

Comparative potable water sampling in Southern Costa Rica

Abstract

The goal of this study was to assess the potable water quality of four communities located in the Southern Zone of Costa Rica: Tinamastes, Platanillo, Barú, and Dominical. Household members were interviewed about their potable water quality perception. Potable water samples taken from the households were analyzed for temperature, dissolved oxygen content, turbidity, conductivity, and the presence of *E.coli* and fecal coliform colonies. The results from our interviews suggested overall high water quality perception, however our water assessment suggests possible *E.coli* contamination in Barú and Dominical communities and fecal contamination in all communities sampled. Currently the Costa Rican Ministry of Environment and Energy (MINAE) does not have recommended fecal coliform standards, however the absence of total coliform is recommended. We suggest routine monitoring and cleaning of the community potable water tanks and household pipes.

Introduction

Earth's surface consists of 70% water. While water appears bountiful on earth, drinking or potable water is not as easy to access due to potable water's need to be safe for humans to drink. The quality of water, whether it is used for drinking, irrigation or recreational purposes, is significant for health in both developing and developed countries worldwide (WHO, 2001). According to the United Nations' World Health Organization (WHO) more than one billion people in low and middle-income countries lack access to safe water for drinking, personal hygiene and domestic use (WHO, 2001). To support this statement, as of the year 2000, 27 percent of the populations of lesser-developed countries did not have access to safe drinking water (Shiklomanov, 2001). The lack of safe potable water has caused many organizations such as WHO, the Joint Monitoring Program, UNICEF, the U.S. Environmental Protection Agency (EPA), Costa Rica's MINAE, and many other country-specific programs to regulate and analyze potable water in developed and developing countries.

These organizations set guidelines to determine whether or not a country's potable water is considered safe for human consumption. The World Health Organization establishes guidelines for countries to use as a basis for safe potable water. In the United States, Congress passed the Safe Drinking Water Act in 1974 allowing the EPA to set potable water quality standards, examine individual state's water quality, and establish National Primary Drinking Water Regulations (NPDWRs) to unearth contaminants in the water that may effect public health.

In order to establish these guidelines and regulations, the organizations analyze the quality of potable water using two parameters: chemical/physical and bacteriological. Chemical/physical parameters include heavy metals, total suspended solids (TSS), temperature, conductivity, turbidity, and dissolved oxygen (WHO, 2001). Temperature of potable water is analyzed because bacteria such as total coliforms can grow if the temperature is too high. Temperature also affects the amount of oxygen that can be dissolved in the water. Conductivity is the measurement of water's ability to conduct electricity (Test Parameters, 2007). Conductivity indicates how much solids are dissolved in the water and is measured in micro-Siemens. High conductivity is an indicator of contamination (Test Parameters, 2007). Turbidity is the degree to which a body is not clear and is measured in NTUs (Test Parameters, 2007). Dissolved oxygen's presence in water is a sign of non-contaminated water. The absence of oxygen is a signal of severe pollution. Waters of consistently high dissolved oxygen are usually considered healthy (Test Parameters, 2007).

The bacteriological parameters that organizations use to regulate potable water include total coliforms. Total coliforms are gram-negative, aerobic or facultative anaerobic, nonspore forming rods (U.S. National Park Service, 2007). All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood

and in other places outside the human body (EPA, 2006). Although they are not usually pathogenic themselves, their presence in drinking water indicates the possible presence of pathogens (Baduini personal communication, 2007). Water polluted by feces contain total coliforms and are often related to outbreaks of diseases.

Two forms of total coliform bacteria are *Escherichia coli* (*E. coli*) and fecal coliform. *E. coli* is always found in feces and is, therefore, the indicator organism of choice for determining fecal contamination and the possible presence of enteric pathogens (WHO, 2001). In addition, some strains of *E. coli* are pathogenic (Baduini personal communication, 2007). The EPA has determined that higher *E. coli* bacteria counts indicate that people who come into contact with the water may have a greater probability of illness. But it is important to remember that as *E. coli* counts go up, the chance that someone will get sick goes up (U.S. National Park Service, 2007). Fecal coliform may indicate that the feces of humans or other animals have contaminated water, but as recently as April 2006, many official websites including the EPA failed to address the fact that presence of fecal coliforms does not necessarily indicate the presence of feces (Doyle and Erickson, 2006).

In Costa Rica, the government agency that performs similar acts as the U.S. EPA is MINAE, Ministerio del Ambiente y Energía. The organization that regulates potable water services is Instituto Costarricense de Acueductos y Alcantarillados (AyA). However, AyA controls only 46.3% of Costa Rica's water usage. In fact, one in five communities receive water directly from streams (Baduini personal communication, 2007). Most rural communities do not have government controlled and cleaned water coming into the homes. In actuality, while 97.5% of Costa Ricans have access to water in their households, 40% of the water provided by municipalities or communities is not potable (Segura Bonilla et al., 2004). However, in 2000,

AyA started a project to provide government water to rural communities (Baduini personal communication, 2007). The project named ASADAS, *asociaciones de administración de agua*, unites communities to receive government water.

Communities' perceptions of water quality are important as well. They determine whether or not potable water is safe to drink in their community. They can unite and join ASADAS if they perceive their water to be unclean. Individuals can boil the potable water if they believe it is unsafe. They can, therefore, also continue to drink the potable water if they feel it is not contaminated. People in the communities are drinking the potable water and, therefore, their perceptions of potable water quality are valid.

In the Southern Zone of Costa Rica, the communities of Tinamastes and Platanillo are involved in ASADAS and receive government potable water. The community of Barú collects potable water from a tank near the town. In the community of Dominical, a town on the Pacific coast, the people obtain the potable water from a nearby spring. In this experiment, interviews were conducted to evaluate peoples' perceptions of own potable water quality. Then, water samples were taken from five houses in each community, Tinamastes, Platanillo, Barú, and Dominical for assessment of temperature, conductivity, turbidity, *E.coli* and fecal coliform to determine overall quality of water in the area and comparison of water quality within the communities. We hypothesize that the overall levels in Tinamastes and Platanillo, due to their affiliation with ASADAS, will be of better quality than the levels in Barú and Dominical. Also, we hypothesize that the overall levels in Dominical will have the worst quality than the levels in the other three communities.

Methods

Household Interviews

Interviews of twenty people from the four communities were conducted between November 27 and December 1, 2007. Interviews consisted of a brief introduction of ourselves, our project and verbal permission to conduct the interview. Questions were semi-structured open ended including:

¿Cuántas personas viven en su casa? (How many people live in your house)

¿Donde recibe su agua potable? ¿De alguna naciente? (Where do you receive your potable water, from a spring?)

¿Su familia toma el agua del tubo? (Does your family drink from the tap?)

¿Qué tan limpia es su agua potable - en una escala de uno a diez? (How clean is your potable water, on a scale from one to ten?)

En su opinión, ¿Qué tan limpia es el agua potable en Costa Rica – en una escala de uno a diez? (In your opinion, how clean is the potable water in Costa Rica on a scale from one to ten?)

Algunas veces, ¿piensa usted que el agua potable esta sucia y no la toma? (Sometimes do you think the potable water is dirty and don't drink it?)

¿Qué hace usted cuando el agua del tubo viene del color café? ¿Cómo reacciona usted, hierve el agua? (What do you do when the water from the tap is brown? How do you react? Do you boil the water?)

¿Podemos muestrear un poco de su agua? (Can we sample a little of your water?)

Families were notified of the presence or absence of *E.coli* and fecal coliform in their water samples between December 11-13, 2007 with the following letter (see Notification Letter in Index).

Potable Water Sampling

Note: To ensure the reliability of our results, before beginning sampling in the communities all water bottles, De-ionized water, forceps, and filtration apparatuses were

sterilized in a pressure cooker. Instruments were placed in the pressure cooker with boiling water for 20 minutes and allowed to cool before use.

After interviewing and receiving permission from the household, water was sampled in two bottles, one sterilized for total coliform analysis. The second water bottle was used to immediately collect Dissolved Oxygen (mg/L and percentage), temperature, and conductivity measurements using a YSI 85 probe. Turbidity measurements were recorded in the lab using a LaMotte 2020 e/i Turbidity meter. Two 5mL pipettes of each household's potable water were vacuum filtrated onto gridded filter paper and incubated in a Petri dish with blue indicator for *E.coli* and fluorescent indicator for fecal coliform presence. All samples were filtered no more than 4 hours after initial collection. After 24 hours of incubation at 37.5° C, the *E. coli* and Fecal coliform colonies were counted and recorded using the following equations:

$$E. coli/100mL = (\text{Number of blue colonies} / \text{Volume of sample filtered}) * 100$$

$$\text{Fecal coliform}/100mL = (\text{Number of fluorescent colonies} / \text{Volume of sample filtered}) * 100$$

In addition a rain study was conducted in Platanillo on November 30, 2007. Potable water samples were collected from one household at four time points including roughly one hour after initial rainfall, 3 hours after, 12 hours after, and 24 hours after. Samples were analyzed for turbidity in the lab the following day.

Results

Potable Water Samples

All measurements recorded were compared to MINAE standards. The average water temperature from the households sampled from all four communities was 25.71°C (Tinamastes 23.46; Platanillo 25.12; Baru 27.26; Dominical 27°C). This value falls within the MINAE recommended and maximum acceptable temperature measurements of 18-30°C. MINAE recommends turbidity levels between >1 and 5 NTU, the average of the communities was 2.39 NTU (Tinamastes 3.62; Platanillo 1.04; Baru 2.11; Dominical 2.77 NTU) (see Figure 1). The average dissolved oxygen level for all communities was 209.86% (Tinamastes 109.82; Platanillo 235.04; Baru 297.66; Dominical 196.90%), MINAE does not have specific regulations on dissolved oxygen levels (see Figure 2). The recommended water conductivity from MINAE is 400 Us/cm, the average from the households sampled was 209.86 Us/cm (Tinamastes 109.82; Platanillo 235.04; Baru 297.66; Dominical 196.90Us/cm) (see Figure 3).

MINAE's recommended and maximum value of *E.coli* per 100mL samples is zero. An average of 12 colonies/100mL were counted from Tinamastes, 0 in Platanillo, 148 in Baru, 690 in Dominical. Fecal coliform colony counts are not included in MINAE's assessment of water quality, however Total Coliform recommended and maximum value is zero in 100mL samples. The average Total Coliform count per 100mL from Tinamastes was 470 colonies, 522 in Platanillo, 1484 in Baru, and 1670 in Dominical (see Figure 4).

The turbidity study in Platanillo found 31 hours before rainfall the turbidity was 3.48 NTU. During initial rainfall the turbidity was 1.71 NTU and 12.75 hours after initial rainfall, the turbidity peaked at 4.13 NTU. However, 26 hours after the initial rainfall, the turbidity had not returned to the initial 1.71 NTU during the initial rainfall (see Figure 5).

Household Interviews Results

The interviewees from the communities of Tinamastes, Plantanillo, and Baru receive potable water from tanks. The tanks of Tinamastes and Platanillo are managed by ASADAS. The potable water from Dominical is from a spring. Overall all interviewees believed that their water is of good quality, on average 8.5 on a scale of 1 to 10. However, when asked of the water quality in Costa Rica in general, most recognized that there are areas where the water quality is not as good. Because of this, their opinion of water quality of Costa Rica on a scale of 1 to 10 was lower, accounting for areas with poorer quality, on average 6.9 out of 10.

Not all of the households interviewed drink directly from the tap. Two households, one of Tinamastes and one of Platanillo have filters which remove some of the chlorine. When asked what they do when the water is brown in color, all interviewees of all communities said that do not use the water, not even boiling it. One interviewee of Tinamastes replied that when the water is brown in color, they call the tank operators. On the day we tested the water in this area, the tank was being cleaned and some people did not have water. Another interviewee of Tinamastes mentioned that the family has a deposit of water, which they use when the tank is being cleaned, or when the water is brown in color.

Discussion

Note: Samples that had colonies of *E.coli* or fecal coliform that were too numerous to count were assumed to have over 100 colonies in the 5mL sample and given a value of 2000 colonies/100mL to graph.

Total Coliform counts including *E. coli* and Fecal Coliform counts were compared to three sources, MINAE, EPA, and WHO regulations. According to all three organizations, no *E. coli* or Fecal Coliform colonies should be present in water intended for human consumption. The WHO indicates that Total coliform bacteria levels are not acceptable indicators of the sanitary quality of water supplies, particularly in tropical areas, where many bacteria of no sanitary significance occur in almost all untreated water supplies (WHO, 2001). However, we believe that the *E. coli* and fecal coliform counts are reliable indicators of fecal contamination because the tanked water in the communities is treated with chlorine, currently the most widely used method for disinfecting potable water in Costa Rica (AyA, 2007).

From our assessment, all of the potable water sampled requires additional assessment for confirmation of fecal contamination by MINAE or AyA. Although all communities had fecal coliform present, Barú had the largest amount, Tinamastes the least. Additionally, Dominical had the highest *E. coli* count, Platanillo the lowest with no *E. coli* detected. Notably, the samples from the Tinamastes and Platanillo households that had filters contained the most *E. coli* and fecal coliform counts of the respective communities.

E. coli can grow in sediment and mobilize when water flow increases (WHO, 2001). In tropical areas with noted rainy and dry seasons like Costa Rica, we have found increased coliform levels in the dry season in comparison to the rainy season (Mirabeau and Guillermo unpublished data, 2007). From this data, future studies may be conducted in the dry season to assess the drinking water quality of the four communities we assessed during the beginning of the dry season.

Although the turbidity from all communities was within MINAE recommended levels, Tinamastes had the highest turbidity on average, Platanillo lowest. From the rain study in Platanillo, we found that the turbidity was 3.48 NTU 31 hours before the major rainfall and decreased to 1.71 NTU during the initial rainfall, peaking at 4.13 NTU around 12 hours after the rain. The MINAE recommended turbidity is between >1 and 5 NTU. Due to the large range of turbidity within this community, it is plausible that the turbidity can be above the MINAE recommended NTU during extremely heavy rainfalls of the rainy season. Future rainfall and turbidity studies can be conducted to determine whether this occurs in other communities as well.

A previous study has examined the effect of water quality of Dominical and increased tourism (Weinkauff, 2006), noting the necessity for continued monitoring of the waterways. Weinkauff notes that the dissolved oxygen levels were within acceptable standards; however the microbiological safety of the water for drinking or recreational contact was uncertain due to the widespread presence of fecal coliform contamination. No other studies could be found to date addressing the potable water quality of the Southern Zone.

As the WHO notes, potable water contamination is not only related to fecal contamination. Organisms can grow in the water source or in the pipes of the water systems (WHO, 2001). These organisms can cause outbreaks and individual cases as well. The presence of *E.coli* increases the probability that someone will get sick, therefore members of the households included in this study have an increased probability of becoming ill from the water. In future studies, to determine the source of bacteria, we suggest testing of the actual community water tanks in addition to different household's potable water within the same communities. In

addition the continued monitoring of the community tanks and spring in Dominical is encouraged.

When notifying the families of the presence or absence of either *E.coli* and/or fecal coliform, we received a range of reactions. Some stated that they would notify their local water authority of our results, and others were unsure of what the results meant. We hope that future studies will continue to monitor the water quality of this area and keep the communities informed of their efforts and results.

Acknowledgments

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1__ Diciembre 2007

Queridos vecinos,

Nosotras somos estudiantes del Centro Firestone en Barú. Nosotras hablamos con un miembro de su familia y muestreamos su agua potable el ___ de Noviembre. Su agua potable fue analizada en nuestro laboratorio para detectar *E.coli* y fecal coliforme. Estas son bacterias del excremento. Los resultados de nuestro análisis presentaron que su agua potable contiene:

_____ *E.coli*

_____ fecal coliforme

Si su agua tiene *E.coli* o fecal coliforme, le recomendamos hervirla o clorarla. Además le recomendamos hablar con la organización local que suministra su agua para más información o para solucionar el problema.

¡Gracias!

Janelle y Leanna

Notification Letter. Letter received by families of Tinamastes, Platanillo, Barú, and Dominical that participated in the study. English translation:

Dear neighbors,

We are students of the Firestone Center in Barú. We spoke with a member of your family and we sampled your drinking water the ___ of November. Your drinking water was analyzed in our laboratory to detect *E.coli* and fecal coliform. These are bacteria of the excrement. The results of our analysis presented that your drinking water contains:

_____ *E.coli*

_____ fecal coliform

If your water has *E.coli* or fecal coliforme, we recommend you to boil it or put chlorine in it. Otherwise we recommend that you speak with the local organization that supplies your water for more information or to solve the problem.

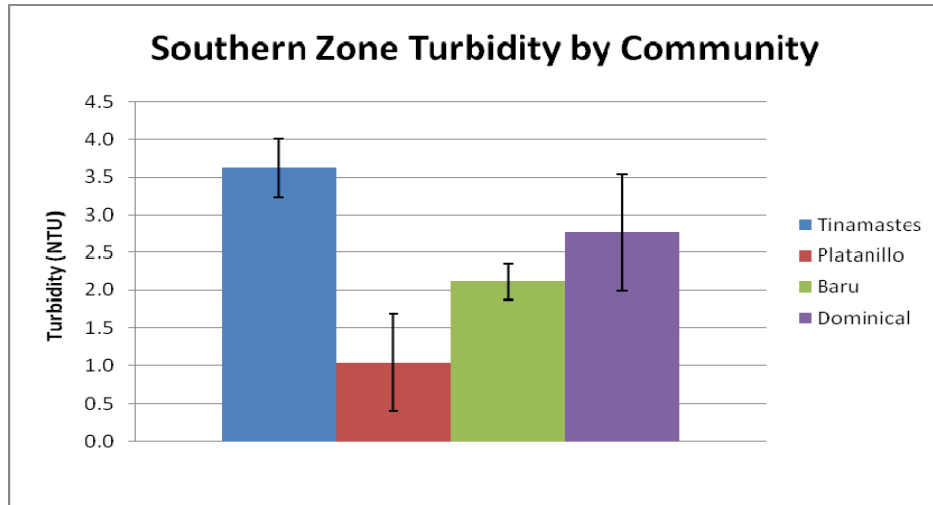


Figure 1. Turbidity measurements of potable water samples by community in Southern Costa Rica mean community NTU plotted with standard error of mean. Increasing trend of turbidity from Platanillo to Dominical. Lowest turbidity found in Platanillo (1.04NTU), highest in Tinamastes (3.62NTU). Sample measurements were taken after interviewing a member of the household using a YSI 85 probe between November 27-30, 2007.

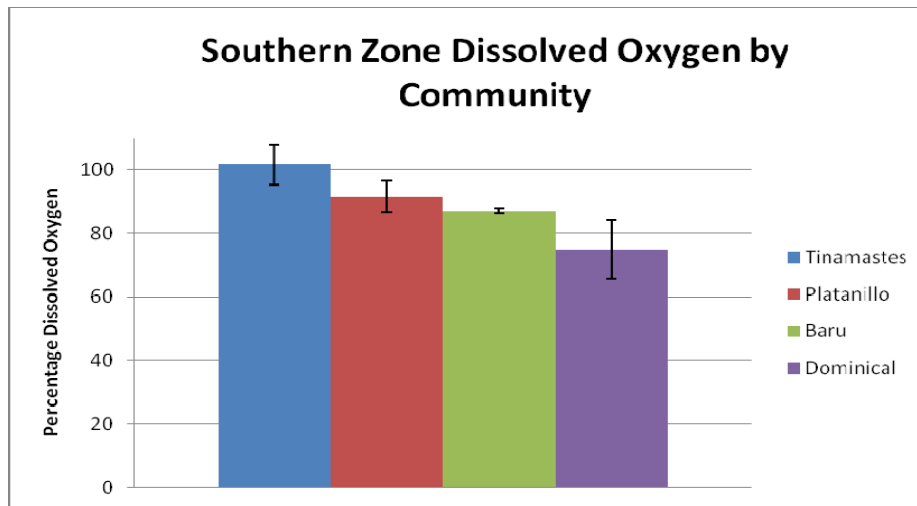


Figure 2. Dissolved oxygen measurements of potable water samples by community in Southern Costa Rica. Mean of community percentage plotted with standard error of mean. Decreasing trend found from Tinamastes (101.64%) to Dominical (74.96%). Sample measurements were

taken after interviewing a member of the household using a YSI 85 probe between November 27-30, 2007.

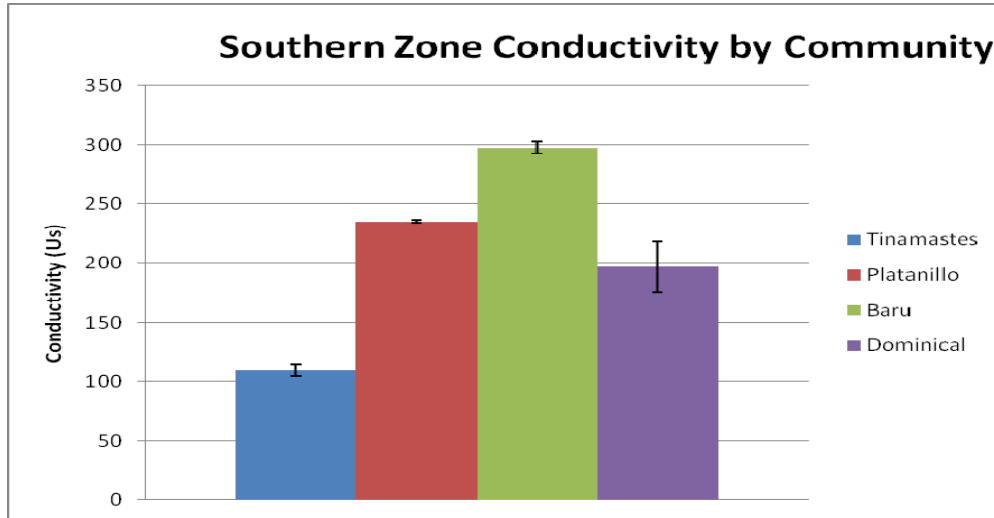


Figure 3. Conductivity measurements of potable water samples by community in Southern Costa Rica. Mean community Us measurements plotted with standard error of mean. Sample measurements were taken after interviewing a member of the household using a YSI 85 probe between November 27-30, 2007. Lowest conductivity was found in Tinamastes (109.82Us), highest in Barú (297.66Us).

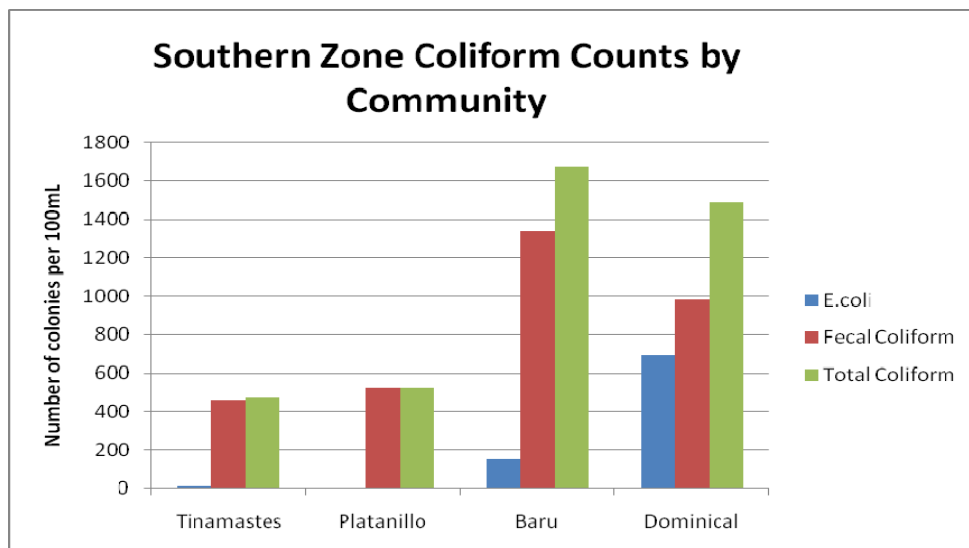


Figure 4. E.coli, fecal coliform, and total coliform counts by community in the Southern Zone of Costa Rica. Mean community colonies plotted with standard error of mean. Samples were collected after interviewing a member of the household and filtered at the Firestone Ecology Center between November 27-30, 2007. Colonies present were counted after 24 hours of incubation at 37°C.

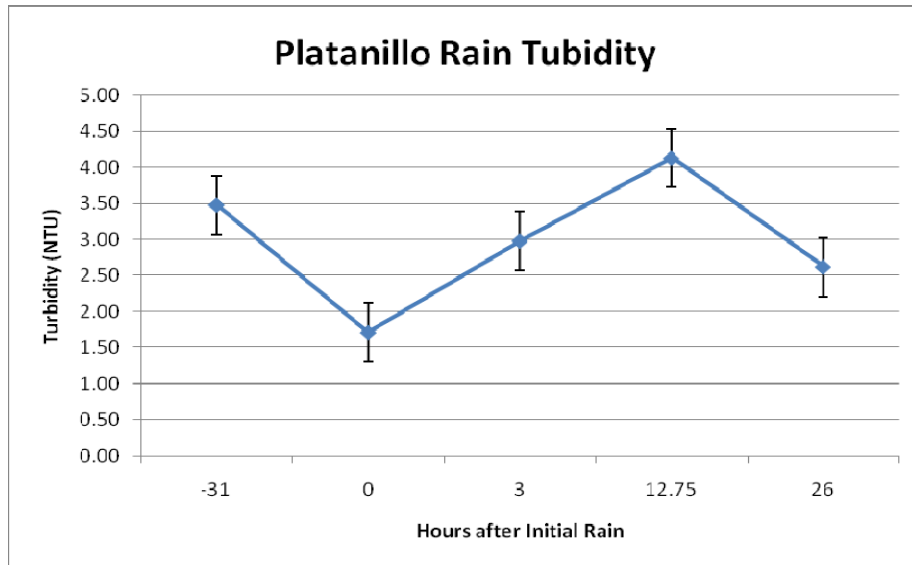


Figure 5. Turbidity measurements of rain study conducted in Platanillo on December 1, 2007. Samples were collected from a household hours before and after significant rainfall and turbidity was measured at the Fireston Center in Barú. NTU measurements plotted with standard error bars.