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Solar-Powered Desalination Systems for Off-Grid Water Production in India and Gaza and Usage Sensor for Household Water Treatment Devices

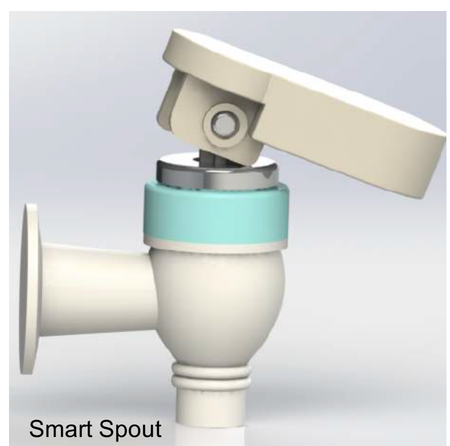
The Challenge: Thousands of children die from the poor biological quality of water sources and the absence of effective water treatment in India despite the availability of biological water filters. Natasha observed that even people who had access to such filters weren't always using them because they were at least as concerned with the taste, smell, and appearance of their drinking water as with its biological purity—but the filters do nothing to improve the water's appeal. Fully 60 percent of India's groundwater is too salty for drinking or agriculture. When Natasha traveled to India, she routinely met people who complained about high salinity making their water taste salty and ruining their cookware. Brackish water also causes increased coughing, severe stomachaches, and kidney stones. Clearly, removing biological contaminants wasn't enough; a water treatment plant needed to include desalination.

One-quarter of India's people live in villages of 2,000 to 5,000 people. Village-scale desalination plants typically use reverse osmosis (RO), which pumps water through a membrane. All the energy consumed by small RO plants goes into pumping. Most small pumps are less than half as efficient as those in large plants, making energy consumption per unit of water much higher, and RO only treats 30 to 60 percent of the feed water, leaving much waste water for disposal. Despite these inefficiencies, companies and non-governmental organizations (such as Tata Projects) have created a sustainable business model that enables them to sell affordable water where reliable power is available to run their RO plants. However, most small villages lack reliable access to electricity. Tata would love to reach the large market of underserved off-grid communities, but adding a photovoltaic (PV) power system to their existing RO plants more than doubles the capital cost and makes their water unaffordable.

Aesthetic questions aside, 1.2 billion people drink microbially contaminated water. Household water treatment and safe storage (HWTS) devices can greatly alleviate this problem, but only if people use them consistently. HWTS providers rely on user surveys to gauge how frequently households use the devices over time. However, we all tend to exaggerate our socially desirable habits. The same impulse that tempts people to fib to their dentists about their flossing habits leads people to tell HWTS distributors what they want to hear, throwing survey results off by as much as 300 percent. Big-picture data about how usage varies over time and with the seasons, as well as within a family, village, or country, is built up from these individual surveys. Knowing that their foundational data is unreliable leaves the industry guessing about how to improve HWTS usage.

The Solution: Natasha's lifelong habit of questioning assumptions to better solve practical problems such as desalination led her to a 1950s-era technology called electrodialysis reversal (EDR) that could address the RO energy problem. No one had ever tried to use EDR for small, off-grid desalination, so no one had looked at what an optimal EDR system would look like or how it should be set up for easy maintenance by villagers with minimal training. EDR is a simple, robust technology that removes salt by applying a voltage to water rather than forcing it through a membrane, largely bypassing pump inefficiency. EDR uses anywhere from 30 to 75 percent less electricity than RO depending on the feedwater salinity and the purity desired. To remove 2,000 mg of salt per liter, a PV system costs half as much for EDR as for RO, making it economical to run desalination plants on solar power where the electric grid is spotty or absent. EDR also recovers 95 percent of the feed water, reducing waste by a factor of 10.

Another one of Natasha's inventions helps to measure actual HWTS usage, rather than relying on the honesty of user reports. The measurement of HWTS usage would greatly improve the statistics that distributors need to understand why people stopped using the devices and to develop more effective training programs in response. The only sensor currently marketed for this purpose measures water flow directly. It's bulky, expensive, and energy-intensive. Natasha's team realized that distributors only need to know when a HWTS is activated and for how long. A simple tilt switch that records how long the spout handle is depressed would suffice. Her resulting Smart Spout is more than 10 times cheaper and dramatically smaller than the aforementioned flow sensor. It fits easily into the spigot of a HWTS, it lasts more than a year (versus the previous device's four-week lifespan), and syncs wirelessly with a smartphone.


Smart Spout

Application and Commercialization: Natasha set up a small prototype in her lab to validate the EDR model's potential. At the same time, the U.S. Agency for International Development (USAID) announced its Desal Prize for the same goal. She promptly applied and turned her prototype into a full-scale system in under five months. Her team placed first out of nearly 70 applicants, winning the $140,000 prize and an additional $150,000 to build a pilot plant in Jalgaon, India. The pilot plant has been supplying water to a hydroponics facility since January 2016. Meanwhile, USAID's Middle East Mission and UNICEF asked her to test a system in Gaza to understand the different design requirements and constraints imposed by a heavily populated, war-torn region. Tata Projects, interested in adding EDR to its village-scale product line, is also funding the group's future research. USAID funded the installation of their first in-village test system, in conjunction with Tata, in January 2017. Tata plans on commercializing Natasha's technology to reach the 300,000 villages with intermittent power. Selling water and taking advantage of their existing service and maintenance programs covers their full cost.

Smart Spout technology is currently at the demonstration phase, with the goal of testing 500 units in Ghana in the next year.