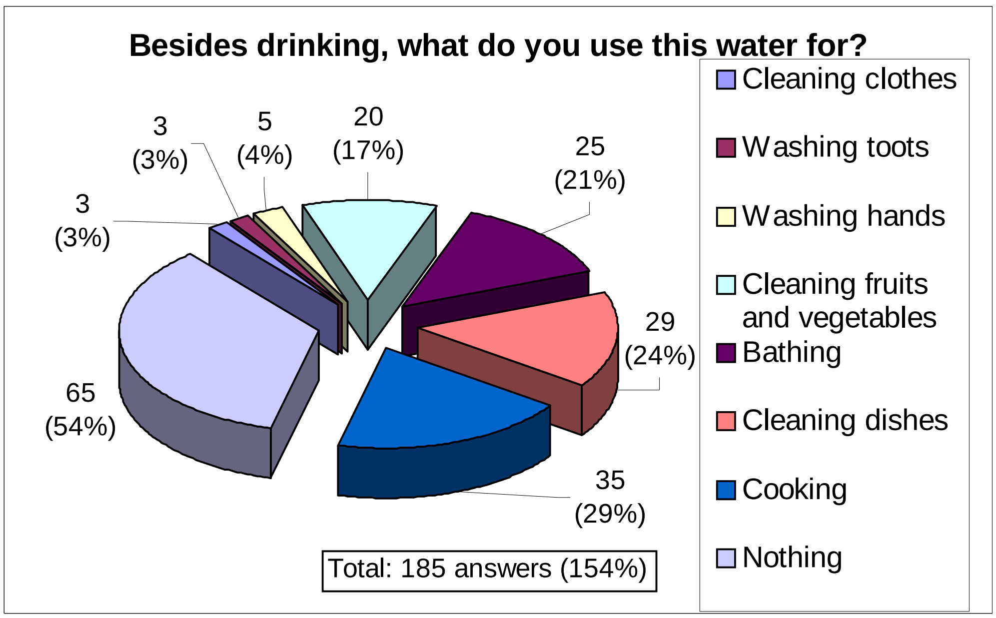



**Figure 2.13: Other uses of drinking water**

**Question 11: What did you use to "scoop" drinking water out of the drinking water container that you are using today?**

Everyone using the system uses the spigot to obtain water from the container. However, for people without the system, answers varied. Also, some types of scoops seem to have influence on diarrhea incidences. There are differences between the scooping methods of people who had diarrhea and the ones who did not have diarrhea for the population without the Safe Water System (Figure 2.14).

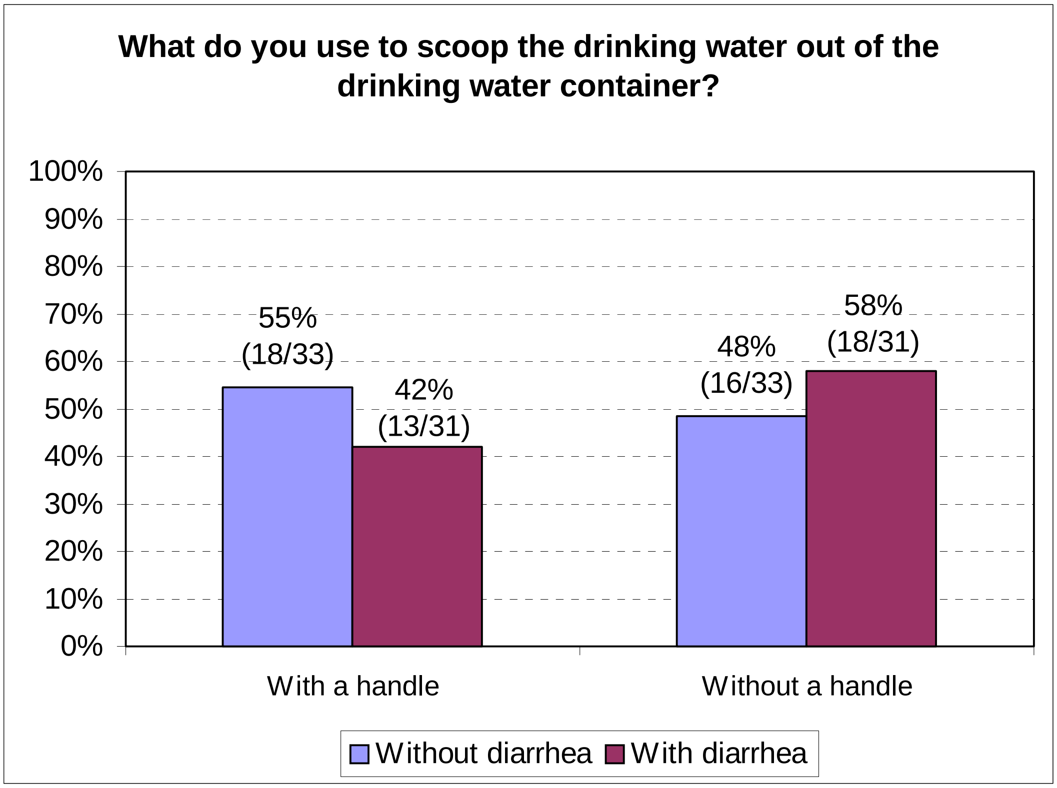



**Figure 2.14: Influence of the scooping method on diarrhea incidences**

An interesting point is that there are fewer diarrhea incidences when people scoop their drinking water with a tool that has a handle. The cup, the pitcher, the direct spill and the mug, and the use of a spigot put together show a higher rate of "no diarrhea" (55 percent) compared to people using a tool without a handle (48 percent). In fact, a scoop with a handle reduces the risk that the hand touches and contaminates the water. By the same means, it reduces the risk of contracting diarrhea.

**Question 12: Does anyone ever touch water in your drinking water container with their hand, for example, when they are scooping out water?**

As for the previous question, all the people with the system do not touch the water when they are scooping it out from the container since the spigot enables an easy transfer of water without any hand contact. However, for people without the system, it is more difficult to scoop water out from the container without touching water and this may increase the risk of contracting diarrhea (Figure 2.15).

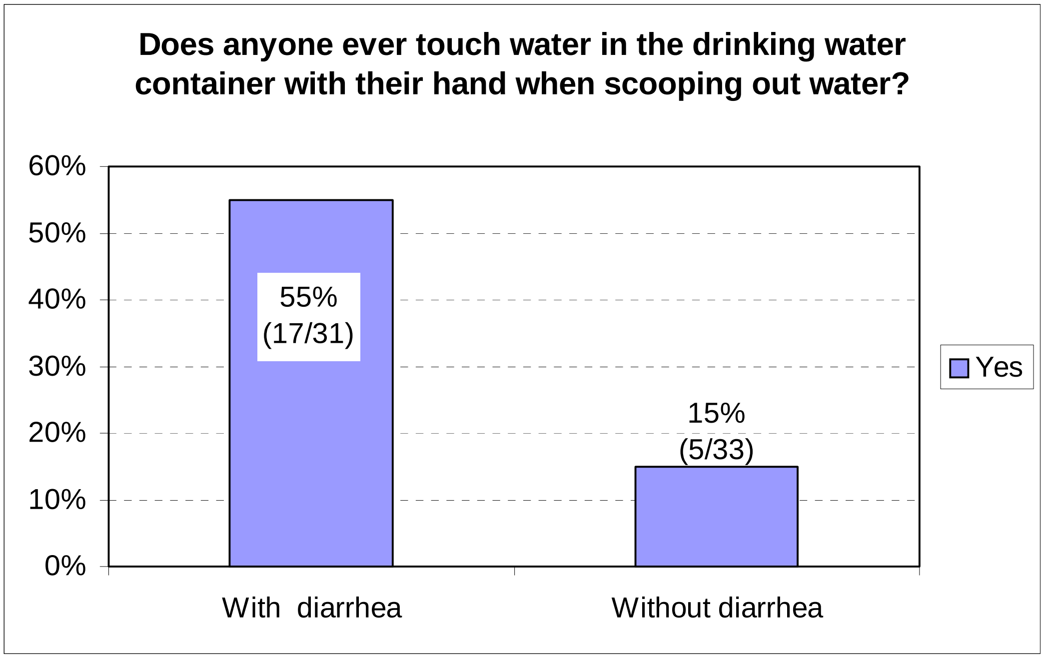



**Figure 2.15: Impact of touching water on diarrhea incidences**

In fact, we see a net difference between the ones who did and the ones who did not have diarrhea incidences. That is to say, 85% of those who did not have diarrhea did not touch the water with their hands while putting water in their cups, compared to only 45% for the ones with diarrhea. This is evidence that hands transport bacteria and contaminate the drinking water. It is also interesting that all who reported touching the water used a glass, a mug or a bowl.

**Question 13: When the water is dirty, what do you do to make it clear?**

After a heavy rain, the Trois-Rivieres river becomes muddy and loaded in sediments. Therefore, people use a sediment removal technique to clear the water (Figure 2.16).

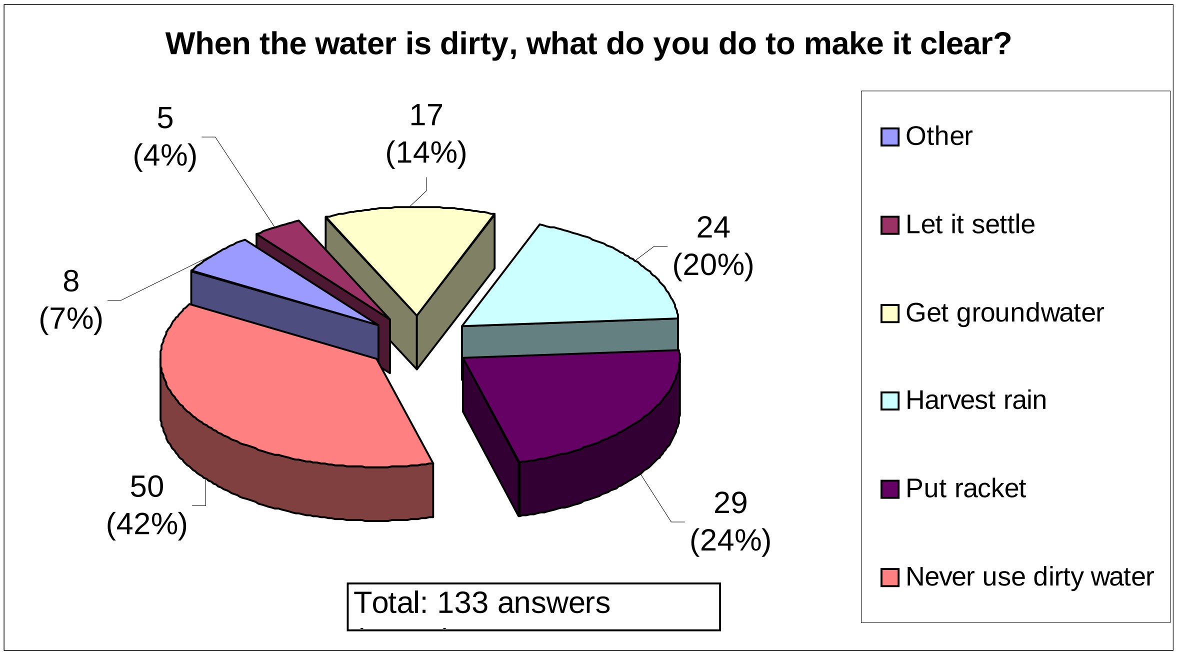



**Figure 2.16: Methods for clearing the water when loaded in sediments**

The category with the majority of the answers (42 percent) is “never use dirty water.” In fact, since they mostly use the water from the “sous dlo,” they do not consider it dirty. So, they do not have the impression of using dirty water when they use the “sous dlo.” This observation was made when I asked someone who had answer “never use dirty water” what they do after it rains. They then answered that it did not matter since they used the water from the “sous dlo.” However, after a heavy rain, the river and the “sous dlo” get muddy. Even though the “sous dlo” filters part of the sediments, the water collected from the “sous dlo” is still loaded in sediments. As it will be discussed in Section 4.2, this turbidity increases the number of coliforms present in the water, both in the river and in the “sous dlo.” The water should not be used for drinking without being cleared. The answers did not vary from people with the system to those without the system or from people with diarrhea to those without diarrhea.

However, some others mentioned the rain and groundwater as alternative sources. Another common practice is to put racket, a sticky cactus, in the water and let it settle. By visual inspection, I found that this technique significantly helps sedimentation.

### *2.3.4 Safe Water System Use*

Six questions related to the Safe Water System were also asked of people with the system. These questions are necessary to evaluate the impact of different uses of the system on diarrhea incidences.

**Question 1: Who is responsible for adding the Dlowòks to the water?**

When women are responsible for adding the Dlowòks, there are less diarrhea incidences in the family (Figure 2.17). In fact, for the category of people without diarrhea, females were responsible to add the Dlowòks in 94 percent of the cases (29 households out of 31), compared to only 72 percent in the category of people with diarrhea.

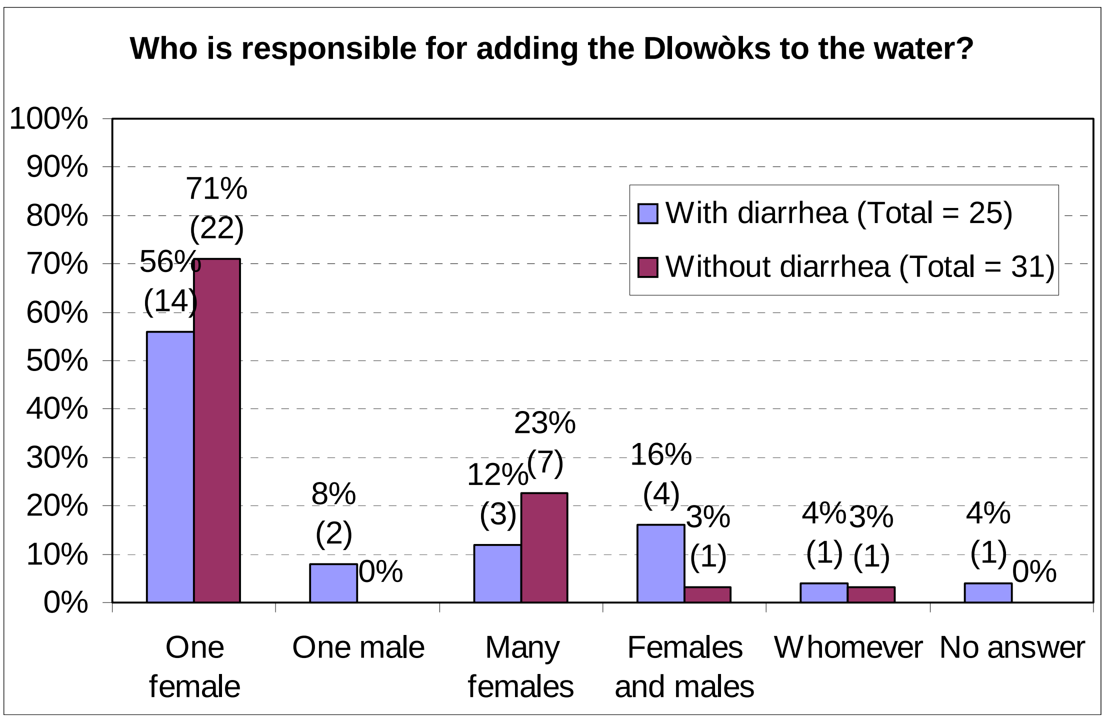



**Figure 2.17: Effect of the number and sex of people responsible to add Dlowòks to the water**

**Question 2: When do you add Dlowòks to the water?**

Households where there is no diarrhea add Dlowòks to their drinking water more often (Figure 2.18). In fact, 77 percent of the people without diarrhea add Dlowòks to the water at most every two days, compared to only 44 percent for people who presented diarrhea incidences.

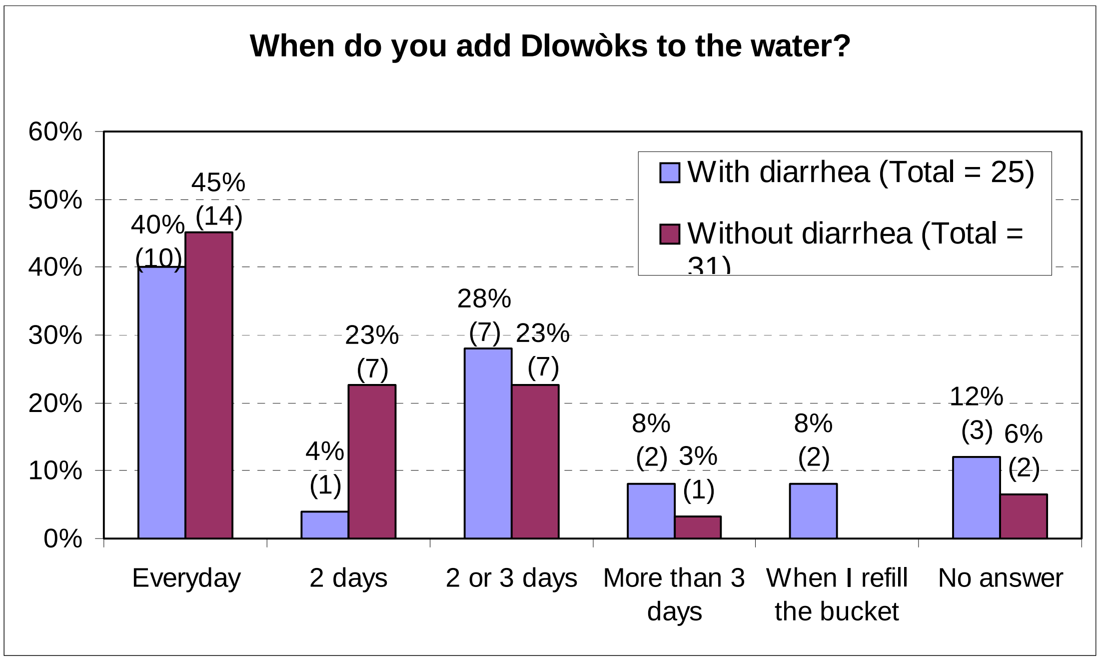



**Figure 2.18: Effect of the interval between at which people add Dlowòks to the water on diarrhea incidences**

**Question 3: When was the last time you added Dlowòks to the water?**

This question was more to connect with the chlorine residual test. However, as in the previous question, more people without diarrhea had added Dlowòks the same day the survey was conducted (Figure 2.19).

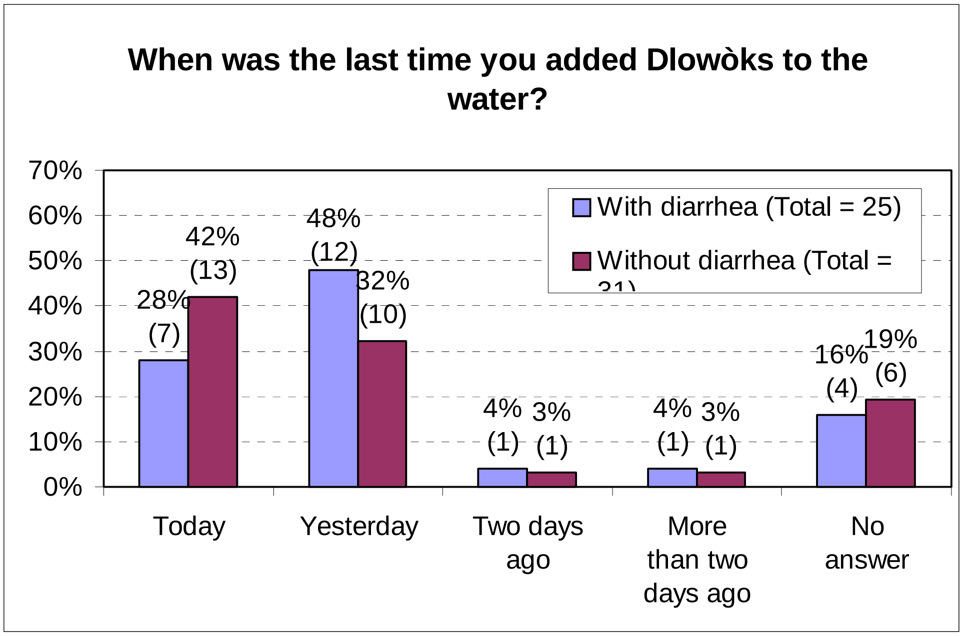



**Figure 2.19: Effect of time of treated water staying in the bucket before consumption on diarrhea incidences**

**Question 4: When was the last time you saw Eledere for your Safe Water System?**

I realized that Eledere visited almost all the households the week before we arrived. It is possible that coaching happened. Also, the answers to surveys conducted by Eledere's team relate shorter time intervals between Eledere's visits than surveys conducted by other teams that did not include Eledere. People possibly wanted to protect him and show him they were being kind. Therefore, future evaluation of similar projects should be announced to the staff only a few days before the starting date to prevent coaching. Also, a Safe Water System technician should not conduct the surveys.

**Question 5: Where do you store your Dlowòks?**

This question was asked so people would show us their buckets and invite us to enter in their home. Most people put the Dlowoks near the bucket, either directly on the lid, or on a table just beside the bucket, behind dishes. An interesting fact is that some people hide the bottle so that children do not find it and play with it. One household even had it locked in a shelf so that only the woman of the house could have access to it.

**Question 6: Is there water in the bucket?**

This question led into the next question, which was to ask the people to give us a sample of water. Most people did not object, although some hesitated. However, when we explained that we would do laboratory experiments to find out if there were bacteria in their water, they all agreed to help and provide a sample of water.

## 2.4 Summary of the Survey Results

This section highlights the major conclusions that were found based on the survey results.

Health benefits from the Safe Water System:

1. SWS use decreases diarrhea incidences by 40 percent.
2. Safe use of the SWS (with chlorine residual in the drinking water) decreases diarrhea incidences by 55 percent.
3. The use of the SWS does not lower diarrhea incidences of male children under three years old.
4. The use of the SWS decreases diarrhea incidences of females under three years old by 35 percent.
5. Safe use (with chlorine residual) of the SWS decreases diarrhea incidences of females and males of three and four years old by 30 percent when compared to the total population of children of three and four years old using the SWS.
6. For people with the system, 95 percent of the people add the correct quantity of Dlowòks to their drinking water.
7. Having a female responsible for adding Dlowòks to the drinking water lowers the risk of having diarrhea incidences in the family.
8. Adding Dlowòks everyday lowers the risk of having diarrhea.

Other health related findings for people with and without the system:

1. Trusting the source of drinking water increases the risk of having diarrhea.
2. People with the system wash their hands less often than people without the system.
3. People with the system have soap in their homes more often than people without the system.
4. For people without the system, more people without diarrhea incidences (58 percent) reported treating their drinking water than people with diarrhea incidences (42 percent).
5. For people without the system, using the drinking water only for drinking lowers the risk of having diarrhea.
6. For people with the system, using the drinking water for other purposes than drinking lowers the risk of having diarrhea.
7. For people without the system, scooping the water with a tool that does not have a handle increases the risk of having diarrhea.
8. Touching the water in the drinking water container when scooping out water increases the risk of having diarrhea.

Given these findings, SWS technicians should recommend to people to add Dlowòks every day. Also, attendance of women at informational meetings should be a prerequisite to obtaining a SWS. Moreover, sanitation targeted at children under five years old should be part of the educational aspect of the SWS.

Implementing the SWS on a larger scale will modify unsanitary behavior and provide health benefits to the people who are not included in the pilot project.

# Chapter 3: Chlorine residual results

## 3.1 Fighting Waterborne Diseases by Chlorination

Chlorination is one of the most common methods for treating water. Chlorine solutions react with bacteria, viruses, and protozoa and neutralize their health hazard. The reaction is a function linearly proportional to time and chlorine concentration. The CDC provides the respective constants for the inactivation of various bacteria, viruses, and protozoa (2002). In Haiti, we are most interested in: *Escherichia coli* (*E.coli*), *Salmonella Typhi* (typhoid fever), *Vibrio cholerae* (cholera), hepatitis A, and *Giardia lambia* (Giardia). The first three are bacteria, Hepatitis A is a virus, and Giardia is a protozoan. In fact, these pathogens have known health effects in Haiti.

Each of these contaminants requires a specific chlorine concentration and exposure time in order to be inactivated. The Jolivert Safe Water System project staff recommends letting chlorine react in water 30 minutes before drinking. The recommended chlorine residual concentrations associated with a contact time of 30 minutes are presented in Table 3.1 (CDC, 2002).

**Table 3.1: Effect of chlorination on inactivating bacteria, viruses, and protozoa of concern**

| | Chlorine residual (mg/L) | Time (min.) | Removal (%) |
|---|---|---|---|
| *E.coli* | 0.4 | 30 | 99.99 |
| Typhoid fever | 0.1 | 30 | 99 |
| Cholera (smooth strain) | 0.033 | 30 | 100 |
| Cholera (rigose strain) | 2.0 | 30 | 99.999 |
| Hepatitis A | 0.014 | 30 | 99.99 |
| Giardia | 3* | 30 | 100 |

* (Viessman and Hammer, 1993)

The World Health Organization stipulates: "Unlike many chemical agents, the dose response of pathogens is not cumulative" (2003). Therefore, to inactivate all of these pathogens, the required amount of chlorine residual would be of 3mg/L, since the one limiting is Giardia. However, for effective disinfection, the WHO recommends a residual concentration of free chlorine of 0.5mg/L after at least 30 minutes contact time (WHO, 2003). Thus, this value will be used as the required residual for drinking water. From Table 3.1, we see that this WHO requirement will not account for all targeted pathogens, such as Giardia and the rigose strain of Cholera. In fact, as is presented in the next section, *E.coli* was used as a fecal indicator for the water samples. Its presence indicates the possibility of contamination by fecal pathogens, but its absence does not signify the absence of more resistant pathogens such as Giardia.

Also, chlorine will inactivate pathogens only after it has reacted with organic matter naturally in the water. The remaining chlorine is the chlorine residual, which is used for disinfection. The chlorine introduced in water follows different stages (Figure 3.1). The point at which the breakpoint occurs depends on the amount of organic matter present in the water. The chlorine demand of water supplies varies from 0.2 to 40 mg/L (White, 1986). For clean (snow melt) rivers, the chlorine demand ranges between 0.2 and 1.2 mg/L and for clean rivers are around it ranges from 2 to 4 mg/L.Unfortunately, the breakpoint curve was not constructed for the Trois-Rivières river water, and the chlorine demand is unknown. Further studies should therefore establish a breakpoint curve corresponding to the level of organic matter is present in the Trois-Rivères river water in dry and wet seasons. But, in order to perform the analysis, and to have an idea of the concentration of chlorine that should be used for the SWS, I will estimate the chlorine demand at 0.5mg/L of chlorine. In fact, when there is no rain, the river is fairly clean. Moreover, due to soil filtration, I expect a lower chlorine demand for the "sous dlo."

To provide a residual of 0.5mg/L, the total added chlorine should therefore be 1.0 mg/L. Since the users add about 5mL of hypochlorite solution to 20 liters of water, the hypochlorite solution produced by the SWS should have a minimum concentration of 4000mg/L (0.4 percent) in order to achieve the needed 1mg/L level in the water being treated. If $C_r$ is the required concentration of chlorine in the drinking water, $V_w$ is the volume of water to be treated, $M_c$ is the total mass of chlorine needed to treat that volume of water, and $V_c$ is the volume of hypochlorite solution that we add to the water, here is how we find the concentration of the hypochlorite solution $C_s$ (mg/L) that we add to the water:

$$C_r * V_w = M_c$$
$$M_c / V_c = C_s$$

In our case, this is:

1.0mg/L * 20*L* = 20mg

20mg/(5mL) = 4000mg/L = 0.4 %

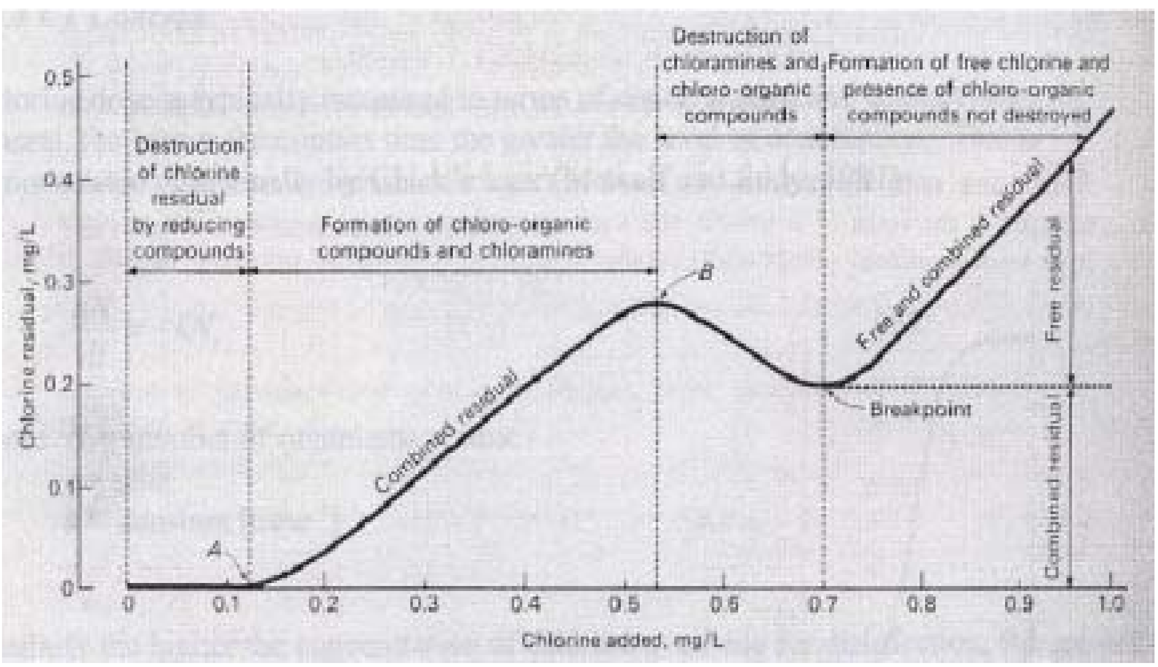



**Figure 3.1: Breakpoint curve**
**(Metcalf and Eddy, 1991)**

## 3.2 Dlowòks as a Safe Hypochlorite Solution

Elédère, the SWS technician, was asked to sample chlorine from every chlorine solution he produced after our visit in Jolivert. He stored the chlorine samples in an environment similar to the environment people have in their household. That is to say, on a shelf, at air temperature, and with similar lighting. From January 23rd to March 11th, he produced nine hypochlorite solutions. This is an average of one new solution every five days. A total chlorine residual test was performed by titration at MIT, on April 19th, 2003. A complete methodology for the titration is included in Appendix IV. Figure 3.2 shows how the chlorine concentration changes with time after the production of the hypochlorite solution.

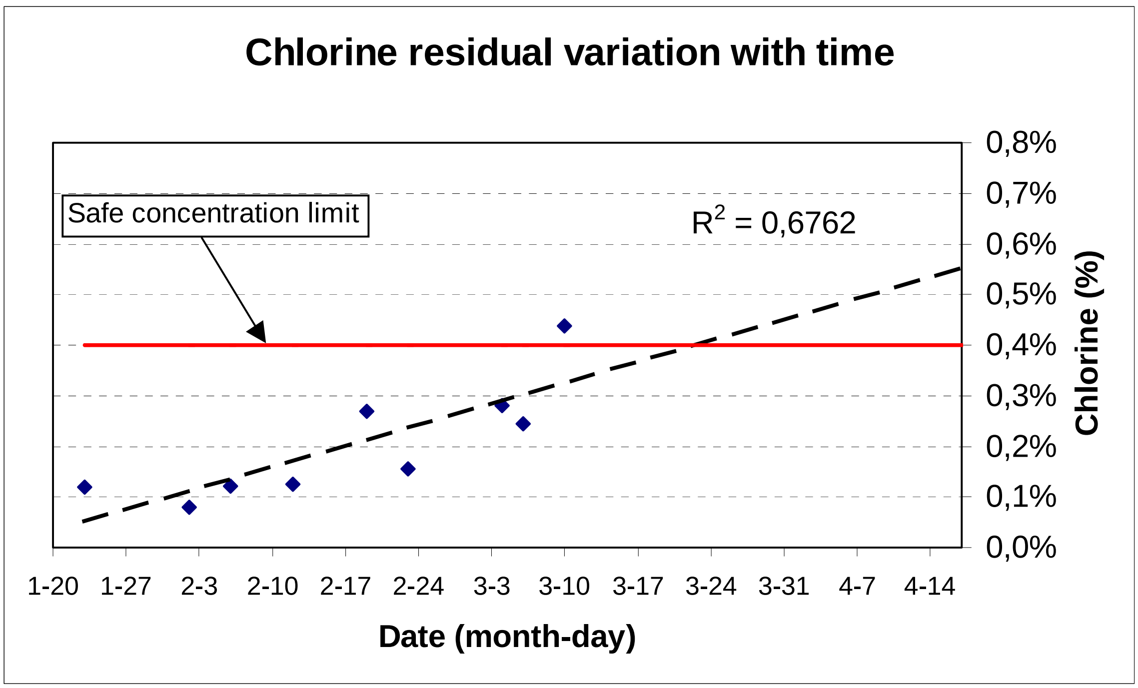



**Figure 3.2: Decay rate of chlorine in a Haitian environment**

From Figure 3.2, we see that, in order to use safe hypochlorite solutions, the product should be consumed within three and a half weeks after its production. To account for the variability of the concentration of the produced solution, this should be reduced to three weeks, which ensures a theoretical concentration of 0.42 percent, which is about 25 percent higher than the required 0.4 percent to inactivate *E.coli*. Given this, I recommend that no hypochlorite solution be sold one week after its production, and that consumers refill their bottles at most every two weeks.

# Chapter 4: Bacteriological Sampling: Methods and Results

Another method used to evaluate the SWS pilot project was to measure its performance at inactivating bacteria in the water. The presence of total coliforms and *E.coli* in both the household drinking water, and the water sources was measured using a membrane filtration methodology. This section first discusses the methods used and, then, the results found.

## 4.1 Methods

The bacteriological results rely on two tests. The first one is membrane filtration testing, which provides enumeration of coliform forming units for total coliform and *E.coli* in a water sample. The second one is the chlorine residual test, which reveals the presence of free chlorine in a water sample. The latter one was conducted in the households while the first one was conducted in the laboratory at the Jolivert clinic.

### *4.1.1 Membrane Filtration*

After completion of the survey at each home, two 100mL samples of drinking water were collected in sterile whirlpack bags with dechlorinating agent. They were stored in a cooler with ice packs. No more than four hours later, duplicate membrane filtration tests were performed. This test consists of filtering a specific amount of water through a membrane filter (pore size 0.45μm), which traps the bacteria (Maier, 2000). The filter is then placed in a petri dish, which we saturate with a culture medium that will enhance the growth of certain bacteria. The petri dishes are then incubated for 18 to 24 hours (24 hours in our case) at 35°C, to let the microbial colonies grow. The culture medium used is mColiBlue24 broth, from Millipore Corporation. It grows *E.coli* colonies blue and the remaining total coliform colonies red.

Two blanks were run with each set of samples using deionized water. The blanks were all blank, except one blank that had one total coliform forming unit in results of samples taken in the afternoon of January 16$^{th}$. All samples were duplicated. The average relative percent difference of the samples was 14 percent for total coliform, and 7 percent for *E.coli*.

All samples from January 13$^{th}$ and January 14$^{th}$ were run with samples of water of 100mL. Due to the difficulty in counting the numerous colonies for the households without the system, the samples from January 15$^{th}$ afternoon were run with a 50mL dilution. For the same reason, all the samples from households without the system taken on January 16$^{th}$ and 17$^{th}$ were run with a 20mL dilution. These dilutions were measures approximately using the marks on the filtration cups. The samples from the sources were run with 0.5, 1.0, 5, and 10mL dilution. These dilutions were measured with a pipette, and a graduated cylinder.

Sometimes, smearing occurred and the results were unreadable. Probably due to respiration of bacteria, condensation formed on the inside top surface of the petri dishes, drops of water sometimes dropped on the membrane filters and smeared the red and blue dots of coliform forming units. These results were discarded. In the majority of the cases, only one of the duplicates was smeared.

### *4.1.2 Chlorine Residual*

The chlorine residual test verifies that there is a chlorine residual in the drinking water. Chlorine reacts with the bacteria molecules and other oxidizable matter in the water until there is either no more chlorine to react or no more bacteria to inactivate. If the chlorine residual indicates the presence of residual chlorine, it means that there are no more bacteria. On the other hand, if the test shows no presence of free chlorine, there is a possibility that bacteria remain in the water.

The tests were conducted with a colorimetric swimming-pool test kit. After adding one drop of the testing solution, a yellow color develops. Our analysis relies on the following grading of color:

a. No coloration
b. Pale yellow
c. Yellow
d. Dark yellow
e. Very dark yellow/orange

The plastic vial in which the test was performed was rinsed with the household's drinking water before performing the test.

## 4.2 Bacteriological Results from the Sources

As mentioned previously, people get their drinking water mostly from the "sous dlo," but groundwater water is also available. The bacteriological results from the different water sources are presented in Table 4.1. The method used was the membrane filtration methodology explained in the previous section.

**Table 4.1: Bacteriological results from the sources of water**

| Source | Date | TC (cfu/100mL) | EC (cfu/100mL) |
|---|---|---|---|
| River | 19-jan | 3145 | 400 |
| River after rain | 20-jan | 64000 | 16000 |
| "Sous dlo" | 19-jan | 7284 | Tltb* |
| "Sous dlo" after rain | 20-jan | 26000 | 6000 |
| De Riyon | 13-jan | 126 | 0 |
| La Boule | 17-jan | 1290 | 420 |

*** Tltb: too little to be. The dilution was too small to ensure that there were no *E.coli* in the water sample**

When there is no rain, the “sous dlo” has more TC than the river (about 200%) but fewer EC (about 15%). The higher concentration of TC in the “sous dlo” could be due to the scoop and hand contamination that does not occur in the river since the water is flowing. The “sous dlo” is not flowing and any bacteria that are introduced remain in the hole. On the other hand, the lower concentration of EC may result from the filtration of the water through the soil.

De Riyon and La Boule are the two groundwater sources from which we could obtain water samples. De Riyon is obviously the best source of water because of its low TC presence, and absence of EC. These results support the assumptions made before that the soil filters EC. However, smaller dilution should be done in order to verify the absence of EC. It looks like the spring La Boule source has only 40% of the concentration of TC that the river has, but contains much more EC. However, the WhirlPak bags from La Boule leaked after the sampling and the results may be compromised by sample contamination.

The samples from the river and the spring after a heavy rain show high values. It is however interesting to see that the river TC increases by a factor of 20 while the TC for the “sous dlo” increases by a factor of 3.5. This probably reflects the effect of filtration done by the soil. In fact, the sediment load in the “sous dlo” was much lower than the one in the river.

Another source that people have used (near Bassin Bleu) is a ground water source called Tiboukan. However, it was impossible to get samples there since the pipe was broken. It would be interesting to find out who is responsible for repairing the pipe. That person could also be interested in working along with the SWS.

## 4.3 Bacteriological Results from Household Sampling

Of the 120 homes visited, 113 provided a sample of their drinking water. To show a general picture of the results, I divide the results into categories. The first category represents zero presence of colonies, which is the requirement for drinking water in the United States of America (AWWA, 1999). Then, categories are made in such a way that the number of households in each category are in the same range. We can see, from Figures 4.1 and 4.2, the results for total coliforms and *E.coli* with respect to whether the household did or did not have the system.

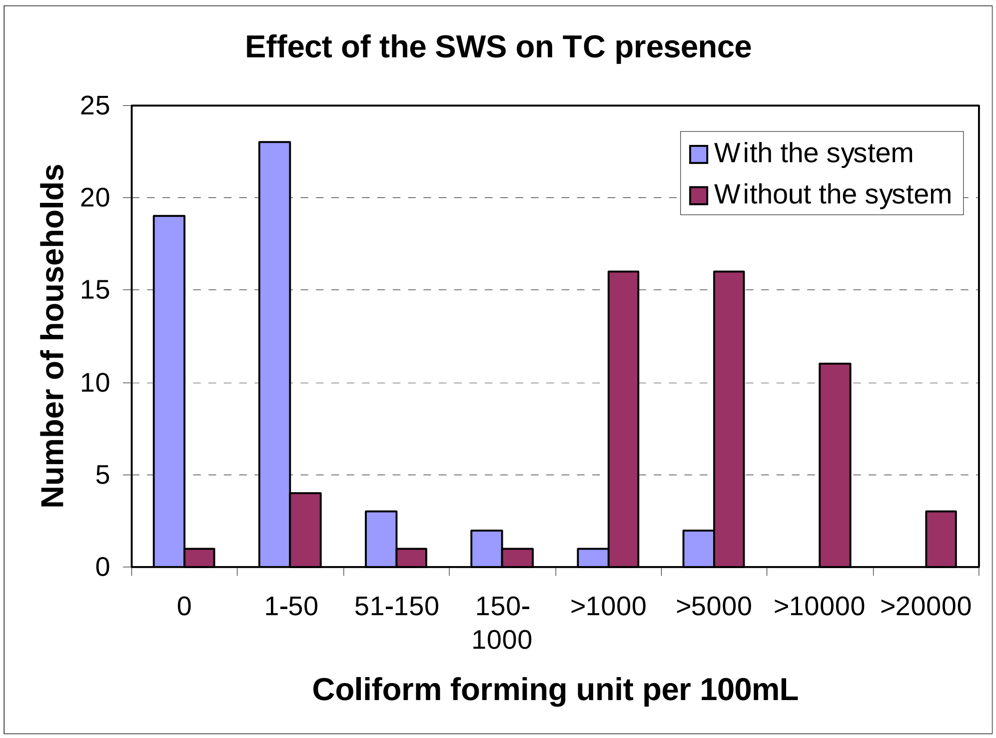



**Figure 4.1: Effect of the SWS on the TC presence in drinking water**

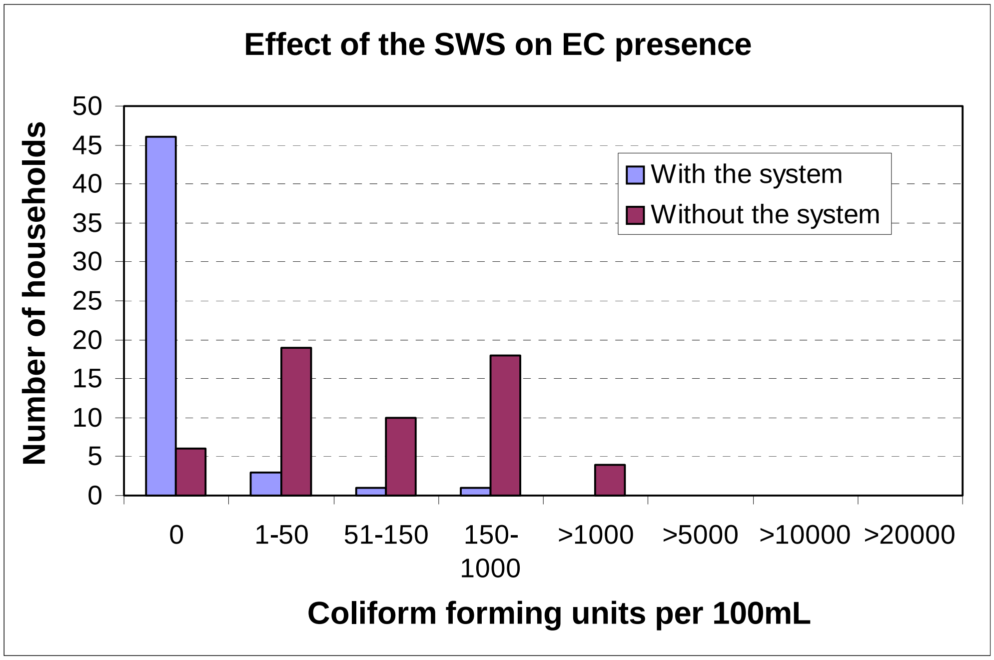



**Figure 4.2: Effect of the SWS on the presence of EC in drinking water**

By looking at the actual numbers of coliform forming units, the mean of TC and EC for the with- and without-system populations was calculated and are presented in Table 4.2. As can be seen, the system improves the quality of water significantly. In fact, the mean of total coliform forming units is reduced by a factor of ten while the *E.coli* forming units are reduced by factor of 20.

**Table 4.2: Average bacteriological concentrations in the drinking water of the populations with the system and without the system**

| | Without system (all) | With system (all) | With system (with chlorine residual) |
|---|---|---|---|
| Total coliform (cfu/100mL) | 3000 | 300 | 35 |
| *E.coli* (cfu/100mL) | 160 | 8 | 0 |

Also, if all households with the system where there was no chlorine residual are taken out (to look only at the households that use the system correctly), the mean drops to 35 cfu/100mL for TC and to near 0 cfu/100mL for EC (only one household had one cfu). This shows that the Dlowòks is very efficient at killing bacteria. However, a question remains: why are there so many households who have no chlorine residual in their drinking water?

## 4.4 Chlorine Residual Results

Fifty-five percent of the population had chlorine residual in their drinking water (Figure 4.3). However, 33 percent did not have any chlorine residual and 7 percent had too much chlorine in the water. The three households with no answers are the ones in which there was not enough water to do the chlorine residual test when we visited them.

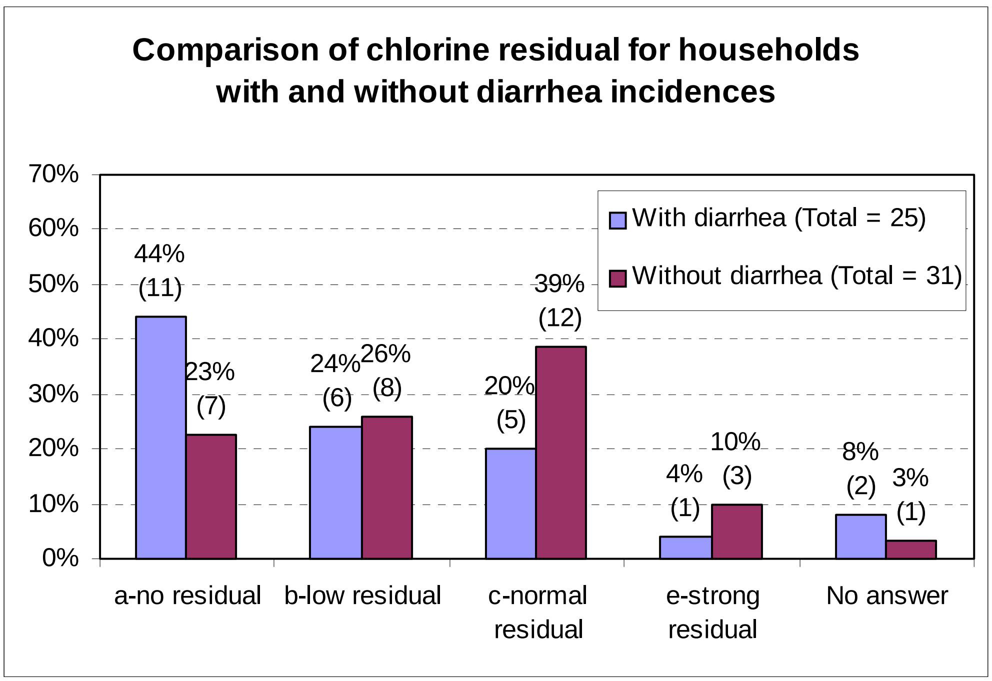



**Figure 4.3: Comparison of chlorine residual for households with and without diarrhea incidences**

The answers to the diarrhea incidence question in the survey are not significantly different for those who have no chlorine residual than the rest of the population. However, people with no chlorine residual have a higher rate of diarrhea incidence (60 percent or 11/18) than the rest of the people with chlorine residual (35 percent or 12/35). This shows the importance of the chlorine residual in the drinking water.

From the measurements of coliform forming units for the households that have no chlorine residual (17 households), two had high values (TC = 5000 and 7710 cfu/100mL, EC = 66 and 310 cfu/100mL). This means that they probably did not put chlorine in their water yet. In fact, one of these two households reported that the last time they put chlorine in their water was about three weeks ago, while the other one said it was "yesterday." The latter answer may be false, because it was also noted that the chlorine solution had a strong odor, which indicated it was still effective. This means that they probably did not put disinfectant in the water.

Also, two other households without chlorine residual had zero colony forming units. One of those reported that the last time Dlowòks was added to the water was three days ago and the other one said it was added the day before. This indicates that they probably added the correct quantity of Dlowòks, but that there were too many coliforms or too much chlorine demand to react with the chlorine, leaving no residual.

The thirteen others with no chlorine residual have an average of colony forming units per 100mL of 102 for total coliform and only one household has 8 cfu/100mL for *E.coli*. This shows that chlorine was added, since the numbers are much lower than the source concentrations. There are no significant differences in their answers to the health survey compared with the rest of the population. It is possible that their solution was too old, or that they did not put enough of the solution in the water, even though they all reported using one capful of the Dlowòks, which is the correct quantity.

Possible solutions to ensure that the there is always chlorine residual when the people drink the water includes alkalinization of drinking water and adding Dlowòks to the drinking water more often. In fact, when chlorine reacts with ammonia, it releases hydrogen ions, increasing the pH of the solution. Alkalinization of the water neutralizes acids without significant change in pH (Viessman and Hammer, 1993). Addition of lime

(CaO) or caustic (NaOH) can be used for alkalinization (White, 1999). Since lime is commonly used in Haiti, this could be included in the Safe Water System procedure easily. The other solution would be to recommend to people to add Dlowòks to their drinking water everyday. We could suggest that the first day they add a cap full of Dlowòks and only half a cap the following day. I think the latter solution is more likely to work, since Dlowòks has a disinfectant connotation, whereas it is less likely that people will understand that they need to add lime to their water. Therefore, they might not take this responsibility as seriously.

I also verified whether those who lived farthest from the clinic were more likely to have no chlorine residual than those who lived closer. As I expected, in Bassin Bleu, where households with systems are farthest from the clinic, four out of the five households did not have chlorine residual. Systems in households closer to the clinic were much more likely to show chlorine residuals. This situation suggests that more attention should be directed towards outlying communities. Chapter 5 will discuss more about the issue of distance from Dlowòks supplier.

## 4.5 Correct Use and Safe Use of the System

From the results of chlorine residual measurements, a correct use of the system was defined as having a reasonable amount of chlorine residual, without being excessive. In the survey, it includes the categories of level of chlorine residual b and c. The categories “a”, “d”, “e”, and the homes that did not have any Dlowòks solution enter in the category of incorrect use of the system. However, the level of chlorine residual “d” and “e” are safe. In fact, they indicate a high level of chlorine in the water, and therefore the absence of bacteria. No result showed chlorine level of “d”. Figure 4.4 shows the degree of correct and safe uses of the system.

The graph shows a net decrease in the compliance degree relative to the distance. An exception is La Hatte, which has low compliance even though it is relatively near the clinic. The reason for this could be that only five households in La Hatte were surveyed, which may not be enough to get a representative result. But the results in that community are still in a reasonable range (40 percent). On the other hand, the results from the Bassin Bleu clearly indicate a problem, with a compliance rate of 14%.

In addition to relative distance from the clinic, the following factors may help to explain why Bassin Bleu has a low compliance rate. Since Bassin Bleu is a town of medium size, its residents are used to meeting most of their needs close by and may not find it convenient to go to the clinic for disinfectant. On the other hand, people from the smaller communities are more accustomed to leaving their neighborhood to satisfy their essential needs. Therefore, they are more likely to travel to the clinic to buy their chlorine solution.

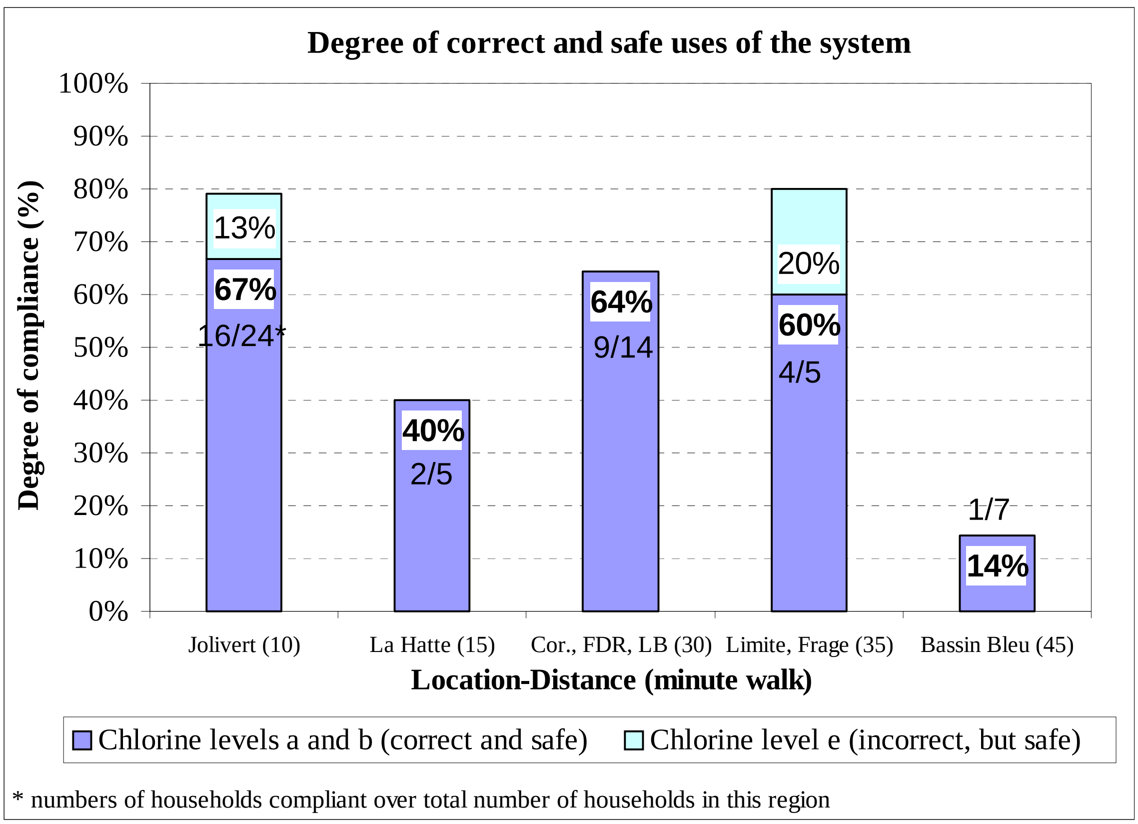



**Figure 4.4: Degree of correct use and safe use of the system based on chlorine residual levels in function of the distance from the clinic**

The correct use of the system for the total population was also calculated and compared to the compliance for the total population except Bassin Bleu, which is the farthest community (Table 4.3).

**Table 4.3: Degree of correct and safe use of the system**

| | Correct use | Safe use |
|---|---|---|
| Total population | 55 % | 63 % |
| Tot. pop. w/o Bassin Bleu | 61 % | 65 % |

In order to reduce walking distances and make the purchase of Dlowòks easier for the Bassin Bleu population, I recommend that Dlowòks be made available in Bassin Bleu. It would then be possible for the population of Limite, only about one kilometer from Bassin Bleu, to switch its purchase location and reduce the walking time it takes to buy the Dlowòks to about 10 minutes.

Since it was impossible to meet the one household having the system in Benjamin, it is not possible to assess its compliance. However, since it is located about a 40-minute walk from the clinic, and, since it is physically separated from Jolivert by the river, I recommend not including it into the Jolivert market. A possibility would be to provide someone with chlorine solution on the other side of the river, in Fond-du-Roc, who could supply the Fond-du-Roc and Benjamin communities.

Also, in some cases, the value of the time invested into the walk to the chlorine supplier may vary in proportion to the location of the supplier. For example, if the chlorine supplier is located in a place where people go to do other things such as buy food or visit a doctor, the time spent to walk to the chlorine supplier may not matter as much as if the time spent in walking is only to go get the chlorine solution. Strategic supplier locations should therefore be chosen. The supply planning will be developed in more details in Chapter 5.

## 4.6 The Eight Buckets Tests Results

As the results from the survey show, people use different methods to treat their water, or clean it when full of sediment. The variety of the methods used intrigued me enough that I included them in the bacteriological testing. Tests were conducted using calcium hypochlorite grains, citrus, and racket. The tests were run from a single water source: a rain barrel.

Calcium hypochlorite pellets are commonly sold in markets and kiosks wrapped in saran wrap. One grain is a sphere of approximately one millimeter diameter. During the survey, people without the system said that they used varying numbers (between one and three) of the grains in their 5-gallon buckets (20-liter) to treat water. Therefore, tests were conducted with three different concentrations of calcium hypochlorite, in order to identify the safe proportion of grains per liter that should be used to clean the water. The first test was with one calcium hypochlorite grain in one gallon of water, the second, two grains for four gallons, and the third, one grain for four gallons.

Since six percent (6%) of those people surveyed reported that they treated water with citrus (lime juice), tests were also conducted using citrus as a treatment agent. My assumption was that people may add citrus to water simply to give the water a better taste. Three different concentrations of lime juice were added to four gallons of water and tested. The first one was with three drops of juice, the second with the juice of one entire lime, and the last one with the juice of two limes.

The next test was with racket. Racket is a cactus that is used as a coagulant to clarify water. It foams and gets sticky when the skin is broken. We put a small quantity (about 15 $cm^2$) of racket in the water and stirred vigorously. Although racket is not used as a treating agent, I thought that if it acts as a coagulant for the sediments in suspension in water, it might remove the bacteria attached to the sediment. It is interesting to note that the lady who showed me how to use the racket, Madam Evelyn, insisted that the buckets be placed in the shade. It is probably due to of differential temperature problems due to the sun's heat that cause movement in the water in the bucket, making the sedimentation harder.

Finally, the control water was taken the last, at the bottom of the barrel of rainwater. The barrel contained sediments in the bottom, which have more bacteria, as the results suggest (Table 4.4).

**Table 4.4: The eight buckets test results**

| | | TC (cfu/100 mL) | EC (cfu/100 mL) |
|---|---|---|---|
| Control water | | 46715 | 15 |
| Calcium hypochlorite grains | 1gr./1 gal. | 25 | 0 |
| | 2gr./4 gal. | 460 | 0 |
| | 1gr./4 gal. | 9680 | 0 |
| Citrus | 3 drops | 12400 | 0 |
| | 1 citrus | 8900 | 300 |
| | 2 citrus | 8250 | 200 |
| Racket | | 8140 | 0 |

The control water contained high values of TC and EC. This confirms the hypothesis that the concentration of bacteria was higher at the bottom of the barrel. Despite that, we can easily rank the different techniques with regard to TC. The most successful disinfectant of those in this test was one grain of calcium hypochlorite in a gallon, followed by 2 grains in 4 gallons. Third in disinfectant ability is racket. This result suggests that racket has some qualities in removing bacteria from the water, as expected. Finally, the citrus results are not very conclusive. They show that citrus is probably not useful to the disinfectant process. Using citrus may even increases the *E.coli* colony units because people squeeze the citrus with their hands, which may have *E.coli* on them that further contaminates the water.

So, as an alternative method to the SWS, I would recommend using at least five grains of calcium hypochlorite in a four-gallon bucket, for safety, but further tests should be done in order to define the exact safe quantity.

# Chapter 5: Project Growth Analysis

After we compared the surveys on health issues and analyzed the bacteriological results, we completed a preliminary analysis so that we might present some early results of our study to the Jolivert Safe Water for Families Project staff. After hearing our report, we joined the staff in a discussion of the issues raised by the report. Many interesting suggestions about how problems should be addressed and about how the project should expand were made. The meeting included Bill Gallo, Christophe Velcine, Eledere Odin, Madame Evelyn, Daniele Lantagne, and I.

One of the main issues in expanding the program is that a new bucket is too expensive for the majority of the families. Two ideas were discussed to resolve this problem. The first one is to adapt used buckets for safe water storage by adding taps and labels with directions for use. The other one is to subsidize the initial costs of buckets and lease or lend them to the population.

Another issue is how to make it easer for people some distance from the clinic to buy Dlowòks. Results from the survey showed that this problem is especially apparent in Bassin Bleu, where people tend to refill their chlorine bottles less often. Three ideas were mentioned to address this problem:

1. Assign a safe water technician the responsibility of visiting distant locations once a week to refill the bottles for the same price as the clinic,
2. Provide a local kiosk with Dlowòks and supply it at a higher price to provide profit for the kiosk owner,
3. Find volunteers in remote regions who are willing to store Dlowòks and supply people at the same price as the clinic.

If the Dlowòks is sold at a remote location, the issue of refilling the bottles is raised. One possible solution is to have users refill their chlorine bottles from bulk containers. A second is to have users bring their empty bottles in to trade for a full one, an option that would require more bottles.

Finally, another issue is whether or not schools should enter the program during the early stages. The consensus was that the educational benefits would be great, but the health benefits might be minimal since most of the students would not have systems at home, at least at the beginning of the project.

The following sections review each issue and alternatives.

## 5.1 The Affordable System

### *5.1.1 Bring Your Own Bucket*

The complete Safe Water System includes the bucket, the spigot, the label, the chlorine bottle, and the transportation of all this material from Port-au-Prince to Jolivert. The costs associated to each component are as follow (Table 5.1):

**Table 5.1: List of prices relative to the SWS material**

| | Price (US$) | Price (H$) |
|---|---|---|
| Bucket and lid | 3.30 | 23.10 |
| Shipping (Port-au-Prince to Jolivert) | 1.00 | 7.00 |
| Spigot (including shipping) | 1.00 | 7.00 |
| Label | 0.20 | 1.40 |
| Disinfectant bottle and label plus shipping from US | 0.25 | 1.75 |
| **Total** | **5.75 US$** | **40.25 H$** |

The price of a new bucket is probably more than most people in the communities around Jolivert would be willing to pay. However, since most households use similar buckets to store their drinking water, they may be able to supply a bucket that they already own, reducing the total cost by more than half. Another option is for a family coming into the program to buy a used bucket and lid. Used buckets are available in Haiti for approximately half the cost of a new bucket. In any case, people who come to the clinic with a clean bucket that has a lid would pay only for the installation of a spigot and the instruction sheet. In addition, they would be required to attend an educational session about the Safe Water System procedures.

### *5.1.2 Loan a Bucket*

Another alternative, which would require the cost of the bucket to be subsidized, is to loan or lease the buckets. People would pay a small amount at the beginning, but the bucket would remain the property of the Jolivert SWF project. If, for any reason, they left the project, they would return the bucket to the clinic and get their initial investment back. If they lost the bucket, they would be responsible for the total cost. The users would not pay much, but the process would require large subsidies to afford the initial bucket purchase. Moreover, this solution is risky since it requires keeping track of all the buckets. Positive and negative incentives would have to be implemented in order to be sure that the buckets are returned.

## 5.2 Chlorine Solution Availability in Remote Regions

### *5.2.1 SWS Technician Sells Chlorine*

This idea is to assign a safe water technician the responsibility of visiting remote regions once a week to refill the bottles. The advantage is that the price would be the same as the clinic’s price. The SWS technician would go sell the chlorine at remote locations each week at the same time. Since the technician's salary is fixed, that would only be a supplemental task to his/her job. However, there may be a problem with finding a time slot that will allow all families to get their bottles refilled. Vending chlorine in shops may be more appropriate.

### *5.2.2 Vending Chlorine in Small Shops*

A solution to the supply of chlorine in remote regions could be to provide a small shop with chlorine solution. People could then have chlorine refills at any time of the week. The only problem is that the price would need to be a little bit higher to compensate the vendor for his/her trouble and to make this solution sustainable. Since the chlorine refills usually cost two gourdes, the shop bottles could cost three gourdes. This increase in price may be offset by the benefits of being able to buy the chlorine at any time of the day, everyday, and reducing the time walking back and forth to get the chlorine. The SWS technician would have to change the chlorine bottles in the kiosks every week to ensure the chlorine quality. He/she would also record the sales and collect the money from the chlorine sold.

### *5.2.3 Volunteer Responsible for Chlorine Distribution*

This solution is similar to the "small shop" one. The difference is that the chlorine solution would be available from a volunteer household instead of from a shop. The price for a chlorine refill would therefore be the same as in the clinic. This solution would be workable only with appropriate volunteers. The volunteer would have to be well-known, honest, and respected in the community so that people would feel comfortable going to refill the bottles and so there would be no question of corruption in the process. The volunteer could have the supply of chlorine for free as a reward.

## 5.3 Safe Water Systems in Schools

Implementing the SWS in schools may help prevent those children from contracting diarrhea, but the main issue is education about safe water. Until the units are in the schools, children with the Safe Water System at home should be encouraged by their parents to carry to school the water that they drink during the day. To accomplish this, education at the household level should be reinforced, encouraging mothers and fathers to educate their children about how the SWS works and why they should only drink that kind of water.

In schools, the SWS could be part of a long-term educational program regarding health effects of some local waterborne diseases, and safe water and sanitation issues in Haiti. Then students could also help spread the information. They could participate in informative drawings showing sanitary precautions that can help prevent waterborne diseases, or even helping to publicize the SWS in the region.

The presence of a SWS definitely presents advantages such as its long-term educational aspect and the possibilities for students to get involved in the improvement of the quality of life of their neighborhood.

There is reluctance on the part of the Jolivert SWF Project to immediately include schools in the program. To the Jolivert project, it seems more effective to implement a sustainable supply structure for the population before allowing schools to join the project.

## 5.4 Recommendations for Project Growth

Since most people already store their drinking water in buckets, I recommend that it be possible for them to join the program without buying another bucket. However, for people who do not have buckets, I think they should buy one. I do not recommend the "loan a bucket" solution because of the administrative complications it implies.

For the supply of Dlowòks in remote regions, I suggest that small shops sell the Dlowòks solution. After our visit in January, the program bought a bicycle for the SWS technician. That way, he can go to Bassin Bleu and supply the households with Dlowòks. However, with the expansion of the project to a large scale, this solution will not be viable. The customers have to be able to obtain Dlowòks when they need it. A permanent provider of Dlowòks in remote regions is essential, especially in cities.

Finally, I think that schools should be included in the project expansion plan. Their participation in the SWS project would be mostly educational, and students should be involved in promoting the SWS along with sanitary practices.

# Conclusions

The Jolivert Safe Water System pilot project presents health benefits but does not reach the main target population, the children under five years old. However, health benefits are observed in the other age categories. The overall decrease in diarrhea incidence is of 40 percent. In order to reach the target population, sanitary awareness should be enforced.

Also, the population included in the pilot project uses the system properly. This indicates that proper education was accomplished. When women are responsible for adding the Dlowòks to the drinking water, there are less diarrhea incidences. Involvement of women in the project expansion should be a priority.

Moreover, the SWS decreases the presence of total coliforms by a factor of ten and descreases the presence of *E.coli* by a factor of twenty. Fifty-five percent of the households used the system correctly and 63 percent used the system safely. Thirty-two percent of the households in pilot project did not have chlorine residual. To overcome this, I recommend that users add one capful of Dlowòks the day they fill their bucket, and that they add half a cap Dlowòks on the subsequent days. Also, the SWS technician should inform people and insist that they should not keep the same bottle of Dlowòks more than two weeks. He should keep records of when users buy their solution and identify the ones that buy it not often enough. Smaller bottles of chlorine solution should be used to ensure that the Dlowòks available in one bottle is not enough to supply for more than two weeks.

The project should expand to a larger population. The hypochlorite generator can produce enough solution to supply 2000 families. I recommend that new SWS users have the possibility to bring their own buckets to the clinic in order to fix them so that they meet the SWS requirements on safe storage containers. Also, I suggest that Dlowòks be sold in small shops in remote regions. Schools should be included in the project expansion and should serve for educational and promotional purposes.

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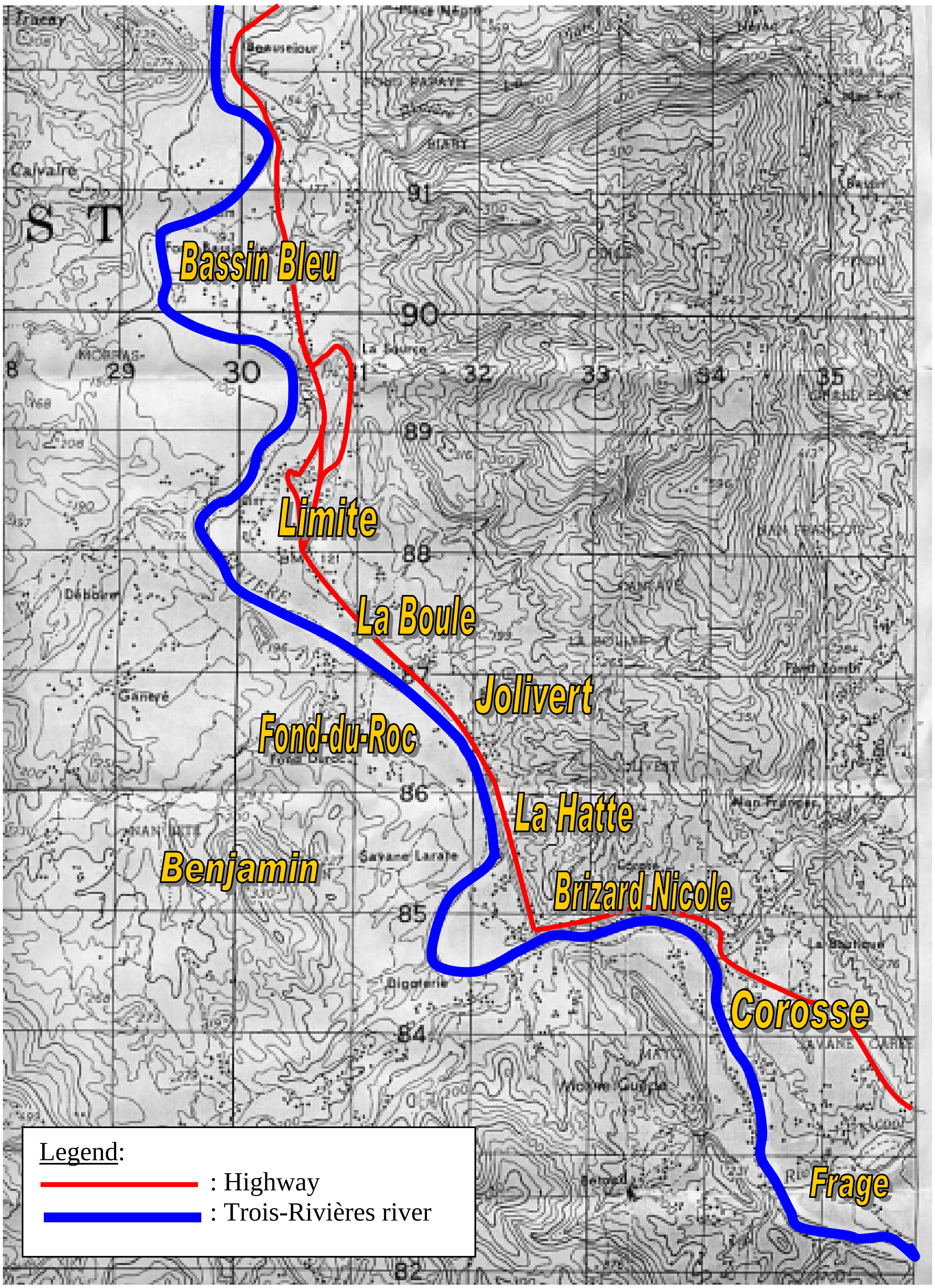
# Appendix I: Map of Jolivert and the Surrounding



# Appendix II: English Version of the Survey

**MISSIONS OF LOVE, INC.**
**CLINIC JOLIVERT**
**SAFE WATER FOR HAITIAN FAMILIES**
**(DLO PWOP POU FANMI AYSIEN)**

**Water Vessel/Disinfection Project Questionnaire: Baseline Survey for Jolivert.**
**To be used with the Individual Family Health History Questionnaire**

Hello. My name is _________. I work with the Safe Water for Jolivert Program. We are starting a project to provide safe drinking water to improve the health of the people in Jolivert and surrounding communities. In order to ensure that this project is succeeds in improving the water that you use, we would like to know about you, your family, your water handling and health practices.

The questions we are about to ask will take about 10 minutes of your time. The answers you provide will not be shared with anyone outside of this project, and will only be used for the benefit of you and the community. Please think carefully about each question, and answer as best you can. You can choose not to answer any of the questions. We would like to speak to the person that knows the most about water use and health of your family members. Who would that be?

Technician's name:

Family Name:

Date:

**I would like to know about the water that you are currently using.**

1. How many people live in the house?

| No. | Age | Sex |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |

If there are children: Do the children wear dippers?

2. Where do you get the water that you drink? (Mark all the sources used)

    a. From a "spring" (*source dlo)* dug in the river bed
    b. Directly from the river
    c. From a source that flows out of the ground

d. From a well
e. From a cistern
f. From catching rain in a barrel or bucket
g. Other: ______________________________________

3. Is this water safe to drink? **Yes** **No** **DK**

4. Do you do something to your water to make it safe? **Yes** **No** **DK**

5. (If YES) What do you do? (Circle all that apply)

a. Boil
b. Add bleach
c. Add Dlowòks
   - What quantity of Dlowòks do you add to your water
d. Add citrus
e. Other_________________________

6. How is drinking water stored in the house?

a. Bucket
b. Cooking pot
c. Jerry can
d. Barrel (Dwoum)
e. Clay pot (Kanari)
g. Other___________________

7. Is the container covered? **Yes** **No** **DK**
Does it have a cloth on top of the lid? **Yes** **No** **DK**

8. If so how?

a. With a lid
b. With a screw cap
c. With a cloth
d. Other___________________

9. Do you use the water in this container for other uses than drinking? **Yes** **No** **DK**

10. Besides drinking, what do you use this water for? Please tell me all that apply to you.

| | | | |
|---|---|---|---|
| a. Cooking | **Yes** | **No** | **DK** |
| b. Washing fruits and vegetables | **Yes** | **No** | **DK** |
| c. Cleaning plates and utensils | **Yes** | **No** | **DK** |
| d. Washing clothes | **Yes** | **No** | **DK** |
| e. Bathing or washing | **Yes** | **No** | **DK** |

f. Other: _____________________

11. What did you use to "scoop" drinking water out of the drinking water container that you are using today?

a. Cup
b. Pitcher

c. Bowl
d. Bucket
e. Hands
f. Pour water directly from container
g. Other: ______________________

12. Does anyone ever touch water in your drinking water container with their hand, for example, when they are scooping out water? **Yes** **No** **DK**

13. When the water is dirty, do you do anything to make it clear?

a. I do not do anything.
b. I let it settle.
c. I put in raket.
d. I put in toch.
e. Other. ______________________

**The next question is about diarrhea.**

14. Have you, or anyone in your family had diarrhea or a disease like typhoid, in the past week?

a. No one
b. ___________ (write age and sex)
c. ___________
d. ___________
e. ___________
f. ___________
g. ___________
h. ___________
i. ___________
j. ___________

**I am going to ask you some questions about the habits of people in your household.**

15. Where do people in your family go to the bathroom? I will read a list of options. Please tell me which of the following apply to your family:

a. On the ground **Yes** **No** **DK**
b. In a latrine or bathroom **Yes** **No** **DK**
c. Other_________________________________

16. Does anyone in your family go to the bathroom on the ground?
**Yes** **No** **DK**

17. If yes, who (circle)?
a. Children <5
b. Other_____________

18. How many rooms are there?

(DON'T READ)
19. Are there visible feces in the yard? **Yes** **No**

20. In what quantity:

a. __none

b. __ Small amount (1-2 feces)
c. __ Large amount (>5feces)

22. When do you wash your hands? (Do not read the choices)

a. Before cooking
b. Before eating
c. After going to the bathroom
d. After changing the baby's dipper
e. Other:____________________

23. Is it possible to see your soap? **Yes** **No**

24. Is there electricity in the house? **Yes** **No**

25. Flies present in house? **Yes** **No**

26. About how many *(circle)*?
a. Less than 10
b. Too many to count

**Questions relative to the Safe Water System**

1. Who is responsible for adding the Dlowoks to the water?
Always?

2. When do you add Dlowoks to the water?

Every __________ days.

3. When was the last time you added Dlowoks to the water?

It has been _____ days.

4. When was the last time you saw Eledere for your Safe Water System?

5. Where do you store your Dlowoks?

Can I see it, please?

6. Is there water in the bucket? **Yes** **No**

Chlorine residual test:
Color: a. No color
b. Light yellow
c. Yellow
d. Dark yellow
e. Very dark yellow/Orange

Take two water samples. Write the number of the house on each bag and on the survey.

Thank you very much.

# Appendix III: Survey Results Tables

Question 1: List of people living in the household with their respective age.

| Age (year) | Female | Male |
|---|---|---|
| Under 5 | 62 | 53 |
| 5-16 | 126 | 110 |
| Over 16 | 224 | 163 |
| TOTAL | 412 | 326 |

Question 2: Where do you get your drinking water?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| "Sous dlo" | 23 | 92% | 29 | 94% | 29 | 94% | 28 | 85% | **109** | **91%** |
| River | 0 | 0% | 0 | 0% | 1 | 3% | 1 | 3% | **2** | **2%** |
| Groundwater | 3 | 12% | 2 | 6% | 3 | 10% | 2 | 6% | **10** | **8%** |
| Well | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | **0** | **0%** |
| Rainwater | 0 | 0% | 0 | 0% | 1 | 3% | 1 | 3% | **2** | **2%** |
| Other | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | **0** | **0%** |
| Total | 25 | 104% | 31 | 100% | 31 | 110% | 33 | 97% | **120** | **103%** |

Question 3: Do you think your water is safe to drink?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 18 | 72% | 19 | 61% | 21 | 68% | 17 | 52% | **75** | **63%** |
| No | 7 | 28% | 9 | 29% | 6 | 19% | 10 | 30% | **32** | **27%** |
| Don't know | 0 | 0% | 3 | 10% | 4 | 13% | 6 | 18% | **13** | **11%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 4: Do you do something to your water to make it safe?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 25 | 100% | 25 | 81% | 13 | 42% | 19 | 58% | **82** | **68%** |
| No | 0 | 0% | 6 | 19% | 16 | 52% | 14 | 42% | **36** | **30%** |
| No answer | 0 | 0% | 0 | 0% | 2 | 6% | 0 | 0% | **2** | **2%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 5: (If yes) What do you do?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Boil | 0 | 0% | 0 | 0% | 1 | 3% | 0 | 0% | **1** | **1%** |
| Calcium Hypochlorite | 0 | 0% | 1 | 3% | 9 | 29% | 13 | 39% | **23** | **19%** |
| Dlowòks | 7 | 28% | 5 | 16% | 1 | 3% | 1 | 3% | **14** | **12%** |
| Dlowòks - 1 | 17 | 68% | 25 | 81% | 1 | 3% | 0 | 0% | **43** | **36%** |
| Dlowòks - 2 | 1 | 4% | 0 | 0% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Citrus | 0 | 0% | 0 | 0% | 2 | 6% | 5 | 15% | **7** | **6%** |
| Nothing | 0 | 0% | 0 | 0% | 18 | 58% | 15 | 45% | **33** | **28%** |
| Total | 25 | 100% | 31 | 100% | 31 | 103% | 33 | 103% | **120** | **102%** |

Question 6: How is drinking water stored in the house?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Bucket | 25 | 100% | 31 | 100% | 24 | 77% | 21 | 64% | **101** | **84%** |
| Kanari | 0 | 0% | 0 | 0% | 13 | 42% | 14 | 42% | **27** | **23%** |
| Gallon | 1 | 4% | 0 | 0% | 1 | 3% | 3 | 9% | **5** | **4%** |
| "Dwoum" | 0 | 0% | 0 | 0% | 0 | 0% | 2 | 6% | **2** | **2%** |
| Total | 25 | 104% | 31 | 100% | 31 | 123% | 33 | 121% | **120** | **113%** |

Question 7: Is the container covered?
Does it have a clothe on top of the lid?

| nswer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 9 | 36% | 4 | 13% | 25 | 81% | 23 | 70% | **61** | **51%** |
| Yes/Yes | 8 | 32% | 17 | 55% | 1 | 3% | 2 | 6% | **28** | **23%** |
| Yes/No | 8 | 32% | 9 | 29% | 4 | 13% | 8 | 24% | **29** | **24%** |
| No | 0 | 0% | 0 | 0% | 1 | 3% | 0 | 0% | **1** | **1%** |
| Half closed | 0 | 0% | 1 | 3% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 8: If so, how?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Lid | - | 0% | - | 0% | 25 | 81% | 28 | 85% | **53** | **44%** |
| Screw cap | - | 0% | - | 0% | 1 | 3% | 2 | 6% | **3** | **3%** |
| Cloth | - | 0% | - | 0% | 1 | 3% | 1 | 3% | **2** | **2%** |
| Plate | - | 0% | - | 0% | 8 | 26% | 2 | 6% | **10** | **8%** |
| Peel of banana | - | 0% | - | 0% | 0 | 0% | 1 | 3% | **1** | **1%** |
| No answer | - | 0% | - | 0% | 0 | 0% | 1 | 3% | **1** | **1%** |
| Total | 25 | 0% | 31 | 0% | 31 | 113% | 33 | 106% | **120** | **58%** |

Question 9: Do you use the water in this container for other uses than drinking?

| Answer | With the System | | | | Without the System | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 3 | 12% | 3 | 10% | 3 | 10% | 3 | 9% | **12** | **10%** |
| No | 20 | 80% | 27 | 87% | 28 | 90% | 30 | 91% | **105** | **88%** |
| No answer | 2 | 8% | 1 | 3% | 0 | 0% | 0 | 0% | **3** | **3%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 10: Besides drinking, what do you use this water for?

| Answer | With the System | | | | Without the System | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Cooking | 7 | 28% | 9 | 29% | 12 | 39% | 7 | 21% | **35** | **29%** |
| Cleaning fruits and vegetables | 7 | 28% | 4 | 13% | 5 | 16% | 4 | 12% | **20** | **17%** |
| Cleaning dishes | 9 | 36% | 11 | 35% | 5 | 16% | 4 | 12% | **29** | **24%** |
| Cleaning clothes | 2 | 8% | 0 | 0% | 1 | 3% | 0 | 0% | **3** | **3%** |
| Bathing | 5 | 20% | 13 | 42% | 5 | 16% | 2 | 6% | **25** | **21%** |
| Washing teeth | 0 | 0% | 3 | 10% | 0 | 0% | 0 | 0% | **3** | **3%** |
| Washing ands | 2 | 8% | 2 | 6% | 1 | 3% | 0 | 0% | **5** | **4%** |
| Nothing | 11 | 44% | 9 | 29% | 19 | 61% | 26 | 79% | **65** | **54%** |
| Total | 25 | 172% | 31 | 165% | 31 | 155% | 33 | 130% | **120** | **154%** |

Question 11: What did you use to "scoop" drinking water out of the drinking water container that you are using today?

| Answer | With the System | | | | Without the System | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Robinet | 25 | 100% | 31 | 100% | 1 | 3% | 1 | 3% | **58** | **48%** |
| Cup | - | 0% | - | 0% | 2 | 6% | 3 | 9% | **5** | **4%** |
| Pitcher | - | 0% | - | 0% | 0 | 0% | 1 | 3% | **1** | **1%** |
| Bowl | - | 0% | - | 0% | 1 | 3% | 4 | 12% | **5** | **4%** |
| Glass | - | 0% | - | 0% | 17 | 55% | 12 | 36% | **29** | **24%** |
| Directly in a glass | - | 0% | - | 0% | 1 | 3% | 2 | 6% | **3** | **3%** |
| Mug | - | 0% | - | 0% | 9 | 29% | 11 | 33% | **20** | **17%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 103% | **120** | **101%** |

Question 12: Does anyone ever touch water in your drinking water container with their hand, for example, when they are scooping out water?

| Answer | With the System | | | | Without the System | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 0 | 0% | 0 | 0% | 17 | 55% | 5 | 15% | **22** | **18%** |
| No | 25 | 100% | 31 | 100% | 14 | 45% | 28 | 85% | **98** | **82%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 13: When the water is dirty, what do you do to make it clear?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Do nothing | 0 | 0% | 1 | 3% | 0 | 0% | 1 | 3% | **2** | **2%** |
| Let it settle | 1 | 4% | 1 | 3% | 3 | 10% | 0 | 0% | **5** | **4%** |
| Racket | 6 | 24% | 4 | 13% | 9 | 29% | 10 | 30% | **29** | **24%** |
| Toch | 1 | 4% | 0 | 0% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Groundwater | 3 | 12% | 5 | 16% | 5 | 16% | 4 | 12% | **17** | **14%** |
| Rain | 5 | 20% | 6 | 19% | 8 | 26% | 5 | 15% | **24** | **20%** |
| Never serve with dirty water | 12 | 48% | 16 | 52% | 10 | 32% | 12 | 36% | **50** | **42%** |
| Other | 0 | 0% | 0 | 0% | 0 | 0% | 4 | 12% | **4** | **3%** |
| No answer | 0 | 0% | 1 | 3% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Total | 25 | 112% | 31 | 110% | 31 | 113% | 33 | 109% | **120** | **111%** |

Question 14: How many people in the family had diarrhea last week, and who?

| SWS | People | Less than five years old | | | | From 5 to 16 years old | | | | More than 16 years old | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Female | | Male | | Female | | Male | | Female | | Male | | | |
| Without | Total | 35 | **33%** | 25 | **29%** | 62 | 14% | 70 | 8% | 112 | 19% | 84 | 21% | 388 | **18%** |
| | With diarrhea | 11 | | 7 | | 8 | | 5 | | 21 | | 17 | | 69 | |
| With | Total | 27 | **32%** | 28 | **39%** | 64 | 7% | 40 | 2% | 112 | 6% | 79 | 7% | 350 | **11%** |
| | With diarrhea | 9 | | 11 | | 5 | | 1 | | 7 | | 6 | | 39 | |

Question 15: Where do people in your family go to the bathroom?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| On the ground | 6 | 24% | 7 | 23% | 16 | 52% | 15 | 45% | **44** | **37%** |
| Latrines | 19 | 76% | 24 | 77% | 15 | 48% | 18 | 55% | **76** | **63%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Questions 16 and 17: Does anyone in your family go to the bathroom on the ground?
If yes, who?

Question 18: How many rooms are there?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| 1 | 2 | 8% | 3 | 10% | 4 | 13% | 2 | 6% | **11** | **9%** |
| 2 | 13 | 52% | 16 | 52% | 16 | 52% | 17 | 52% | **62** | **52%** |
| 3 | 2 | 8% | 3 | 10% | 4 | 13% | 4 | 12% | **13** | **11%** |
| 4 | 6 | 24% | 4 | 13% | 5 | 16% | 6 | 18% | **21** | **18%** |
| 5 | 0 | 0% | 3 | 10% | 2 | 6% | 4 | 12% | **9** | **8%** |
| 6 | 1 | 4% | 2 | 6% | 0 | 0% | 0 | 0% | **3** | **3%** |
| 7 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | **0** | **0%** |
| 8 | 1 | 4% | 0 | 0% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 19: Are there visible feces in the yard?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 0 | 0% | 2 | 6% | 7 | 23% | 5 | 15% | **14** | **12%** |
| No | 13 | 52% | 8 | 26% | 11 | 35% | 17 | 52% | **49** | **41%** |
| No answer | 12 | 48% | 21 | 68% | 13 | 42% | 11 | 33% | **57** | **48%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 20: In what quantity:

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Nothing | | 0% | | 0% | 1 | 3% | 1 | 3% | **2** | **2%** |
| Few | | 0% | 1 | 3% | 5 | 16% | 4 | 12% | **10** | **8%** |
| A lot | | 0% | 1 | 3% | 1 | 3% | | 0% | **2** | **2%** |
| Total | 25 | 0% | 31 | 6% | 31 | 23% | 33 | 15% | **120** | **12%** |

Question 22: When do you wash your hands?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Before eating | 4 | 16% | 5 | 16% | 8 | 26% | 9 | 27% | **26** | **22%** |
| Before cooking | 6 | 24% | 11 | 35% | 8 | 26% | 14 | 42% | **39** | **33%** |
| After toilet | 15 | 60% | 21 | 68% | 23 | 74% | 17 | 52% | **76** | **63%** |
| After changing the baby's dipper | 1 | 4% | 0 | 0% | 1 | 3% | 0 | 0% | **2** | **2%** |
| When dirty | 3 | 12% | 8 | 26% | 9 | 29% | 11 | 33% | **31** | **26%** |
| After work | 2 | 8% | 1 | 3% | 1 | 3% | 1 | 3% | **5** | **4%** |
| Other | 4 | 16% | 7 | 23% | 8 | 26% | 7 | 21% | **26** | **22%** |
| No answer | 2 | 8% | 2 | 6% | 1 | 3% | 0 | 0% | **5** | **4%** |
| Total | 25 | 148% | 31 | 177% | 31 | 190% | 33 | 179% | **120** | **175%** |

Question 23: Do you have soap right now?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 21 | 84% | 27 | 87% | 24 | 77% | 24 | 73% | **96** | **80%** |
| No | 4 | 16% | 3 | 10% | 7 | 23% | 9 | 27% | **23** | **19%** |
| No answer | 0 | 0% | 1 | 3% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 24: Do you have electricity?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 2 | 8% | 2 | 6% | 2 | 6% | 4 | 12% | **10** | **8%** |
| No | 23 | 92% | 29 | 94% | 29 | 94% | 29 | 88% | **110** | **92%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 25: Are there flies in the house?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Yes | 15 | 60% | 16 | 52% | 15 | 48% | 17 | 52% | **63** | **53%** |
| No | 8 | 32% | 12 | 39% | 8 | 26% | 9 | 27% | **37** | **31%** |
| No answer | 2 | 8% | 3 | 10% | 8 | 26% | 7 | 21% | **20** | **17%** |
| Total | 25 | 100% | 31 | 100% | 31 | 100% | 33 | 100% | **120** | **100%** |

Question 26: If so, how many?

| Answer | With the System | | | | Without the System | | | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diarrhea | | No Diarrhea | | Diarrhea | | No Diarrhea | | **HH** | **(%)** |
| Less than 10 | 11 | 44% | 10 | 32% | 14 | 45% | 14 | 42% | **49** | **41%** |
| Too many to count | 3 | 12% | 6 | 19% | 1 | 3% | 3 | 9% | **13** | **11%** |
| No answer | 1 | 4% | 0 | 0% | 0 | 0% | 0 | 0% | **1** | **1%** |
| Total | 25 | 60% | 31 | 52% | 31 | 48% | 33 | 52% | **120** | **53%** |

**Safe Water System Use**

Question 1: Who is responsible for adding the Dlowoks to the water?

| Answer | Diarrhea | | No Diarrhea | | **Total** | **(%)** |
|---|---|---|---|---|---|---|
| 1 female | 14 | 56% | 22 | 71% | **36** | **64%** |
| 1 male | 2 | 8% | 0 | 0% | **2** | **4%** |
| Many females | 3 | 12% | 7 | 23% | **10** | **18%** |
| F and M | 4 | 16% | 1 | 3% | **5** | **9%** |
| Whomever | 1 | 4% | 1 | 3% | **2** | **4%** |
| No answer | 1 | 4% | 0 | 0% | **1** | **2%** |
| Total | 25 | 100% | 31 | 100% | **56** | **100%** |

Question 2: When do you add Dlowoks to the water?

| Answer | Diarrhea | | No Diarrhea | | **Total** | **(%)** |
|---|---|---|---|---|---|---|
| Everyday | 10 | 40% | 14 | 45% | **24** | **43%** |
| 2 days | 1 | 4% | 7 | 23% | **8** | **14%** |
| 2 or 3 days | 7 | 28% | 7 | 23% | **14** | **25%** |
| More than 3 days | 2 | 8% | 1 | 3% | **3** | **5%** |
| When I refill the bucket | 2 | 8% | 0 | 0% | **2** | **4%** |
| No answer | 3 | 12% | 2 | 6% | **5** | **9%** |
| Total | 25 | 100% | 31 | 100% | **56** | **100%** |

Question 3: When was the last time you added Dlowoks to the water?

| Answer | Diarrhea | | No Diarrhea | | **Total** | **(%)** |
|---|---|---|---|---|---|---|
| Today | 7 | 28% | 13 | 42% | **20** | **36%** |
| Yesterday | 12 | 48% | 10 | 32% | **22** | **39%** |
| 2 days ago | 1 | 4% | 1 | 3% | **2** | **4%** |
| > two days ago | 1 | 4% | 1 | 3% | **2** | **4%** |
| No answer | 4 | 16% | 6 | 19% | **10** | **18%** |
| Total | 25 | 100% | 31 | 100% | **56** | **100%** |

# Appendix IV: Titration Methodology

The titration followed the HACH methodology for total chlorine (HACH, 2000), using the iodometric method, for chlorine concentrations between 20 and 70,000 mg/L. Duplicates were done for the first and the last samples and presented relative errors of 3 and 4 percent. The methodology is as follow:

1. Select a Sodium Thiosulfate cartridge that corresponds to the expected chlorine concentration.
2. Insert a clean delivery tube into the cartridge.
3. Install the cartridge on the titrator body.
4. Flush the delivery tube and reset the titrator counter to zero.
5. Use a pipette and measure the volume of chlorine sample corresponding to the expected chlorine concentration.
6. Add the content of a Dissolved Oxygen 3 Powder Pillow.
7. Add the content of the Potassium Iodide Powder Pillow that corresponds to the type of cartridge we use. (The solution turns yellow/orange.)
8. Place the delivery tube tip into the solution and swirl while titrating until the solution is pale yellow.
9. Add one dropperful of starch indicator solution. (The solution turns blue.)
10. Continue the titration until the solution turns colorless.
11. Record the numbers of digits.
12. Get the chlorine concentration by multiplying the number of digits with the multiplier that corresponds to the sample volume used.

In our case, the samples from February 7$^{th}$ to March 11$^{th}$ were conducted with the titration cartridge 2.00 N, with 4mL of sample volumes, for expected chlorine concentrations between 2000 and 9000mg/L. The corresponding multiplier was then 22.2. A second sample of the solution from February 7$^{th}$, and samples from January 24$^{th}$, and February 3$^{rd}$ were conducted using the titration cartridge 0.113 N, for a expected chlorine concentrations between 500 and 2000mg/L. The corresponding sample volume was then 1mL and the multiplier was 5.