Evaluating the Use of Bioindicators and Bioassays as Techniques for Water Quality Monitoring at the Community Level

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CATHALAC is an international organization that works to promote sustainable development through applied research and education on water resources and the environment. Its projects are focused in four main areas: Integrated Watershed Management, Climate Change, Environmental Modeling and Analysis, and Risk Management.

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EXECUTIVE SUMMARY

Access to safe drinking water is a problem all around the world. Over 1 billion people lack access to improved drinking water sources. Contamination can pose serious immediate and long term health risks for communities. It is estimated that there are more than 500,000 diarrheal deaths annually caused by contaminated water. In Panamá, there is a large discrepancy between water coverage in urban and rural communities. In urban areas 92.9% of houses have access to drinking water sources, while in rural communities the coverage is only 78.11%. Also while in urban communities the water supply is regularly monitored and is treated when necessary, in rural communities the responsibility of the monitoring and treatment of the water often falls to the community.

My project was to evaluate the possibility of using bioassays as water quality monitoring techniques in rural communities. In Panamá the definition of a rural community is one with a population of less than 1500 people.

I performed a small workshop about water in a fifth grade class at a school in a community called la Feuillet, in Chorrera, Panamá. The school gets their water from a well on the school grounds, and the water is not treated. The workshop included an introduction about the importance of water, its uses, different sources of water and different types of contamination. I then continued to explain some basic concepts of scientific testing, such as the purpose of using positive and negative controls in tests.

The two bioassays that I taught to the class were an onion bulb bioassay and a lettuce seed bioassay. Both tests' methodologies came from the AQUAtox project developed by the International Development Research Centre (IDRC). I also did a coliform test with the students. Three days later I returned to the school to review the results with the class. For the bioassays, growth was measured and then we calculated the average length and the variation (percent change) between the negative control and the sample.

The results from the onion bulb bioassay indicated that the water at the school did not have chemical contamination. Unfortunately none of the seeds for the lettuce seed bioassay sprouted, so these results could not be used. This may have happened because the seeds were no longer viable. The coliform test only needs 48 hours before it can be observed, so the class and teacher recorded their observations after 48 hours. Their observations indicated an absence of coliform bacteria, but after 72 hours the test resembled a positive result. Four more tests were performed at the school to confirm the result, and all four showed an absence of coliform bacteria.

Overall the workshop went very well. Based on the success from this class there is definitely potential for further implementation of the bioassays as water monitoring techniques. This project, however, was only done in one class at one school. It would be important to teach the bioassays to different classes within the same schools and at different schools in different communities around the country. This would give a better idea of interest in the bioassays and potential for using the bioassays to monitor the water for contamination. For this to happen the project would need proper funding from either an external organization or from the government. For bioassays to be used as community level water monitoring, tests would have to be performed several times a year. Water quality can change very quickly and that is why it is important that the monitoring occurs at different times throughout the year. To do this monitoring at schools, the teachers and administration would need to be willingly to include the water testing in their curriculum. It will be important to continue working with the schools to evaluate their ability to

run the tests alone, without instruction or financial help. Although the coliform tests are very important, especially in areas where the water is not treated, it may be difficult for some communities to get the tests, or the tests may be unaffordable. If the bioassays were to be used for community level water monitoring, it would be important to test water sample from several different locations and different sources. Even if the water monitoring is being done through the schools, water should be tested from not just the school.

El acceso al agua potable es un problema en todo el mundo. Más de mil millones de personas no tienen acceso a fuentes de agua potable. La contaminación puede causar serios problemas de salud para las comunidades. Se estima que hay más de 500.000 muertes por diarrea cada año en todo el mundo causadas por el agua contaminada. En Panamá, existe una gran discrepancia entre la cobertura de agua en las comunidades urbanas y rurales. Además, aunque las comunidades urbanas han seguimiento regular de sus suministros de agua y tratamiento cuando sea necesario, en las comunidades rurales de la comunidad debe controlar y tratar su agua.

Mi proyecto fue a evaluar la posibilidad de utilizar los bioensayos como técnicas de monitoreo de la calidad del agua en las comunidades rurales. En Panamá la definición de una comunidad rural es una comunidad con menos de 1.500 personas.

He realizado un taller sobre el agua en una clase de quinto grado en una escuela en la comunidad de la Feuillet, en Chorrera, Panamá. La escuela recibe su agua de un pozo y el agua no es tratada. El taller fue una introducción sobre la importancia del agua, sus usos, diferentes fuentes de agua y los diferentes tipos de contaminación. También le expliqué algunos conceptos básicos de las pruebas científicas, como el propósito de usar los controles positivos y negativos en las pruebas.

Los dos bioensayos que enseñé a la clase eran un bioensayo de cebolla y un bioensayo de semillas de lechuga. Las metodologías para los bioensayos vinieron del proyecto AQUAtox que fue desarrollado por el Centro Internacional de Investigaciones para el Desarrollo (CIID). También hice una prueba de coliformes con los estudiantes. Tres días más tarde volví a la escuela para revisar los resultados con la clase. Para los bioensayos, se midió el crecimiento y luego se calculó el promedio y la variación entre el control negativo y la muestra.

Los resultados del bioensayo de la cebolla indicaron que el agua en la escuela no estaba contaminada. Desafortunadamente, ninguna de las semillas para el bioensayo semillas de lechuga germinadas, por lo que estos resultados no podrían ser utilizado. Esto puede haber ocurrido porque las semillas ya no eran viables. La prueba de coliformes sólo necesita 48 horas antes de poder observar, por lo que la clase y el maestro registraron sus observaciones del color después de 48 horas. Sus observaciones indicaron una ausencia de bacterias coliformes, pero después de 72 horas de la prueba se parecían a un resultado positivo. Tomé cuatro muestras más en la escuela para confirmar el resultado, y los cuatro mostraron una ausencia de bacterias coliformes.

En general, el taller fue muy bien. Existe la posibilidad de continuidad de los bioensayos como técnicas de monitoreo de agua. Sin embargo, este proyecto sólo se llevó a cabo en una clase en una escuela. Sería importante enseñar a los bioensayos a diferentes clases dentro de las mismas escuelas y en diferentes escuelas de diferentes comunidades de todo el país. Esto daría una mejor idea de las posibilidades de utilizar los bioensayos para monitorear el agua.

Sin embargo, para continuar con el proyecto necesita una financiación adecuada, ya sea una organización externa o desde el gobierno. Para que los bioensayos que se utilizará para el monitoreo del agua a nivel comunitario, los ensayos tendrían que realizarse varias veces al año. La calidad del agua puede cambiar muy rápidamente y es por eso que es importante que el monitoreo se produce en diferentes momentos a lo largo del año. Será importante seguir trabajando con las escuelas para evaluar su capacidad para ejecutar las pruebas sólo, sin instrucción o ayuda financiera. Si los bioensayos se iban a utilizar para el monitoreo del agua a nivel comunitario, sería importante probar muestra de agua de diferentes lugares y diferentes fuentes.

INTRODUCTION

Water is necessary for all life on earth. Approximately 65% of the adult human body is made of water by weight. Not only is water essential for sustaining life, but it is also important for many other parts of human life. The different types of water usage can be classified into two major categories: instream uses, where the usage occurs in the natural setting, such as hydroelectric power generation, and shipping, and withdrawal uses where the water is moved to a different location for other uses and later is returned to the natural environment in rivers, lakes, streams or the ocean. Some examples of withdrawal usage is diversion of water for consumption, household usage, or irrigation. Both categories of usage can cause degradation to the quality of the water and contamination. Withdrawal usage consumes some of the water, and sometimes the water is returned to the ocean, so less fresh water is available for future use (Environment Canada).

As the effects of human-induced climate change are increasingly noticeable, water related problems will become more drastic and devastating. Water scarcity is already a problem being faced worldwide with 2.7 billion people lacking adequate water for at least one month per year (World Wildlife Fund). With projected population growth, there will be an increase in demand for water in many sectors which will exacerbate the already existing water problems. By 2025 it is expected that that half of the world's population will be living in water stressed areas. More than a billion people do not have access to improved drinking water sources, most of whom live in rural areas (WHO). Improved drinking water sources are ones that are protected from outside contamination by nature of their construction or by active intervention (JMP). Although improved drinking water sources are meant to be protected from outside contamination, without proper monitoring of the water and treatment when necessary, contamination can still occur.

According to the 2010 census 92.9% of homes in Panamá have access to improved drinking water sources which is a large improvement from 1990 where the number was just 80.17%. The rural sector of Panamá however only has a coverage of 78.11% (See Appendix 1 for more information on water access in Panamá by region) (Ministerio de Salud). This discrepancy continues in the policies of water monitoring and improvements. In Panamá there are 5,135 rural aqueducts, 2,342 of which are supervised by Rural Water Management Boards (Juntas Administradoras de Acueductos Rurales or JAARs) (ANAM 2011). The JAARs are only equipped to treat the water with chlorine and to test the levels of chlorine in the water.

In a study done by the Ministry of Environment in Panamá in 2005 where 95 rivers were tested, 30% showed contamination and 60% showed slight contamination. When the same rivers were tested in 2010, 25% showed slight contamination and 10% showed contamination. This shows improvement in the water quality, but also shows that continuing testing and improvement should be done (ANAM 2011). In the National Plan for Integrated Water Management the Ministry of Environment states five different possible sources of contamination in Panamá, including discharge of waste water, discharge of solid waste and use of chemical products. Panamá has various technical regulations that have the principal objective of avoiding possible contamination of hydrological resources (see Appendix 2 for Regulations). The Ministry of Environment, ANAM has the responsibility of supervising these regulations (ANAM 2011).

A rural community in Panamá is defined as a community with a population of less than 1,500 people (ley 2 1997). In the Decreto Ley no.2 de 7 de enero de 1997, Article 10 sets out the responsibilities of the Ministry of Health in rural communities (see Appendix 3 for Artículo 10). Although Article 10 clearly states that Ministry of Health is responsible for promoting mechanisms for the management of water supply systems and advising municipalities, districts and groups of people in specific aspects of management and delivery of potable water, it is not clear who is responsible for the monitoring of the water quality in rural communities.

The Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) is an international organization that works in integrated water management among other disciplines. One of their specific objectives under the theme of integrated water management is to "provide countries in the region with tools and/or inputs for managing the quality and quantity of water resources" (CATHALAC). My internship project fell under this specific objective. My project goal was to evaluate the use of bioindicators and bioassays as techniques for water monitoring at the community level. There is a need for water monitoring in rural communities of Panamá as many water sources are unmonitored and untested. This is why my project is important in the region. This project has potential to be used as a reference if a water monitoring project was to be implemented in rural communities.

Types of Contamination

Contaminants can be defined as polluting or poisonous substances that make something (water) impure. Water can contain certain levels of contamination without being harmful. Drinking water contaminant can be broken down into four general categories: physical, chemical, biological, and radiological. Physical contaminants mostly impact the physical characteristics of water. Some examples of physical contaminations are sediment or organic material suspended in the water. Physical contamination is found most commonly in rivers, lakes, and streams, and is often caused by soil erosion. Chemical contaminants are elements or compounds that can either be naturally occurring or man-made. Some examples of chemical compounds or nitrogen and phosphorous often coming from fertilizers, bleach, salts, pesticides, and heavy metals. Chemical contamination can come many sources, such as industrial waste, and agricultural run-off (Environmental Protection Agency 2014). Chemical contamination can also be naturally occurring, for example arsenic which occurs naturally in soil, water and rock (Finnegan

2012). Biological contaminants are any microorganisms found in water. These microorganisms can be naturally occurring or can come from external sources, for example human waste. Some examples of biological contamination are bacteria, viruses, protozoa, and parasites. The final category of contaminant is radiological. Radiological contaminants are chemical elements that can emit radiation, such as cesium, plutonium and uranium (EPA 2014).

Effects of Contamination

Contamination in water can have a variety of health effects. Biological contamination can cause various gastrointestinal illnesses as well as hepatitis, meningitis and pneumonia (CDC, EPA). For example the contaminant Legionella can cause Legionnaire's Disease which is a type of pneumonia (EPA). Different types of chemical contamination can also cause health problems. For example, short term exposure to copper can cause gastrointestinal distress and long term exposure can cause liver or kidney disease (EPA). Arsenic can cause health problems such as cancer, and cardiovascular and neurological diseases (The Water Page).

Water Quality Tests

There are many different types of tests that can be used to monitor water. The three tests used in this project were an onion bulb bioassay, a lettuce seed bioassay and a coliform test. A bioassay is a test that uses living things, such as plants or insects that can be used to measure the toxicity of water (Cornell University). Plant bioassays can detect different chemical contaminants. Arsenic, a naturally occurring element inhibits plant growth therefore the bioassays would be able to detect elevated arsenic levels in water. Bioassays can also detect contamination by other heavy metals, nitrogen, and phosphorous. Coliform tests are used to measure the presence or absence of coliform bacteria in water. Although coliform bacteria are not dangerous to human, they are present in human and animal fecal matter, and therefore can be an indicator for potential harmful microorganisms also found in human and animal fecal matter. Since there are so many different microorganisms that can potentially contaminate water, testing for the presence of coliforms is a practical way of indicating the presence of other contaminants (Department of Health NY).

METHODS

The bioassay tests I chose to evaluate came from the AQUAtox program developed by the International Development Research Centre (IDRC) in Canada. In addition to the Lettuce Seed Bioassay and the Onion Bulb Bioassay, I chose to include a coliform test in the workshop performed at the school because of the high risk of diarrhoeal diseases when fecal bacteria is present in drinking water sources. The water used for all the tests was taken directly from the school tap. This water comes from a well on the school grounds and is not treated.

My project was done at a school called La Doradilla in the community La Feuillet in El Espino, Chorrera, Panamá. The school receives their water from a well on the schools grounds. This water is not treated. The rest of the community also receives their water from wells.

Lettuce Seed Bioassay

For the lettuce seed bioassay 20 seeds are placed in a Petri dish on a piece of filter paper that is saturated with water (Figure 1). The filter paper is saturated with water by transferring water from a collection container to the Petri dish lined with filter paper using a pipette. A different, clean pipette was used for each solution (positive control, negative control, and the sample). The positive control for this test is a 5g/L salt water solution which mimics the effects of contaminated water, inhibiting the growth and germination of the seeds. The negative control was bottled water, which is free from contamination and should allow the seeds to germinate and grow. After the seeds were placed on the filter paper the Petri dishes were covered and then wrapped in tin foil to provide the darkness needed for the seeds to sprout. The seeds were then left for 3 days to germinate. The AQUAtox methodology recommends leaving the seeds for 5 days for germination, but unfortunately because of time constraints with the schools schedules, we could only leave the seeds for three days.

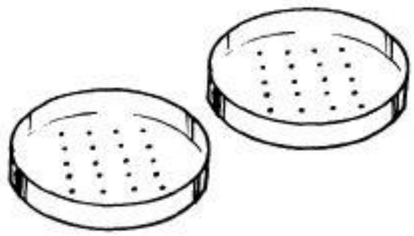


Figure 1: Lettuce Seed Bioassay

After the seeds have been left to germinate for several days, the Petri dishes can be removed from the tinfoil, so that the growth of the seeds can be measured. First the number of seeds that are sprouted for each solution are counted and recorded. Then for each sprouted seed the length from the nodule to the tip is measured and recorded (Figure 2). With these measurements, the average length for both the sample and negative control, percent change in root growth and percent change in sprouting are calculated (see equations below).

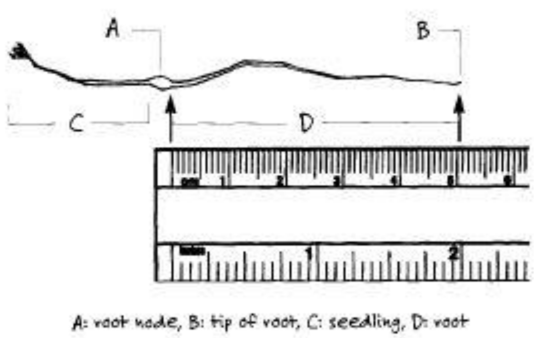


Figure 2: Measuring lettuce roots

$$Average\ Length\ =\ \frac{Total\ Length}{\#\ of\ Sprouting\ Seeds}$$

$$\% \, change \, root \; = \; \frac{Average \, length \, of \, sample - Average \, length \, of \, negative \, control}{Average \, length \, of \, negative \, control} \times 100$$

$$\% \, change \, sprouting = \frac{\# \, Sprouting \, seeds \, with \, sample - \# \, sprouting \, seeds \, with \, negative \, control}{\# \, sprouting \, seeds \, with \, negative \, control} \times 100$$

Onion Bulb Bioassay

For the onion bulb bioassay, 16 onions were used. First the onions were carefully cleaned. The outer brown layers of the onion skin was removed and the onions were places in a bowl with clean bottled water. The onions were then dried to remove excess water and were placed on top of test tubes labelled and filled with water which was either positive control, negative control or the sample water (Figure 3). Four onions were used for both the positive control and negative control, and eight were used for the sample. Similarly to the lettuce seed bioassay the negative control was bottled water and the positive control was a solution of salt water. However for the onion bulb bioassay the salt water solution used was 10g/L NaCl. The onions are then left for three days in an area with indirect sunlight to allow the roots to grow. When the water level decreases, the water is topped up using a pipette.

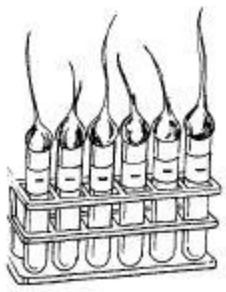


Figure 3:Onion Bioassay

After the onions have been left to grow for three days the onions can be measured. The onion with the shortest roots or the least growth is discarded from each group. Each root bundle on each onion is measured, excluding any exceptionally long or short roots (Figure 4). Then the average length of the roots for each test group is calculated as well as the percent change in root growth (see equations below).

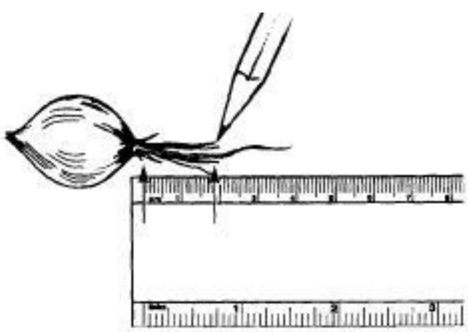


Figure 4: Measuring Onion Roots

$$Average\ Length = \frac{Total\ length}{\#\ of\ root\ bundles}$$

$$\%\ change\ in\ root\ growth\ = \frac{Average\ length\ of\ sample - Average\ length\ of\ negative\ control}{Average\ length\ of\ negative\ control} \times 100$$

Coliform Test

A coliform test was performed to determine whether coliform bacteria was present in the water. For this test, test tubes are provided in the kit and water is filled up to the line on the test tube. The test tube is then left upright for 48 hours. The class and teacher monitored the coliform test for colour changes and recorded their observations for the results to be evaluated later.

Implementation of tests

The bioassays and coliform tests were taught to 5^{th} grade students at a school in Feuillet, Chorrera, Panamá called La Doradilla. Before the beginning the instruction of the water quality tests, I gave an introduction on the importance of water, the meaning of clean water and the different forms of contamination. I then briefly explained some basic principles of scientific testing, including the importance of using different containers and pipettes to prevent contamination of samples, and the importance of including positive and negative controls in tests.

After the introductory information, we began the tests. Each step of each test was clearly explained to the students, with frequent questions asked to the students to ensure they understood how the bioassays worked and were set up. The bioassays were set up and the results were measured and recorded with student participation to allow a handson approach to learning. Every student had the opportunity to perform a step of at least one of the tests.

Evaluation of the classroom workshop

Each student was given a short worksheet to fill out where they answered questions about what they learned, whether or not they liked learning about the different water quality tests and bioassays and whether or not they would want to do them again. The teacher of the class also filled out a form and gave feedback on the workshop with the class.

All of the above methodology was completed in accordance with the ethics guidelines from the McGill Code of Ethics and TCPS.

LIMITATIONS

The onion bulb bioassay requires that you have rather small onion bulbs. In Canada and the USA these can be found easily in garden stores where you can buy onion bulbs for planting. However, in Central America most onions are grown from seeds, so small onion bulbs are harder to find. Larger grocery stores often only have very large onions. I was able to find some onions that were the right size in small grocery stores, but because of this size limitation I was not able to do a very large sample size for each type of water. The AQUAtox instructions recommend using 6 onions for each water sample, so that you can exclude outliers while still having a representative sample size. I used 4 onions for the positive and negative controls, and 8 for the water sample.

The ideal way to best measure the possibility of schools using bioassays to monitor the water quality in their area would be to have the class run the tests on their own, and then return to the school to review the results with them. By having the school run the tests by themselves, it would be easier to evaluate whether they could continue with the monitoring without further instruction. Unfortunately because of time constraints I was not able to do this. It would take more organization in advance and full support from the teacher and the school's administration to do this without disrupting the students' regular learning, or curriculum. Evaluating whether or not the class can run the tests is important because to be able to monitor water well, samples must be taken and taken throughout the year. Water quality can change very rapidly, especially in areas prone to high variations in weather (heavy rains), so the water must be monitored at several different times during the year, at different seasons and also if any contamination is suspected (after a chemical spill). In addition, running the tests alone would give a more accurate representation of the students' interest in the tests because having a workshop run by a guest teacher or lecturer is very different from the students' regular classroom routine and learning environment which can affect their enthusiasm for the workshop.

RESULTS

Bioassays and Coliform test

Unfortunately no seeds from any of the water samples (positive control, negative control, water sample) in the lettuce seed bioassay germinated. For the onion bioassay, none of the onion bulbs showed very much growth. The onions grown in the positive control salt water solution grew the least and the onions grown in the negative control (bottled) water grew the most. The growth between the negative control and the water sample from the school was very similar. For the coliform test, the teacher and students recorded their observations after 48 hours; the time needed for a coliform test. Their observations indicated that the water did not have a presence of coliform bacteria (yellow without bubbles), however when I returned to the school after 72 hours the test showed the characteristics of a positive result. I returned to the school and collected water for four more coliform tests to confirm the results. All four of these tests showed an absence of coliform (negative result) (see Figure 5 as a reference for determining coliform test results).

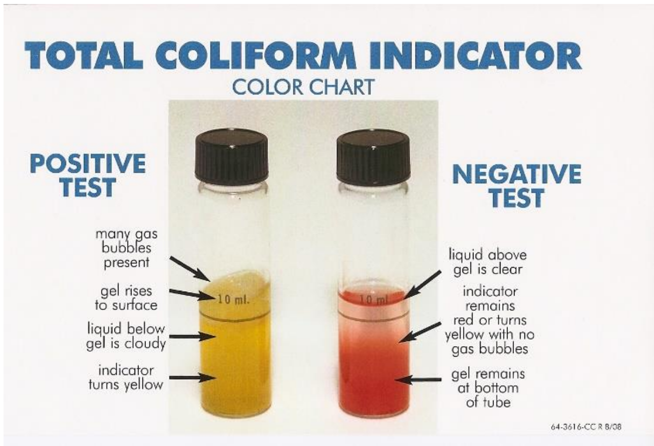


Figure 5: Total Coliform Indicator Reference Colours

Overall

Overall the workshop went very well. At the end of the class where we reviewed the results of the tests, each student received a worksheet with question about what they liked, what they learned and their willingness to do the tests again in the future. The teacher also received a feedback form with a few basic questions about the workshop and the bioassays.

In the feedback form from the class, every student said that they enjoyed learning about water and doing the tests. Also every student said that they would be interested in doing the class again. Some examples of the things that the students liked best were the bioassays, especially the onion bulb bioassay, the opportunity to take part in the tests, measuring the roots of the onions and calculating the variation, and seeing the water colour change in the coliform tests. Some of the main things the students said they learned from the presentation were the importance of water in the world, and the importance of clean water, the potential risks of contaminated water (adverse health effects), and the concepts and purpose of using positive and negative controls in scientific experiments and testing.

Vielza, the teacher of the class was very enthusiastic and positive about the idea of having a presentation on water quality and water monitoring using bioassays. She has previously worked in the Darien, and is accustomed to always boiling her water regardless of the source. In her feedback she mentioned that she thought the presentation was very successful and effective. She thought the students were very attentive and that they learned a lot from the presentation. She also wrote that she would like to more workshops similar to this one to further the children's learning, and that the workshop should include more information on water. When asked if she would consider continuing the tests with future classes, she said that she would.

DISCUSSION

None of the lettuce seeds sprouted. This may have occurred for several reasons including there being too much water in the Petri dishes for the seeds to sprout. However since not a single seed germinated in any of the Petri dishes the most likely reason is that the seeds were too old and were no longer viable. This could be prevented by buying new seeds. If the tests were being done more often it would be easier to know how old the seeds were. If a portion of the seeds in the negative control Petri dishes do not sprout that could indicate a need for new seeds. Since the seeds did not germinate in any of the types of water the data cannot be used/ had the seeds germinated in only the negative control then there may have been contamination present in the water, but since the negative control did not sprout no results can be concluded from this bioassay.

For the onion bulb bioassay the results were more difficult to interpret. While the onion roots did show growth, there was very little growth for any of the bulbs. Normally with more, if the calculated variation is greater than 10% then that can indicate possible contamination. A difference of more than 10% with the negative control shows greater growth than the sample indicates contamination of the water by a growth inhibiting contaminant, for example Arsenic (Finnegan 2012). If the water sample showed more growth than the negative control with greater than 10% variation between the two then there would be evidence of contamination from substances that aid growth such as phosphorus or nitrogen. These can also be harmful to human health similarly to growth inhibiting contaminants and often can result from runoff in agricultural areas. Since the onion bulbs showed such little growth, extremely small differences in growth can cause quite large percent change or variation values. The students helped measure the roots, and some of the roots were very small and difficult to measure. Therefore, a portion of the difference between the onions' growth may be accounted for by error in measurement. Although the variation was only 12.5%, which is greater than the rough contamination threshold of 10% Due to the similarity of growth and because the difference between the average lengths of the roots was less than 0.5mm, it can be concluded that the water does not show evidence of contamination that can be detected by the bioassays. The bioassays however cannot detect contamination by bacteria.

The original coliform test was left at the school for the class to observe the results. The characteristics they observed indicated a negative result however after 72 hours the test appeared to show a positive result. Four more samples were taken and the tests were taken to CATHALAC to observe the results. All four tests showed negative results. It is not ideal to perform more tests as coliform tests cost money, but it is very important to have clear results for the tests. A possible way of preventing this problem would be to take pictures of the tests at 24, 36 and 48 hours. This would provide a reference to analyze the results, and make it easy to review the results later. Coliform tests are very simple to perform, but also provide very important information about water. If water shows presence of bacteria it can be treated easily with chlorine or by boiling the water.

Although the project went very well, there are some factors to consider when reviewing the results. Since the workshop and the instruction of the bioassays were only done in one class at one school the sample size is small. It would be interesting in future studies to investigate whether other classes or other schools would have the same level of interest in the project and its potential for use as a way of monitoring water. Another factor that may have influenced the results of the project is that fact that I was a guest at the school. Guest lectures can make the workshop more special and unique. A workshop offered by a guest in classroom is outside of the students' regular routine and therefore could make them more interested in the topics covered. This is why it could be important to evaluate the receptiveness of a class to a similar presentation that is presented by the class's teacher. It is important that the students and the teacher are invested in the project and really care about the results if the bioassays are to be used as a means of water monitoring. If they are being used for water quality monitoring then the results of the tests are important, and the workshop and bioassays are not just a learning exercise.

The teacher of the class where I did my project mentioned in her feedback that she would like more information on water and more tests to be included in the workshop. My project was focused on the bioassays rather than environmental education. However if these tests were implemented in schools, teachers could use it as an opportunity for more environmental education regarding water and water quality. They could also bring up other topics related to water besides water quality, such as biodiversity in aquatic environments, water scarcity, and also topics not just related to fresh water, such as ocean acidification. In their discussions of water quality they could also teach the students more about the other effects of water contamination. My main focus was the direct effects on humans, like health problems since we were testing well water meant for human consumption. The teacher also was very supportive of having a presentation on water and water quality in her classroom. From her experience through working in the Darien she understands some of the problems that can be associated with unsafe or contaminated drinking water. She also always boils her water even though other people in the community do not necessarily treat their water. This enthusiasm may not be matched by other teachers in other classes or at other schools. Without full teacher support using these techniques to monitor water through schools would not be possible. This project did not get the community involved, but for a water quality monitoring system to take place it could be very beneficial to have the community involved.

IMPLICATIONS

The success of this project shows the opportunity for future projects and eventually the implementation of water monitoring projects using bioassays in Panama and around the world. Although the initial implementation of a large scale rural water monitoring program would need funding to be able to teach people the techniques and provide some of the starting materials, the costs of the tests outlined in this project are very low, and require very little investment in equipment. The bioassays could provide a very important indication of whether or not water in an area is contaminated. Even though the bioassays cannot determine what the contamination in the water is, it can provide communities with evidence of contamination so they can contact the Ministry of Health (MINSA) and further testing and proper treatment can be done. Despite the fact that the coliform tests are more expensive than the bioassays, they are still very important for monitoring water intended for human consumption, especially to prevent illness. As discussed earlier, coliform tests detect the presence of coliform bacteria, which are not harmful to human health but are found animal and human fecal matter. Human and animal fecal waste can have a variety of pathogens including various bacteria, protozoa, and viruses. Boiling the water is a very effective way of removing the pathogens. Other treatments, such as the addition of chlorine will not always effectively remove all the pathogens (CDC 2009).

Not only could the tests be used as a water monitoring technique but they could provide an opportunity to teach communities about environmental issues that may affect their areas, and places around the world. Many of the environmental issues currently faced are connected, such as deforestation and water scarcity and the most effective way of preventing environmental degradation is through knowledge and education.

RECOMMENDATIONS FOR FUTURE PROJECTS

As mentioned briefly in the discussion section, based on the results of this project there is potential for future projects similar to this one. One important future project would be to assess the feasibility of using the bioassays as water monitoring techniques through school on a larger scale. This project mostly focussed on assessing the potential interest and potential feasibility for the bioassays, while a future project could spend more time investigating the actual possibility of using the bioassays in schools. It could also include a test school that would run the tests several times throughout the year and give feedback on whether or not they would want to continue and how the tests or workshops could be changed to ensure continuation of the project. This project could also include a community aspect. It would be interesting to compare workshops given to adults to workshops give to children at schools. I think to ensure long term continuation of the water monitoring it would be important to involve the communities as well as the schools. Ultimately the testing does not need to be run through the schools, but having the schools involved could generate interest in the monitoring so that students get involved with the community project. If the testing is run through school then coordination with the schools to include the tests in their curriculum could be very effective in ensuring long term monitoring in the community. These projects could be done as future internship through organizations such as CATHALAC, however for a successful large scale implementation of these test as water monitoring techniques, more funding would be needed.

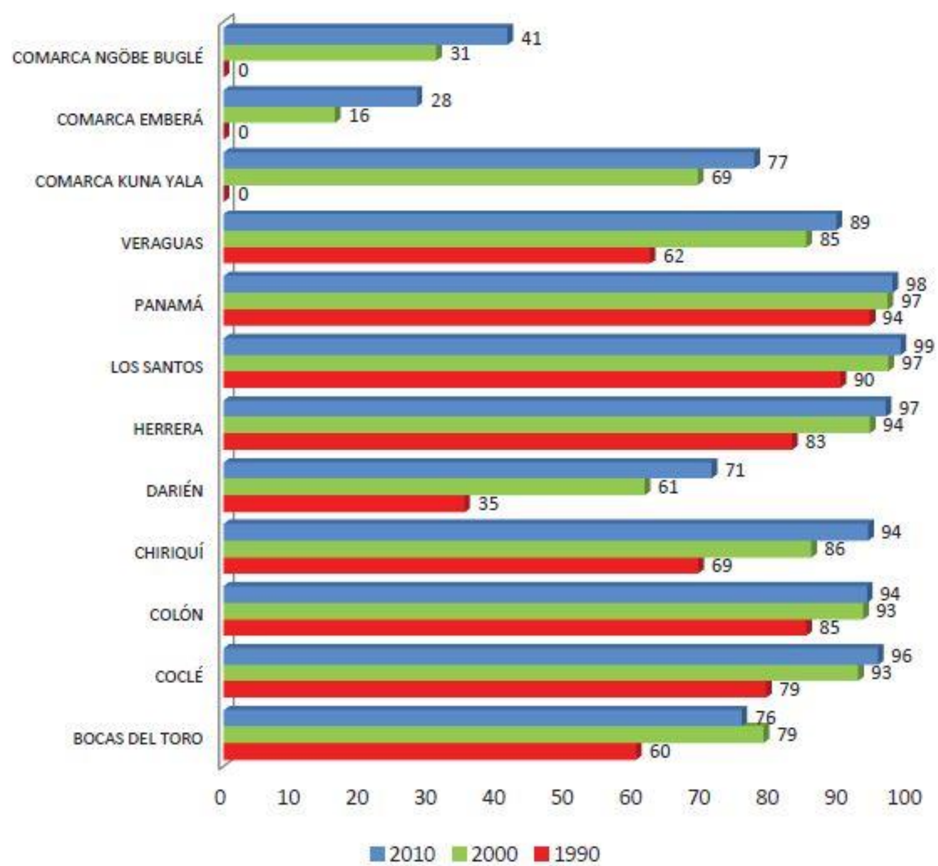
CONCLUSION

There is a clear need in Panamá and around the world for effective water monitoring tests that can be used in rural communities. Water quality affects everyone and can have serious adverse effects if the water is contaminated. CATHALAC recently did a project where they taught people to use equipment to measure water quality and how to interpret the results. Unfortunately when the project ended, the equipment was all collected and the communities did not have a way to continue measuring the water quality. Bioassays are a good option for testing because very little equipment is required and the materials are inexpensive. My project showed that there is an interest at least in the one classroom where the project was done for water quality testing. With further studies and projects, water monitoring programs using bioassays could be a fairly simple solution to the current lack of water monitoring in some rural communities in Panamá.

APPENDICES:

Appendix 1:

GRÁFICA 6: PORCENTAJE DE ABASTECIMIENTO DE AGUA EN LA REPÚBLICA DE PANAMÁ, SEGÚN PROVINCIA Y COMARCA: CENSOS DE POBLACIÓN Y VIVIENDA DE PANAMÁ: AÑO 1990, 2000 Y 2010



Fuente: Instituto Nacional de Estadísticas y Censo de la Contraloría General de la República de Panamá.

Appendix 2:

2.6.2. Monitoreo de la calidad del agua

Panamá cuenta con varias normas técnicas que tienen como principal objetivo evitar posibles contaminaciones del recurso hídrico:

- *Reglamento Técnico DGNTI-COPANIT 24-1999*: Reutilización de las aguas residuales tratadas.
- *Reglamento Técnico DGNTI-COPANIT 35-2000*: Descarga de efluentes líquidos directamente a cuerpos de aguas superficiales y subterráneas.
- *Reglamento Técnico DGNTI-COPANIT 39-2000*: Descarga de efluentes líquidos directamente a sistemas de recolección de aguas residuales.
- *Reglamento Técnico DGNTI-COPANIT 47-2000*: Usos y disposición final de lodos.

Source: Plan Nacional de Gestión Integrada de Recursos Hídricos de la República de Panamá 2010-2030

Appendix 3

Artículo 10. Comunidades Rurales - Funciones y atribuciones. Para los efectos de esta Ley, se consideran comunidades rurales aquellas con menos de mil quinientos (1,500) habitantes, con población dispersa y sin servicio de alcantarillado de alcantarillado sanitario.

El Ministerio de Salud, en las comunidades rurales, tendrá las siguientes funciones y atribuciones:

1) Formular los objetivos, las políticas y los planes de desarrollo para este segmento de la población;
2) Diseñar y promover mecanismos para fomentar la eficiencia y eficacia en la administración y gestión de los sistemas de abastecimiento de agua potable y alcantarillado sanitario en localidades rurales;
3) Promover la organización de las comunidades rurales como mecanismo de apoyo en la gestión y administración de sistemas;
4) Promover la ampliación y mejoramiento de los servicios existentes, así como la ampliación de la cobertura a nuevas comunidades;
5) Asesor y asistir técnicamente a los municipios, corregimientos, cooperativas, organizaciones no gubernamentales y agrupaciones de clientes en los aspectos específicos de la gestión y prestación de los servicios de abastecimiento de agua potable y alcantarillado sanitario;
6) Preparar normas técnicas de ingeniería para la construcción, operación y mantenimiento de sistemas rurales, así como normas relativas a la estructura y valores tarifarios; procedimientos administrativos y contables que deberán ser aplicados por los comités de salud, las Juntas Administradoras de Acueductos Rurales (JAAR) u otros prestadores rurales;
7) Diseñar los mecanismos para proveer asistencia financiera para la ampliación y mejoramiento de los sistemas existentes y la construcción de nuevos sistemas;
8) Llevar a cabo programas de educación sanitaria de la población; y,
9) En general, cualquiera otra función que le señale esta u otras leyes.

La construcción de obras de agua potable y alcantarillado sanitario en comunidades rurales serán ejecutadas por entidades públicas existentes, el sector privado o por las organizaciones no gubernamentales.

Source: Decreto Ley no.2 de 7 de enero de 1997

Appendix 4:
The class at Doradilla

Source for Figures 1-4: AQUAtox International Handbook

Source for Figure 5:

http://www.hydrotense.eu/WebRoot/StoreNL2/Shops/491664435/MediaGallery/coliform-data.jpg

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