Problem Statement:

Many regions in the United States put their citizens at risk by providing contaminated drinking water. In many cases, such a problem can go unnoticed for months, even years, at which point there is no way of knowing how much damage has been done. Knowing this, our group attempted to answer the question: how might we identify regions in the USA with unsafe drinking water in an unintrusive, economically-feasible way?

Water contaminants are not always obvious. Unsafe water can be used for years before contamination is detected. Because of this, health problems as a result of unsafe water can have plenty of time to develop, and by the time the cause has been discovered it is often too late for cases like lead poisoning. Early detection of water contaminants with deleterious effects could minimize health risks. This is especially important for lead, as there is currently no known cure for lead poisoning.

The water crisis in Flint, Michigan is not an isolated incident. An NBC article found the ten worst cities of water contamination, most of which were on the east coast. Many of the cities had unhealthy levels of lead and arsenic, and others had chemicals from herbicides, hazardous radium isotopes, and uranium (McIntyre). These cities are homes to millions of people, and they are being poisoned by their own drinking supply.

What is more concerning is the lack of public knowledge, especially because officials have previously withheld information, just like in Flint, MI and there is now a mass distrust in officials. A New York Times article pointed out several cases where months passed before citizens were alerted that there were contaminants in the water. One such case occurred in Washington DC where residents had been drinking as much as twenty times the federally approved level of lead for over three years. It also mentioned how, despite a decades-old ban, there are still millions of lead pipes used to transport water (Wines). In another worrying situation, a New Jersey town tested its water and only found two homes with lead above safe levels. However, a few harsh winters later, the town was checked again, and almost half the homes tested had incredibly high lead levels (McIntyre). Chlorine from the road salt had gotten into the water supply, corroded the pipes, and allowed the lead to enter the water supply. It has become significantly less common to test for contaminants once the water leaves the treatment plant.

This oversight could be happening in more than just this town. The Associated Press and other news organizations had been trying to gain more information about the complaints and pollution regarding the gas drilling in Pennsylvania in 2011 when the Pennsylvania Department of Environmental Protection stonewalled them (Begos).

Without data to back communities up, ordinary citizens have no leverage against the government and existing water problems may never be fixed. It was an independent research group that first discovered the problem in Flint, not the government or the citizens.

Contaminated water supplies cause a myriad of costs to society; each possible contaminant can cause several health problems. Long enough exposure can even cause chronic conditions like Legionnaire's disease, which can require a lifetime of care.

Reasons for contaminated water can range from outdated infrastructure, unusual weather patterns, corrosion of pipes, environmental factors, and negligence, etc. Causes of contamination are specific to chemicals and condition, which makes preventing the problem difficult.

Access to clean water is a basic human need. Addressing this issue would help get one step closer to that goal. There would be a greater faith in the water supply, and more accountability for the government. Families would not be dependent on bottled water or boiled water.

Works Cited

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McIntyre, D. "10 U.S. Cities with the Worst Drinking Water." *Msnbc.com*. NBC, 03 Feb. 2011. Web. 13 Feb. 2016.

Wines, Michael, and John Schwartz. "Unsafe Lead Levels in Tap Water Not Limited to Flint." *The New York Times*. The New York Times, 08 Feb. 2016. Web. 13 Feb. 2016.

Proposed Work:

One of the causes behind the Flint water crisis was that the government officials ignored the complaints of the consumers regarding the water quality and appearance. This led to the problem snowballing into a very big issue of water quality which was discovered only when volunteers from Virginia Tech looked into the matter. Our goal is to identify regions of unsafe drinking water in the US through periodic tests of water quality, in the homes of users. Then we would provide the data to researchers so that action can be taken in the initial stages of the problem when it is less complex and can be cured faster. The water sensors we propose to design will be strategically placed across homes in a city and will conduct periodic tests for water quality. That information will be uploaded to servers for researchers to analyse.

Objectives:

Hardware

The first objective is to develop an effective sensor array which is capable of measuring water quality based on certain properties. Returning to our problem statement, we have concluded through research and discussion with experts that the best way to unintrusively collect water quality data is through an automated system. Water quality matters because issues in water, when identified early, can often be solved with little or no harm to the people drinking it. When these problems are left untreated, they can affect thousands of lives in a negative way. For example, the Flint, Michigan water crisis could have been prevented had there been further investigation into water quality when reports of issues first began. This would have saved lives and prevented lead poisoning in some of the residents of Flint. Effectiveness of the sensor array is characterized by low cost, accurate readings, relevant data, low power demand, and ease of use/reliability (especially with respect to calibration). We believe that low cost can be maintained by investing in open-source, commonly used sensors such as those that measure the pH of water or detect changes in color like those that would occur in chemical tests for traces of lead. Accuracy can be accomplished by refining the sensors, as well as filtering out static in data and quantifying sensor error. In addition, by performing sensor calibration at appropriate times, we can help prevent some error that may be present. Relevance will be attained by using sensors and tests to provide researchers, and in particular homeowners with the data that is most useful to them in identifying poor water quality. For the power source, we are looking to develop a rechargable battery pack that runs off some type of hydroelectricity, be it from pressure change or a water turbine or some other source. Most likely, the type of hydroelectricity that we use will be determined by the location of installation, which we haven't finalized yet, and the end design. Ease of use can be brought about by very little maintenance from the owner. In other words, the owner would not have to prompt the system to make measurements or do any non-crucial upkeep.

Software

The second objective is to develop a phone app that can connect wirelessly to the device and provide real-time and trend data to the user from their paired sensor device. The phone app is important because it provides our interface between sensor and user in a way that most people have access to and can easily understand. In addition, it can provide a system to notify the user that there is something that needs their attention through push notifications. This is necessary since it is our way of conveying data to the homeowner, who may not be as well-versed in the technical aspects and thus unable to understand the data that we are providing to them. A very integral part of our design sprung from putting information back into the hands of the general populace, so giving them this information in a comprehensive user interface is key to the success of our idea. In order to bring this about, we will need to develop screens for an app, and then beta-test them with focus groups to determine the most effective form of the app. From there, we will have to go on to coding, where we most likely will need to bring in a

Computer Science major since none of our team's current members are well-versed in app coding. Ideally, the app will be developing over time, and even after we have released the first version we will be making updates and additions that increase ease of use as well as the amount of data that people have access to. The success of the app will be determined over time, as we cannot make one design and stick to it without making any revision. However, success will be determined in part by the actions that homeowners take if the sensor is picking up unsafe measurements. If people take action by themselves and use the data provided by the app to support their argument that their water is not safe, we will have succeeded. Our biggest challenge here will be creating an app that people actually consult and use, and not just delete after a couple of months.

A similar but separate objective to that of the app is the creation of a database containing anonymous data from our sensors. This database is a necessity for creating a regular access point for the data gathered from our device. One of the largest problems facing water quality research is the lack of data available to researchers. It should have an intuitive interface and be comprised of easily read, informative infographics, as well as downloadable spreadsheets that contain all the individual raw data points for more in-depth analysis. This data should be capable of being organized and downloaded at various regional levels, from municipality to county or state. Our measures of the success of our database would be page visits, download count, and positive feedback from users - which would primarily be researchers. Points of difficulty in developing the database will come in deciding what data we have to include and finding a way of presenting it to researchers that is coherent.

'People' - Legal, Political, Marketing, Finance

Another objective we have is in the actual marketing of the product. The overall success of our project relies on relatively large-scale installation of the device, and the only way that we can attain this is through effective marketing. When it comes to this front, we have not done much research or planning towards the public relations with our product, however we do have some baseline points to look at further. We need to reach out to researchers and NGOs about potentially funding or subsidizing some of the production of our project. In addition, we could potentially use NGOs as a means of broadcasting what we are doing and spreading the word. We face a significant amount of obstacles here, especially since we are engineers and not necessarily the best at the business and marketing side of the project. This will definitely be a learning experience for us that we will have to develop as we go and get advice from on a lot of people. We need to convince people that our sensor array is something that they need, and that might not be obvious from the get-go. Success in this field is easily measured by having a relevant amount of sensors out so that we can get enough readings to provide meaningful data to researchers and detect trends that may be occurring in a specific region.

Our last objective deals more with policy than our actual device. We want to make sure that we are able to maintain a low cost option even if other companies decide to make more expensive versions, as well as make sure that we are not stepping on any government toes. The first portion can be attained through patenting a design, which will allow open access to our idea but without an outsider being able to make significant profit off of it to the detriment of the general population. The second portion comes about more through maintaining contact with the government so that they understand we are not trying to undermine their authority but rather act as third-party between the providers of water and the consumers of water so that there is transparency in the quality of water from start to finish. Challenges arise here in our understanding of existing laws and policies, but by talking to the right people we can overcome these difficulties.

Project Team:

In Team HydroGauge, we have seven students, in addition to the possible inclusion of one student later on. We have two Biomedical Engineers, one Biology major, one Electrical Engineering major, one Civil Engineering major, one Aerospace Engineer, and one Mechanical Engineer. The student we may include later on would hopefully be a Computer Science major, due to the possibility of a need for app programming and construction.

We anticipate that our two Biomedical Engineers can contribute their knowledge of chemistry, and medicine, while also contributing to user interface, as well as personal relations. This knowledge is important because for our project, we need to be able to understand the effects of lead contaminated water, as well as the chemistry involved in testing the water for this lead. We plan for our Biology major to contribute her knowledge of human biology, while also contributing to user interface and personal relations. This knowledge is also important for our project because it adds to our knowledge about the effects of lead on the body, as well as user interface and personal relations are very important aspects of a successful team. We anticipate our Electrical Engineer can contribute his knowledge of sensors and embedded systems so that he can work with the technical side of our product. Also working with the technical side of our project is our Civil Engineer, who can contribute her knowledge of infrastructure and water systems. This knowledge is crucial to our team because our main solution to our problem consists of sensors, embedded systems, and infrastructure, therefore it allows us to create a technically accurate and innovative device. We expect our Aerospace engineer can contribute her knowledge of fluids, as well as her enthusiasm for the project and the water crisis. This knowledge is crucial to our team because we are working with water. Also, enthusiasm for working with the water crisis is essential to our success because it leads to dedication. We anticipate our Mechanical Engineer to contribute his knowledge of hardware, as well as contributing to user interface. This knowledge is also crucial to the technical side of our project. Since we have decided to move in the direction of an app, in addition to our in home sensor, we anticipate having a lack of knowledge in the programming aspect of the app. To fill this lack of knowledge, we would expect to include a new member on to our team that shared our enthusiasm for the project, as well has the knowledge to help program and work with the app.

In addition to our team members, we have identified three individuals that would be very helpful moving forward with our project. Dr. Aral, a professor here at Georgia Tech, has already been very helpful with giving us knowledge about sensors, as well as water quality issues, and we anticipate continuing to work with him to get more information about our project space and our possible solution. Susan Davis, of whom we have also had contact with already, has shared her knowledge of the water crisis, and she is also very knowledgeable about solutions that will work and solutions that won’t work, so we anticipate that she would be helpful moving forward with our project. Lastly, we have identified Christian Braneon who works for the EPA to hold knowledge that would be very helpful moving forward with our project. The EPA will have a lot of knowledge about water quality, and any connections with them will be helpful to us.

Timeline:

February 2016
-Begin exploring limitations of Arduino microcontroller and identify useful sensors.

September 2016
-Have a prototype sensor array ready for testing and development.
-Begin designing installation unit.

October/November 2016
-Continue testing and refine prototype and sensors.
-Begin prototyping installation package.
-Begin app development (possibly bring in a CS specialist).

December 2016
-Begin testing across multiple locations and database uploading.

February 2017
-Begin developing and refining the product based on public feedback.

March 2017
-Talk to data experts at Georgia Tech and continue to refine our database system.

Budget:

Materials and supplies is expected to total, at most, $2000 for prototyping and testing over two years. As our project is centered around an electronic device, we only need one unit of each sensor we test because they can be reused/recombined with different devices as our testing and prototyping necessitates. The expensive part of creating our device will be testing its reliability. Because it will be testing water in pipes in houses, we will need to be able to simulate the conditions of the water and control the properties and makeup of the water to ensure our sensors are measuring properly and our device is functioning as expected. Also, when we reach the stage of larger-scale testing, such as installation in several buildings, the cost per sensor decreases when they are purchased in bulk.

We do not plan to purchase services because the resources at Georgia Tech and our team's skillset cover the needs of our solution's development.

We also plan to attend a conference in Orlando, FL in the fall of 2017. The total cost of travel is expected to total $7000 including the cost of attendance and housing for our 7 members.

Expected Outcomes and Future Directions:

After this project is over, we expect to develop a system capable of monitoring water quality and having the data regarding the water quality for an entire region. This would help researchers to detect and possibly predict any drop in water quality. This would also provide researchers and citizens complaining about the water quality with data to back their claims instead of leaving them helpless when asked for any proof to support their arguments.

This system, on implementation, would therefore encourage the water filtration plants to do a better job as far as water filtration and distribution is concerned. This will also enable us to detect any defects in the pipe system of a certain district, which would be caused in case the water quality of that certain district is significantly lower than the surrounding region.