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The Battle of the Water Filters: Environmental Justice AND Microbiology

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As part of our general biology course that includes a lab, students are required to partake in a group research project that results in a lab report and a poster. An intriguing and successful project was to have a "contest" to see which water filters worked the best. The students learned about Rita Colwell's experiment of decreasing cholera infection rates in Bangladesh by using sari cloth to filter the local drinking water. (She recorded a decrease of cholera by 48% in those who used the sari cloth.) Our students tested cotton cloth (T-shirt), denim, and a LifeStraw to filter water from the East River in the Brooklyn Bridge Park in New York City. They used nutrient and McConkey agar plates for their tests. The LifeStraw filter reduced bacteria ten-fold whereas there was no reduction in bacteria with the two types of cloth. This project could be used as an inquiry-based exercise with a focus on environmental justice in which students can simulate experiments that they might conduct while living in an area where the water supply might be compromised. We presented this poster before the disastrous flooding in Houston and devastation wrought by two hurricanes in the Caribbean, so a project like this might be apropos now more than ever.

Keywords: inquiry-based learning, water quality analysis, water filters, microbiology

Link to Original Poster: http://www.ableweb.org/volumes/vol-39/poster/?art=74

Introduction

Water quality in New York City has been compromised for a long time. We feel that students who grow up in New York City take clean drinking water for granted. After all, we have the best-tasting water in the country, according to many taste tests (and by us!). However, the bodies of water that surround us are less than pristine. A lawsuit against utilities dumping pollution into the Hudson River created the Hudson River Foundation (HRF) in 1981. This organization funds projects that attempt to mitigate pollution and understand living organisms and processes in this estuary. The HRF runs a striped bass tagging program, which has shown that the fish have returned to the river. The Billion Oyster project is an attempt to restore this mollusk to the river. However, Superfund sites still lurk, such as the Gowanus Canal, and Newtown Creek.

Nationally, water contamination exists as well. Balaze et al. (2012) found that there were higher arsenic levels in drinking water in certain areas of California that contained a greater proportion of people from disadvantaged backgrounds. We have also recently been haunted from the press by the high lead levels in Flint, Michigan.

Water supplies globally have also been in jeopardy. Our students have learned about water-borne illnesses such as cholera. Huq et al. (1996 and 2010) showed that old sari cloth (with its tighter weave) filters better than old sari cloth in Bangladesh. Students also learned that compliance is also a huge issue in public health---in other words, the citizens in a country have to actually execute the proper filtering project (Clasen et al. 2007). Often students do not understand that the easily curable diarrhea that occurs in their world is a large threat and is often the biggest killer in third world countries. They also do not know that the answer to "Why don't they just boil their water?" lies in economics. "They" either do not have or cannot afford to buy fuel with which to boil the water.

Worldwide, people are continuing to grapple with economical ways to filter water. For example, Ehaie et al. (2017) evaluated silver-embedded ceramic tablets as a way to safely disinfect water in a section of South Africa. Kallman et al. (2011) found similar results in rural Guatemala. They were able to do so with residual silver levels below accepted levels. A review study (Stubbe et al.

2016) noted that solar water disinfection (SODIS), ceramic filters, and biosand filters appeared to be the most widely used in developing countries, but that there was a wide disparity in how well they filtered water. Bai et al. (2013) conducted a fascinating study in which they elucidated the role that some of the microorganisms play in breaking down pollution as they form a biofilm around the sand grains in biosand filters. Even though these were the most economical, they noted that the filter must also be reliable for the people to use.

Poor people need to come up with ingenious ways to filter their water to protect against disease such as cholera that we in the USA do not encounter. We introduce the concept of environmental justice as being something for all, not just the rich. We should continue to provide interventions for people in extreme poverty, such as those in Rwanda. Rosa et al. (2014) introduced LifeStraw filters and improved cook stoves in an attempt to reduce the negative effects of water and air pollution. Using the filters, they were able to reduce fecal coliforms in the water supply of 121 households by 97.5 %. Additional studies of biosands, such as those by Thomson and Gunsch (2015), revealed that biosands take up to three months to develop biofilms that effectively filter cholera bacteria as efficiently as they do coliforms.

The Battle of the Water Filters project was an attempt to make students think about environmental justice in the world as well as in our city. In the process, they learned some key concepts in microbiology such as serial dilution and the use of selective media.

New Citizen-science Water Quality Project

Two students, Zanna and Maria Shapiro (they are two of triplets!) are participating in a project with Rob Buchannon in which water from various natural water bodies around New York City is being tested for enterococci. The IDEXX method is being utilized. Students collect the water from a beach in the Brooklyn Bridge Park and take it to the River Project where it is tested. The results are posted weekly on the New York Water Trails website. The testing began six years ago in response to a fire at the North River Waste Water Treatment plant in which sewage was inadvertently released into the Hudson River. This independent water testing by citizen scientists is hoped to bring transparency to any future water pollution problems. St. Francis College is aspiring to be a future testing site.

Many undergraduate students in introductory biochemistry courses find it challenging to understand how different levels of protein structure relate to each other. To address this problem, we introduced an inquiry-based laboratory exercise in which students are challenged to explain how the effects of mutations on different levels of protein structure lead to changes in protein function and ultimately to genetically-inheritable diseases. The implementation of this exercise in a large, second-year undergraduate, introductory biochemistry course led to a high level of student satisfaction and a more integrated view of biochemistry and genetics.

Selected Results

Figure 1. Results from coliform tests (Group 1) in which a simple plus/minus coliform test that works through a pH change if coliform bacteria are present. The samples change from red to yellow if coliform are present. Generally, the LifeStraw filtered better than the other filters the students devised.

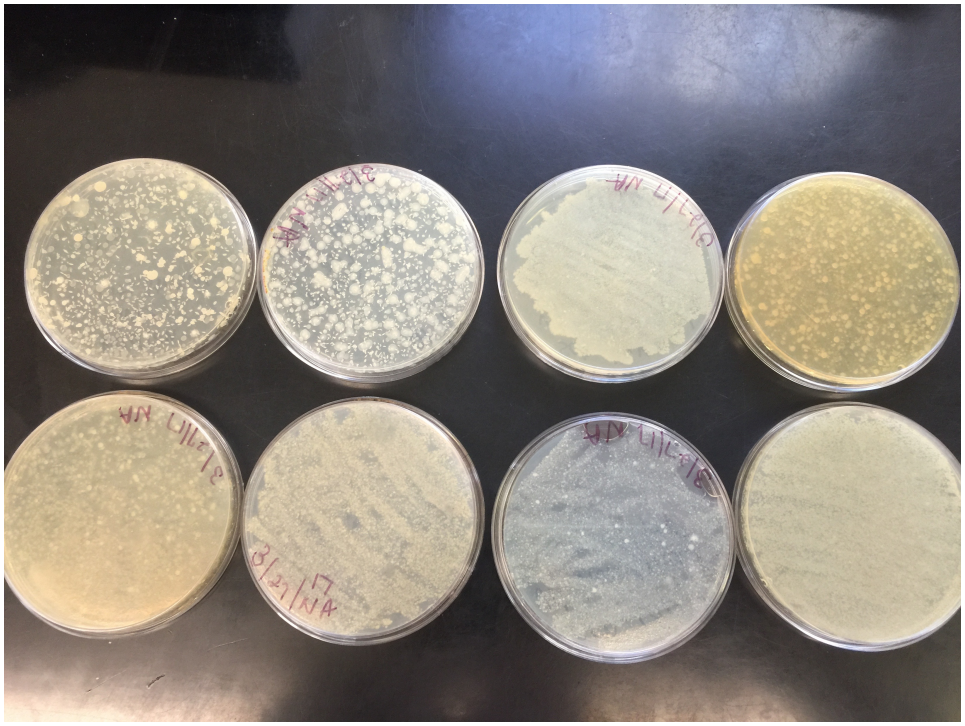

Figure 2. Nutrient agar plates with filtered and unfiltered water from various NY locations (Group 1).

Table 2. Some actual plate counts from Figure 2.

Filtered with:	Hudson River Cfu's	Prospect Park Pond—cfu's	Schroon Lake (NY)—cfu's	Twin Lake (NY)—cfu's
LifeStraw	25 lg. white 240 sm. white	104 lg. 400 sm. white	Too many to count	320 small
Homemade filter	350 sm. white	lawn	Too many to count	Too many to count

Top row---unfiltered
Middle row---filtered with cotton
Third row—filtered with denim

Figure 3. Water from Brooklyn Bridge Park on McConkey agar plates (Group 2)

Table 3. Plate counts from Figure 3.

Cfu's Nutrient agar unfiltered	**25 (10^{-3} dilution)**
Cfu's/ml Nutr. agar filtered w cotton T-shirt	23 (10^{-3} dilution)
Cfu's/ml Nutr. Agar filtered w denim	19 (10^{-3} dilution)

Student Outline

Objectives

Students will learn about environmental justice and water quality.
Students will learn how to prepare serial dilutions.
Students will learn about various types of water filters.

Methods and Data Collection

You will decide which filter type you would like to use, and which water sources you will collect from. Your instructor will assist you in:

a. conducting the presence/absence of coliform test using the LaMotte tubes. Follow the instructions for filling the test tubes with your water samples. Make sure you incubate the samples at the temperature noted for the time noted, which may be as long as 24 hours.
b. To do actual plate counts you will need to make serial dilutions of your water in nutrient agar so the cells of the proper tonicity. If you decide to use a LifeStraw as a filter, it will be necessary to blow the water through the filter (an alternate is to let it drip through slowly). If you are using cloth, you need to cut your cloth into measured squares and filter over a sterile test tube or beaker.
c. After you have made your serial dilutions, plate out 1 ml on each plate of the appropriate dilution. Incubate at 37 degrees overnight and count the colonies the next day. Appropriate media might be nutrient agar and or McConkey agar.
d. Make tables of your results, and discuss the results with your lab partner and instructors.

Materials

LifeStraw from LifeStraw Co.
LaMotte Coliform Test Kit: 4-3616
McConkey agar plates
Nutrient agar plates
Sterile nutrient broth to make serial dilutions of water.
Standard microbiological procedures

Notes for the Instructor

This project was a way to connect environmental justice to biology for the students. (There were no clear "winners" of which filter worked better, although the Life Straw generally fared better than cloth or gravel.) The students learned about the plight of people who do not have clean drinking water, and how we take our drinking water sources for granted. They learned how filters such as sari cloth can indeed reduce the incidence of water borne illnesses such as cholera in countries such as Bangladesh. They are challenged to create their own water filters, in addition to a LifeStraw, of which we tell them the story of how this company was founded (from their website). When they looked at the results of their own homemade filters they were puzzled as to why they did not work that well, at least on coliform bacteria, that was present in several unfiltered water samples. We asked them to generate a list of reasons why their filters might not work as well. We pointed out to them that Rita Colwell folded her sari cloth filters several times to produce the maximum filtering capacity. We drew out of them that perhaps gravel is not the best filter, as it might harbor much bacteria. This project laid the groundwork for future battles that might include additional types of filters such as the silver-embedded ceramic tablet of Ehdaie et al. (2017). This was truly an exciting "battle" that we hope we will be able to "fight" again next year!

The difficult thing about this project is trying to get the students to coordinate their schedules to do this project outside of lab, because sometimes it is necessary to check overnight results. We let them use their own types of filters in this "inquiry-based" exercise.

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