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$15,000 "Eat it!" Lemelson-MIT Student Prize Graduate Winner

Electrochemical Water Purification Technology, Chlorine Generator, and Real-time Water Quality Monitoring

The Challenge: Access to clean, safe drinking water is a growing issue in the United States and around the world. Currently, there are two billion people globally without access to safe drinking water and every day 800 children die from waterborne illnesses.[1] As our population increases, this issue will continue to grow as well. It is imperative that new water quality systems are created in order to combat the current failing water infrastructure in the U.S. and globally.

After the Flint, Michigan lead contamination crisis in 2014, 60% of U.S. residential consumers had increased water quality safety concerns and 22% made more of an effort to purify their water.[2] As higher levels of contaminants are being discovered and infrastructure continues to degrade around the country, ensuring the provision of clean water will inevitably become a decentralized responsibility. The situation is not specific to Flint. In 2017, more than 50% of major water treatment plants were in noncompliance and 37% of violations were from total coliform, a fecal bacteria, in water.[3]

In the current U.S. water treatment paradigm, ground and surface water is pumped to a municipal community water system where it is filtered and disinfected, and then pumped through a distribution network of pipes to residential and commercial buildings. Consumers use this water for drinking, cooking, and showering, and then it is fed to the waste system and discharged back into the ground and surface water. Oftentimes this discharged water is contaminated with volatile organic compounds and other toxins, metals, pathogens, and further contaminants that have made their way past the municipal treatment plant, leached into the water from the distribution system, or have been added from consumer waste and disposal. Concerns over lead solubilization (such as in Flint) that may be exacerbated by low pH, causing chlorine depletion and pathogen growth, have recently added to the overall interest in water quality and monitoring technology. The existing monitors widely used in water treatment

[1] http://www.ipsnews.net/2017/07/2-billion-people-dont-access-clean-water-opens-fissures-inequality/
[2] http://reports.mintel.com/display/748104/
[3] https://www.pnas.org/content/115/9/2078

plants in the U.S. require liquid chemical reagents and regular maintenance. The need for off-the-shelf, inexpensive and robust sensors for real-time wireless communication is evident, so that treatment plant operators and ultimately homeowners can avoid future catastrophes.

Another concern to municipalities and homeowners is the ability to disinfect both drinking water and pool and spa water efficiently and inexpensively. Homeowners and operators have to worry about testing, buying, and adding chemicals for disinfection. This is inefficient, maintenance heavy, and costly. In addition, municipalities by law have to chlorinate water so that pathogens cannot grow inside a distribution piping system to peoples' homes. Currently, municipalities disinfect at the outlet of the treatment plant with chlorine that is typically not generated on site, and oftentimes is either at levels too high or too low at different points in the distribution pipe system. Municipalities need to find a better way to dose chlorine in distribution systems to reduce pathogen growth and keep people safe.

The Solutions: Julie's primary invention is an electrochemical water purification system that uses low levels of electricity to purify water faster and more efficiently than conventional treatment methods. This electrochemical technology uses electricity to zap contaminants in water through advanced oxidation reactions. The technology disinfects pathogens, destroys organic contaminants, removes metals, and normalizes pH to produce truly clean and safe water. This system is currently being deployed in residential and small community pilots around the world as part of Julie's startup, Aclarity, LLC.

Figure 1: Electrochemical Water Purification for whole house use.

Julie also led a team to co-invent a real-time water quality monitoring solution that can be integrated into the electrochemical water purification system. Julie's primary invention, coupled with her invention for real-time water quality monitoring and automation, is the first miniaturized, decentralized treatment plant for buildings to protect against growing water quality issues. This technology is changing the current paradigm of water treatment by potentially freeing modern society from the need to conduct all water treatment at a centralized location, and providing a comprehensive treatment option that conserves water, reduces waste, and saves energy.

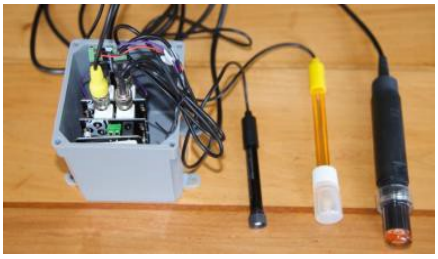
Figure 1: Wireless Real-Time Water Quality Monitoring.

Compared to conventional water filters that catch or concentrate contaminants into a brine, Julie's primary invention chemically destroys contaminants like bacteria and carcinogens, and precipitates metals, which can be recycled. This reduces pollution and does not waste water in the way that membrane technologies do with brine. Because the device only turns on when water is running, this significantly saves energy compared to technologies that need high pressure or ultraviolet light, which is on constantly. The key anode material has a lifetime of years as opposed to months, which

eliminates maintenance and conserves resources. Plastic and metal pieces are being optimized for reuse and recyclability. Moreover, a majority of the current in-home treatment systems on the market only involve one treatment process relying on a single selective removal mechanism (e.g. Brita), frequently need replacing and/or maintenance, have high lifetime costs, are not controlled based on water quality, and do not provide real-time monitoring or a combination thereof. Julie developed the electrochemical residential products with these key concerns in mind.

Relatedly, Julie's secondary invention is an on-demand electrochemical chlorine generator that utilizes low levels of electricity and can be powered by a solar panel to produce chlorine on-site, using about 4.7 times less electricity than generating conventional liquid chlorine for disinfection. This technology has the potential to disrupt both the municipal disinfection and pool and spa market based on its significant chlorine generation. The end result is a product that generates chlorine on-site, regulated by Julie's water quality and monitoring sensors device. This technology would alleviate the burden of transporting chlorine liquid or gas, testing, purchasing, and adding chemicals, thereby resulting in cost savings, reduction of environmental footprint, ease of maintenance, and increased safety for municipalities.

Figure 2: Electrochemical Chlorine Generation.

Commercialization: Julie's electrochemical water purification system is patent pending and the technology is available through an exclusive license through her startup, Aclarity, LLC, of which Julie is the CEO and Co-founder. Although primarily focusing on commercializing in the U.S. residential market, this technology could also be used to treat drinking water at low cost and maintenance at the municipal size, at contaminated waste sites, schools and office buildings, for disaster relief, and remote off-the-grid locations with solar panels. This invention has the potential to change the face of water treatment and provide millions of people with truly safe drinking water. Aclarity is currently developing partnerships with industry leaders to pilot, manufacture, and distribute whole-house point-of-entry and under-the-sink point-of-use devices to supply stores.

Julie's electrochemical chlorine generation has numerous potential market applications, including pools, spas, and municipal disinfection. Aclarity is researching potential companies that would be interested in partnering to manufacture products to meet the specific market needs. The device is currently in the design and prototyping phase for piloting. Lastly, Julie's water quality monitoring sensor has two promising markets for commercialization: municipal water quality monitoring in distribution systems, and residential tap water quality monitoring and detection.