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A Genetic Approach to Designing a Novel Biological Sensor to Monitor Water Contamination

Cynthia Bui
Madison High School

Anissa Rosbaugh
Madison High School

Israel Gonzalez
Madison High School

Julie Lu
Madison High School

Colin Kuhns
Madison High School

See next page for additional authors

Presenter Information
Cynthia Bui, Anissa Rosbaugh, Israel Gonzalez, Julie Lu, Colin Kuhns, Joel Crandall, Alyssa Faulk, and Miriam Nguyen

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Maseeh College of Engineering and Computer Science
PORTLAND STATE UNIVERSITY

MADISON HIGH SCHOOL

Biomedical Sciences

Cynthia Bui, Anissa Rosbaugh, Israel Gonzalez, Julie Lu, Colin Kuhns, Joel Crandall, Alyssa Faulk, & Miriam Nguyen

Madison High School, Biomedical Sciences, Portland Public Schools, Portland, Oregon

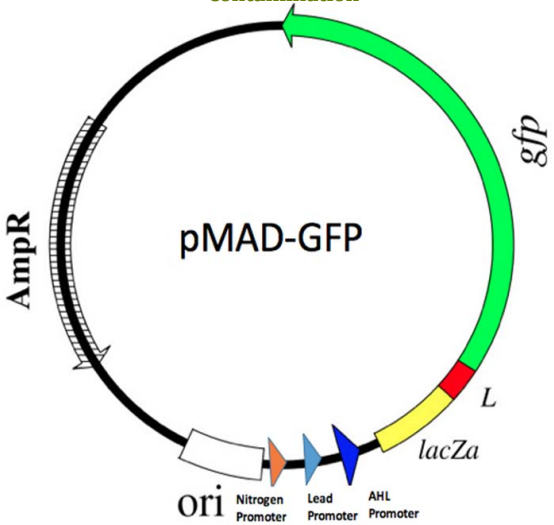
PROBLEM/OPPORTUNITY

Many cities across the country have experienced extreme water problems. The City of Portland has issued several water boiling advisories due to *E. coli* contamination. Additionally, there has been incidents of serious contaminants like lead leaching in water systems (Flint, Michigan). The Portland Water Bureau does not use a water treatment plant due to the quality of our water sources; a chlorination plant is used to chlorinate the water from the Bull Run Watershed (our main water source). Not having a water treatment plant makes Oregon more prone to a prolonged absence of potable water should the supply be contaminated. Up until three months ago, Portland had open reservoirs that exposed clean and treated water to the open-air environment, which allowed for recontamination. Despite those now being closed and not in use, Portland's water system still has various gaps where water can be contaminated.

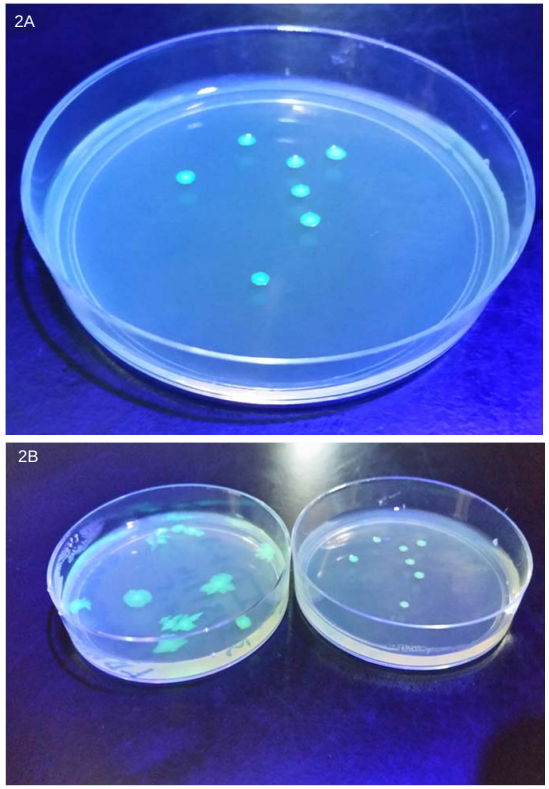
Portland's water usage peaks during the summer and tapers off just before kids go back to school. As a result of that decline in usage, a lot of water sits in pipes just waiting to be pumped to homes. The weather is still quite warm all the way through mid-September and possibly well into October. As a result the unused water sitting in pipes heats up with the weather and serves as a breeding ground for a plethora of bacteria and contaminants that pose putative short and long term health risks to the citizens of Portland.

The city is equipped to detect *E.coli* and other contaminants—although not as quickly as we (the Water Bureau and the citizens) would hope. As of right now, we still test for *E.coli* the basic way: grow it in a LB petri dish, which takes up to three days. Should another outbreak occur, more people will get sick before the Bureau can call a city-wide water shutdown. Our current system simply is not practical, nor is it completely secure.

Figure 1: Genetic method to detect water contamination



Figures 2A and 2B: Green Fluorescent Protein (GFP) expression of *E.coli* in the presence of arabinose.



THE OBJECTIVE

Our main objective is to equip the city with a precautionary system to better handle *E.coli* outbreaks as well as any post-chlorination contamination; there is no sensor in place to detect water contamination after it has already been through the filtration system. To address this problem we have devised a genetic strategy to putatively detect contamination in real-time using genetically modified bacteria. We have created a biosensor that detects phosphorus, nitrogen, and lead, as well as AHL, a signaling molecule that coordinates group activity among bacteria. By targeting these particular substances, we aim to make this system specific enough to counter any potential post-chlorination outbreaks while simultaneously remaining general enough to be applicable to other situations and locations.

THE MECHANICS

Our biosensor is mainly based on the concept of quorum sensing, a stimulus and response system used by bacteria to communicate about population control (Miller *et al.*, 2001). It uses a harmless strain of genetically modified *E.coli* to detect levels of nitrogen, phosphorus, and the AHL protein (a signaling molecule used to coordinate group activities among bacteria). On top of their naturally occurring AHL receptors, our modified bacteria have also been equipped with nitrogen and phosphorus receptor proteins (by the use of an exogenous signaling cascade). Thus, our *E.coli* has been genetically modified for transmitting transient water contamination to a stable fluorescence stimulus response in real time (Nasser *et al*., 2007).

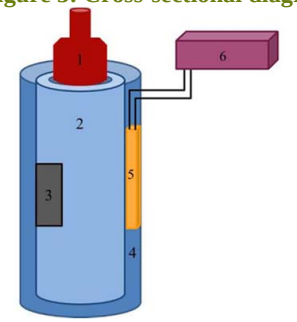
The biosensor we designed encloses the modified *E.coli* in a dark chamber, with a valve that lets a water sample in. Enclosed along with the *E.coli* is a fluorescence detector that quantifies the amount of emitted light—if it were to cross a specific threshold (which can be determined by the city), a wireless transmitter connected to the light detector signals the water bureau to be on alert for a possible contamination situation.

POSSIBLE APPLICATIONS

The system would be placed in strategic locations around the city—potentially at sample-collecting sites, as it makes use of a previously existing structure and will thus save the city money. Seeing as they would be dispersed around the city, the photosensors would be connected to a simple wireless radio transmitter. The wireless transmission will allow for real-time sensing, which will prevent the spread of contaminants and help keep our city safe.

We also chose to make this system detect general contaminants in order to make it more applicable on a larger scale. With the increasing amount of water-related problems, we wanted to try and find something that would work in most places. Our system can also be used to detect excessive fertilizer usage (as nitrates are commonly found in fertilizers), as well as warn the public of possible lead contamination. In this manner the biological sensor can accommodate a multiplicity of uses in major urban water systems in Portland and beyond.

Figure 3: Cross-sectional diagram of a biosensor



1. Water valve (can be found at sample collection sites)
2. Chamber interior
3. Internal water-activated *E.coli* chamber
4. Exterior wall
5. Photosensor
6. Wireless, long distance radio transmitter

LITERATURE CITED

1. Miller MB, *et al.* Quorum sensing in bacteria. Annu Rev Microbiol. 2001;55:165-99.
2. Nasser W, *et al.* New insights into the regulatory mechanisms of the LuxR family of quorum sensing regulators. Anal Bioanal Chem. 2007;387(2):381-90.