2016

Assessing Household Drinking Water Needs: Reaching Many One Water Filter at a Time in Los Robles, Nicaragua

Erinkate E. Springer

ASSESSING HOUSEHOLD DRINKING WATER NEEDS: REACHING MANY ONE WATER FILTER AT A TIME IN LOS ROBLES, NICARAGUA

By

ERINKATE ELIZABETH SPRINGER

B.S., Humboldt State University, Arcata, CA, 2003

Professional Paper

presented in partial fulfillment of the requirements

for the degree of

Master of Science

in Resource Conservation, International Conservation and Development

The University of Montana

Missoula, MT

May 2016

Approved by:

Dr. Stephen Siebert

College of Forestry and Conservation

Dr. Ron Wakimoto

College of Forestry and Conservation

Dr. Vicki Watson

Environmental Studies Program

Dr. Scott Whittenburg

Dean of the Graduate School

Springer, Erinkate, M.S., Spring 2016

Resource Conservation

Assessing Household Drinking Water Needs: Reaching Many One Water Filter at a Time

Chairperson: Stephen Siebert

Water quality and water scarcity have dominated international health and environmental management initiatives for decades because of the devastating impacts poor water quality has on child mortality and general public well-being, particularly in developing countries. Non-profit organizations, private utilities, and government agencies have invested significant financial resources and time to increase access to improved water sources in low-income countries. However, the sustainability of water improvement project benefits have been disappointing due to a lack of community and household capacity to operate and maintain introduced water systems. This paper evaluates a community/household based water improvement project introduced by a small non-governmental organization, Proyecto Nica Agua, in Los Robles, Nicaragua. The project sought to build local community capacity to develop and sustain a water improvement project based on individual household use of ceramic water filters, hygiene and sanitation education, community service projects and watershed education.

Household health surveys, informal interviews, water quality sampling, and on-site observations were used to evaluate the effectiveness and potential sustainability of the introduced water system. The introduction of ceramic water filters resulted in a 90% reduction in reported cases of diarrhea since the beginning of the project 2011. This study found that reported cases of water-related illnesses (i.e., diarrhea, parasites and kidney infections) were eliminated after two years of filter use (n=20 households). In a survey of village residents, 78% of respondents (n=201 households) indicated a willingness to maintain their water filters, while 82% reported they would participate in another community service project as a means to maintain or replace water filters. *Escherichia coli* was present in 90% of water filter samples, however the accuracy of the tests cannot be confirmed. In informal interviews 74% reported not knowing the origin of contamination in the water supply. The results of this study were used to develop a watershed education curriculum to provide information about the effects of human activities on both surface and groundwater supplies. The curriculum is currently being used in Los Robles and in other regions of Nicaragua where Proyecto Nica Agua has extended their project.

Preface

This professional paper is original, unpublished, independent work by the author, Erinkate Springer in partial fulfillment of the requirements for a Master's Degree in Resource Conservation with an emphasis in International Development and Conservation at the University of Montana. The fieldwork conducted for this paper was approved by the Institutional Review Board at the University of Montana.

My involvement with Proyecto Nica Agua began during the 2012 summer prior to my enrollment in the University of Montana, specifically on a wildfire in eastern Oregon with my coworker, friend and co-founder of Proyecto Nica Agua, Mat Mendonça. Mat was looking for assistance with his recently initiated ceramic water filter program.

ACKNOWLEDGEMENTS

I take this opportunity to express my deep appreciation to my chair Dr. Stephen Siebert for his endless patience, motivation and guidance through the course of my graduate studies and writing of this professional paper.

I would also like to thank my committee members: Dr. Vicki Watson and Dr. Ron Wakimoto for respected suggestions regarding this paper.

I must also express my gratitude to Mat Mendonça, the co-founder of Proyecto Nica Agua, an incredible co-worker and friend. Asking me to become a part of Proyecto Nica Agua was truly an opportunity that I accepted with the utmost respect and dignity. Thank you to Sarah Grossberg, John Thompson and Dariel Castro-Potoy, Communidad Connect representatives, that paved the path for me to live and study in Los Robles. Your guidance, encouragement and kindness I can only attempt to replicate in my own life.

To my friends, Melissa and Jeff Pernell, thank you for your love and your home; a place of laughter and joy that keeps my spirits high. To Jessica Young and KT Scheer, without your willingness to answer the phone and listen to me rant about diarrhea and the injustice of water quality issues in the world I would have never arrived at this point without imploding. To Erin and Jon Mooney, who provided me with the best advice, “Just write it.” Thank you.

I cannot leave out my father and brother, my role models, thank you for your unconditional love and support throughout my life.

Lastly, to Robert Rosenthal, my best friend and partner, the earth is 4.5 billion years old and I am incredibly grateful to have existed in the same place and at the time as you.

This research could not have been done without the financial assistance from the Alaback and Brewer Melipal Fellowship for Conservation and Education in Latin America 2013/2014, the National Smokejumper Association Scholarship 2014 and 2015, and the Shane Ewing Scholarship 2016.

DEDICATION

For Julie Ann Springer, my mother, the light at the end of the tunnel. Your relentless love and support is the unbreakable foundation that I could jump from without fear. “I did it, Mom! This is for you.” I love and miss you so much.

For Sally Rosenthal-Tor the brilliance and compassion you used to fight cancer was the train that kept me going.

For the Blandon’s, without the immediate acceptance into your family and home, a complete stranger I could not have ever imagined to finish my research in Los Robles. You contributed more to my life than I can ever hope to give back. “*Gracias muchas por abrir su* corazón *sin juicio.*” *Siempre te llevaré dentro de mi corazón.*

Table of Contents

Table of Contents Continued

List of Tables

List of Figures

I. INTRODUCTION

Water scarcity, contamination and poor sanitation adversely affect billions of people around the world, particularly in developing nations where water problems contribute to poverty and high rates of childhood mortality (WHO/UNIFCEF 2014). At a global level, approximately 2.5 billion cases of diarrhea occur annually among children under the age of five and 1400 children die each day due to diarrhea-induced illness (You et al 2012; WHO/UNICEF 2014; Pinzón-Róndón et al. 2015). It is estimated that 88% of diarrhea-induced deaths are attributable to contaminated water supplies, poor hygiene and unsanitary conditions (WHO/UNICEF 2010). The United Nations Millennium Development Project (MDP) set out to confront lack of access to water sources and improved sanitation by establishing the "United Nations Water for Life Decade" in 1990 (UNDESA 2015) and Millennium Development Goal (MDG): Target 7c committed to "halve the proportion of the population without sustainable access to safe drinking water and basic sanitation" by 2015 (WHO 2011a).

The indicator used to monitor the progress of Target 7c is the proportion of the population that gained access to "an improved water source" (WHO/UNICEF 2010). An "improved water source" was coined in 1990 and equated to safe drinking water. However, no system was established to gather water quality data or set a baseline to compare current statistics against past conditions (Bain et al. 2012). Improved water sources include piped water systems that either deliver water to a residence or to a public tap, boreholes, protected dug wells, protected springs and rainwater collection according to the Joint Monitoring Programme (WHO/UNICEF 2010). However, improved water sources do not necessarily mean safe drinking water and assuming so has overestimated the proportion of the population that has reliable access to clean water and underestimated the risk of exposure to microbiologically contaminated drinking water (Bain et al. 2012).

A study in India where 99.6% of urban and 97.7% of rural households reportedly had access to safe water as defined by the MDG Target 7c standards, found that 41.5% of urban and 60% of rural households were actually using contaminated water (Johri et al. 2014). Bain et al (2012) studied the water quality in five countries that had met MDG Target 7c goals. They evaluated improved water sources for the presence of thermotolerant coliform bacteria, fluoride, arsenic and nitrate compounds and found that the proportion of the population without access to safe drinking water was actually 7% greater (Bain et al. 2012). The UN Department of Economics and Social Affairs officially ended the "Water for Life Decade" in 2015 by celebrating the tremendous financial investments and labor by government agencies, NGOs and international aid organizations from around the world to address the lack of access to safe water and improved sanitation (UNDESA 2015). However, access to clean, reliable drinking water and sanitation problems remain major challenges throughout much of the world.

At present, it is estimated that 1.9 billion people use either improved or unimproved water sources that have fecal contamination (Bain et al. 2014b). Other studies indicate that 1.8 billion people are exposed to fecal contamination through their drinking water (Onda et al. 2012). Coliform bacteria are often used as an indicator of possible waterborne pathogens and cause more disease than any other drinking water contaminants (Bain et al. 2012). Coliform bacteria are also common in "improved water sources", including piped systems and groundwater (Bain et al. 2014b). Water samples tested in many lower income countries found higher proportions of microbial contaminated water from "improved sources" than in high-income countries (Bain et al. 2012; Lim et al. 2012).

Nicaragua, the second poorest country in the western hemisphere (CIA 2016), is a water resource rich country, but struggles with limited access to clean drinking water due to considerable seasonal variations in rainfall, hydrogeological conditions (Garcia 2005; Novo & Garrido 2010) and inadequate wastewater treatment. Since 1990 the availability of improved drinking water sources increased by 76-90% in Nicaragua via installation of piped water systems (UNICEF 2015), yet water quality studies found that 17% of the population with piped water were exposed to contaminated water, primarily by coliform bacteria (Bain et al. 2012).

At present, some 900,000 to two million people in Nicaraguans are believed to lack access to potable water (wateraid.org 2014; communidadconnect.org 2014). The World Health Organization (2010) tested the water of 46 municipalities across Nicaragua and found that 44 tested positive for high levels of fecal coliform. This situation makes it difficult to meet the MDG and leaves Nicaragua as the only Central American country lacking widespread access to improved drinking water sources. Researching water improvement projects in

Nicaragua through a Google search I found that over thirty NGOs have implemented water improvement projects in Nicaragua, yet many have failed functionally and operationally due to the absence of long-term monitoring (Davis 2014) and lack of community involvement in their design and maintenance. For example, in Terrabona, Nicaragua, 47 water systems were installed by various NGOs over a fifteen year period starting in 1998, but only 54% were functioning properly in 2013 (El Porvenir 2013).

In Los Robles, Nicaragua, the focus area of this study, a piped water system was installed over a two-week period by a large NGO that was funded by USAID (Mendonça pers. comm). The project included the construction of three terraced holding tanks filled with pebbles to filter mountain spring water captured from the highest peak, Cerro El Diablo. Pipes made of polyvinyl chloride (PVC) were installed to feed the water to Los Robles (Figure 1). The piped system has failed repeatedly in terms of both water delivery and structural integrity (author's pers. obs. 2013; pers. com. Grossberg 2013; pers. com. Blandón 2013). Globally, the cumulative cost of failed water systems, such as that in Los Robles, is estimated to be US$ 1.2 billion (Carter et al. 2014) and affects both rich and poor countries (Kayser et al. 2014). The cumulative costs include economic loss to those receiving assistance, installation and replacement costs and associated health costs from increased incidences of water related diseases. Increased exposure to microbiologically contaminated water due to improperly managed and constructed water systems is also found in both developing and developed countries (Kayser et al. 2014).

In Norway, Nygard et al. (2007) discovered that gastrointestinal illnesses were twice as likely to occur in households because of low water pressure resulting from breaks in the water system, than in intact systems. In the United States, soil and water samples adjacent to a piped water system exhibited microbial contamination; fecal coliform was found in 50% of the soil samples and 46% of the water samples (Nygard et al. 2007). When water pressure decreases due to a break in the system, the potential for microbial contamination of the water supply increases (Hunter et al. 2005; Nygard et al. 2007). The risk of illnesses increase to nearly 100% for cryptosporidium when water supplies fail for even one day and 100% for thermotolerant coliform if failure lasts for 34 days (Hunter 2009). In countries like Norway and the United States, accessibility to health care can be less of an issue. However, in developing countries with poor or limited access to health care, gastrointestinal illnesses can result in widespread and persistent sickness and mortality. Neglected infrastructure can result in exposure to high levels of toxins, for example high levels of lead have affected populations in Flint, Michigan (Keller 2016). An outbreak of Legionnaires' disease, sever pneumonia, has been linked to Flint's failed infrastructure and change in water chemistry (Guarino 2016).

In Los Robles, a community without immediate access to a health clinic at the time of this study, and the financial resources to obtain proper medical care, interruptions in the water supply can have serious effects, especially in children under the age of five. Training community members on the procedures, operation and maintenance of a water system and providing hygiene education can potentially increase the effectiveness of water improvement projects. A study reviewing the sustainability of foreign aid development projects in five countries in Central America and Africa found that the most sustainable water quality programs incorporated training of local health workers and the construction of local health clinics (Bossert 1990).

Dysfunctional water improvement projects are not restricted to piped water systems. Boreholes and hand pumps often break or need maintenance after installation and the departure of the organization that introduced them (Bossert 1990; Hobbes 2014; Kayser et al. 2014). Play pumps that required children to play on a carousel to generate energy for water to be pumped into a water storage tank, were an innovation founded on good intentions in an effort to bring water to villages throughout Africa. The sponsoring organization raised 16.4 million dollars to construct water pumps in villages only to find out that two years later the pumps were abandoned, broken and unmaintained (Hobbes 2014). Communities were never asked if they wanted a Play pump and in some villages adults paid children to operate the carousel (Hobbes 2014).

Water projects that provide "point of use" interventions have been shown to be functional for short periods or until the organization left the community. Point of use refers to interventions that are most commonly used in the household immediately prior to consumption and include solar disinfection, chlorine, boiling or a filter. A systematic review of point of use disinfection treatments found that after a year of implementation, chlorine, chlorine coagulant and solar disinfection (SODIS) did not reduce diarrheal disease (Hunter 2009). One of the problems of point of use water interventions and the aforementioned water infrastructure projects is that limited project life (typically less than 2 years) often means monitoring and evaluation cease when projects conclude (Bossert 1990). Hunter (2009) found that the median time for monitoring the effects of disinfection treatments on reducing diarrheal disease was only twenty-six weeks.

Ceramic filters were found to be more effective for a longer period at reducing the risk of diarrheal disease (Hunter 2009). However, ceramic filters are expensive, fragile, and rarely is a supply chain established in rural communities for households to replace parts with the result that they often revert back to using potentially contaminated water. In Los Robles I witnessed this while visiting households for interviews. Many households had empty plastic receptacles meant to hold the ceramic filter and catch filtrated water. When asked where the plastic buckets came from household respondents said an aid group gave the filters to them at various times in the past. This exemplifies the widespread tendency of many water improvement projects failing to incorporate community or household capacities to operate, maintain, and acquire replacement parts to sustain clean drinking water supplies.

Los Robles, Nicaragua: Project of Proyecto Nica Agua

Proyecto Nica Agua, which is a subset of Communidad Connect, a Nicaraguan non-profit, sought to create a sustainable water improvement project that is community operated and maintained. In 2010, Proyecto Nica Agua (PNA) began a pilot study in Los Robles to determine how to achieve this. PNA's approach is to educate the community on proper hygiene and sanitation techniques on the assumption that hygiene and water handling knowledge will increase health and prevent waterborne diseases; research elsewhere suggests that potable water and sanitation facilities alone do not necessarily reduce gastro-intestinal diseases (Esrey et al. 1991; Halvorson et al. 2011).

An analysis of water and sanitation recovery efforts after Hurricane Mitch in 1998, an environmental catastrophe in Nicaragua, examined potential variables that can lead to a reduction in water related illness caused by waterborne diseases, poor hygiene and a lack of clean water (Lantagne 2001). At the time that this study was published, the mortality rates for children under 5 years old in Nicaragua was at 66% (Lantagne 2001). Distance to a water supply, better education for mothers, hand-washing, domestic cleanliness and the use of diapers were all found to affect the incidence of diarrhea, especially in children under five (Gorter et al.1995;

Lantagne 2001). Point of use water treatment, such as Filtrón's water filters, can reduce the risk of water related illness that occur between water collection and consumption (Wright et al 2001; Clasen et al 2004). PNA's introduction of the Filtrón ceramic water filters in Los Robles was coupled with hygiene education and organizing a group of community health leaders to train, implement, and sustain the project.

Project participation in Nicaragua often involves NGOs representing the interests of principal landowners (e.g., farmers in this case) (De Costa Silva 2011). The piped water system project in Los Robles is an example of this as the organization met with Jinotega (a city 18km south of Los Robles) city officials and ENACAL, the utility service for Nicaragua to design and implement the water supply and payment system. Representatives from affected communities that were required to pay for and maintain the water service were not consulted prior to installation of the piped water system (pers. com. Grossberg 2013).

PNA has taken an alternative approach by focusing on participation from the entire community, and specifically trying to involve women and children in the development and implementation of community water improvement projects. Success of community participation in humanitarian projects is well documented, however much can be learned from failed attempts as well (Botes & van Rensburg 2000). Often development interventions are designed and implemented before or without community involvement, frequently resulting in a promotional campaign to get participants to "buy in" to preconceived ideas (Botes & van Rensburg 2000). A villager in South Africa put it well, 'They (the developers) arrived already knowing everything. They come here and look around, but they see only what is not here'. 'Developers just came overnight, they just arrived. They did not tell the people. They made us think that they were coming to save us' Informal settler KwaZulu Natal South Africa (CRIASS 1994, p. 16 in Botes & van Rensburg 2000).

Community organizations are not democratically elected so involvement can segregate others from participating in development projects (Botes & van Rensburg 2000). Isolating parts of the community was a concern PNA sought to overcome and did so by involving a group of respected community health leaders from the beginning of the water project. The *brigadistas* (community health nurse) conducted the filter trainings, taught the hygiene and sanitation workshops, and assisted with filter distribution. During my stay in Los Robles, I witnessed how highly regarded these women were because I lived with a *brigadista* (community health nurse) that was constantly visited by people seeking counseling and relief from various illnesses, and women going into labor.

Communidad Connect purchased a coffee farm in Los Robles prior to the establishment of Proyecto Nica Agua in part to create a relationship with the community and to provide fair wage employment opportunities for workers. Working in conjunction with the community health leaders who are respected in the community addressed one of the key elements for creating a sustainable project: training local health workers (Bossert 1990). PNA's strategy requires recipients of a Filtrón water filter to attend sanitation and hygiene workshops and trainings on the proper use and maintenance (cleaning and storage) of the filter that are led by the *brigadistas*. In conjunction with the health seminars each household must complete 16 hours of community service to receive a filter. *Obra sociales* (community service projects) provided an opportunity for recipients to gain ownership in the water project while connecting with the community at large. Filtrón water filters may be inexpensive for Americans, but are very costly for the people of Los Robles who on average make only one to four dollars per day (Guillermo 2007). Providing a means for households to acquire a filter through work that benefits the community has the potential to instill a sense of ownership and responsibility for maintaining the filter. Successful foreign assistance is often founded on the adage, 'teaching people how to fish is better than giving donations of food' (Goulet 1989). Some of the community service projects included reforestation, road improvement, school maintenance, and constructing a health clinic.

Experience and research has shown that people care most about what affects them directly (Stapp 2000). Connecting environmental factors that affect people on a personal level has been shown to elicit change (Donahue et al. 1998; Stapp 2000). Watershed organizations and projects proliferated in the United States based on this philosophy. For example, the Global Rivers Environmental Education Network (GREEN) grew out of an outbreak of Hepatitis in a Michigan high school as a result of contamination in Lake Huron due to sewage effluent (Donahue et al. 1998). Scientists and high school students worked together to educate the community, city government and culpable businesses. Today GREEN works across the globe focusing on school and community watershed education curricula with a focus on the importance of water quality and water resources to maintain a high quality of life (Donahue et al. 1998). Environmental factors affecting water supplies extend to personal practices (e.g., hygiene) and can increase overall community participation for change, especially if the change is palpable (Wang et al. 2013). Incorporating environmental education into water improvement projects may contribute to improved health and long term project sustainability.

Many attempts around the world have sought to reduce contaminated water in populations without improved water sources and to reduce the prevalence of water related illnesses. Increasing hygiene awareness (Halvorson 2003, Halvorson et al 2004), education interventions to improve water quality (Hunter et al. 2010; Desai & Rifai 2013), instituting point of use chemical and biological interventions (Esrey et al 1991; Clasen et al. 2004; Fewtrell et al. 2005; Hunter 2009) and increasing access to improved water sources (WHO 2011a) have been implemented and studied, yet largely on an individual project basis. The aim of this paper is to examine a water improvement project that is incorporating community participation, hygiene and sanitation education, point of use ceramic water filters, a watershed education curriculum and a two-year monitoring period after project initiation.

II. METHODS

This study, conducted in Los Robles, compares baseline household health information gathered prior to filter use, including the prevalence of water related illnesses (i.e., diarrhea, parasites and kidney infections) to the prevalence of these illnesses after using a ceramic water filter for six months, one year and two years. Water samples from public wells, the piped water system and the water filters were tested for *Escherichia coli*, heavy metals, total nitrates, lead and pesticides (atrazine and simazine). Household surveys were employed to determine how the community perceived the water improvement project, the community service projects they completed, benefits and problems associated with using the water filter, and the ways Proyecto Nica Agua could improve efforts as they expand to other communities in Nicaragua. Informal interviews with heads of households were conducted to identify key environmental components to incorporate into a watershed education curriculum that sought to assist the community, manage its water supply, reduce water-related illnesses, and to serve PNA administrators as a reference for future educational workshops.

Figure 1. Location of the piped water system's water catchment tanks in relation to Los Robles, Nicaragua.

2.1 Study Area

Los Robles is located in the Jinotega Department in the northern highlands of Nicaragua (Figure 2). The closest city with health facilities lies 30 km to the south in the town of Jinotega. Los Robles lies in the Jingüina sub-watershed where altitudes range between 700 and 1680 meters. The community is divided into nine *barrios* (neighborhoods) and the population is approximately 2000. Los Robles has a dry-tropical climate that consists of a rainy season between the months of May and October and a dry season between November and April. Mean annual average rainfall for is 1650 mm with 5mm to 46 mm falling mostly between the months of December and April and 145mm to 305 mm falling mostly between May and November (BBC 2012, Camacho Bonilla et al. 2002).

The majority of Los Robles residents rely on multiple water sources including public wells, private wells, a piped water system, streams, rainwater and *Lago Apan*ás, a reservoir (pers**.** observation 2013-2014). Mountain spring water from Mount Datanli-El Diablo supplies the piped water system via a series of holding tanks. The water collection, use and storage decisions are made by the *Doña* or *abuela* (grandmother) who is the primary care giver and considered the head of the household. Due to seasonal variability in precipitation (definitive dry and wet season) and reliance on public wells throughout the community, water is often stored in and around the house in containers made of plastic, metal and/or ceramic (pers. observ. 2013). The variety of water sources in Los Robles provides a unique opportunity to investigate variations in water quality and efficacy of the filters in relation to some of the primary sources (i.e., public wells, piped water system).

Economically the people of Los Robles rely on coffee whether they grow and sell it, work in beneficiaries (coffee processing plants), or harvesting the beans (Grossberg 2013). Subsistence farming and trade within the community are essential due to the seasonality of coffee production (Grossberg 2013). Many of the men and younger women leave the community and often the country in search of employment which leaves the mother-in-law or the most senior woman of the family as the primary care giver and head of household (Grossberg 2013). The cultural norm is for a couple just married to move in with the paternal family or build a house on the paternal family land in order to share resources (Grossberg 2013)

Figure 2. Location of project and Los Robles, Jinotega, Nicaragua

Source: www.mapsopensource.com

2.2 Project Initiation and Organization

Proyecto Nica Agua is a non-profit organization that partnered with Communidad Connect in 2010 to assist in water purification, education and community development throughout Nicaragua. At the time of this study, Proyecto Nica Agua was focused on promoting one method of water purification: ceramic water filters in conjunction with hygiene education. Surveying the population in Los Robles, testing their water and providing hygiene education were the first steps made to distribute the ceramic water filters. A Proyecto Nica Agua representative and community nurse informed the community of the project by going door to door. Walking house to house not only provided census data of Los Robles, but also the opportunity for PNA to become acquainted with community members and their living situation. Community meetings were held for households that wanted to participate in the project. Family surveys were conducted during these meetings. In 2012 I was able to participate in the family surveys for the last group of the community that wanted to register for a water filter. During this time a community health clinic was being constructed and opened as well. Households represented in this study were chosen because they were beginning the process of receiving a water filter or received a filter during one of three follow-up evaluations (6 months, 1 year, 2 years) during my time in Los Robles. Due to the limited time of my stay, September through December (2013) and March to May (2014), I could not contact each family that received a filter over the course of the project. Each family represented in this study verbally consented to participate in the evaluations and water testing. Households included in the surveys were chosen solely based on the date a water filter was received.

2.3 Preliminary Household Health Surveys

Household evaluations were conducted in four phases over the course of two years. The first phase was the initial family health survey (Appendix A.1). Households were contacted through community meetings and home visits by a community nurse and Proyecto Nica Agua representative. Walking house to house was the only way to census the community. Going door to door also provided an opportunity to become acquainted with community members prior to beginning the project. Households that decided to participate in the water filter program were required to attend a hygiene and sanitation workshop that included the preliminary household survey.

The survey gathered baseline data regarding the incidence of water borne illnesses in each household (i.e., incidences of diarrhea, parasites and kidney infections). Diarrhea was defined as three or more watery stools per day. The survey also gathered information on hygiene and sanitation behaviors including the prevalence of hand washing, the presence of latrines, and water purification methods. Information on the number of people living in each house, water storage methods, and their knowledge of water purification techniques was collected as well.

2.4 Follow-up Evaluations and Water Filter Monitoring

The next phase of evaluations occurred six months after a household received a water filter. The first follow-up survey (Appendix A.2) gathered information on whether households had problems or questions regarding the use of the filter. The follow-up evaluations included: incidence of waterborne illnesses (diarrhea, parasites, and kidney infections), use of filtrated water (cooking, hand-washing, and cleaning dishes), filter maintenance and cleaning practices, and suggestions for Proyecto Nica Agua.

The third and fourth phases of monitoring filter use included follow-up surveys after one year and two years. Each of these surveys included the same questions as the first evaluation. In addition respondents were asked to evaluate the community service project they participated in and their overall perception of the water project. Each home visit included observations made by the surveyor concerning the condition of the water filter.

2.5 Water Tests

2.5a Water Sources

Water tests were conducted for well water, *agua potable* (piped water system), rainwater catchment and filtered water from the Filtrón filters. Excluded from the water tests were streams and the lake because of a limited quantity of water tests and the fact that households that rely on these water sources were not visited in any of the home visits. Watersafe® Water Test Kit WS-425B test eight parameters based on more stringent levels than the EPA guidelines for "maximum contaminant levels" of lead, pesticides, total chlorine, total nitrates, nitrites, hardness, pH and bacteria. Measuring parameters before they exceed the EPA guidelines allows time to reduce potential risks before drinking-water is contaminated. The results are immediate except for bacteria, which takes forty-eight hours for a result. Bacteria tests indicate only the presence or absence of bacteria; if the test is positive the likelihood of potentially harmful bacteria is high.

In addition to the Watersafe® water tests, I tested each water source for heavy metals using SenSafe Water Metals Check test strips. Each test strip has an absorbent window that indicates the presence of Cadmium, Cobalt, Copper, Iron, Lead, Mercury, Nickel, Zinc or other +2 valence metals. Detection levels are: <10, 20, 50, 100, 200, 400, and 1000 ppb (µg/L). These detection levels are holistic and do not identify the specific metal's concentration.

Water tests were conducted during the wet season and the dry season: between the months of October and December 2013 and March and May 2014, respectively. The goal was to test an equal number of samples from public wells, water filters and the piped water system, however the piped water system was predominantly inoperative resulting in more samples of well water. In order to obtain a random sample of tests, every fourth house visited for a follow-up evaluation was chosen to conduct water tests of the filter and/or the piped water system. If the house had a well they used as a primary water source, I tested both their well water and the filtrated water. When only a filter was present I tested the filtered water and excluded the filter from the next house when a well was present. If a house had a functioning tap that supplied water from the piped water system a sample was tested. In total thirteen tests were conducted for both water filters and wells while seven tests were completed for the piped water system.

2.5b Individual Test Procedure

Lead and pesticide tests detect dissolved lead below the EPA Action level of 15 parts per billion (ppb) for lead and pesticides (atrazine 4ppb and simazine 3 ppb). A water sample is placed in a vial with a pipette, swirled on a flat surface and then two test strips are placed into the water sample with arrows pointing down and left for 10 minutes. I used a stopwatch to keep time. The test strips were removed from the water sample after 10 minutes and the results read via color matching (Appendix D). When possible water samples from each source were taken directly with the pipette. Each test was kept in a sterile packet.

Total Nitrate/Nitrites and Nitrite tests measure levels (5 ppm) below the EPA guidelines: 10 ppm for Total Nitrate/Nitrate and 1 ppm for Nitrate. Test strips were submerged for two seconds into a water sample, removed, and after one-minute color on the reagent pad matched to a color chart (Appendix D). The color is only stable for one minute.

The tests for pH, hardness and chlorine were included in one sterile packet. Each test strip was immersed into a water sample and removed immediately. The strips were held level for fifteen seconds. Then each test strip was matched to a corresponding color chart (Appendix D). According to EPA guidelines for drinking water, pH levels are recommended to fall between 6.5 and 8.5. Maximum contaminant level for chlorine is 4 mg/L or 4 ppm according to EPA guidelines.

Bacteria tests consisted of collecting 5 ml of water in a provided vial containing a bacterial growth powder. After shaking for 20 seconds the water sample was placed on a flat surface in a warm area (70-90 F) for forty-eight hours. If the solution changes from yellow to purple it is highly likely that potentially harmful bacteria were detected and more stringent tests are recommended (WaterSafe 2013).

2.5c Water Test Training

The water tests were used as tools to train the *brigadistas* (community nurses) on how to sample water sources in the community. During each test the nurses assisted me with collecting water samples and after instructing them on how to read the test results, collaborated on matching the test strip colors to the color charts.

2.5d Informal Household Interviews

A household survey was developed and conducted during the follow-up evaluations to assess conditions, changes and filter use. A *brigadista* escorted me and assisted in interpreting answers and questions to eliminate confusion. Interviews were conducted in Spanish and each question was read to the participant, as illiteracy is fairly high in Los Robles. Answers were recorded by the *brigadista* to ensure accuracy in the interpretation. The representative of Communidad Connect, Sarah Grossberg, reviewed, edited and approved the questions to avoid cultural bias.

A total of eight questions (Appendix A.4) were asked regarding uses of filtered water, the source of water contamination, the importance of collaboration of community members and foreign aid groups, recommendations for projects that would improve the community, and whether the piped water system is worth the cost to their family.

2.5e. Watershed Education Curriculum

The results of the surveys were used to design a watershed education curriculum (Appendix E) that was then incorporated into PNA's water improvement project. The foundation of the curriculum was based on a review of past watershed education materials taught in schools in California during my undergraduate studies, water filter materials, and groundwater issues in Nicaragua. I consulted with Communidad Connect and PNA representatives in March 2014 prior to a demonstration workshop that presented the curriculum and activities to community nurses. In addition, participation in the National Geographic Facilitated Learning through Outdoor Watershed Education Course provided a platform to receive feedback on the content of the curriculum from educators around the globe. Revisions were made to the final curriculum based on their comments.

III. RESULTS

3.1 Preliminary Household Health Surveys

Preliminary family evaluations included 201 households representing 45% of the households (450) in Los Robles. Thirty-four percent of households reported suffering from diarrhea every month (Table 2). Parasites and kidney infections affected 17% and 25% of households, respectively. A majority of respondents (82%) stated that drinking contaminated water contributed to health problems, yet 73% did not use any water purification methods prior to consumption. Respondents (67%) listed possible purification methods: Clorox, boiling, solar disinfection and both sand and ceramic filters (Table 1).

A majority of household respondents (80%) indicated they washed their hands prior to cooking and preparing food, however only 67.1% reported washing their hands after going to the bathroom. In the sample surveyed, 67% of households had a latrine, mostly located outside of the house (60%), while 7% reported having indoor bathroom facilities (Table 1). Households without latrines reported having access to a neighbor's facility or use other methods outside (i.e., open air pits and streams) 31% and 2% respectively. Outdoor latrines consist of a whole in the ground in a wood structure resembling an outhouse. For the purpose of this study latrine was kept consistent, but indoor latrines resemble a modern day bathroom. The primary water source used by respondents was the piped water system (66%) followed by public wells and private wells (22% and 3% respectively); the remainder: 2% of households do not have access to either source and likely rely on rainwater collection (Table 1).

Table 1. Household water and sanitation survey in Los Robles (201 households, 1345 people), 2011-2013.

Primary Water Source	**Percent**
Private well Public well Piped water system Rainwater Unknown	3% 22% 67% 6% 2%
Knowledge of water purification **Yes 67%**	**Known Type:** bleach, boil, sand filter, ceramic filter, solar
Use purification technique	**Yes** 27%
Nature of Sanitation System	**Yes** Outside 60% Inside 7% **No** Open air 2% Other 31%

Table 2a. Reported change in self-diagnosed incidence of water related illnesses before and after using the water filter over two years (2011-2013) in Los Robles (20 households,105 people).

Water related illness	**Pre-filter**	**60 days**	**1 year**	**2 years**
Diarrhea	34%	10%	15%	0
Parasites	16%	20%	0	0
Kidney Infection	24%	10%	0	0

Table 2b. Household perception of the benefits of using the water filter over a two-year period (2011-2013) in Los Robles (20 household respondents,105 people).

Benefits of using the water filter *	**60 days**	**1year**	**2years**
Decrease in illness	25%	45%	60%
Water is healthier	35%	25%	50%
Reduced Stress	10%		10%
Improved hygiene	5%		
Broken		25%	5%
No response	45%	5%	

*Greater than a 100% because multiple responses were reported

3.2 Follow-up Evaluations and Water Filter Monitoring

Twenty households in this study were followed over the two-year period of water filter monitoring and evaluations. Over the entire study period household cases of diarrhea decreased from 34% at the time of the preliminary health survey to 10% in the first follow-up visit (after 6 months) and decreased to 0% after two years of water filter use (Table 2a).

Cases of parasites increased from 17% to 20% between the pre-treatment surveys and after sixty days of filter use, but the one-year and two-year evaluations revealed no reported incidence of parasites (Table 2a). The increase in the cases of parasites may be contributed to a seasonal change in rainfall or the accuracy of memory recall. Kidney infections decreased from the preliminary pre-treatment survey (25%) to 10% at the first evaluation and there were no reported cases of kidney infections after one-year and two-years of filter use (Table 2a).

The respondents tracked over two years stated that the primary benefit of having a water filter was the decrease in illness. The second most commonly cited benefit was that water was healthier and cleaner. There was an increase in homes with broken filters at the one-year evaluation; 25% of households had a broken filter, but at the final evaluation the number of reported or observed broken filters decreased to 5% of filters in use (Table 2b).

The decrease in broken filters reflects the willingness of households to either pay (74%) for replacement parts or complete community service projects (82%) to replace parts (Table 3). A majority of households surveyed in the final evaluation indicated the community service project they completed was either necessary or important to the community, 35% and 31% respectively. Road improvement projects, including resurfacing and filling potholes, were completed by 35% of the sampled population. School maintenance, including landscaping, cleaning up debris and painting, was completed by 18% of water filter recipients and planting trees was completed by 12% of participants.

Households that participated in a "*limpieza*", meaning cleaning with no specific description of what was cleaned, had no opinion (16%) or no value (2%) on what they thought of their service project. These respondents are represented in the 24% who had no response on the whether the community service project was worth the effort to receive a water filter.

Overall perceptions of Proyecto Nica Agua's water project were positive; the filters were appreciated and perceived to have benefited the households that used them and the community in general. The questions were open-ended and respondent statements were recorded as verbatim as possible. The variety of responses to how well the water project preformed are grouped into categories with similar themes (Table 3). The most common response (36%) was that the water project was good for the community. Healthier water and an increase in hygiene awareness were reported 16% and 4% of responses, respectively.

Thirteen percent of respondents wanted to see an increase in the availability of environmental workshops while 7% wanted improved distribution of water filters throughout the community. Educating the community on the health risks of trash in the waterways and reforestation were recommendations suggested by respondents. Providing workshops offers more educational opportunities and alternative methods for families to acquire the hours of service needed to obtain a water filter.

Table 3. Community perceptions of the Proyecto Nica Agua project and the required community service projects in Los Robles (51 household respondents, 306 people).

Type of community service project	
Road Improvement	35%
School maintenance (painting, landscaping)	18%
Reforestation	12%
Clean ditches to improve water flow	10%
Construction of community health clinic	10%
Donation of materials	8%
Farm work for Proyecto Nica Agua	6%
Held education workshops in home	2%
Willingness to participate in another service project	
Yes	82%
Willingness to buy or replace water filter	
Yes	74%
No	13%
Will work for it	7%
Does not know	9%
How respondent described the service project	
Necessary	35%
Okay	2%
Hard	2%
Easy	8%
Important to the community	31%
Beneficial	4%
Not valuable	2%
No opinion	16%
Perception and recommendations of the water project	
Good for the community	36%
Increase in hygiene awareness	4%
Water is healthier	16%
Need for more environmental workshops	13%
Need for greater distribution	7%
No response	24%

3.3 Water Testing

The presence of bacteria was detected in 90% of the water filter tests, 91% of the well water tests, and 100% of the piped water system tests (Table 4). Water samples from the filters were collected in what households reported to be clean cups and taken directly from the tap of the filter receptacle, thus it is possible that contamination occurred during water collection, but nevertheless indicates use of contaminated water. Well water samples were taken from buckets attached to the wells. Bacteria could have been transferred during the collection process from the well bucket. Water samples from the piped water system were collected directly from the standpipe tap where bacteria could potentially be transmitted to samples, but again documents use of contaminated water.

The WaterSafe test kits cannot be relied on to accurately portray the amount of bacterial contamination in a water sample. Accurately testing for bacterial contamination in water supplies requires the incubation of a water sample that has passed through specific membrane filters in a laboratory in order to count the number of bacteria colonies (Howard et al. 2003). Due to the fact that the tests used in this study only indicate presence or or absence it is possible the bacteria observed does not pose a significant risk for diarrhea especially since reported cases of diarrhea decreased with filter use.

Lead was not detected by the WaterSafe test kit. However, the test kit indicated that pesticide (atrazine and simazine) residuals were detectable in 16% of samples from the piped water system. Test strips for both lead and pesticides are very sensitive and cannot be moved during the testing period, thus it is possible that tests were positive due to handling of test vials.

The test kit indicated that heavy metal concentration of 50 ppm or greater were found in 33% of water filter tests, 72% of well water tests, and 50% of the water tests from the piped water system. The difference in metal concentrations between water filters and well water cannot be attributed to water filter because they cannot remove elements in solution. The SenSafe tests do not indicate which heavy metal concentration is above recommended levels. Consequently, it would be necessary to conduct individual metal tests to determine the cause of the elevated results.

The test kit indicated that Nitrate concentrations of 2 ppm or greater were found in 33% of water samples from water filters, 27% of public well water samples, and 50% of water samples from the piped system. Nitrite concentrations of 1 ppm or greater were not detected by the test kit in the water filter samples. Nine percent (9%) of well water samples and 16% of piped water samples were positive for nitrite concentrations of 1 ppm or greater. The test strips for both nitrates and nitrites are subject to interpretation of the water sample collector potentially inject bias into the analysis.

Table 4. Percent of water samples from water filters, public wells, and piped water system that exceeded WaterSafe guidelines during the wet season in Los Robles 2013.

Test Parameter	**Public Well Water (N=13)**	**Piped Water System (N=7)**	**Water Filter (N=20)**
Bacteria (*E. Coli*)	91%	100%	90%
Lead	0	0	0
Pesticides	0	16%	0
Atrazine			
Simazine			
Heavy Metals	72%	50%	33%
Nitrate	27%	50%	33%
Nitrites	9%	16%	0

Table 5. Perceptions of piped water system expenses and potential sources of water contamination in Los Robles (n=27 households, 162 people).

Piped water system is worth the expense*	**Percent**
Yes	48%
No water	37%
Expensive but worth it	11%
Installation problem	4%
Does not have the service	7%
Piped water is safe to drink	
Yes	4%
No	19%
Does not know	74%
No water	4%
Source of water contamination	
Does not know	74%
Animals	7%
Lack of infrastructure	7%
Trash	4%
Water is not contaminated	4%
Feces	4%

*Multiple responses result in over 100% representation.

3.4 Informal Household Interviews

Among the participants in the interviews, 74% said they did not know how water becomes contaminated or the source of contamination (Table 5). However, when respondents were provided potential sources of pollution they noted that trash, feces and pesticides could result in dirty drinking water. The majority of houses used filtered water for cooking and preparing food, but not for washing dishes, hand washing and personal hygiene including brushing teeth and bathing.

All respondents reported that foreign aid organizations should involve the community when starting a community development project. Projects that respondents thought are necessary in the community include reforestation, a park for children, classes in English and more trash bins and recycling (Table 7 Appendix B).

The piped water system was reported by 48% of respondents to be worth the cost even though 11% said that the service was expensive and 37% had not had water for as long as 45 days (Table 5). A few respondents (4%) mentioned that they felt the piped water system was installed improperly, but that the service was still important. When asked if they thought the piped water was safe to drink without treatment, 19% of respondents said no and 74% said they did not know (Table 5). Only 4% of respondents said the water was safe to drink.

3.5 Watershed Education Curriculum

I developed a watershed education curriculum based on information from the household health surveys, informal interviews, water tests and community observations. Due to reliance on well water during the dry season, an emphasis was placed on groundwater recharge and contamination. The percent of the water supply that originates from groundwater sources in Nicaragua varies between 73% (ENAADG 2000) to 90% (Adams 2000) depending on the reporting source. Either way, aquifers are an important water source across the country. I developed a flip chart in Spanish as a visual learning aid to match the hygiene and sanitation education material format already in use by PNA. A water cycle manual was developed as a reference for PNA staff and community health nurses to create workshops for community members to attend to fulfill community service hours.

I presented an initial demonstration of the flipchart to community health nurses along with hands on activities outlined in the water cycle manual. Both were well received and their recommendations were incorporated into the final stages of PNA in Los Robles. The curriculum has been employed in the next project site located in RAAN (Región Autónoma del Atlántico Norte/North Caribbean Coast Autonomous Region).

IV. Discussion

The proportion of the world's population with reliable access to safe drinking-water has increased in part because of the United Nations Millennium Development Goals that emphasized the negative impacts, especially among poor populations, of drinking contaminated water. However, interventions to improve water supplies, sanitation facilities and hygiene education, have not always succeeded in providing clean water (Fewtrell et al 2005). Nevertheless, small non-profits such as Proyecto Nica Agua have combined hygiene and sanitation education, watershed education and point of use filtration systems with community participation in efforts to develop sustainable community maintained and operated water improvement projects. The combination of multiple strategies may not guarantee clean drinking water, but improves the probability of sustaining access to clean water while simultaneously precipitating significant change from the ground up. Elements of PNA's water project success may result, in part, from the length of time devoted in Los Robles and other communities, and the way in which interventions were introduced. This methodology is in line with recommendations from studies that indicate spending enough time on each component and implementing them in a phased manner can result in successful and sustained water improvement programs that reduce risk of waterborne illnesses (Fewtrell et al 2005, Hunter 2009).

4.1 Household Health Surveys

The piped water system, an improved water source, is now available to many residences in Los Robles via a stand-pipe. The overall perception of survey respondents in Los Robles was that access to piped water was valuable and important even though the system was not always functioning. Convenience to a water supply has been cited as one of the primary motivations for communities to support water improvement projects (Fewtrell et al 2005; Sorenson et al. 2011, Brown et al. 2013). Advantages of on-site water supplies include reduced time allocated to water collection and an increase in social well-being, that results from having the same access to utilities as the rest of the community (WHO 2004), outweigh the costs of the water service and lapses in water availability (Tumwine et al. 2002; Devoto et al. 2011; Brown et al. 2013).

Reliable water availability may contribute to the effectiveness of hygiene education because water quantity has been shown to increase personal hygiene behaviors. Increased hygiene awareness was reported by households as one of the benefits of PNA's project. Education has also been associated with increased motivation for participation in community projects (Akamani & Hall 2015), especially when aimed at household heads (Frost et al. 2005). Proyecto Nica Agua was able to connect potential disease transmission pathways from water sources to consumption via education efforts which provided a means to address these issues at individual household levels. Orienting workshops to community interests and capacities facilitated dissemination of accessible, yet important information that resulted in hygiene behavior changes as reported by participants in the follow-up evaluations. Participation in the service projects, some of which include education opportunities, were required to receive a water filter and were effective in increasing the distribution of the filters throughout Los Robles. The increase in knowledge gained from the workshops led participants to share information with neighbors and those neighbors then seeking out PNA because they too wanted a water filter (Mendonça 2013).

Establishing a reliable supply chain and post project support system likely contributed to the success of PNA in Los Robles. As mentioned earlier, many water improvement projects fail due either to lack of training in how to maintain the system or lack of access to replacement parts. In the twenty households surveyed over two years, an increase in broken filters was observed at the year follow-up visit. However, during the final evaluation (i.e., after two years) the number of broken filters decreased because households chose to pay for replacement parts, donate material to the community health clinic or complete another community service project. The time spent in a workshop or service project depended on the part (i.e., ceramic filter, spigot, bucket) that needed to be replaced. The vulnerability of ceramic filters and spigots to breaking, along with limited availability of replacement parts were cited as disadvantages by Rivera (1999) who assisted in the development of the Nicaraguan filter company after Hurricane Mitch. Los Robles established a distribution center to ensure the availability of replacement parts and reduce the time a household may have to revert to using contaminated water.

Water filters are constructed in Managua where they are picked up on a regular basis. In Los Robles, the supply cache is located at the community health clinic, a centrally located building, where households can readily get parts they may need. The majority (78%) of respondents expressed willingness to replace their filters through community service or payment. Bossert (1990) reported that sustainable water projects must be designed so that users can become autonomous and the benefits and activities continue indefinitely after the life of the project. In Los Robles, the coordinator of the water filter program is a community health nurse who is not only continuing the project locally, but has taken the water filter project to neighboring villages (Mat Mendonça 2015). The training of health workers and the construction of health clinics have been cited as the most sustainable outputs of water improvement projects (Bossert, 1990) and were two of the biggest contributions provided to Los Robles by Proyecto Nica Agua.

Some of the households fulfilled their community service hours by working on the development of the community health clinic. During my time in Los Robles I helped build the health clinic and observed that community members were overwhelmingly pleased with the work. Children, women and men all happily contributed hard work in order to see the project through to completion. Other service projects including planting trees, improving roads and working in the school were perceived as a benefit to the community. When asked about their willingness to participate in more community projects, 82% indicated willingness, but 4% felt that previous projects were not valuable. Not valuable projects were described loosely as “cleaning”. Experience and research has shown that people care more about what affects them directly (Stapp 2000). Incorporating projects suggested by respondents may encourage greater interest and participation in community service projects.

4.2 Water Tests

Monitoring water quality has been cited as a missing link in many water improvement projects (Fewtrell et al. 2005; Bain et al. 2012; Hunter 2009). Testing water samples from wells and water filters has been one of

PNA's objectives since it commenced work. The water samples tested in this study showed the presence of bacteria (*E. Coli*) in nearly all samples. However, decreases in cases of diarrhea and water related illnesses were noted as the primary benefit reported by survey respondents. Unfortunately, there is no way to report high or low levels of contamination because the tests do not indicate the amount of bacteria per 100 ml. There is evidence that immunity increases and persists after experiencing an episode of diarrheal disease (Frost et al. 2005; Hunter et al. 2009) and Frost et al. (2005) found that low-dose exposure may reduce the incidence of disease.

It should be noted that both the WaterSafe Test Kits (Table 7 Appendix B) identify concentrations of potentially harmful substances in drinking water below standards based on the EPA guidelines. The EPA standards for hazardous substance concentrations are represented in milligrams or micrograms per liter (epa.gov 2016). MCL's indicate the threshold of a contaminant where it will not cause deleterious health effects. Water sampling results indicate WaterSafe's recommended concentration levels for clean drinking water. The EPA guideline for *E. coli* is zero, however, *E. coli* is not always harmful to humans, but can indicate the presence of other hazardous bacteria species (epa.gov 2016).

Another aspect that may have contributed to the discrepancy between reported cases of illness and the presence of bacteria in filtered water could be recall by survey respondents. The structure of the questions asked the number of cases of water related illnesses since using the filter. The interval of time between filter use and survey response was two months to one year which is well beyond the recommended recall period of two weeks (WHO 2006). Traumatic incidences have a better chance of being remembered (Mendez & Fras 2011), but if diarrhea is common it may be difficult to accurately recall the exact number of cases in a family per year. Devoto et al (2009) provided households in Morocco with a diary to write the daily occurrence of fever, diarrhea, and other illnesses. The diaries were collected on a weekly basis and provided a more detailed health analysis of pre and post treatment effects (Devoto et al. 2009). Incorporating the use of a diary might prove to be an effective way to more accurately quantify the incidence of water related illnesses between follow-up evaluations.

Possible sources of bacteria could be traced to the plastic parts that make up the filter. The filter consists of a ceramic pot that sits in a plastic receptacle, similar to a double boiler; a plastic spigot is inserted in the bottom of the plastic bucket and the whole system is capped with a plastic top (Appendix C.1). Households are recommended to keep the filter system and spigot covered. The most common material used for this purpose was plastic bags, as observed in the household visits. Contamination by bacteria is possible between filling the filter and using the water. Lavanya and Ravichandra (2013) found higher rates of microbiologically contaminated water from household storage containers than piped water systems.

The water samples collected from the piped water system were positive for bacteria and some for nitrates. During household visits we advised household representatives to filter the piped water prior to consumption. In the future it should be noted that contamination is possible even when water comes from an improved source, especially due to the number of responses that reported the piped water was thought to be safe to drink. Studies of improved water supplies have provided evidence that microbiologically contaminated water is common (Devoto et al. 2009; Bain et al. 2012; Brown et al. 2013) and that is certainly the case in Los Robles.

Well water sample results were mostly positive for bacteria. The wells tested were public wells about 20 meters deep with cement covers. To retrieve water plastic buckets on ropes was the most common method used and buckets could have been the source of bacteria recorded in the samples.

None of the water samples showed evidence of lead. However, the piped water system did have samples that showed the presence of pesticides. The filters are primarily used to reduce bacteria pathogens and the filter manufacturer does not indicate they have the ability to remove chemical residues from pesticides (Rivera 1999). In line with past studies that found water systems contaminated due to breaks in pipes and reduced water pressure (Nygard et al 2007), the pesticide contamination of the piped water system in Los Robles may be related to the shallow depth of the installed water system.

Water samples tested for nitrates that exceed WaterSafe's limit at 2 ppm were higher in the filters as compared to the public well tests. However, EPA's maximum contaminant level for nitrate is 10 ppm (Table 7, Appendix B). Nitrate concentrations were highest in samples from the piped water system. Nitrates become toxic when reduced to nitrite ions (Terblanche 1991) and children less than a year old are particularly vulnerable to nitrates in drinking water and exposure can lead to methemoglobemia (Terblanche 1991). Leaching of nitrates into water supplies can occur when there are heavy concentrations of animal and human waste during times of increased precipitation (Fewtrell 2004). The tests were taken during the months of October, November and December when there was significant rainfall. Another explanation may be that broken infrastructure results in low water pressure and leakage of hazardous compounds into the water systems (Nygard et al. 2007; Kayser et al. 2014).

Heavy metals in potable water can cause reduced growth and development, cancer, and organ damage (Järup 2003; Revoori 2014). The focus in Los Robles was on reducing water related causes of gastrointestinal illnesses, but most of the community collects and stores rainwater due to the lack of access to wells and piped water, and the fact that the latter is often inoperable. Rainwater is most efficiently collected from metal roofs made of zinc and aluminum. Therefore, it is important to investigate these materials as possible sources of contamination and the ability of filters to remove metals even though the company does not report they can do so (Rivera 2009). Water samples from all sources tested positive for heavy metals at varying levels. The SenSafe Heavy Metal Test Kits test a conglomeration of heavy metals, rendering the results inconclusive. Rainwater was sampled, but excluded from the results because only one sample was tested. However, it had a concentration of 1000 mg/L heavy metals. Due to the composition of the roofs, the metal Zinc may be in high concentration of this sample. EPA guidelines indicate Zinc concentrations at 5000 mg/L or greater increase risks to health. In fact more stringent heavy metal tests are needed to have any confidence in the presence/absence of lead or other metals. The water filters cannot remove elements that are in solution however, further examination of the ability of colloidal silver to remove certain anions (elements with a negative charge) is warranted. The reduction in heavy metals in the filtered water may be due to the type of clay used to make the ceramic filter. Kaolinite clays have been found to remove heavy metals due to high amounts of cations, positively charged particles, that adhere to some metals, including Cadmium 2+, Iron, Cobalt, Aluminum 3+, Zinc and Copper (Revoori 2014).

Chlorine tests were not included in the results because all samples were negative. Finding chlorine residuals in water supplies, especially from piped systems, indicate disinfection practices (Hubbard et al. 2011; WHO 2014). The source of the water piped into Los Robles comes from springs, which are gravity fed through three holding tanks. When visiting the water treatment plant I spoke with the manager and observed the administration of bleach into the holding pools. Hubbard et al (2011) suggests that the absence of chlorine residuals presents a good opportunity to train community participants on the preparation and use of chlorine solutions to disinfect water at the point of consumption. The use of chlorine solutions has not been well received by communities because of the taste and odor of the treated water and is often the first water quality intervention to be abandoned after water projects are completed (Esrey et al. 1991; Hunter 2009). One household study that randomly gave chlorine tablets and their placebo counterparts found no difference between the intervention and control in the levels of diarrhea reported (Austin 1993; Jain et al. 2010).

4.2a Water Test Training

One of the challenges in rural water supply improvement projects is the lack of time allocated to community training of water quality monitoring. During the collection and analysis of water samples the community health nurse was encouraged to participate. On most occasions assistance was met with enthusiasm and provided a second opinion during analysis. WaterSafe water tests are relatively inexpensive and easy to use. Kayser et al (2014) found that successful water supply programs have monthly water quality testing post-construction. Without the ability to monitor water quality due to environmental and social aspects water improvement projects will likely become ineffective (Jiménez & Pérez-Foguet 2010). In Bolivia, a water improvement project that used point of use filtration systems surveyed participants before and after educational workshops to determine their effectiveness (Quick et al. 1999), but did not survey the nurses' methods for monitoring the water quality. However, Proyecto Nica Agua is going to supply more of the WaterSafe test kits to the community for use on a more regular basis. Perhaps PNA can employ a process to determine their effectiveness at using the water tests.

4.3 Informal Household Interviews

Household interviews provide a means to acquire intimate knowledge about a community. The methodology for choosing participants in this study was not random as is recommended by researchers studying the effectiveness of household water interventions (Esrey et al 1991; Fewtrell et al. 2005; Clasen et al. 2009; Hunter 2009). However, willingness to pay for point of use filtration systems was evident among those surveyed. This finding is supported by other studies which found that household treatment was the most effective and least expensive way to reduce diarrheal disease (WHO 2011b). Clasen (2009) used a randomized control study to measure the effectiveness of point of use water treatment and recommends using water filters due to the extreme variability of water treatment on the transmission of bacterial contamination. Briscoe (1984) concluded that improvement of water quality alone might not disrupt transmission.

In general, households reported satisfaction with the PNA project because of a reduction in family illness. This sentiment was not restricted to the water filters, but extended to the piped water system. Some households were without water for up to 45 days, but still reported the value of having a water tap on their premises. Possibly this is due to the educational workshops, participation in community service projects, and convenience of collecting water when it is working. There is evidence that the more people are informed about the effects of poor water quality, the more they are willing to pay to improve it (Wang et al. 2013; Stough-Hunter et al. 2014). These observations suggest the value of watershed education.

Survey respondents reported they did not know how the water in Los Robles was contaminated. The amount of personal investment in environmental issues (i.e., climate change, pollution, deforestation) has been linked to levels of interest people have in their surrounding environment (Stough-Hunter et al. 2014). Dunlap and Jones (2002) define environmental concern as "the degree which people are aware of problems regarding the environment and support efforts to solve and/or willingness to contribute personally to their solution." Social influence may have precipitated more involvement in Los Robles, but the hygiene and sanitation workshops support the findings of Dunlap and Jones (2002).

Overall, household opinions concerning Proyecto Nica Agua and the piped water system were positive. The small and non-random nature of the sample size may have influenced results. Perhaps if a larger random sample of the community was surveyed additional criticisms would have been recorded. The presence of a foreigner may also have contributed to positive comments. Nevertheless, responses from the interviews and conversations with community members throughout the study period indicate strong support and gratitude for the project. As one respondent put it, "I am grateful for the volunteers to leave their country and families to come and help us."

The feedback concerning the projects initiated by Proyecto Nica Agua were informative and provide insight into activities that could potentially benefit Los Robles while also eliciting community participation. More educational workshops and classes in English were often mentioned as desired activities. A connection to the environment is evident in Los Robles due to the fact that the majority of households economically depend on the ecosystem through growing and harvesting crops or raising livestock. However, that human activities may affect the quality of environmental resources was not appreciated by all those surveyed in the community. Developing an environmental education component that complements PNA activities and the local culture could help disseminate information to understand the complex and diverse pathways that affect water quality.

4.4 Watershed Education Curriculum

The development of the education curriculum was based on the experience and insights I gathered while working in Los Robles and the household health surveys, water tests, informal interviews and observations during the rainy season (September and December). Originally the curriculum focused on hands on activities in the streams, but following suggestions from Sarah Grossberg (Communidad Connect) and Nerys Blandón (community coordinator) the focus changed to a more comprehensive water cycle oriented workshops that community members could attend to qualify towards community service requirements. Educational workshops where information is connected to real world activities such as hand washing, latrine placement and livestock in houses, introduce meaningful watershed knowledge and interventions (The Chesapeake Bay Foundation, 2004).

Flip charts are convenient tools to present important information that is accessible to a wide audience, especially where illiteracy may be an issue. PNA uses flip charts to demonstrate how to maintain and use the water filters, and appropriate hygiene behavior and sanitation practices. The flip chart designed for the environmental portion of the project focuses on basic elements of the water cycle, including groundwater and aquifer recharge, pollution flow, human activities contributing to water quality, steps that can be taken to improve water quality and the effects on water consumption (Appendix E).

The *Manual del Ciclo del Agua* (Water Cycle Manual) was designed to provide the community nurses and PNA workers with a reference to compliment the flipchart (Appendix E). Ideas for hands on activities outside and in workshops are provided as teaching tools that are accessible to both adults and children. Creating groundwater models using plastic bottles, gravel, and food coloring provide a visual way to present the complex underground water cycle. Due to seasonal variation in rainfall, well water from community wells is heavily relied upon when artisanal or hand dug wells dry up or the piped water system is down or shut off during the dry season (pers. obs. March 2014). A demonstration of the groundwater water model was used in the preliminary trial using the water cycle curriculum material and presented to community nurses and Communidad Connect representatives.

A return visit to PNA projects sites would be desirable to assess the effectiveness of the curricula and suggest possible modifications. I have tried to connect with PNA workers in Nicaragua to determine how the curriculum is used, but have yet to receive a response. Feedback through email from Mat Mendonça indicated that the flip chart is widely used along with the groundwater model demonstration, but he could not provide information on the use of the curricula outside of Los Robles and Tola, a community in the Pacific region of Nicaragua using the water filters.

V. Conclusion and Recommendations

Proyecto Nica Agua was developed out of compassion from a volun-tourist, Mat Mendonca who was moved by the struggle of a small community that suffering from poor water quality and water borne illnesses. The funding to buy the first ceramic water filters came from his personal savings after a lucrative fire-fighting season. While the project has grown significantly, Proyecto Nica Agua remains a small non-profit funded by people through word of mouth. The cost of the project in Los Robles is very small compared to many other water improvement projects around the world and the community is satisfied and grateful for the filters, hygiene and environmental education and community service projects provided. Due to the willingness of the community to participate, the project continues and has expanded six years after its inception. Not only are water filters still being used in Los Robles, but local residents are taking the water filters to neighboring villages.

5.1. Recommendations

Multiple studies have documented that providing a method for households to actively participate in water improvement projects and health monitoring can reduce the incidence of diarrhea and provide reliable monitoring data. Proyecto Nica Agua could incorporate these approaches in their project in new communities. For example, during the initial household survey, PNA could distribute calendars for families to record the incidences of water-related illnesses and return them when they receive their filter. The first calendar will provide a baseline of water-related illnesses prior to using a water filter. Participating households could be given another calendar to record cases of water-related illnesses after use of the water filter commences with brigadistas providing new calendars on a regular basis to track water-related illnesses and the effectiveness of filter use.

Calendars should be collected and evaluated at frequent intervals (i.e., every 60 days or 6 months) to ascertain possible seasonal (wet vs. dry) differences in water-related illnesses and possible means to address them. Designing calendars with hygiene and water conservation practices on pages opposite of the months puts important water related illness prevention education into the home. Training more community members or establishing a cadre during the initial phase of the water project to conduct simple water tests on all water sources will help the community and PNA track changes in bacteria, pesticides, etc. as well as any seasonal variations. This could enable households to take steps to eliminate contamination by washing the filters, changing the plastic covers on the filters, cleaning the storage containers, increasing hand washing, and using small quantities of *Clorox* (chlorine bleach).

To improve water quality monitoring chlorine could be stored at the health clinic to ensure those that need chlorine can be educated on the proper ratio of disinfectant to water. Providing an incubator and associated supplies at the health clinic to quantify bacteria colonies would benefit the community especially during the rainy season when bacterial contamination has been reported to be higher.

Another recommendation for increasing the accuracy of water tests includes training *brigadistas* on proper water sample collecting methods so that samples could be stored at the health clinic and stabilized with chemical reagents for later laboratory analysis. When Comunidad Connect representatives travel to Managua for water filters they could bring the water samples for analysis. To conduct analysis in Los Robles, simple and inexpensive tests are available to detect *E. coli*, such as the use of portable incubators and UV lights which count the number of colonies within a water sample (see Lovibond 2016, Accepta 2016).

Another potential means to improve rural health conditions would be to educate households on the effects that animals (i.e., chickens, pigs, dogs, cats) in the home can have, especially where young children are present. Pigs and chickens can transmit diseases to humans. Murray (1990) found that animal transmitted *Enterococcus faecalis,* the third most common pathogen after *E. coli* and *Streptococcus*, is responsible for widespread urinary tract infections, endocarditis, and sepsis. Most homes in Los Robles have dirt floors and animals defecate in the home where children also play (pers. obs. 2013-2014). A study by Kifle et al. 2015 found that the most likely population to contribute to a zoonotic outbreak from touching animals is children between 0-9 years of age. The cleanliness of kitchen and living room floors has been strongly associated with good hygiene behaviors and reduced cases of diarrhea (Gorter et al. 1998).

The education materials designed for PNA explore livestock-health relationships, but keeping animals from entering homes may be difficult due to cultural traditions. Educational workshops could increase awareness and possibly result in livestock management changes to at least provide separate spaces for livestock and children in the home.

Communidad Connect hosts foreign volunteer groups that complete domestic projects including laying cement floors and building latrines. Incorporation of these activities into community service projects for the community to carry out to meet their service requirement has the potential to improve overall community health by increasing the number of homes with cement floors and sanitation facilities. In addition, community service projects to construct fences to keep animals outside of the residence area immediately could benefit home health and hygiene.

The health conditions and water needs of Los Robles households and the efficacy of the water project should be periodically reevaluated. If or when clean and reliable drinking water quality is achieved, addressing stream habitat conditions and incorporating stream restoration activities into the project could improve overall water quality, conservation, and community well-being. Until then, establishing reliable methods to gather household health information before, during and after project implementation could improve the effectiveness of the program's ability to track changes in water related illnesses and filter use. Developing a water sample testing protocol that is easy to use and conduct on a regular basis during both wet and dry seasons could provide pertinent information on the status of water supplies. Lastly, incorporating hygiene related projects (e.g., cement floors, building latrines, etc.) into the community service arm of Proyecto Nica Agua's program has the potential to improve living conditions while also decreasing risks associated with unsanitary conditions.

The community of Los Robles has benefited immensely from Proyecto Nica Agua's development assistance by demonstrating that they can function autonomously (i.e., maintain and expand the use of water filters) and that they can extend water improvement projects to neighboring villages. The presence of Proyecto Nica Agua has resulted in some *brigadistas* starting new projects, including the creation of a community banking system (pers.com. Nerys Blandón, 2013/2014), learning about and teaching child/infant CPR (I participated in a session), and teaching tooth brushing and washing hands in youth programs. The confidence and commitment these women have is a very important indirect benefit of Proyecto Nica Agua's water filter program that is likely to benefit the people of Los Robles and other villages in many ways in addition to securing reliable and clean drinking water.

REFERENCES

References

Accepta. 2016 [cited 20 March 2016]. Available from http://www.accepta.com/water-testing-water-quality-analysis-equipment/microbiology-testing-monitoring-equipment.

Adams R. U.S. Agency for International Development, Washington, DC, 26 June 2000. [cited 2015 December 10]. Available from http://www.usaid.gov

Akamani K, Hall TE. Determinants of the process and outcomes of household participation in collaborative forest management in Ghana: quantitative test of a community resilience model. Journal of Environmental Management. 2015; 147: 1-11.

Arnold B, Arana B, Mäusezahl D, Hubbard A, Colford JM. Evaluation of a pre-existing, 3-year household water treatment in rural Guatemala. International Journal of Epidemiology. 2009; 38:1651-1661.

Austin CJ. Investigation of in-house water chlorination and its effectiveness for rural areas of the Gambia [dissertation]. Tulane University School of Public Health and Tropical Medicine, New Orleans, 1993.

Bain RES, Gundry SW, Wright JA, Yang H, Pedley S, Bartram JK. Accounting for water quality in monitoring access to safe drinking water as part of the Millennium Development Goals: Lessons from five countries. Bull World Health Organ. 2012; 90: 228-235A. doi:10.2471/BLT.11.094284

a. Bain RES, Wright JA, Christenson E, Bartram JK. Rural: urban inequalities in post 2015 targets and indicators for drinking-water. Science of the Total Environment. 2014; 490: 509-513.

b. Bain RES, Cronk R, Hossain R, Bonjour S, Onda K, Wright J, Yang H, Slaymaker T, Pruss-Ustun, Bartram J. Global assessment of exposure to fecal contamination through drinking water based on a systematic review. Tropical Medicine and International Health. 2014; 19(8): 917-927.

Basavaraju A, Praveena D. Bacteriological analysis of drinking water in relation to diarrheic illness in and around Khammam. Annuals of Tropical Medicine and Public Health. 2013; 6(6): 618.

BBC. BBC Weather. UK. BBC's website. 2012. [cited 2015 Oct. 10]. Available from http://www.bbc.com/weather/features/18026834

Botes L, van Rensburg D. Community participation in development: nine plagues and twelve commandments. Community Development Journal. 2000; 35(1): 41-58.

Bossert TJ. Can they get along without us? Sustainability of donor-supported health projects in Central America and Africa. Social Science & Medicine. 1990; 30(9): 1015-1023. doi:10.1016/0277-9536(90)90148-L

Briscoe J. Water supply and health in developing countries: selective primary healthcare revisited. American Journal of Public Health 1984; 74: 1009-1013

Brown KA, Khanafer N, Daneman N, Fisman DN. Meta-analysis of antibiotics and the risk of community-associated *Clostridium diifficile* infection. Antimicrob Agents Chemother. 2013; 57(5): 2326-2332.

Camacho Bonilla MG. Plan de Manejo Reserva Natural Cerro Datanli-El Diablo. MARENA, Nicaragua. 2002. [cited 2015 Oct. 10]. Available from http://www.enriquebolanos.org/ministerios_informes_pdf/Reserva%20Natural%20Cerro%20Datanl%C3%AC-El%20Diablo.pdf

Carter R, Chilton J, Danert K, Olschewski A. Siting of Drilled Water Wells – A Guide for Project Managers. RWSN Publication 2014-2011, RWSN, St Gallen, Switzerland. 2014.

Chesapeake Bay Foundation. A guide to creating meaningful watershed experiences. Chesapeake Bay Program Education Workgroup. 2004; 1-8.

CIA: The World Factbook (US). Central America and Caribbean: Nicaragua [Internet]. Washington DC; 2016 January 16 [cited 2016 Jan 22]. Available from https://www.cia.gov/library/publications/the-world-factbook/geos/nu.html

Clasen TF, Brown J, Collin S, Suntura O, Cairncross S. Reducing diarrhea through the use of household-based ceramic water filters: a randomized, controlled trial in rural Bolivia. The American Society of Tropical Medicine and Hygiene. 2004; 70(6): 651-657.

Clasen TF, Roberts IG, Rabie T, Schmidt WP, Cairncross S. Interventions to improve water quality for preventing diarrhea (Review). The Cochrane Collaboration. Wiley Publishers. 2009. Pp.119

Clasen TF. Millennium Development Goals water target claim exaggerates achievement. Tropical Medicine & International Health. 2012; 17(10): 1178-1180.

Clasen TF, Alexander KT, Sinclair D, Boisson S, Peletz R, Chang HH, Majorin F, Cairncross S. Interventions to improve water quality for preventing diarrhoea. Cochrane Database Syst Rev. 2015 Oct 20;10:CD004794.

Communidad Connect. Proyecto Nica Agua. 2014 [cited 2015 Oct. 15]. Available from http://www.communidadconnect.org

CRIASS. Taps and Toilets . . . or more? A beneficiary assessment of the IDT capital subsidy scheme. Development Centre for Research, Information and Action in Africa, Aukland Park. 1994; p.16.

Davis S. How much water is enough? Determining realistic water use in developing countries (Internet). Improve International. 2014 [cited 2015 Dec. 12]. Available from https://improveinternational.wordpress.com

Davis S. Why water systems fail part 9: lack of government support (Internet). Improve International. 2014 [cited 2016 Feb. 24]. Available from https://improveinternational.wordpress.com/2014/08/25/why-water-systems-fail-part-9-lack-of-government-support/

Davis S, Pocosangre A, Hicks P. Six factors for improving rural water services in Central America. Global Water Initiative 2014 [Internet; cited 2015 Nov 25]. Available from: https://improveinternational.wordpress.com/2014/03/31/sixfactors-for-improving-rural-water-services-in-central-america/

De Costa Silva G. Assessing environmental justice of community based watershed management: a tool to adaptive capacity in Latin America. Local Environment. 2011; 16(5): 455-460.

Desai AM, Rifai HS. *Escerichia coli* concentrations in urban watersheds exhibit diurnal SAG: implications for water-quality monitoring and assessment. Journal of the American Water Resources Association. 2013; 49(4): 766-779.

Devoto F, Duflo E, Dupas P, Pons V. Happiness on tap: the demand for and impact of piped water in urban Morocco. World Bank Working Paper. 2009: 68-99.

Donahue TP, Lewis LB, Price LF, Schmidt DC. Bringing science to life through community-based watershed education. Journal of Science Education and Technology. 1998; 7(1): 15-23.

Dunlap R and Jones R. Environmental concern: conceptual and measurement issues. In: Dunlap R, Michelson W (eds) Handbook of environmental sociology. Greenwood Press, Westport, 2002. 482–524 pp.

Empresa Nicraguense de Aceductos y Alcantarillados, Gerencia de perforacion de Pozos (ENAAGP), Departamento de Investigacion de Fuentes , Ing. B. Berrios, Informacion Requerida por USAID. Managua, July 2000.

EPA. National primary water regulations drinking water contaminants. Technical document: EPA 816-F-09-004. 2015 [cited 2015 Oct. 20]. Available from http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf

EPA. Table of regulated drinking water contaminants. 2016 [cited 2016 Feb. 25]. Available from http://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants

Esrey SA, Feachem RG, Hughes JM. Interventions for the control of diarrheal diseases among young children: improving water supplies and excreta disposal facilities. Bulletin of the World Health Organization. 1985; 63(4): 757-772.

Esrey, SA, Potash, JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Bulletin of the World Health Organization. 1991; 69(5): 609-621.

Esrey SA. Water, waste and well-being: a multicountry study. American Journal of Epidemiology. 1996; 143(6): 608-623.

Fewtrell, L. Drinking-water nitrate, methemoglobinemia, and global burden of disease: a discussion. Environmental health perspectives. 2004; 112(14): 1371-1374.

Fewtrell L, Kaufman RB, Kay D, Enanoria W, Haller L, & Colford Jr. JM. Water, sanitation, and hygiene interventions to reduce diarrhea in less developed countries: a systematic review and meta-analysis. Lancet Infect. Dis. 2005; 5: 42-52.

Frost FJ, Roberts M, Kunde TR, Craun G, Tollestrup K, Harter L, Muller T. How clean must our drinking water be: the importance of protective immunity? The Journal of Infectious Diseases. 2005; 191: 809-814.

Garcia, Luis. “Water Quality Issues in Latin America.” In Water Quality in the Americas, edited by D. Rodriguez, 1-14. New York: Springer-Verlag, 2005.

Gleick PH. Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020 [Internet]. Pacific Institute Research Report. Pacific Institute for Studies in Development, Environment, and Security. 2002. [cited 19 Oct 2015] Available from www.pacinst.org

Gorter AC, Sanchez G, Pauw J, RM, Sandiford P, Smith GD. Childhood diarrhea in rural Nicaragua: beliefs and traditional health practices. Bol Oficina Sanit Panam. 1995; 199(50:377-390.

Gorter AC, Sandiford P, Pauw J, Morales P, Perez RM, Alberts H. Hygiene behavior in rural Nicaragua in relation to diarrhea. International Journal of Epidemiology. 1998; 27: 1090-1100.

Goulet D, Participation in development: new avenues. World Development. 1989; 17(2): 165-178.

Grossberg S. Interview by author. Proyecto Nica Agua Representative. Los Robles, Nicaragua. Dec. 3, 2013.

Guillermo R. Comunidad Connect-Los Robles Report. 2007; pp. 3.

Halvorson SJ. Environmental Health Risks and Gender in the Karakoram-Himalaya, Northern Pakistan. The Geographical Review. 2002; 92(2): 257-281.

Halvorson SJ. A Geography of Children’s Vulnerability: Gender, Household Resources, and Water-Related Disease Hazard in Northern Pakistan. The Professional Geographer. 2003; 55(2): 120-133.

Halvorson SJ. Women’s management of the household health environment: responding to childhood diarrhea in the Northern Areas, Pakistan. Health & Place. 2004; 10: 43-58.

Halvorson SJ, Williams AL, Ba S, Dunkel FV. Water quality and waterborne disease in the Niger River Inland Delta, Mali: A study of local knowledge and response. Health & Place. 2011; 17: 449-457.

Heyward B. A Comparative Study of Community Participation in the Philippines. Masters Thesis. The Center for Development Studies. Faculty of Social Sciences Flinders University of South Australia. 2006.

Hobbes M. Stop trying to save the world: big ideas are destroying international development. 2014 [cited 2015 Dec. 12]. Available from http://www.newrepublic.com/article/120178

Howard G, Pedley S, Barrett M, Nalubega M, Johal K. Risk factors contributing to microbiological contamination of shallow groundwater in Kampala, Uganda. Water Research. 2003; 37(14): 3421-3429.

Hubbard B, Sarisky J, Geltin R, Baffigo V, Seminario R, Centurion C. A community demand-driven approach toward sustainable water and sanitation infrastructure development. Interational Journal of Hygiene and Environmental Health 2011; 214 (4): 326-334

Hunter PR, Chalmers RM, Hughes S, Syed Q. Self-reported diarrhea in a control group: a strong association with reporting of low- pressure events in tap water. Clin Infect Dis 2005; 40: e32–e34.

Hunter PR. Household Water Treatment in Developing Countries: Comparing Different Intervention Types Using Meta-Regression. Environ. Sci. Technol. 2009; 43(23): 8991-8997.

Hunter PR, Toro GIR, Minnigh HA. Impact on diarrheal illness of a community educational intervention to improve drinking water quality in rural communities in Puerto Rico. BMC Public Health 2010; 10: 219-230.

Jain S, Sahanoon O, Blanton E, Schmitz A, Imoro T, Hoekstra M, Quick R. The Impact of Sodium Dichloroisocyanurate Treatment on Household Drinking Water Quality and Health in Peri-Urban Ghana: a Randomized Placebo Controlled, Double-Blinded trial. International Symposium and 4th Annual Network Meeting, Accra, Ghana, 2-5 June 2008.

Jain S, Sahanoon OK, Blanton E, Schmitz A, Wannemuehler KA, Hoekstra RM, et al. 2010. Sodium Dichloroisocyanurate Tablets for Routine Treatment of Household Drinking Water in Periurban Ghana: A Randomized Controlled Trial. The American Journal of Tropical Medicine and Hygiene 82:16-22.

Järup L. Hazards of heavy metal contamination. Br Med Bull 2003; 68(1): 167-182.

Jarvis WR, Martone WJ. Predominant pathogens in hospital infections. J Antimicrob Chemother. 1992; 29:19–24.

Jiménez A, Pérez-Foguet A. Challenges for water governance in rural water supply: lessons learned from Tanzania. International Journal of Water Resources Development 2010; 26(2): 235-248.

JMP. 2014. Progress on drinking water and sanitation: 2014 update. Geneva, Switzerland: World Health Organization (WHO) and UNICEF 2014.

Johnston RB**,** Berg M, Johnson CA, Tilley E, Hering JG. Water and sanitation in developing countries: Geochemical aspects of quality and treatment. Elements. 2011; 7:163-168.

Johri M, Chandra D, Subramanian SV. MDG 7c for safe drinking water in India: an elusive achievement. The Lancet. 2014; 383: 1379.

Kayser GL, Moomaw W, Portillo JMO, Griffiths JK. Circuit rider post-construction support: improvements in domestic water quality and system sustainability in El Salvador. Journal of Water, Sanitation and Hygiene for Development. 2014; 4(3): 460-470.

Kifle YW, Goeyvaerts N, Kerckhove KV, Willem L, Faes C, Leirs H, Hens N, Beutels P. Animal ownership and touching enrich the context of social contacts relevant to the spread of human infectious diseases. PLoS ONE. 2015; 10(7): e0133461. doi:10.1371/journal.pone.0133461 [cited 19 March 2016]. Available from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4508096/

Kostyla C, Bain RES, Cronk R, Bartram JK. Season variation of fecal contamination in drinking water sources in developing countries: A systematic review. Science of the Total Environment. 2015; 514: 333-343.

Lantagne DS. Investigation of the potters for peace colloidal silver impregnated ceramic filter. Report 1: Intrinsic effectiveness. USAID. 2001.

Lanvanya V, Ravichandran S. Microbial contamination of drinking water at the source and household storage level in the peri-urban area of southern Chennai and its implication on health, India. Journal of Public Health 2013; 5: 481-488.

Lim SS, Vos T, Flaxman AD et al. 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380: 2224–60

Lovibond. 2016. [cited 20 March 2018] Available from http://www.lovibond.com/en/industrialwater/microbiology/di10dipslideincubator

Luby SP, Syed AH, Atiullah N, Faizan MK, Fisher-Hoch S. Limited effectiveness of home drinking water purification efforts in Karachi, Pakistan. Int J Infect Dis. 1999; 4:3–7.

Mackintosh G, Colvin C. Failure of rural schemes in South Africa to provide potable water. Environ. Geol. 2003; 24(7): 937-948.

Mendez M, Fras I. The false memory syndrome: Experimental studies and comparison to confabulations. Medical Hypotheses. 2011; 76(4): 492-496. doi: 10.1016/j.mehy.2010.11.033

Mendonça Mat. Personal communication. Los Robles, Nicaragua. December 2013.

Mendonça Mat. Email communication. October 25, 2015.

Murray BE. The life and times of the Enterococcus. Clin Microbiol Rev. 1990; 3:46–65.
Mwabi JK, Adeyemo FE, Mahlangu TO, Mamba BB, Brouchaert BM, Swartz CD, Offringa G, Mpenyana-Monyatsi L, Momba MNB. Household water treatment systems: A solution to the production of safe drinking water by the low-income communities of Southern Africa. Physics and Chemistry of the Earth. 2011; 36: 1120-1128.

Novo P, Garrido A. "The New Nicaraguan Water Law in Context: Institutions and Challenges for Water Management and Governance." Discussion Paper, for the International Food Policy Research Institute. 2010; pp. 20.

Nygård K, Wahl E, Truls K, Tveit OA, Bøhleng E, Tverdal A, Aavitsland P. Breaks and maintenance work in the water distribution systems and gastrointestinal illness: a cohort study. International Journal of Epidemiology. 2007; 36: 873-880.

Pinzón-Rondón AM, Zárate-Ardila C, Hoyos-Martinez A, Ruiz-Sternberg AM, Vélez-van-Meerbeke A. Country characteristics and acute diarrhea in children from developing nations: a multilevel study. BMC Public Health. 2015; 15: 811-822.

Porvenir E. Cobertura de Agua y Saneamiento rural Municipio – Terrabona 2013. El Porvenir: Denver. 2013.

Quick RE, Venczel LV, Mintz ED, Soleto L, Aparicio J, Gironaz M, Hutwagner L, Greene K, Bopp C, Maloney K, Chavez D, Sobsey M, Tauxe RV. Diarrhea prevention in Bolivia through point-of-use water treatment and safe storage: a promising new strategy. Epidemiol. Infect. 1999; 122: 83-90.

Revoori R. A study of the removal of toxic metal ions in drinking water using modified and unmodified clays [Thesis]. Lamar University. 2014; 111 p.

Rivera R. Capabilities and short history of the Filtron design ceramic water filter (CWF). 1999; 2 p.

Sandiford P, Gorter AC, Smith GD, Pauw JPC. Determinants of drinking water quality in rural Nicaragua. Epidem. Inf. 1989; 102: 429-438.

Sorenson SB, Morssink C, Campos PA. Safe access to safe water in low income countries: water fetching in current times. Social Science & Medicine. 2011; 72: 1522-1526.

Stapp W. Watershed Education for Sustainable Development 1. A Paul F-Brandwein Lecture. The Journal of Science Education and Technology. 2000. 9(3): 183-197

Stelmach RD, Clasen T. Household Water Quantity and Health: A Systematic Review. Int. J. Environ. Res. Public Health. 2015; 12: 5954-5974; doi: 10.3390/ijerph120605954.

Stough-Hunter A, Lekies KS, Donnermeyer SF. When environmental action does not activate concern: the case of impaired water quality in two rural watersheds. Environmental Management. 2014; 54: 1306-1319.

Terblanche APS. Health hazards of nitrates in drinking water. Water S. A. 1991; 17(1): 77-82.

Tumwine JK, Thompson J, Katua-Katua M, Mujwajuzi M, Johnstone N, Wood E, Porras I. Diarrhoea and effects of different water sources, sanitation and hygiene behavior in East Africa. Tropical Medicine and International Health. 2002; 7(9): 750-756.

Turabian, Kate L. A Manual for Writers of Research, Papers, Theses, and Dissertations. 8th ed. Chicago, IL: The University of Chicago Press. 2008. 448 p.

UNDESA. International Decade for Action: Water for Life [Internet]. UN Dept. of Economics and Social Affairs. Sept. 2015 [cited 14 Dec 2015] Available from https://www.un.org/development/desa/en/news/2016

UNICEF and World Health Organization. Progress on sanitation and drinking water - 2015 update and MDG assessment. Edited by Anna Gorjec. UNICEF. 2015.

Webster, TC, Waite L, Markley B. Water Resources Assessment of Nicaragua. Mobile District & Topographic Engineering Center. U.S. Army Corps. United States Southern Command. 2001. 122 p.

Wang H, Shi Y, Kim Y, Kamata T. Valuing water quality improvement in China: A case study of Lake Puzhehei in Yunnan Province. Ecological Economics. 2013; 94: 56-65

Water Aid. 2014 [cited 2014 Sept. 20]. Available from http://www.wateraid.org/us/where-we-work/page/nicaragua

Walters JP, Javernick-Will AN. Management of rural water services in Nicaragua: a systemic network approach to evaluating stakeholder alignment. International Journal of Sustainable Development & World Ecology. 2015; 22(4): 358-367.

Wolf J, Prüss-Ustün A, Cumming O, Bartram J, Bonjour S, Cairncross S, Clasen T. Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: systematic review and meta-regression. Trop Med Int Health. 2014; 19(8): 928-42.

World Health Organization. Costs and benefits of water and sanitation improvements at the global level. Executive Summary. WHO/SDE/WSH/04.04. 2004 [cited 2015 Oct. 13]. Available from http://www.who.int/water_sanitation_health/wsh0404summary/en/

World Health Organization. Rapid assessment of drinking-water quality in the republic of Nicaragua: Country Report, 1-76, by Jorge Mendoza Aldana. Edited by Kevin Farrell and Federico Properzi. WHO/UNICEF. 2010.

a. World Health Organization. Guidelines for Drinking-Water Quality. 4th edn., WHO, Geneva. 2011.

b. World Health Organization. Evaluating household water treatment options: health-based targets and microbiological performance specifications. Edited by Mark Sobsey and Joe Brown. WHO, France. 2011.

World Health Organization. Preventing Diarrhoea through Better Water, Sanitation and Hygiene: Exposures and impacts in low- and middle-income countries, 1-48. Edited by Dr. Lorna Fewtrell. 2014. [cited 2015 Oct. 10]. Available from http://www.who.int/water_sanitation_health/gbd_poor_water/en/

Wright J, Gundry S, Conroy R. Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. Trop Med Int Health. 2003; 9:106–117

.

APPENDICES

APPENDIX A

Appendix A.1

Comunidad Connect
Proyecto Nica-Agua
Formato Evaluación Familiar
Family Evaluation

Fecha/ Date: ______________________

I) Información del contacto / Contact info

Nombres y Apellidos/ first names and last names: ____

Cédula government issued ID card number: ________________

Nº personas en la casa number of people living in the home: _________

Nº de familias en la casa number of families in the home: __________ Edades por persona ages per person: ____/____/____/____/____/____/____/____/____/____/

Comunidad community: ________________________ Ciudad city: ____________________________

Barrio/Sector neighborhood: _______________________ Teléfono phone number: ___________________

II) Información Económica economic information

¿Cuantas personas trabajan? How many people who live in your home work?

Permanente permanent work: ( ) Tipo de trabajo type of work: _______________________ Ingresos Mensual aprox. Monthly earnings: _______________.

Temporal seasonal work: ( ) Tipo de trabajo type of work: _______________________ Ingresos Mensual aprox monthly earnings: _______________.

III) Información de consumo de Agua y Salud Info about water consumption and health issues.

¿Cuál es la fuente del agua de consumo de la familia? Where do you get the wáter that your family drinks?

Agua Potable tubed water system (running water) ( ) Pozo well ( ) Rio river ( ) Lago lake( ) Otros____

¿Almacenan el agua de consumo? Sí ( ) No ( )
Do you store the water that you drink prior to consumption? Yes ( ) no ( )

¿En que la almacena?
What do you store it in?

a) Barril barril_____ b) Balde bucket_____ c) Pila tank?_____ d) Otro other__________________________

¿Purifican el agua que consumen?Do you purify the wáter that you drink? Sí yes ( ) No no ( ) ¿Cómo purifica el agua? How do you purify it?____

¿Compra Agua Purificada? Do you buy purified wáter? Sí yes( ) No no( ) ¿Cuánto gasta al mes? How much do you spend on purified water in one month______________________

¿Cuál es el tipo de bebida que más consumen en su casa? What is the most consumed beverage in your home?

____

¿Cree usted que el agua que consumen en su hogar le causa enfermedades?
Do you think that the wáter you drink causes illnesses?

Sí yes (   ) No no (   ) ¿Qué tipos de enfermedades? What types of illness?

____

¿Qué tipos de enfermedades son más comunes en su familia?
What are the most common ailments in your family?
____

¿Cuántas veces al mes visita el medico? How many times a month do you visit the doctor? __________ ¿Dónde recibe la atención? Where do you do go for medical attention? ______________________

¿Cuántos casos de diarrea han sufrido su familia? How many cases of diarrhea does your family experience in.. Verano summer_______ Invierno winter ________

En los 2 últimos meses, ha presentado su familia algún caso de:
in the last 2 months has you family had any cases of:

- Infección renal kidney infection– Sí yes(   ) No no (   ) Cuantos casos: how many cases? _________
- Diarrea diarrhea – Sí yes(   ) No no (   ) Cuantos casos: how many cases? ________
- Parasitosis parasites – Sí yes(   ) No no (   ) Cuantos casos: how many cases? _________

¿Visitaron al médico para atender estos casos? Did you visit the doctor for any of these cases?

Sí yes(   ) No no (   ) Cuantos casos: how many cases? _________

¿Cuánto fue el costo del tratamiento? What was the cost of this treatment?_________________

¿Costos de Transporte? What was the cost of transportation associated with this visit? ___________________

¿Cuántos días de trabajo y/o escuela han perdido por estas enfermedades? ____________________________

How many days of work or school have you or your family missed as a result of the previously listed sicknesses?

¿Ingresos perdidos? What were your lost earnings as a result of work missed? _________________

Ubicación del servicio higiénico en el hogar: ____
Where is the bathroom located in your home
Mencione que tipos de animales conviven en su hogar: ____
List the types of animals that you keep in/ around your home

- Observación: ¿Dónde están los animales en relación al área de la casa? Dentro (   ) Afuera (   ) Encerrado (   ) Cocina (   ) Pozo (   ) Otro (   ) ____
- Observation: where are the animals in relation to the area of the home? Inside ( ) outside ( ) fenced in ( ) in the kitchen ( ) near the well ( ) other ( ) _____________

Describa sus hábitos de higiene personal: ____
Describe your personal hygiene habits?

____

Nombre del Encuestador Signature of the interviewer

____

Nombre del Encuestado signature of the interviewee

☐ Entrado en Archivos. Info entered in database

Fecha: date__________________

Gracias por su tiempo

Appendix A.2

Comunidad Connect
Proyecto Nica-Agua

Monitoreo de Filtro No.: 1
First Filter Evaluation (same as second)

I) Datos Personales Personal Information Fecha Date: ___________________

Nombres y Apellidos de cabeza de hogar/First and last name of the head of household:
____

Cédula/Government Issued Identification: ________________________
Comunidad/Community: ______________________ Ciudad/City: ____________________

Barrio/Sector: ____
Neighborhood

II) Actualización de Información/Information Updates
¿Ha cambiado la cantidad de personas en su casa desde la primera visita/Has the number of people living in your home changed since the first interview? Sí ( ) No ( ) En caso afirmativo, ¿Cuál fue el cambio?
____

¿Ha cambiado su número de teléfono?/ Has your phone number changed?
Sí ( ) No ( ) No. Nuevo:_______________________________________

III) Mapeo/Mapping
Coordenadas GPS: ______________________________ Número de foto:
GPS coordinates: Picture Number

IV) Análisis y Manejo del Filtro/Evaluation and Use of the Filter:

1. ¿Cuáles han sido los beneficios que ha obtenido su familia con el uso del filtro?
   What have been the benefits of using the filter for you and your family?

2. ¿Ha tenido problemas con el uso del filtro?
   Have you had any problems with the use of the filter?

3. ¿Cuántos casos de diarrea ha presentado su familia desde la entrega del filtro? How many cases of diarrhea have you and/or your family had since receiving your filter?
   1( ) 2( ) 3( ) Otro: ________ Ninguno ( )

   1 ( ) 2( ) 3( ) Other: ________ None ( )

- *Clarificación: un caso de diarrea se define como 3 o más excrementos líquidos consecutivos/Clarification: a "case" of diarrhea is defined as 3 or more consecutive liquid stools*

First Evaluation Continued

4. ¿Ha presentado su familia algún otro tipo de enfermedad asociada al consumo de agua? (infección renal, parásitos) Have you and/or your family suffered any other type of illness related to water? (i.e. kidney infection, parasites)

   a. Sí ( ) b. No ( ) En caso afirmativo describa que tipo de enfermedad:

5. Si ha tenido algún tipo enfermedad asociada con el consumo del agua/If you have had an illness associated with water consumption:

   a. ¿Ha tenido que visitar al médico para atender la enfermedad?
   Did you had to visit the doctor for these illnesses?

   Sí ( ) No ( ) En caso afirmativo ¿Cuántas veces? ____________

   Yes ( ) No ( ) If yes, how many visits? ________

   b. ¿Ha necesitado algún tratamiento médico? Sí ( ) No ( )
   Did you need any medical treatment for these illnesses? Yes ( ) No ( )

   ¿Qué tipo de tratamiento o medicinas? Describa:

   What type of treatment or medicine? Describe:

   c. ¿Cuánto fue el costo de este tratamiento? (Medicamento)
   How much did this treatment or medicine cost?

   d. ¿Cuánto fue el costo en transporte?
   What was the cost of transport associated with getting to and from the doctor and to get any medicine?

6. ¿Cuántos días de trabajo o escuela han perdido a causa de estas enfermedades? How many days of work or school were missed due to illnesses related to water consumption?

   Días/T_______ Días/E_______

   Days of Work _______ Days of School ________

   En caso de día de trabajo perdido, ¿Cuánto significa en ingresos o salario perdido/When a day of work was lost how much income was also lost?_________________

7. ¿Compra agua purificada?
   Do you buy purified wáter?

   a. Sí ( ) Cuanto gasta al mes_____________ b. No ( )
   Yes ( ) How much do you spend each month_____ b. No ( )

V) Datos sobre el Filtro Information about the Filter

1. ¿Cuántas veces al día rellena su filtro? ____
   How many times a day do you put wáter in your filter?
2. ¿Qué tipo de uso le da su familia al agua del filtro?
   What do you use your filtered water for?

   a. Consumo personal ( ) b. Cocinar ( ) c. Lavar las manos ( )
   d. Higiene personal ( ) e. Otros ( ) ____

   a. Personal consumption [drinking] ( ) b. Cooking ( ) c. Washing hands ( )

d. Personal hygiene ( ) e. Other ( ) ______

3. ¿Cuántas veces ha lavado su filtro en el último mes? _________________________
   How many times have you washed your filter in the past month?
4. ¿Qué utiliza para lavarlo?
   What do you use to wash it?
   a. Filtro/filter: Paste/Piece of rough cloth or brilo pad ( ) Cepillo/Brush ( ) Jabón/Soap ( ) Cloro/Chlorine ( ) Agua filtrada/Filtered water ( ) Agua hervida/Boiled water( ) Otro(s) Other(s):____

   b. Partes Plásticas plastic parts: Paste Piece of rough cloth or brillo pad ( ) Cepillo Brush ( ) Jabón Soap ( ) Cloro Chlorine ( ) Agua filtrada Filtered water ( ) Agua hervida Boiled water( ) Otro(s) Other(s):____

5. Estado Físico del Filtro/Condition of the filter:

   a. Unidad Filtrante: Intacta ( ) Quebrada ( ) Limpia ( ) Sucia ( ) No funciona ( )
      Ceramic Filter: Intact ( ) Broken ( ) Clean ( ) Dirty ( ) Not functioning ( )

   b. Balde: Plastic receptacle: Intacto/Good ( ) Quebrado/Broken ( ) Limpio/Clean ( ) Sucio/Dirty ( ) No funciona/Not working ( )
   c. Grifo/Llave/Spigot: Intacto ( ) Quebrado ( ) Limpio ( ) Sucio ( ) No funciona ( )
   d. Tapa y Aro/Ring and Lid: Intacto ( ) Quebrado ( ) Limpio ( ) Sucio ( ) No funciona ( )

   Observaciones sobre el estado del filtro/Observations about the filter's condition:
   ____

6. ¿Tiene algún otro comentario o sugerencia sobre el proyecto Nica Agua y/o el filtro?
   Do you have any other comments or suggestions for the Nica Agua Project and/or the filter?

Próxima visita de monitoreo. Date of next monitoring visit

FECHA:____

Encuestador Interviewer　　　　　　　　Encuestado Interviewee

Gracias por su tiempo

Appendix A.3

Comunidad Connect
Proyecto Nica-Agua

Último Monitoreo de Filtro
Final Monitoring visit

I) Datos Personales Personal Information Fecha Date: ___________________

Nombres y Apellidos de cabeza de hogar:
____
First names and last names

Cédula:____________________________ Comunidad: ______________________ Ciudad:____________________
Government issued ID number Community City
Barrio/Sector: ____
Neighborhood

II) Actualización de Información Information Updates
¿Ha cambiado la cantidad de personas en su casa desde la primera visita? Sí ( ) No ( ) En caso afirmativo, ¿Cuál fue el cambio?
Has the number of people living in your home changed since the first interview/ Yes ( ) No ( ) If so, what was the change?
____

¿Ha cambiado su número de teléfono? Sí ( ) No ( ) No. Nuevo:_______________________________________
Has your phone number changed? Yes ( ) No ( ) New Number:

IV) Análisis y Manejo del Filtro Revision and Usage of Filter

8. ¿Cuáles han sido los beneficios que ha obtenido su familia con el uso del filtro?
What have been the benefits of using the filter for you and your family?

9. ¿Ha tenido problemas con el uso del filtro?
Have you had any problems with the use of the filter?

10. ¿Cuántos casos de diarrea ha presentado su familia desde el primer monitoreo? 1 ( ) 2( ) 3( )
Otro:Other________ Ninguno None ( )
How many cases of diarrhea have you and/or your family suffered since the first visit?

- *Clarificación: un caso de diarrea se define como 3 o más excrementos líquidos consecutivos/Clarification: a "case" of diarrhea is defined as 3 or more consecutive liquid stools*

11. ¿Ha presentado su familia algún otro tipo de enfermedad asociada al consumo de agua? (infección renal, parásitos)
a. Sí ( ) b. No ( ) En caso afirmativo describa que tipo de enfermedad:
Have you and/or your family suffered any other type of illness related to water? (kidney infection, parasites)

a. yes ( ) b. No ( ) If yes please describe the type of illness:

12. Si ha tenido algún tipo enfermedad asociada con el consumo del agua:
If you have had any type of illness related to water consumption:

a. ¿Ha tenido que visitar al médico para atender la enfermedad?

Did you have to visit the doctor for these illnesses?

Sí ( ) b. No ( ) En caso afirmativo ¿cuántas veces? ____________

Yes ( ) no ( ) If yes, how many visits?________

Final Evaluation Continued

b. ¿Ha necesitado algún tratamiento médico? Sí ( ) No ( )
Did you need any medical treatment for these illnesses? Yes ( ) No ( )

¿Qué tipo de tratamiento o medicinas? Describa:
What type of treatment or medicine? Describe:

c. ¿Cuánto fue el costo de este tratamiento? (Medicamento)
How much did this treatment or medicine cost?

d. ¿Cuánto fue el costo en transporte?
What was the cost of transport associated with getting to and from the doctor and to get any medicine?

13. ¿Cuántos días de trabajo o escuela han perdido a causa de estas enfermedades?
Días/T_______ Días/E_______

How many days of work or school were missed due to illnesses related to water?

Days of Work _______ Days of School ________

En caso de día de trabajo perdido, ¿cuánto significa en ingresos o salario perdido?__________________

In the case of days of work missed, what was the resulting earnings lost? _________________

14. ¿Compra agua purificada?
Do you buy purified water?

a. Sí ( ) Cuanto gasta al mes_____________ b. No ( )
Yes ( ) How much do you spend each month_____ No ( )

V) Datos sobre el Filtro Information about the Filter

7. ¿Cuántas veces al día rellena su filtro? ____
How many times a day do you put water in your filter?

8. ¿Qué tipo de uso le da su familia al agua del filtro?
What do you use your filtered water for?

a. Consumo personal ( ) b. Cocinar ( ) c. Lavar las manos ( )
d. Higiene personal ( ) e. Otros ( ) ____

a. Personal consumption [drinking] ( ) b. Cooking ( ) c. Washing hands ( )
d. Personal higiene ( ) e. Other ( ) ______

9. ¿Cuántas veces ha lavado su filtro en el último mes? ________________________
How many times have you washed your filter in the past month?

10. ¿Qué utiliza para lavarlo? What do you use to wash it?

a. Filtro filter: Paste Piece of rough cloth or brillo pad ( ) Cepillo Brush ( ) Jabón Soap ( ) Cloro Chlorine ( ) Agua filtrada Filtered water ( ) Agua hervida Boiled water ( )Otro(s) Other(s):____

b. Partes Plásticas plastic parts: Paste Piece of rough cloth or brillo pad ( ) Cepillo Brush ( ) Jabón Soap ( ) Cloro Chlorine ( ) Agua filtrada Filtered water ( ) Agua hervida Boiled water ( ) Otro(s) Other(s):____

11. Estado Físico del Filtro: Condition of the filter

a. Unidad Filtrante: Intacta ( ) Quebrada ( ) Limpia ( ) Sucia ( ) No funciona ( )
Ceramic Filter Intact ( ) Broken ( ) Clean ( ) Dirty ( ) Not functioning ( )

b. Balde: Recipient Intacto ( ) Quebrado ( ) Limpio ( ) Sucio ( ) No funciona ( )

c. Grifo/Llave: Spikett Intacto ( ) Quebrado ( ) Limpio ( ) Sucio ( ) No funciona ( )

d. Tapa y Aro: Ring and Lid Intacto ( ) Quebrado ( ) Limpio ( ) Sucio ( ) No funciona ( )

Observaciones sobre el estado del filtro Observations about condition of the filter:

____

V) Evaluación del proyecto

1. ¿Recuerda usted en qué tipo de proyecto de "Obra Social" participó para obtener el filtro?
Do you remember what type of service project you worked on to earn your filter?

2. ¿Cómo considera que fue la "Obra Social" con respecto a su importancia para la comunidad?
What do you think of the service Project that you participated in regarding its importance for the community?

3. En su opinión, ¿Valió la pena participar en la "Obra Social" para recibir el filtro? In your opinion, was it worth it to do the service project in order to receive your filter? Sí Yes ( ) No No ( )

   En caso negativo, ¿por qué no? If not, why not?

4. ¿Participaría usted en otra "Obra Social"? Sí ( ) No ( ) Quizás ( )

   Would you participate in another service Project in the community? Yes ( ) no ( ) maybe ( )

5. Si su filtro ya no funcionara, ¿compraría usted otro filtro? Sí ( ) No ( )

   If your filter no longer functioned would you buy another filter? Yes ( ) no ( )

6. ¿Tiene usted alguna sugerencia para el proyecto Nica Agua?

   Do you have any comments or suggestions for the Nica Agua Project?

_________________________ _________________________

Encuestador Interviewer Encuestado Interviewee

Gracias por su tiempo

Appendix A.4

Comunidad Connect
Proyecto Nica-Agua
Entrevista en las casas/In home interviews.

Fecha/Date____________

Coordenadas GPS/ Latitude and Longitude _________________________________

1. **¿Como usa el agua del filtró? What do you use the filtered wáter for?**

   En consumen de líquidos ________________
   Drinking
   Lavar las verduras ______________________
   Wash vegetables
   Lavar los platos ________________________
   Wash dirty dishes
   Preparar arroz y frijoles __________________
   Cook rice and beans

2. **¿Por qué es el agua esta contaminado en Los Robles y Nicaragua?/** Why do you think the water gets contaminated in town?

3. **¿De donde viene la contaminación?/** What is the source of contamination?
   Las heces de los animales y las personas/human and animal waste ________
   La tierra/the soil ________ La basura/trash ________ Químicos de las agricultores/pesticides ________ Otra/other ________

4. **¿Podria pagar por las partes nuevo si se romperán?/Will you be able to replace the filter is it breaks or is inoperable?**

5. **¿Deben las organizaciones extranjero piden por la apoyo de comunidad?/Do you think it is important for foreign organizations to seek community involvement and input?**

6. **¿Cual es un proyecto que usted necesita en Los Robles? Qué quiere ver en la comunidad?/What projects do you think would benefit Los Robles the most? What would you like to see happen in Los Robles?**

7. **¿Es el Proyecto Agua Potable valió la pena el dinero y su servicio? Qué esta bueno y qué no esta bueno?/Has the water service project service been worth the monthly cost?**

8. **Hay agua potable ahorita? Cuanto días sin agua potable esta mes?/Do you have water now? How many days have you been without water?**

APPENDIX B

Table 7. Comparison of WaterSafe and EPA contaminant level guidelines.

Parameter	WaterSafe Test Kit[1]	EPA Guidelines[2] (<5% of samples test positive each month)
Bacteria (*E. colil*)	None	0 ppm
Chlorine	< 4 ppm	4 ppm
Copper	1.3 ppm	1.3 ppm
Lead	< 15ppm	0 ppm (action level is 0.015)
Iron	0.3 ppm	0.3 ppm
Total Nitrate/Nitrite	< 10 ppm	10 ppm
Nitrite	1.0 ppm	1.0 ppm
Total Hardness	50 ppm or less	500 ppm
pH	6.5- 8.5	6.5 – 8.5

Source:[1] Filters Fast. 2016. https://www.filtersfast.com/Well-Check-Instructions.pdf

[2] EPA. 2016. https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants

Table 8. Reported benefit of owning a filter for households that had follow-up evaluations between 2012-2014.

Benefit of the filter	60 days (n=74)	1 year (n=38)	2 year (n=52)
Reduction in water related illnesses	38%	50%	81%
Water not contaminated	36%	38%	55%
Easy to use	4%	0	4%
Water safe for children	5%	8%	10%
Not Installed/broken	3%	0	4%
No response/Not home	18%	16%	8%
Filtration is slow	1%	0	0

Appendix C

Appendix C

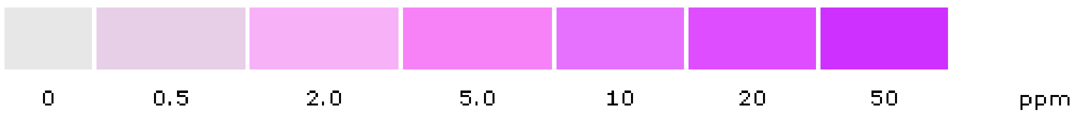
Filtron Water Filters in Los Robles

APPENDIX D

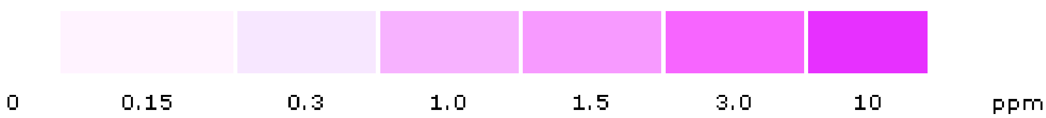
Appendix D.1

WaterSafe Nitrate/Nitrite Test Strip Color Coding

Total Nitrate/Nitrite (as N) (end pad)

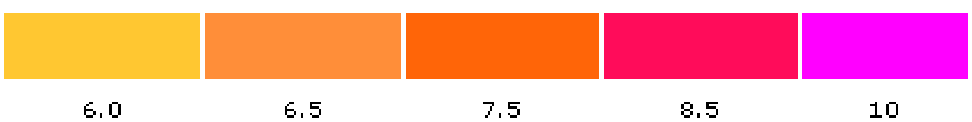


Nitrite (as N) (pad nearest handle)

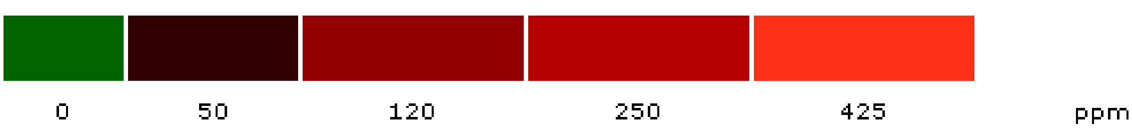


pH/Hardness/Chlorine Test packet and test strips measurement is parts per million

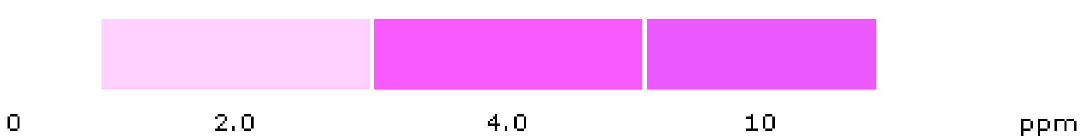
pH Color Indicator



Hardness Color Indicator



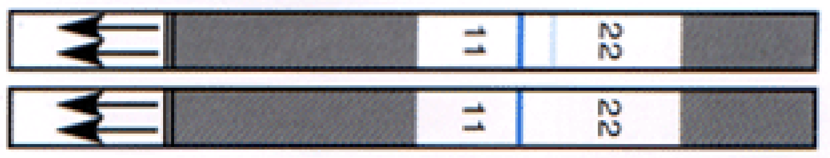
Total Chlorine Color Indicator



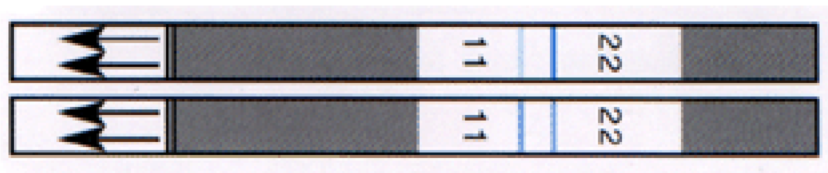
Appendix D.1 continued

Lead and Pesticide Test Strips

Negative: The LEFT line (next to number 1) is darker than the RIGHT line (next to number 2)



Positive: The RIGHT line (next to number 2) is darker than the LEFT line (next to number 1), or lines are equally dark (Both LEFT and RIGHT lines are equally dark)



Note: If no lines appear, or both lines are very light, the test did not run properly and the result is not valid. If a test strip shows a positive result, your water sample may contain lead or pesticides at a toxic level.

APPENDIX E

El Ciclo Natural del Agua:

Una Introducción al Agua Subterránea

Watershed Education Material

What follows is the translation of the vocabulary in the curriculum; the videos and pictures will not be included but can be viewed in the complete Spanish curriculum included in the appendix. Thank you Erin Springer.

Action Plan

I. Who is this for?

This curriculum is aimed at children and adults alike to be used as a reference for Proyecto Nica Agua to train community health leaders to lead educational workshops for communities participating in the water filter program. The workshops will count towards hours required to receive a water filter. Each section can be taught separately or can be combined with concepts from multiple sections. The time line presented below is to be used as a guide only, especially when utilized as a stand alone educational curriculum.

The audience regardless of age a 4th grade education on average compared to school levels in the United States. The flipchart is an essential component for the workshops in order to increase accessibility of the material for the portion of the population that is illiterate.

II. Goals and Intent

The goal of this curriculum along with Proyecto Nica Agua's water improvement project is to connect small communities with the water supply that provides their drinking water, irrigation and fishing activities. Connecting communities that are all sharing the same water source is important to how development continues and what each household contributes to the water supply (pesticides, human waste, cleaning agents, etc.)

Communities that are innately connected to the outdoor environment will gain a larger perspective scientifically answering why what they input into the water can affect households downstream.

Training individuals on how to test their water supply (well, lake, stream, rain water catchment) will provide tools to make their own decisions on how to proceed in the future when water source scarcity arises, diarrhea affects their and the neighbor's children, and the possibility of water privatization.

III. Time line

Day 1: Introduction to the water cycle using visual aids (flipchart and video) and maps showing the location of Los Robles and the water sources used in the community.

Preparation: 1 hr. Setting up the video and flip chart.

Length of class: 1 hr.

Day 2: Building groundwater models to show how contaminants flow through the groundwater system via surface water inputs. Discuss the impacts we have on our water supply (shallow wells, latrines, animal location to water source).

Preparation: 2 hrs. locating bottles and substrate for activity/demonstration.

Day 3: Training on how to test water both outside in streams and inside for water from a ceramic water filter. Discuss time intervals for testing (seasonal variation in rainfall) throughout the year. Water sampling may need to be more frequent during the months of May to December. Discuss how the best practices to maintain and care for the water filters. Discuss simple activities to safeguard against stream degradation.

Preparation: 2 hours for locating a section of the stream and running through tests for review and proper function.

Day 4: All day field day. Walking around the community to various water sources (piped water system, deep wells, shallow wells, lake and stream) to visually determine health of water, sample water to test quality, look for fish and macro-invertebrates in streams and the lake, and incorporate the processes in the water cycle that affect the water at each site visited, including natural and human impacts.

Discuss possible community service projects that can be implemented to enhance the watershed and private water sources (i.e. cover wells, dig wells deeper, plant vegetation to reduce erosion on stream banks).

Preparation: 2 days to find specific locations to conduct water tests, identify areas in need of vegetation, and locations for biotic sampling in order to have an organized and productive field day. Meet with landowners to discuss access and involvement. Find and organize equipment (nets, water tests, etc) for each site. Design a map for the class that will show each place that will be visited.

Method for Determining Success:

Allow community health leaders to discuss the workshops and activities with the participants without my presence. This will be done to receive relevant and critical feedback. Then I will organize a meeting with the community health leaders to get their opinions and find out what the participants enjoyed, learned, did not enjoy and what should be done in the future.

Continue the monitoring and evaluation process for filter owners. Provide calendars for the households to track illnesses and filter problems. Each household and/or business (school or market) will have follow up visits each 6 months up to 2 years. The monitoring process will include an in home visit to check the status of the filter, collect calendars, and distribute new ones. The filter will be examined for cleanliness, functionality and storage.

The evaluation procedure includes a survey based on filter use, illnesses since using filtered water and needs assessment of the household (i.e. replacement parts or hours to complete fulfillment of community service criteria). Are the members of the household able to test their water or do they need more tests?

Table of Contents

The Water Cycle: A Manual about Groundwater Health

PART ONE: THE WATER CYCLE

Objectives

Comprehension of the water cycle, the concepts and vocabulary including ground water, aquifers, and human impacts.

Concepts of groundwater recharge, contamination and how we can protect our water sources.

Activity:

Watch a video about the water cycle including the groundwater cycle.

Questions discussing the video:

1. What were new concepts presented in the video? Any questions on any topics in the video?
2. What did you find the most interesting or important?
3. Was there anything in the video that resonated with you in regards to the water supply here in Los Robles?
4. Before watching the videos did you know that the origin of the well water here in Los Robles is from aquifers?

Vocabulary Definitions

Using the illustration on page 4 define each of the following parts of the water cycle.

- **Precipitation**
- **Evaporation**
- **Run-off**
- **Lake, Ocean or River**
- **Condensation**
- **Infiltration**
- **Groundwater Flow**

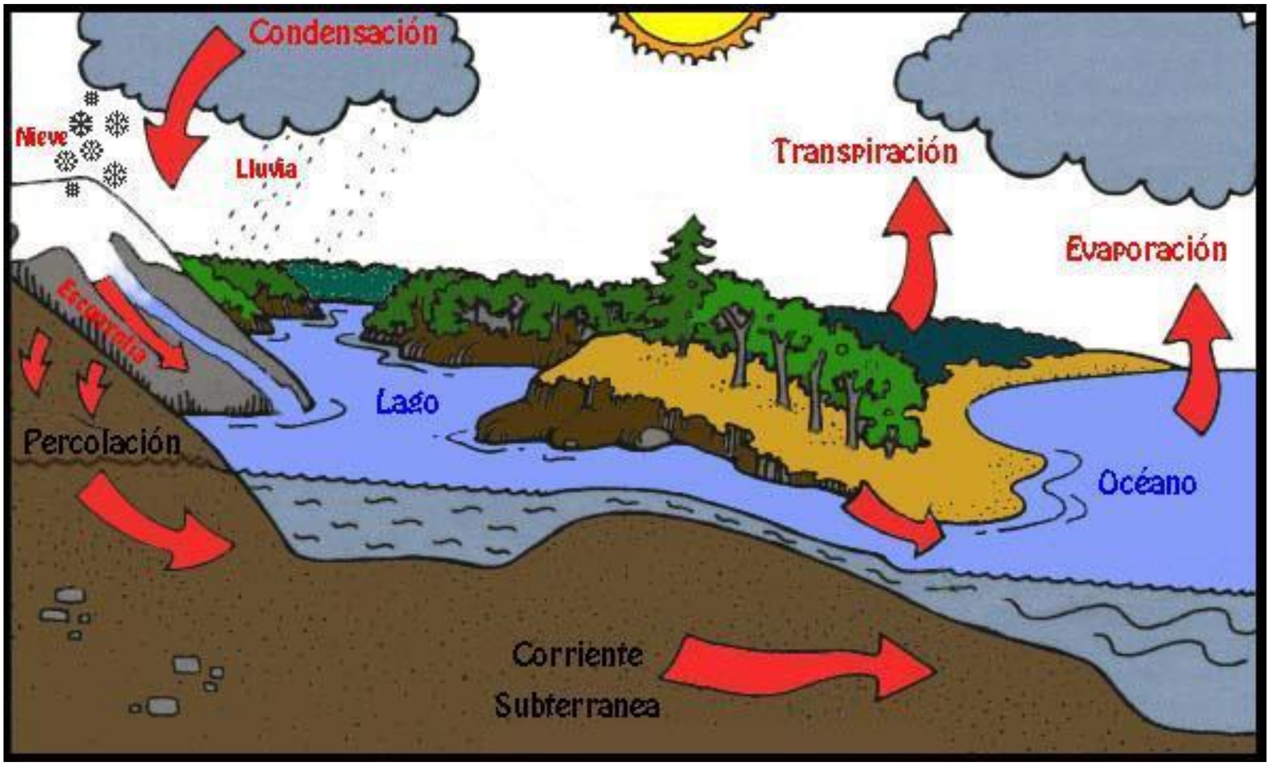


Figure 1.1 The Water cycle

Optional Activity: Fill a glass with water. Explain that the water from a water filter comes from rain. However, the water itself has been around as long as the earth. In the beginning, the water in this glass was part of the ocean. When dinosaurs roamed the earth the water was part of lakes. When Nicaraguans started drinking from wells this water was part of those wells.

DISCUSSION

THE PHASES OF THE WATER CYCLE

The earth has a limited quantity of water. Water is consistently recycled through a series of processes: evaporation, condensation, precipitation and infiltration. The beginning is geographically specific but for the purpose of this presentation we will start the water cycle in the oceans and seas. Ocean water is salty and converts into freshwater through these natural processes. The whole process is called the **Water Cycle**.

Water in the oceans is evaporated (**gaseous state**) because of solar radiation. The sun heats the water resulting in a water vapor. What is this process is called?

1. **Evaporation**: when water changes from a liquid state to a gaseous state. Water vapor comes from trees and plants (**transpiration**), rivers, lakes and the surface of the earth. The vapor rises into the atmosphere and forms clouds.

2. The second phase is **condensation**, water vapor climbs through the atmosphere where it cools. When the water vapor cools significantly it condenses and changes from a gas into a liquid. Clouds are created from suspended water vapor that cools and turns back into liquid.

   Do you know what the next phase in the water cycle is?

3. **Precipitation** occurs after vapor condenses into clouds. Clouds are basically made up of small droplets of water. As these droplets group together and become larger the air cannot hold their weight. The clouds get heavy and water falls back to the earth in the form of rain, hail, sleet or snow. Changes in temperature and pressure drive this process.

   Where does sleet and snow fall? Sleet and snow fall in mountains, high elevations and latitudes near the southern and northern poles.

   Where does rain fall? Does it fall on the land or in lakes?

4. When water falls back to the earth, it may fall into large bodies of water or on land. The water that falls on the land, will either soak into the soil and become part of the groundwater, animals and plants will use it or it may run over the soil and collect in lakes, rivers, and oceans. Infiltration/percolation is the process where water soaks into the soil is integral in recharging **aquifers**.

What is an Aquifer?

(Use Figure 1.2 on page 7 to explain the zones of recharge for water storage.)

An aquifer is an underground layer of water bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt). Aquifers are found at many depths usually occurring below a zone of unsaturation that is referred to as the water table. Water fills the pores and of soil substrate below the water table in the saturation zone, this is what we refer to as an aquifer.

In aquifers, water is moving constantly between areas of recharge and areas of discharge. Groundwater flows from the recharge are to a discharge area. In a regional flow system the recharge area is at the basin or watershed divide (Cerro-El Diablo) and the discharge is at a river in the valley bottom (Rio Jiguina).

A good way to conceptualize aquifers is to think of sand at the beach. When you dig a hole at the beach in the sand, very wet sand is found close to the surface. If you think of the water as a well then the wet sand is the aquifer and the level of the water is the water table.

Parts of Groundwater in the Water Cycle

Objectives:

Understanding the importance of groundwater conservation.

The role groundwater plays in Nicaragua's water supply.

Explain the groundwater diagram and learn the vocabulary.

Understand how water use affects everyone. For example, the human activities that effect aquifer recharge that is now diminished and unavailable to communities.

Vocabulary:

Groundwater: water that is stored underground (aquifer) that is extracted for consumption and agricultural activities. Groundwater is used throughout Nicaragua for irrigation and human consumption in all departments in the country.

Saturation: the process when where no more water can be absorbed.

Unsaturated Zone: this area lies between the surface of the ground and the water table. This zone contains both water and air and is usually horizontal yet, water flows through it vertically. Plant roots can be found here. The pore space in the soil is big enough for water to flow through to the water table.

Saturation Zone: there are two layers in this zone: the upper layer is referred to as the water table and the second layer is called an aquifer.

Water Table: this is the upper layer of the saturation zone and lies above the subsurface materials that are saturated with water (aquifer).

Aquifer: this area is made of layers of soil and rock that are filled with water. Water storage and transport of groundwater into wells and springs occurs in the aquifer.

Impermeable Layer: can be referred to as a confined aquifer where water is held under pressure by layers of substrate above it that do not permit water to pass deeper into the earth. If water does pass through this layer the rate is very slow.

The Recharge Zone: this zone is where water infiltrates and moves downward into the aquifer (zone of saturation). Here groundwater is replenished.

Discussion

THE FLOW OF GROUNDWATER

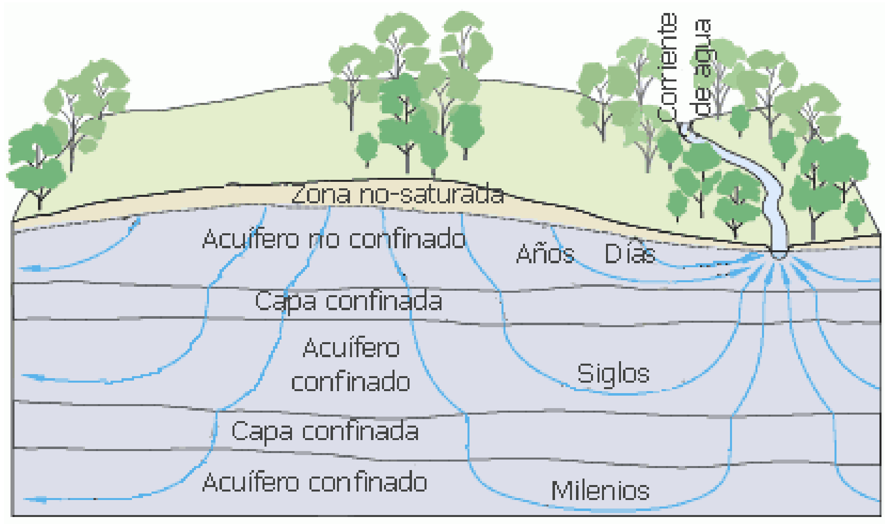


Figure 2.1 Diagram of groundwater and surface water. The arrows represent the flow of groundwater below the earth's surface. (Source: USGS)

In Nicaragua, a portion of rain that falls on land infiltrates into the ground's surface and flows down through the soil filling up **aquifers** and **groundwater**. The rate that water seeps back into the earth is affected by the soil substrate and pore space and gravity. The remainder of the rain that falls onto the land runs off into streams, rivers, or lakes and some returns to the atmosphere via evaporation.

As demonstrated in Figure 2.1, the direction and rate of **groundwater** movement is determined by certain characteristics of the aquifer and **impermeable** layers (where it is difficult for water to flow). For example, surface materials, such as sand or gravel, have faster infiltration rates then materials with tiny pore spaces.

Huge amounts of water are stored underground. The water underground moves very slowly compared to water in rivers. Groundwater is formed as a result of the water cycle. Most of the water that flows below ground is a result of rain infiltrating through the soil.

The topsoil is the zone of unsaturation, where the amount of water changes over time, but does not saturate the soil. Below the topsoil, we find the Zone of Saturation, where all the pores, cracks and spaces are filled with water. The term groundwater is used to describe this zone. What did we learn in the first part, groundwater can also be referred to as an aquifer.

Figure 2.2 Diagram how groundwater flows including the discharge and recharge zones.

The Water Table

The water table and aquifer are terms that are used when discussing groundwater. The biggest difference between these terms is that the water table is a specific part of groundwater and aquifer is all the water below ground in a zone that is often used for the transport of water into a well.

The water table is an upper section of the saturation zone below the earth's surface. The water table varies based on the time of year and has many forms, due to natural causes (dry season versus rainy season) and/or human impacts (excessive use of irrigation water).

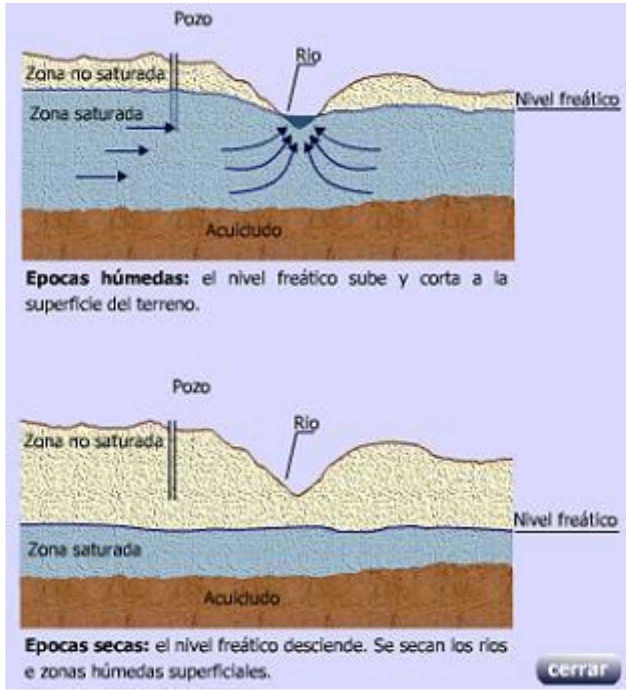


Figure 2.3 Diagram of the levels of the water table and an aquifer as a result of a rainy season (above) and a dry season (below). Wells can run dry during seasons with little to no rain. (Source: Univerisdad Complutense de Madrid)

QUESTIONS TO THE CLASS

1. Does anyone have questions regarding the zones of groundwater or it's capacity?
2. Where does your water come from?
3. Are there times during the year here when you think the level of the water table is deeper in the soil? Why or why not?

ACTIVITY

Build an aquifer.

Supplies: Clear cup, sand, gravel, pebbles, colored clay and water

Directions: Layer large to small (pebbles, clay, sand) and pile gravel up so it represents a hill and fill with water to demonstrate how the water flows through the rocks and stores between the spaces.

DISCUSSION

GROUNDWATER POLLUTION

Figure 2.4 The flow of polluted groundwater from waste to well.

Use Figure 2.4 to discuss the ways in which groundwater can become polluted and the effect sources of contamination can have on well water quality.

Groundwater contamination can be a result of natural causes (for example volcanic ash) and human activities (trash/landfills, pesticides, excrement, and industrial wastes). Waste on top of the ground can infiltrate into the soil and enter the groundwater. Rivers of water flow below the ground similar to those above ground transporting contaminants into water used in wells.

Naturally the soil can clean and filter some of the pollutants out before they reach the groundwater. However, the ability of the soil to naturally filter out chemicals and waste varies on the amount of waste, the location and contents of the material (organic or mineral) and the texture and structure of the soil substrate.

For example, if a tank filled with gasoline has a small, slow leak the soil can filter out the “bad” chemicals before too much reaches the water table. However, if the tank is tipped over and all of the gasoline spills out at once and seeps into the ground the quantity may overwhelm the soils filtration ability. Visualize a large bubble or plume forming that gets picked up by an underwater river and flows downstream to village wells.

Figure 2.5 The sources of groundwater contamination how they flow below ground to wells and into bodies of water like the ocean. (Source: Biologia and Geologia Interactiva)

Using Figure 2.5 explain the different causes of contamination affecting aquifers. Describe the how people are affected by contaminated water sources used for drinking, swimming and environmental functions.

QUESTIONS TO THE CLASS

1. What sources of contamination are in your community?
2. Can you describe how the water in aquifers becomes polluted and unhealthy for consumption?

Groundwater contamination can occur from chemical residues left behind from pesticides, human and animal excrement, gasoline for cars and buses, agricultural activities, and mining activities.

ACTIVITY

Construct a groundwater model.

Supplies: Plastic bottle, scissors and/or knife, different sizes of pebbles and gravel, food coloring, straws, colored clay, water and pipette.

Directions: lay the bottle lengthwise and cut one side off, fill with sand, pebbles and gravel alternating each layer, place two straws (one at either end of the opening these are wells), pour in water, show how water fills the straws and use pipette to extract some demonstrating how a well works. Add food coloring to one "well" and watch how the "contaminated water" flows underground. Pipette water from the opposite "straw well" to show how the water from one well can affect the quality of the water in a neighboring well. The clay can be stretched out between layers of pebbles to demonstrate an impermeable layer.

PART THREE

HOW WE CAN PROTECT OUR WATER

OBJECTIVES:

Explain the importance of proper disposal of both human and animal waste. Latrines are best located at least 20 meters from wells; therefore if you plan to dig a new well try to locate it uphill of your latrine. Wells are best kept with a cover over the top.

Explain the importance of properly placing latrines and animals below wells.

Explain the importance of hygiene (washing hands) and keeping areas clean around water sources in order to reduce transmission of water related illnesses. Explain how to apply best practices during times of increased precipitation.

DISCUSSION

FECAL CONTAMINATION OF DRINKING WATER

Figure 3.1 It is important to keep areas near well free of human and animal excrement.

Human and animal waste carries bacteria, protozoans, and worms that are pathogenic and can cause many illnesses. The water we drink is susceptible to microbial contamination especially during the rainy season. Rain washes excrement of humans and animals into the groundwater where the water can carry bacteria into wells that we use for drinking water.

We are also responsible for contaminating our drinking water if we do not wash our hand regularly with soap especially after using the latrine. This process of contamination is call water washed contamination and can occur when we have dirty hands that touch cups and plates we eat from or collect water using dirty buckets.

Why does this happen? After going to the bathroom our hands can collect bacteria and germs that will contaminate anything we touch afterwards.

Here are some of the pathogens and organisms that cause illnesses and are present because of feces in the water.

1. Bacteria causes diarrhea and vomiting,
2. Protozoa (parasites) cause dysentery,
3. Helminths (parasitic worms: round worms and flat worms) cause chronic diarrhea.

IDEAL LOCATION FOR A LATRINE

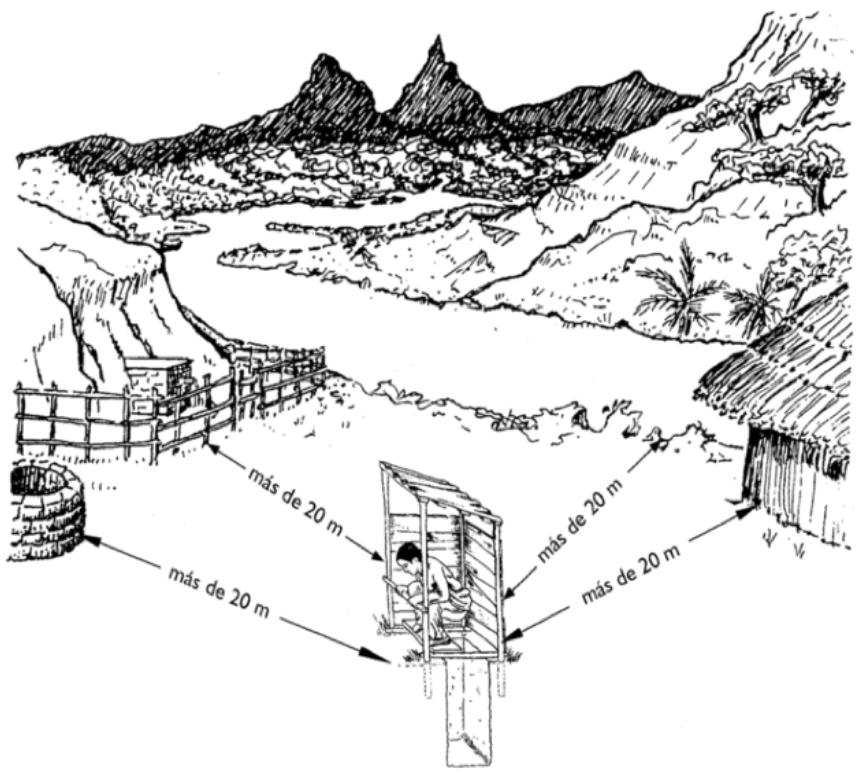


Figure 3.2 Place latrines above firm ground free of potential flooding. If in a mountainous area place it below water supplies and at least 20 meters away.

Figure 3.3 When children or animals leave excrement near the house, clean it up immediately. Teach children to use a latrine or bury their feces, or at least, go far away from home and away from where people get their drinking water.

NITRATES are chemical compounds composed of nitrogen and oxygen that are naturally found in soils and form when microorganisms decompose organic materials, such as plants and human and animal feces. Nitrogen is also used in agricultural fertilizers.

Heavy concentrations of nitrates from human and animal waste can infiltrate into the water table and contaminate drinking water especially during the rainy season. However, during dry months the concentration of nitrate can increase due to a lack of water. High concentrations of nitrates in water can indicate the presence of nitrite (another form of nitrogen and oxygen) a cause of methemoglobinemia (blue baby syndrome) an illness most commonly affecting babies. An excess of nitrates and nitrites in drinking water can inhibit the transport of oxygen through blood leaving cells without enough oxygen to function.

QUESTIONS TO THE CLASS

Why should we wash our hands with soap after going to the bathroom?

Why is it good to keep animals far from our wells?

Why is it necessary to keep a cover on the wells?

Where should we build our latrines in relation to our home and well?

Where should we construct or place our wells?

ORIGINAL SPANISH VERSION

Índice de Contenido

PRIMERA PARTE

EL CICLO NATURAL DEL AGUA

OBJETIVOS:

- ✓ Entender el ciclo del agua, los conceptos y el vocabulario clave relacionados con el agua subterránea, los acuíferos, y el impacto humano.
- ✓ Aprender de donde proviene el agua subterránea, cómo es contaminada, y qué podemos hacer para proteger este recurso tan importante.

ACTIVIDAD:

Muestre la película sobre el ciclo del agua y el agua subterránea.

PREGUNTAS SOBRE LA PELÍCULA:

1. ¿Vieron alguna información nueva en esta película? De ser así, ¿tienen alguna pregunta?
2. ¿Les pareció la información importante o interesante?
3. ¿Cómo se compara la información que vieron en la película con la situación en Los Robles?
4. Antes de ver la película, ¿sabían ustedes que el agua de los pozos proviene de los acuíferos?

EXPLICACIÓN

Utilizando la Ilustración 1.1 que aparece en la página 4 de este manual, explique el vocabulario de términos del ciclo del agua.

- **Precipitación**
- **Evaporación**
- **Escorrentía**
- **Lago, Mar o Rio**
- **Condensación**
- **Percolación o Infiltración**
- **Corriente Subterránea**

El CICLO NATURAL DEL AGUA

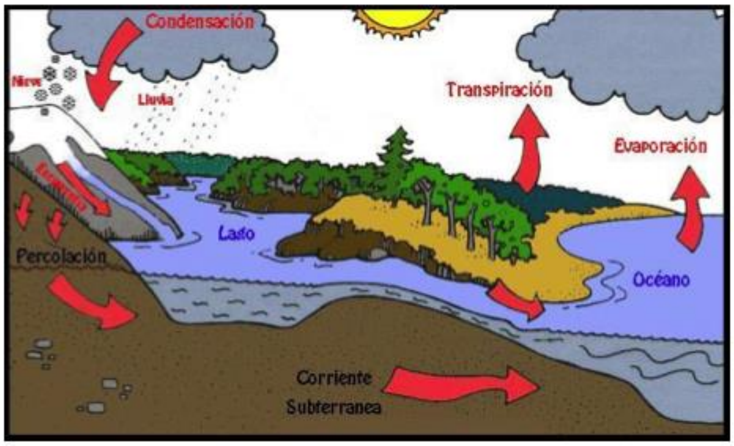


ILUSTRACIÓN 1.1 *Diagrama del ciclo natural del agua y sus términos.*
(Fuente: Ministerio de Educación de Chile)

DISCUSIÓN

LA FASES DEL CICLO DEL AGUA

El ciclo del agua no tiene principio ni fin. No se inicia de por sí en un lugar específico, pero para propósitos de esta presentación, vamos a asumir que se inicia en los mares y los océanos. Los mares y los océanos son grandes masas de agua salada que se convierten en agua dulce mediante un proceso creado por la propia naturaleza. Este proceso se llama **el Ciclo Natural del Agua**.

El Agua que comienza en los mares y en la superficie de la tierra, al ser calentada por el sol, se evapora hacia el aire convirtiéndose en vapor de agua. (**Estado Gaseoso del Agua**) ¿Cómo se llama este proceso?

1. La **Evaporación**: Ocurre cuando el agua cambia de estado líquido a estado gaseoso o a vapor de agua. El vapor de agua sale de los árboles y las plantas (**transpiración**), ríos, lagos y de la superficie de la tierra.
2. En la siguiente fase, la **Condensación**, el vapor de agua contenido en el aire conforme se va elevando o subiendo hacia la atmósfera, se va enfriando. Cuando es muy frío, el vapor se condensa cambiando de estado gaseoso a estado líquido, creando gotitas de agua muy pequeñas que se mantienen suspendidas en el cielo y forman las nubes.

   ¿Saben cuál es la siguiente fase en el ciclo?

3. Durante la **Precipitación**, el viento arrastra las nubes hacia los continentes donde vivimos. A causa del cambio de presión y temperatura, las nubes dejan caer el agua dulce acumulada en forma de lluvia. En los lugares donde hace mucho frío, el agua puede caer en forma de hielo o granizo.

   ¿Saben en dónde cae el hielo y la nieve? El hielo y la nieve caen en las montañas y en lugares altos.
   ¿Dónde cae la lluvia? ¿En la Tierra, el Mar, o en lago?

4. Durante la **Escorrentía**, el agua de la lluvia, el hielo o la nieve, se destila por las montañas formando valles, lagos y ríos. En la **infiltración o percolación**, parte del agua que recorre la tierra, se filtra en la tierra, y forma capas de aguas subterráneas. A esta filtración de capas de aguas subterráneas le llamamos: **ACUÍFEROS.**

¿Qué es un Acuífero?

(*Utilice la Ilustración 1.2 en la página 7 de este manual para explicar las Zonas de Descarga del Agua Almacenada.)*

Un acuífero es una formación geológica permeable que se encuentra por debajo de la superficie terrestre, y permite la circulación y el almacenamiento del agua subterránea por sus poros o grietas. Los acuíferos tienen **zonas de recarga y de descarga**.

En los acuíferos, el agua se mueve constantemente desde las **áreas de recargas** hacia **las áreas de descargas.** La zona o **área de descarga** es la zona donde el agua sale espontáneamente del acuífero, brotando a un manantial, o por descarga al mar o a un río. EL agua de los ríos finalmente desemboca en el mar, donde volverá a evaporarse para empezar de nuevo el **CICLO DEL AGUA.**

ILUSTRACIÓN 1.2 *Diagrama del ciclo del agua señalando las filtraciones, la descarga de agua subterránea y el agua subterránea almacenada.* (Diagrama: USGS)

7

SEGUNDA PARTE

EL PAPEL QUE JUEGA EL AGUA SUTERRÁNEA EN EL CICLO

OBJETIVOS:

- ✓ Conversar sobre la importancia del agua subterránea y los acuíferos en el ciclo del agua.
- ✓ Cerciorarse que la clase entienda cómo los nicaragüenses dependen de los acuíferos.
- ✓ Mostrar un diagrama del agua subterránea y hablar sobre las distintas zonas.
- ✓ Explicar cuáles son las fuentes de contaminación del agua subterránea, y cómo esta contaminación fluye por el subsuelo hasta contaminar a los pozos vecinos.
- ✓ Explicar cómo el uso del agua en una casa afecta la disponibilidad al agua que tienen los vecinos. Por ejemplo, si usted usa mucha agua para el riego de sus cultivos, esto podría disminuir la cantidad de las aguas acumuladas en el subsuelo, reduciendo la disponibilidad al agua que tendrán usted y sus vecinos.

VOCABULARIO

Agua subterránea – agua que ha sido almacenada en el subsuelo (acuífero) y que se puede extraer para beber y para consumir. El agua subterránea se usa en los hogares, en la agricultura y en todos los sectores del país.

Saturación: Se refiere cuando algo está repleto u ocupado por agua.

Zona no-saturada: Es la capa superior del suelo en donde existe el agua en diferentes cantidades, pero en donde el agua no satura el suelo.

Zona Saturada: Se denomina zona saturada a aquella porción del suelo donde todos los espacios vacíos están ocupados por agua.

Acuífero no cofinado: Un cuerpo de agua subterráneo que no está rodeado por una capa impermeable. El material sobre estos acuíferos es poroso.

Impermeable: Se aplica a la sustancia o material que no permite el paso de la humedad, el agua u otro líquido.

Nivel Freático: es la sección superior de la zona de saturación en el suelo. También se conoce como capa freática, manto freático, napa freática o napa subterránea (del francés nappe=mantel)

El nivel freático, es el límite superior de la zona de saturación, y es un elemento muy significativo del sistema de aguas subterráneas. El nivel freático es importante para predecir la productividad de los pozos.

Zona de Recarga Acuífera: son las zonas donde la lluvia se infiltra a través de suelo hacia el acuífero.

DISCUSIÓN

EL FLUJO DEL AGUA SUBTERRÁNEA

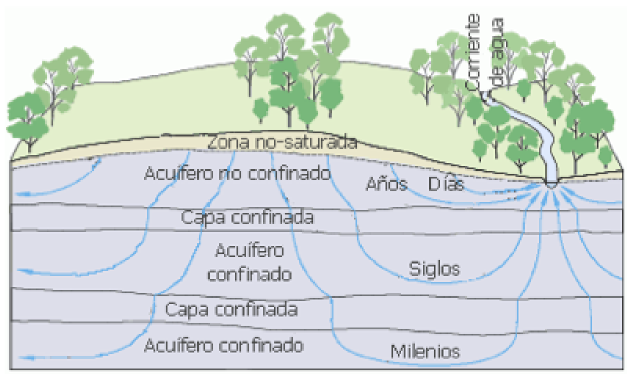


ILUSTRACIÓN 2.1 *Diagrama del agua subterránea y agua superficial con términos de vocabulario. En esta ilustración, las flechas en azul muestran el flujo del agua subterránea bajo la superficie.* (Diagrama: USGS)

En Nicaragua, una porción de la precipitación que ocurre en forma de lluvia, cae sobre la tierra, se infiltra en el suelo y pasa a formar parte del **agua subterránea.** Una vez en el suelo, parte de esta agua se mueve cerca de la superficie de la tierra y emerge rápidamente siendo descargada en los lechos de las corrientes de agua, pero debido a la gravedad, una gran parte de ésta continúa moviéndose hacia zonas más profundas.

Como muestra la ilustración 2.1, **la dirección y velocidad** del movimiento del **agua subterránea** están determinadas por varias características del acuífero y de las **capas confinadas** del suelo (donde el agua tiene dificultad en penetrar). El movimiento del agua por debajo de la superficie depende de la permeabilidad (que tan fácil o difícil es el movimiento del agua) y de la porosidad (la cantidad de espacio abierto en el material) de la roca subsuperficial. Si la roca permite que el agua se mueva de una forma relativamente libre dentro de ella, el agua puede moverse a distancias significativas en un corto período de tiempo. Pero el agua también puede moverse hacia acuíferos más profundos, desde donde demorará años en volver a ser parte del ambiente.

Grandes cantidades de agua son almacenadas en el suelo. El agua se sigue moviendo, aunque de manera muy lenta, y sigue formando parte del ciclo del agua. La mayor parte del agua del suelo proviene del agua de lluvia que se infiltra a través de la superficie del suelo.

La capa superior del suelo, es la **zona no-saturada**, donde las cantidades de agua varían con el tiempo, pero no alcanzan a saturar el suelo. Por debajo de esta capa, se encuentra la **zona de saturación**, dónde todos los poros, grietas y espacios entre las partículas de roca se encuentran llenos de agua. El término agua subterránea es utilizado para describir esta zona. Como aprendimos en la primera parte, al agua subterránea también se le llama "acuífero".

ILUSTRACIÓN 2.2 *Diagrama del flujo del agua subterránea con zonas de recarga y descarga.*

El Nivel Freático

Nivel freático y acuífero son términos que se utilizan cuando se habla de las aguas subterráneas. La principal diferencia entre los dos términos es que el nivel freático hace referencia a una parte específica de las aguas subterráneas y el acuífero es toda el agua subterránea presente en la zona.

El nivel freático es la sección superior de la zona de saturación en el suelo. El nivel freático (nivel del agua subterránea) puede variar con el tiempo y de forma muy diversa, debido a causas naturales (época de sequía/lluvia o al impacto humano. (Uso excesivo del agua por riego)

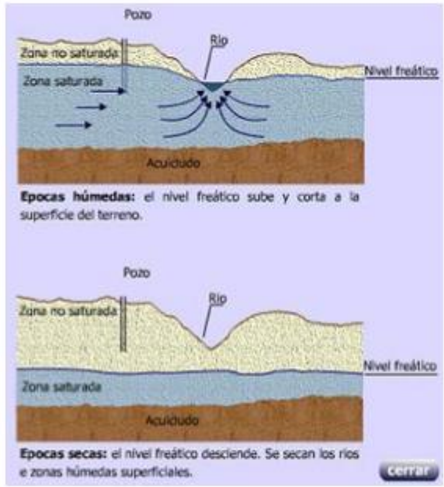


ILUSTRACIÓN 2.3 *Diagrama de una acuífero y del nivel freático durante épocas de lluvia y épocas de sequía. Los pozos se pueden secar si el nivel freático cae por debajo de su profundidad inicial, lo cual puede ocurrir durante años de sequía (Fuente del diagrama: Universidad Complutense de Madrid)*

PREGUNTAS PARA LA CLASE

1. ¿Tienen algunas preguntas sobre las zonas del suelo y la capacidad del agua subterránea?
2. ¿De dónde proviene el agua de ustedes?
3. ¿Hay veces en el año que el nivel del agua baja? ¿Por qué?

ACTIVIDAD

Construya un acuífero usando el juego de construcción de acuíferos.

12

DISCUSIÓN

LA CONTAMINACIÓN DEL AGUA SUBTERRÁNEA

ILUSTRACIÓN 2.4 *Diagrama del flujo de la contaminación de los pozos y las agua subterráneas por desperdicios sólidos.*

Utilice la ilustración 2.4 para hablar sobre la contaminación de las aguas subterráneas.

Explique que la contaminación de las aguas subterráneas puede provenir de fuentes naturales (como por ejemplo la ceniza de un volcán) y de las actividades humanas como lo son los **vertederos de basura**, los pesticidas, el excremento, y los desechos industriales. Dichos contaminantes pueden infiltrar el suelo y llegar a contaminar el agua subterránea y el agua de los pozos.

El suelo es un limpiador o filtrador natural que elimina muchos de los contaminantes. La habilidad natural de los suelos para filtrar los contaminantes varía con la cantidad de contaminantes, la profundidad del mismo, el contenido de materia orgánica y de minerales, y con la textura y la estructura del suelo.

Por ejemplo, si un camión cisterna llegase a derramar gran cantidad de sustancias químicas en la comunidad, el suelo filtraría alguna de ellas. Pero si el derrame de los químicos es grande, esa cantidad abrumaría la capacidad de filtración del suelo, y las sustancias químicas descenderían a través del suelo contaminando el agua subterránea. Debido al movimiento de las aguas subterráneas, la contaminación forma una nube debajo de la tierra que fluye hacia muchos pozos y afecta varios hogares.

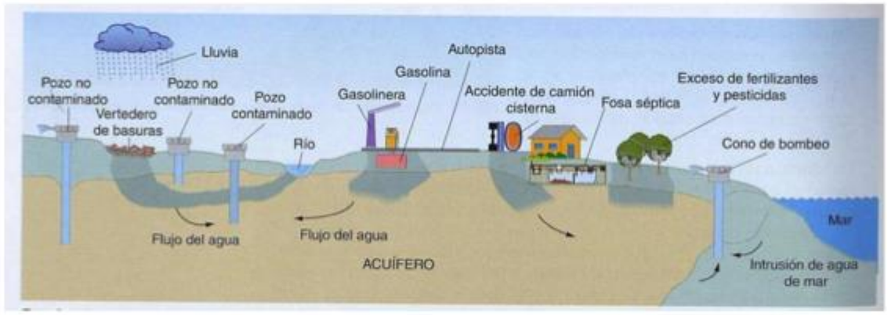


ILUSTRACIÓN 2.5 *Diagrama que muestra las posibles actividades contaminantes de un acuífero*.
(Fuente: biología y geología interactiva)

Empleando la ilustración 2.5, explique las diferentes causas de la contaminación de los acuíferos. Describa que tan importante es para las personas que dependen y beben del agua procedente de pozos y de la superficie (ríos y lagos), que ellas entiendan cómo son afectadas por la contaminación.

Preguntas para la clase:

1. ¿Cuáles son las fuentes de contaminación en su comunidad?
2. ¿Me pueden decir cuáles son las causas de la contaminación de los acuíferos?

EL origen de la contaminación de las aguas subterráneas o acuíferos es muy variado y pueden provenir de sustancias químicas procedentes de los pesticidas, **las heces o excrementos de los humanos y los animales**, la gasolina de los carros, las actividades agrícolas y ganaderas, y de las actividades mineras.

ACTIVIDAD

Use el modelo del acuífero para mostrar como la contaminación de un pozo afecta o contamina a los pozos vecinos.

TERCERA PARTE

¿CÓMO PODEMOS CUIDAR NUESTRA AGUA?

OBJETIVOS:

- ✓ Explicar la importancia de mantener las heces de los animales y de los humanos los más lejos posible o por lo menos, a 20 metros de distancia de los pozos. Si piensa cavar un pozo nuevo, hágalo loma arriba de las letrinas. Es importante que también procure tapar los pozos con una tapa o cubierta.

- ✓ Explicar la importancia de ubicar las letrinas y los corrales de los animales loma abajo de la boca de los pozos.

- ✓ Explicar la relación que existe entre lavarse las manos y mantener limpia las zonas al redor de las fuentes de agua para reducir las enfermedades transmitidas por el agua. Explique cómo se aplica esto durante la época de lluvias.

DISCUSIÓN

LA CONTAMINACIÓN DEL AGUA QUE BEBEMOS POR HECES O EXCREMENTO

ILUSTRACIÓN 3.1 *Es importante mantener las áreas de recarga acuífera y áreas cerca de los pozos libre de las heces de los animales y de los humanos.*

Los excrementos de los humanos y de los animales pueden contener bacterias, protozoarios, lombrices y gusanos que causan enfermedades. Una forma en que se puede contaminar el agua que bebemos, es por medio de la lluvia. La lluvia puede arrastrar el excremento de los humanos y de los animales hacia los pozos y hacia las aguas subterráneas contaminándolas y afectando la calidad del agua que bebemos.

También, nosotros mismos podemos contaminar el agua que bebemos, si vamos al baño y **no** nos lavamos las manos con jabón. ¿Por qué? Porque al ir al baño, si **no** nos lavamos las manos bien, podríamos llevar bacterias y gérmenes en nuestras manos, contaminado todo lo que tocamos, incluyendo a los pozos cuando sacamos agua de ellos.

Estos son algunos patógenos u organismos que causan enfermedades y que pueden estar presente en las aguas contaminadas por heces:

1 Bacterias que causan diarrea y vómitos,
2. Protozoarios que causan disentería,
3 Helmintos, tales como los gusanos redondos (lombrices) y los planos (tenia) que causan diarrea crónica.

UBICACIÓN DE LAS LETRINAS

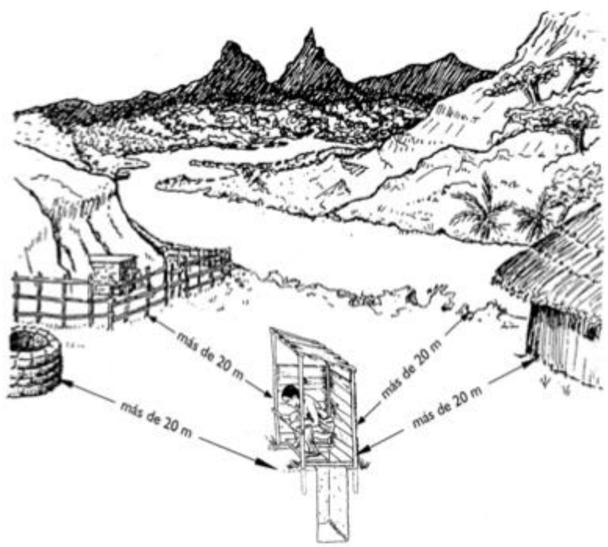


ILUSTRACIÓN 3.2 *Es importante construir las letrinas en terreno firme y libre de inundaciones. Si el terreno es montañoso, la letrina se debe ubicar en una parte más baja que la fuente de suministro de agua para evitar su contaminación. Ubique la letrina a 20 metros de distancia del pozo.*

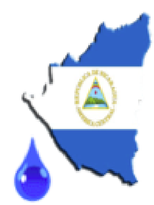
ILUSTRACIÓN 3.3 *Si los niños o los animales dejan excremento cerca de la casa, éste debe limpiarse de inmediato. Los niños deben aprender a usar una letrina o a enterrar su excremento, o por lo menos, a orinar y obrar lejos de la casa, o de donde las personas van a sacar agua para beber.*

EL NITRATO es un compuesto químico que se encuentra naturalmente en suelo, y se forma cuando los microorganismos del medio ambiente descomponen materiales orgánicos, como las plantas y el excremento de humanos y de animales. Los nitratos también se utilizan en los fertilizantes.

El nitrato procedente de la descomposición de las heces de los humano y de los animales puede infiltrarse al agua y causar enfermedades. La presencia de nitrato puede indicar que hay otros contaminantes presentes. La presencia del nitrato puede indicar la presencia de contaminantes microbianos. El exceso del nitrato en el agua del pozo es dañino para la salud y limita la cantidad de oxigeno que transporta la sangre. Como resultado, las células no tienen suficiente oxígeno para funcionar.

PREGUNTAS PARA LA CLASE

¿Por qué debemos lavarnos las manos con jabón luego de ir al baño?
¿Por qué hay que mantener a los animales lejos de los pozos?
¿Por qué debemos tapar o cubrir los pozos?
¿En dónde debemos ubicar las letrinas?
¿En dónde debemos ubicar o construir los pozos?



Water Cycle and Hygiene Flip Chart

El Ciclo Del Agua

LA CLAVE PARA NUESTRA SALUD!

EL CICLO DEL AGUA

OBJETIVOS:

- ✓ Entender el ciclo del agua, los conceptos y el vocabulario clave relacionados con el agua subterránea, los acuíferos, y el impacto humano.

- ✓ Aprender de donde proviene el agua subterránea, cómo es contaminada, y qué podemos hacer para proteger este recurso tan importante.

Mostrar un diagrama del ciclo del agua y explicar los términos de vocabulario que aparecen resaltados o más oscuros en el diagrama.

- **Precipitación:** el viento arrastra las nubes hacia los continentes donde vivimos. A causa del cambio de presión y temperatura, las nubes dejan caer el agua dulce acumulada en forma de lluvia.
- **Evaporación:** Ocurre cuando el agua cambia de estado líquido a vapor de agua. El vapor de agua sale de los árboles y las plantas (**transpiración**), ríos, lagos y de la superficie de la tierra.
- **Nivel Freático:** el nivel freático corresponde al nivel superior de una capa freática o de un acuífero en general. La cantidad depende de la temporada, precipitación, de los tipos del suelo, y de la topografía.
- **Escorrentía:** el agua de la lluvia, el hielo o la nieve, se destila por las montañas formando valles, lagos y ríos
- **Lago, Mar o Rio:** superficie formas del agua
- **Condensación:** el vapor de agua contenido en el aire conforme se va elevando o subiendo hacia la atmósfera, se va enfriando. Cuando es muy frío, el vapor se condensa cambiando de estado gaseoso a estado líquido, creando gotitas de agua muy pequeñas que se mantienen suspendidas en el cielo y forman las nubes
- **Percolación o Infiltración:** parte del agua que recorre la tierra, se filtra en la tierra, y forma capas de aguas subterráneas. A esta filtración de capas de aguas subterráneas le llamamos:
- **ACUÍFEROS**
- **Corriente Subterránea:** el flujo del agua debajo la tierra

Dirección del Movimiento del Agua: el movimiento del agua por debajo de la superficie depende de la permeabilidad (que tan fácil o difícil es el movimiento del agua) y de la porosidad (la cantidad de espacio abierto en el material) de la roca subsuperficie.


El Ciclo del Agua
Agua contenida en el hielo y la nieve
Agua contenida en la atmósfera
Condensación
Sublimación
Precipitación
Evapotranspiración
Evaporación
Escurrimientos de la superficie
Escurrimientos de agua a ríos
Corriente del arroyo
Evaporación
Filtraciones
Manantial
Agua potable almacenada
Agua contenida en los océanos
Descarga de agua subterránea
Agua subterránea almacenada
USGS

VOCABULARIA

Agua subterránea *– agua que ha sido almacenada en el subsuelo (acuífero) y que se puede extraer para beber y para consumir. El agua subterránea se usa en los hogares, en la agricultura y en todos los sectores del país.*

Saturación*: Se refiere cuando algo está repleto u ocupado por agua.*

Zona no-saturada*: Es la capa superior del suelo en donde existe el agua en diferentes cantidades, pero en donde el agua no satura el suelo.*

Zona Saturada*: Se denomina zona saturada a aquella porción del suelo donde todos los espacios vacíos están ocupados por agua.*

Acuífero no confinado*: Un cuerpo de agua subterráneo que no está rodeado por una capa impermeable. El material sobre estos acuíferos es poroso.*

Impermeable*: Se aplica a la sustancia o material que no permite el paso de la humedad, el agua u otro líquido.*

Nivel Freático: *El nivel freático corresponde al nivel superior de una capa freática o de un acuífero en general. La cantidad depende de la temporada, precipitación, de los tipos del suelo, y de la topografía.*

Topografía*: Es el conjunto de características que presenta la superficie o relieve de un terreno.*

¿ALGUIEN TIENE LAS PREGUNTAS O COMENTARIOS?

LAS RESPUESTAS

1. **RADIACIÓN**: los rayos ultravioleta calientan la superficie del agua, el sol evapora a el agua de superficie de lagos rios y oceanos.

2. **EVAPORACIÓN:** es un proceso físico que consiste en el paso lento y gradual de un estado líquido hacia un estado gaseoso, tras haber adquirido suficiente energía para vencer la tensión superficial.

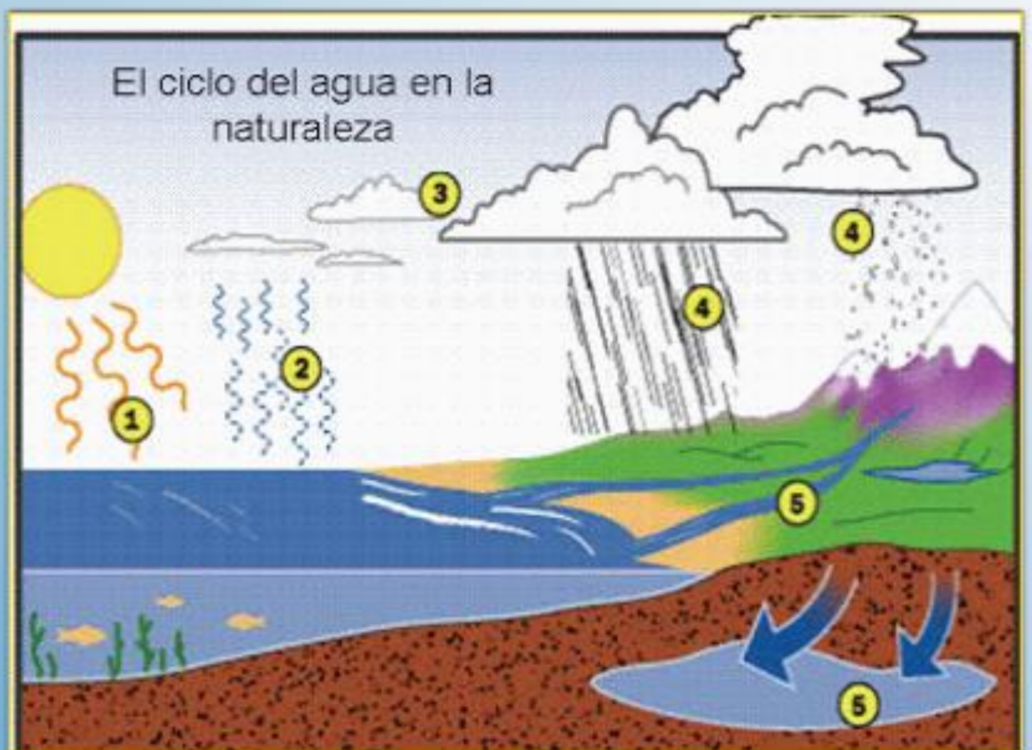
3. **CONDENSACIÓN**: cambio de estado de la materia que se encuentra en forma gaseosa a forma líquida. Es el proceso inverso a la vaporización. Vemos en la forma de las nubes.

4. **PRECIPITACIÓN**: es cualquier forma de hidrometeoro que cae de la atmósfera y llega a la superficie terrestre. Este fenómeno incluye lluvia, llovizna, nieve, aguanieve, granizo, pero no virga, neblina ni rocío, que son formas de condensación y no de precipitación. La precipitación es una parte importante del ciclo hidrológico, responsable del depósito de agua dulce en el planeta y, por ende, de la vida en nuestro planeta, tanto de animales como de vegetales, que requieren del agua para vivir.

   TIPOS DE PRECITACIÓN: el agua condensada en las nubes se precipitan en gotas de agua(lluvia). El agua condensada en las nubes por la alta presion se congelan y se precipitan en forma de nieve.

5. **ESCORRENTÍA**: Las aguas de las altas montañas escurre hacia el mar,lago,rio etc...que hace referencia a la lámina de agua que circula sobre la superficie en una cuenca de drenaje, es decir la altura en milímetros del agua de lluvia escurrida y extendida

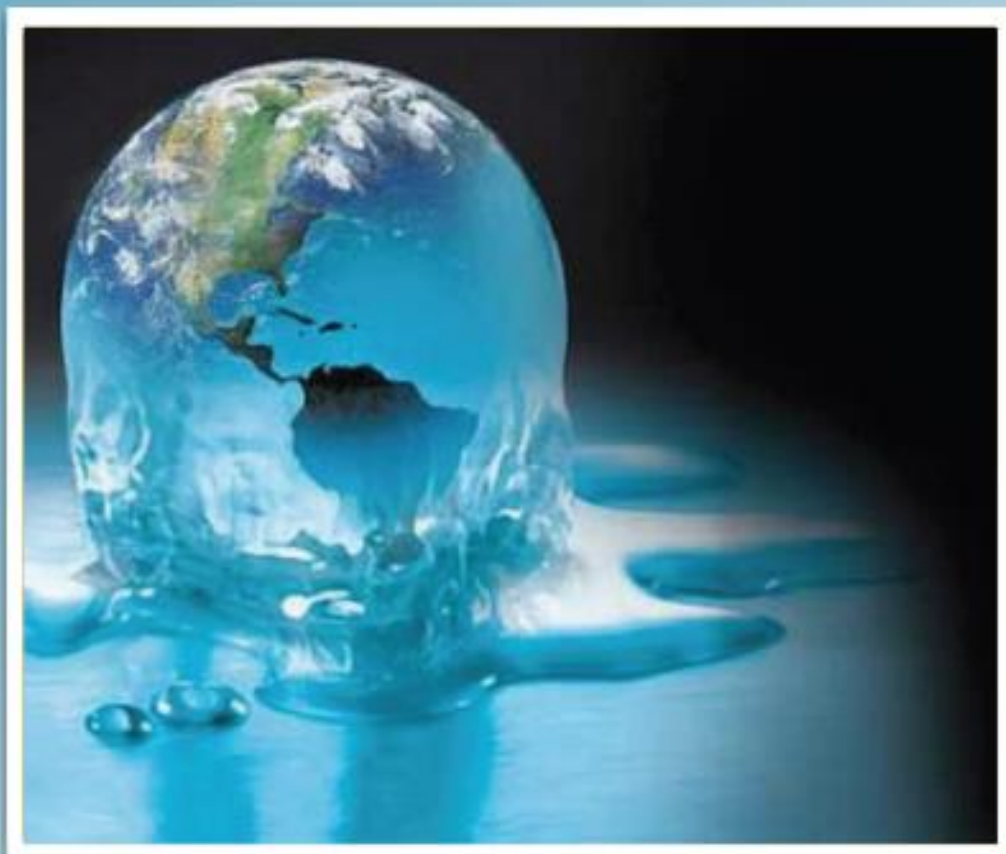
   CORRIENTE SUBTERRÁNEA: el agua escurre de forma diferente y escurre por la profundidad de la tierra.



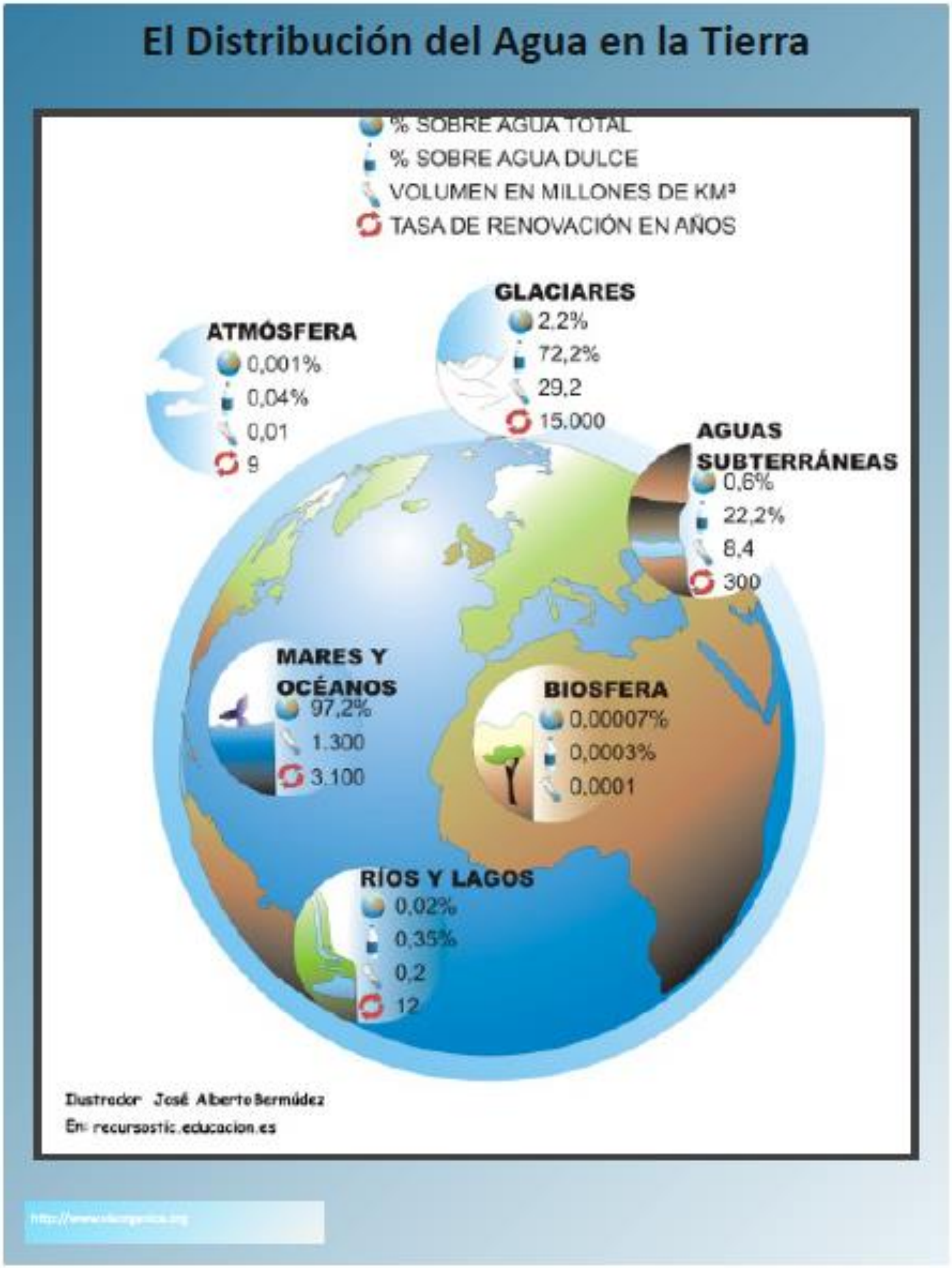
Identifica en cada número del esquema la etapa del ciclo del agua que está sucediendo.

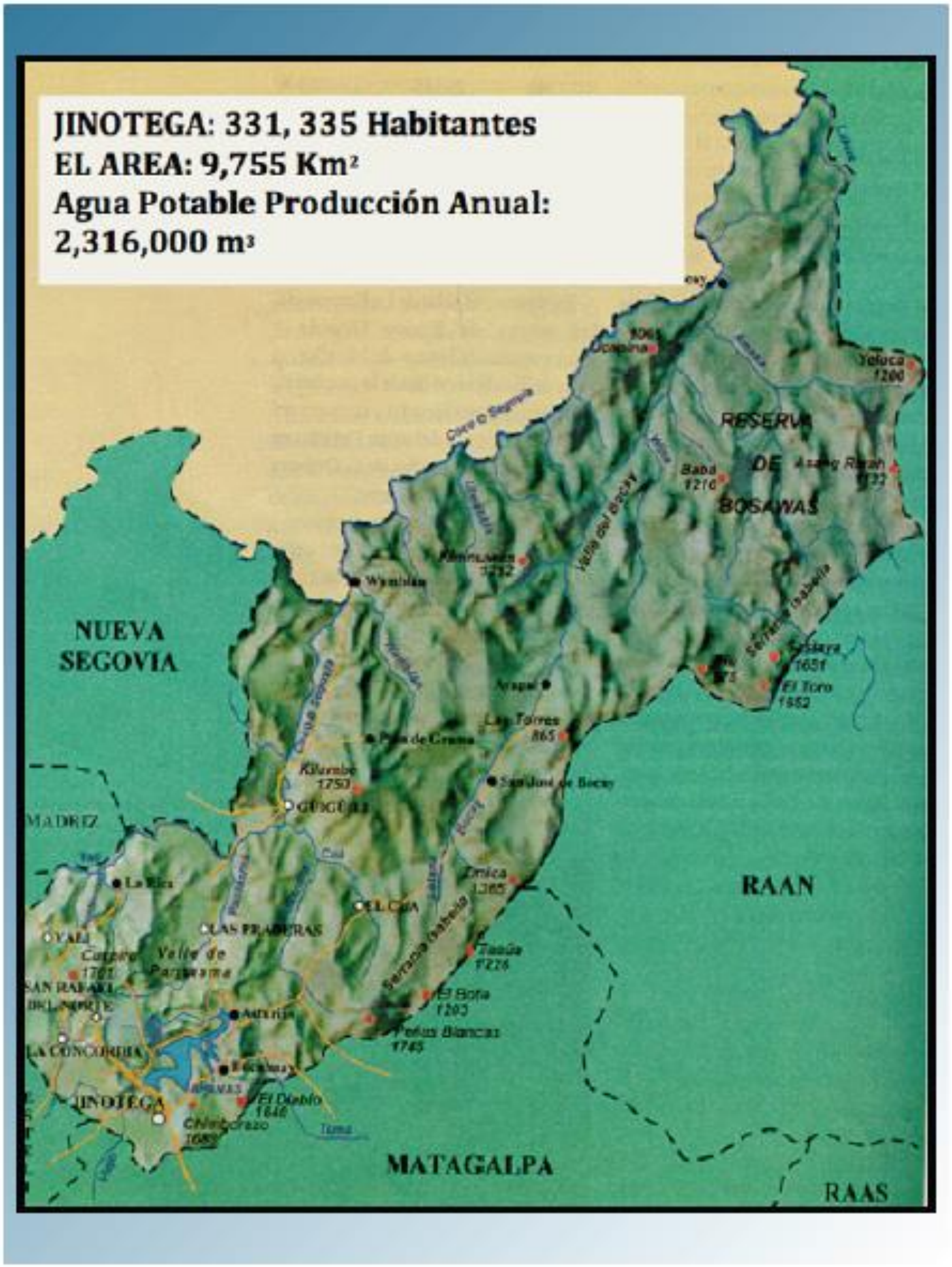
El Distribución del Agua en la Tierra

Type to enter text



¿Qué está el estado del los recursos hídricos en Nicaragua?


El Distribución del Agua en la Tierra
% SOBRE AGUA TOTAL
% SOBRE AGUA DULCE
VOLUMEN EN MILLONES DE KM³
TASA DE RENOVACIÓN EN AÑOS
GLACIARES
2,2%
72,2%
29,2
15.000
ATMÓSFERA
0,001%
0,04%
0,01
9
AGUAS SUBTERRÁNEAS
0,6%
22,2%
8,4
300
MARES Y OCÉANOS
97,2%
1.300
3.100
BIOSFERA
0,00007%
0,0003%
0,0001
RÍOS Y LAGOS
0,02%
0,35%
0,2
12
Ilustrador José Alberto Bermúdez
En: recursostic.educacion.es


JINOTEGA: 331, 335 Habitantes
EL AREA: 9,755 Km²
Agua Potable Producción Anual:
2,316,000 m³
NUEVA
SEGOVIA
RESERVA
DE
BOSAWAS
RAAN
MATAGALPA
RAAS
MADRIZ
LAS PRADERAS
EL CUA
JINOTEGA
LA CONCORDIA
Kilambe
1750
Las Torres
865
Yeluca
1200
El Toro
1652
Peñas Blancas
1745
El Diablo
1648
Valle de
Pantasma

Entre el 73% y el 90% del suministro de agua proviene de fuentes subterráneas y en el caso de la ciudad capital, Asososca, una laguna ubicada en el corazón de Managua, abastece aproximadamente el 14-20% del agua bombeada.(Enacal 2006)

¿Qué son las actividades que usan del agua subterráneas?

1. Uso Agrícola: En los partes de Nicaragua, donde se utiliza en algunos cultivos, consumiendo aproximad ente el 30% del potencial de agua subterránea.

2. Uso de Generación: 35% de la energía del país era suministrada de fuentes hidroeléctricas. Por ejemplo, Lago Apañas.

¿Qué tipo del agua esta Lago Apañas?

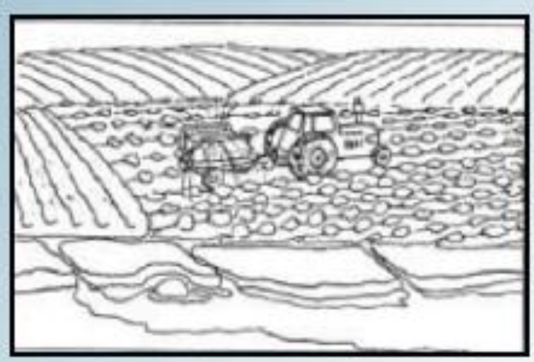
3. Usos para Consumo Humano, Aseo y Otros Fines Domésticos :

El 50% o más del país no recibe agua potable por cañería domiciliar.

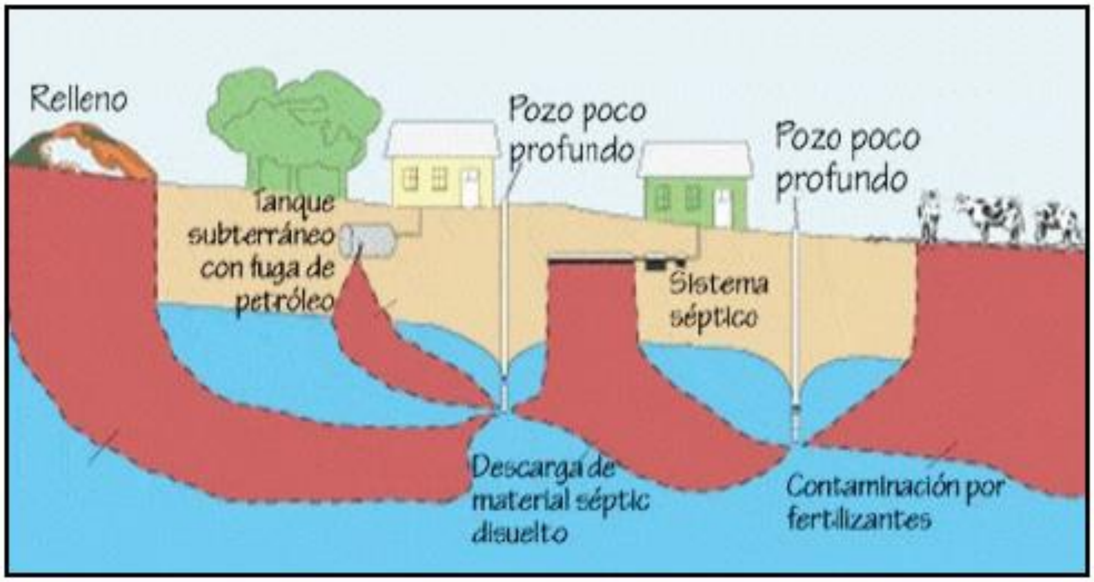
Aproximadamente el 90% de la producción de agua proviene de los pozos.

Maneras Agua de Subterránea se Contamina

Residuos químicos (detergentes, gasolina) y de residous orgánicos (agua fecales)

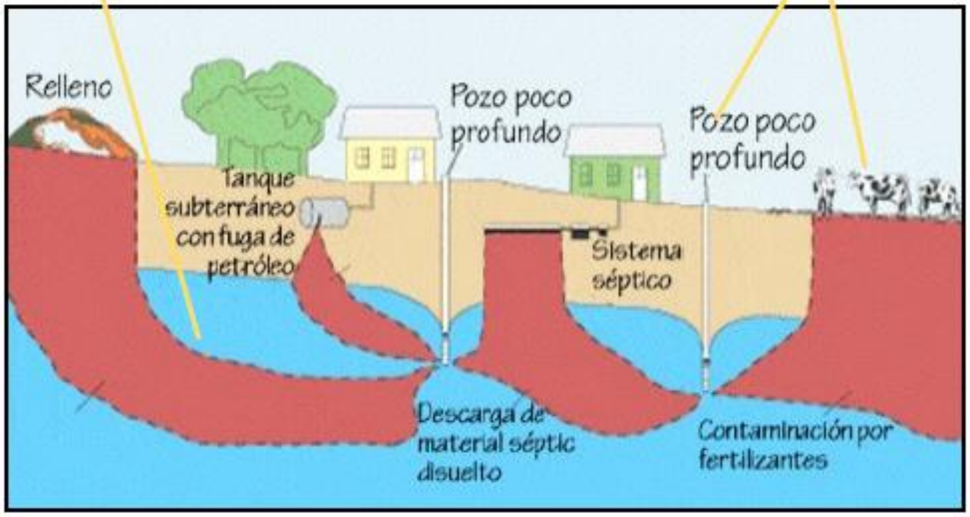


Los residuos (fetilizantes, pesticidas, herbiidas) son arrastrados de los suelos a los ríos.


Relleno
Pozo poco profundo
Pozo poco profundo
Tanque subterráneo con fuga de petróleo
Sistema séptico
Descarga de material séptic disuelto
Contaminación por fertilizantes


¿Qué tanta agua de la terra es utilizable para consumo humano?
Agua utilizable para consumo humano
Agua subterránea
Lagos de agua dulce
Ríos
0.3% es usada para consumo humano
99.7% no disponible para consumo humano

EL AQUÍFERO **EL NITRATO**



Las diferentes causas de la contaminación de los acuíferos. El origen de alguna sustancia nociva para los acuíferos es muy variado y pueden provenir de químicas procedentes de los pesticidas, las heces o excrementos de los humanos y los animal, la gasolina de los carros, las actividades agrícolas y ganaderas, y de las actividades mineras.

El agua potable debe poseer una aprensioncita limpia, no tener color, olor ni sabor, y estar libre de toda contaminación.

¿Cómo se obtiene el agua potable? ¿Cómo se hace que sea adecuada para el consume humano?

Para potabilizarla, el agua se somete a procesos físicos de separación de sustancias, y procesos químicos de desinfección.

Cubierta del Pozo

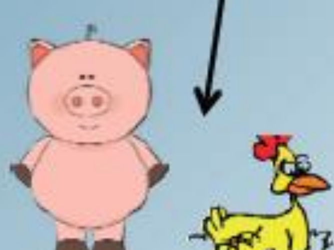
20 M

Proteger el agua de pozo se mantenía puntos de contaminación más o menos una distancia de los 20 metros.

20 M

¿POR QUÉ?

20 M



Las contaminantes tienen patógenos u organismos que causan enfermedades y que pueden estar presente en las aguas contaminadas por heces, pesticidas, gasolina etc.

<u>¿Qué puede hacer usted para controlar la contaminación?</u>
¡Quedarse los animales afuera las casas y cerca de los fuetes de agua!

¡No lo tire en la basura encima de la tierra!

¡Mantiene su hogar del pozo libre de las heces!

Cuando el agua que en el pozo está pura el filtro durará más tiempo.

El agua potable está bueno para su salud y esencial para sobrevivir

Gracias Por Sus Tiempo

Tienen el poder para hacer que sucedan cosas buenas por el bien todos.

Berberse Todo!