Prospectus

A combined process for waste treatment and drinking water production (Technical Topic)

Overcoming the "yuck" factor: public trust surrounding potable reclaimed water (STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Water, both the issue and the problem

Water is an essential human need. While only a daily average of 2.7 liters of drinking water is needed for the body to function optimally, water is also used for other purposes such as sanitation and hygiene activities and industrial processes (Mayo Clinic, 2020). However, water scarcity is becoming an increasingly dire threat to many communities around the world. The UN predicts that by 2050, 6 billion people will suffer from water scarcity (Boretti & Rosa, 2011). While the intensity of water scarcity fluctuates throughout the year due to seasonal changes in the weather, the problem is only getting worse due to climate change's effect on the severity and frequency of droughts in much of the world.

Nowhere is this problem worse felt than in communities in sub-Saharan Africa (SSA). SSA has the most countries of any region in the world which suffer from water scarcity issues (Tatlock 2006). On top of this, only 24 % of the region has reliable safe drinking water services (Souza et al., 2018). Water scarcity isn't the only factor that has contributed to this lack of clean drinking water in the region. 220 million people in SSA still practice open defecation, or defecating without the use of a toilet (Souza et al., 2018). This problem is, often, due to the lack of sanitation infrastructure in these communities. Open defecation often leads to contamination of water supplies which leads to a large number of water-borne diseases such as dysentery and cholera. Children are the most vulnerable population when it comes to water-borne diseases and about 180,000 die each year in SSA due to insufficient water, sanitation and hygiene (WASH) (Irwin & Wallace, 2015). The aim of this project is to develop a process that reclaims water from human waste to address WASH issues comprehensively in the community of Dakar, Senegal in SSA and to successfully integrate this technology through an implementation process that is based in trust between the community and their public water authorities.

Two birds and a stone: Combining water treatment and drinking water production

Currently, in most countries and communities, sewage treatment and drinking water treatment plants are two separate processes. In the U.S., the wastewater that leaves one's house gets pumped to a wastewater treatment plant and goes through several processes that remove all solids and scum, kills bacteria, and residual materials before being put back into a main body of water like a lake or river (United States Geological Survey, 2018). Meanwhile, drinking water treatment goes through a more rigorous four step process of: coagulation/flocculation, sedimentation, filtration, and disinfection (Centers for Disease Control, 2015). This takes water from freshwater sources and removes all solid, chemical, and biological contaminants to make fresh drinking water.

The proposed technological solution is to improve the technology above by integrating aspects of both into a single process that takes waste and makes clean drinking water. This process is not only a good solution because it combines these two processes into one, thereby increasing WASH significantly in communities that don't have either, but it also produces cheap electricity and ash which can be used as a fertilizing agent for crops. The specific process being developed has the same basic unit operations as a pilot project developed by Sedron Technologies, and funded by the Bill and Melinda Gates Foundation, called the Janicki Omni Processor (JOP). A schematic of the JOP, which began operation in Dakar, Senegal in 2015, is shown below in Figure 1.

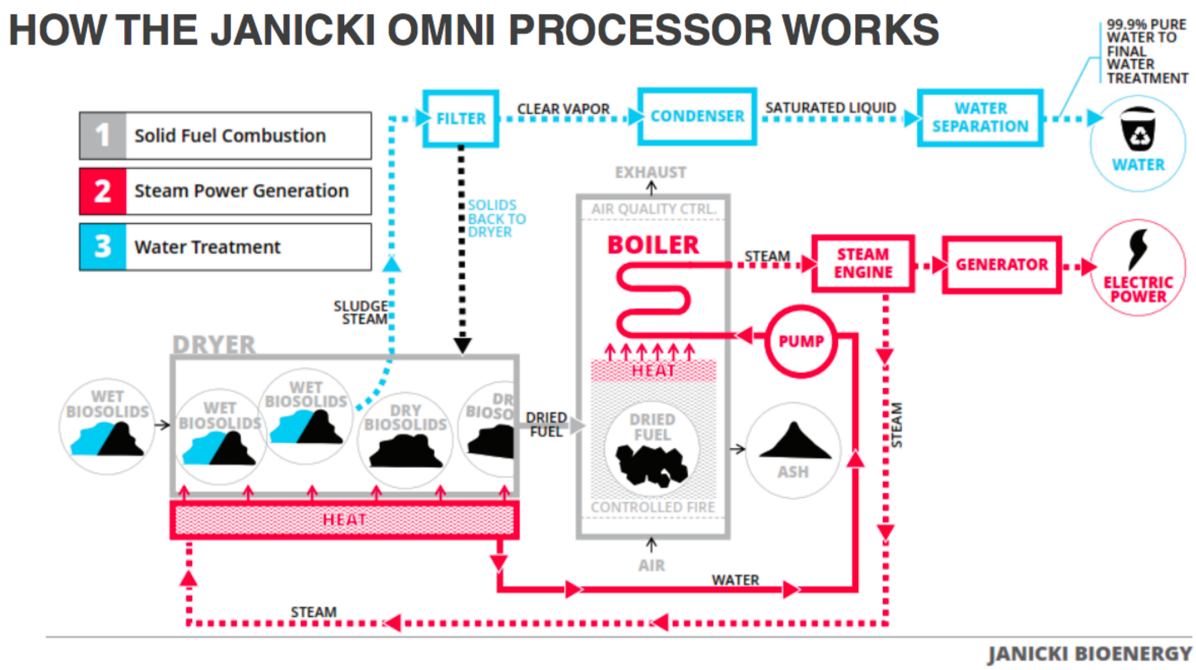

Figure 1. A process flow diagram for the JOP (Image source: Cashman, 2020).

To begin, wet biosolid waste is heated in a dryer to produce unfiltered "sludge steam" as well as dry biosolid waste. From here, the sludge steam will go through a water treatment process and the dried biosolids will go through an electricity generation process. To follow the water treatment process, the sludge steam is filtered to remove any large particulate solids from the vapor. The filtered vapor then enters a condenser, and the liquid water coming out of it goes through a water separation process. As shown in Figure 2, there are a variety of membrane-based separation processes that are used to filter and purify water, reverse osmosis (RO) being the most selective due to its small pore size which have average diameters on the order of less than 1 nm (Shenvi et al., 2015). RO works by forcing water through these small pores, thereby reversing the natural water flow from low concentrations of solute to high, which is called osmosis. Due to the added complexity of the feed stream containing human waste which contains dissolved minerals and salts (Rose et al., 2015), RO membranes will be used for the water separation step to remove all dissolved impurities from the feed to purify the saturated water to near 99.9 %.

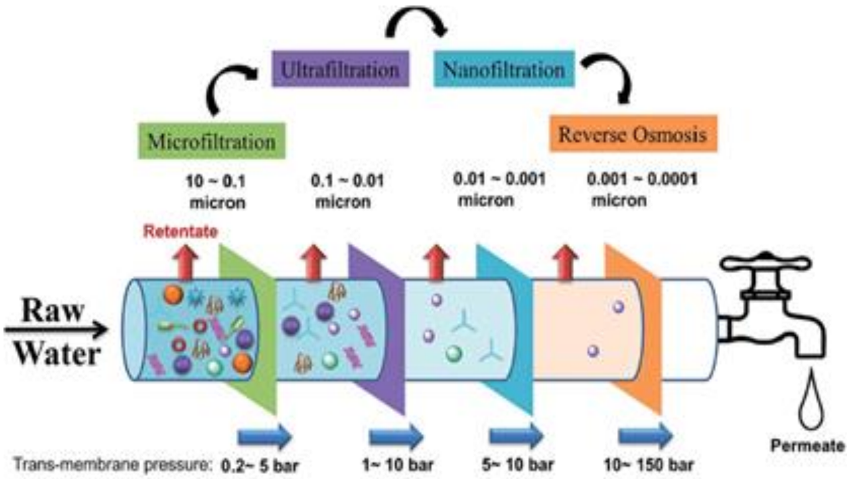

Figure 2. Process of Reverse Osmosis (Image Source: Selatile et al., 2018)

While the evaporated water from the human solid waste gets filtered as described above, the dry biosolids coming out of the dryer enter a combustion chamber as fuel for a boiler. This begins the power generation part of the system. Separate from the filtered water, liquid water runs through the boiler and is converted into steam. Some of this steam is diverted to the dryer to provide the heat needed to dry the incoming waste while most of the steam is fed to a steam engine to create usable electric power. The byproduct of combustion, the ash of the incinerated solid waste, can be collected and used as fertilizer (Cashman, 2020). Our capstone project will differ from the already-functioning JOP by specifying the ill-defined water separation process, as discussed above, as well as using chemical engineering principles to adequately scale-up all unit operations of the process to serve a population of 1,000,000 as compared to the current JOP which serves 200,000 people at most (Sanders, 2018).

Drinking water derived from human solid waste is technically possible to achieve considering 75 % of human feces is water (Rose et al., 2015). However, just because it is possible to produce safe, clean drinking water from waste, doesn't mean that the public won't be hesitant to consume water they know comes from their waste. More than likely, the public must be convinced that the water is safe and acceptable to drink. This barrier of implementation and how engineers and public water authorities can overcome it is an interesting topic that goes beyond the technical and into the social element of the project.

Overcoming the "yuck" factor: Public trust and reclaimed water

When it comes to any technology being developed, successful integration is dependent on the willingness of the intended consumer to trust that the technology will work as intended and is safe to use (Lippert & Davis, 2006). The relatively small, yet persistent backlash around vaccines is an important and relevant example of this element of trust. The measles vaccine is often administered to young children and most public schools require parents to vaccinate their children from measles before they're allowed to be enrolled. After being eradicated in the United States in 2000, the number of cases in measles reached a 15 year high in 2011 (Bloom et al., 2014). This shocking spike in measles cases has been linked to the spreading of a fraudulent scientific article by UK scientist Andrew Wakefield, originally published in 1998. In 2011, in a WebMD survey of 189 parents, 28 % believed that the vaccine to treat measles can cause autism in children (DeNoon, 2011). Even more shockingly, 5.6 % of respondents to this survey said they were convinced vaccines caused autism only after the Wakefield study was debunked. In 2019, a survey of 2000 Americans found that 45 % had some doubt about the safety of vaccines

(American Osteopathic Association, 2019). This is despite the fact that the scientific community is overwhelmingly effective and safe.

This example represents the concerning communication gap between scientific authorities and the public. Some have suggested that this gap can be ameliorated through increasing scientific literacy, finding more creative ways of communicating science, or simply by sharing more peer-reviewed studies with the public. All of these proposed ways of solving the problem come from the idea that there exists a knowledge gap or deficit that scientific authorities must try to fill. Once this knowledge is communicated to the public in a way that they understand, their doubts and propensities about settled science will decrease as well (Brown, 2009). This is known as the *Deficit Model* and there are a few assumptions this model makes that have been identified. The first and most obvious being that the public is ignorant of science, the second is that the public shares negative attitudes towards certain technologies, and the third is that said ignorance about technologies is the root cause of these negative attitudes (Ahteensuu, 2012). This last assumption is directly countered by Brown who posits that the public "[…] make[s] decisions based on a host of factors as well as the scientific 'facts' [which] include ethical and religious beliefs, in addition to culture, history and personal experience" (Brown, 2009, p. 609). In fact, Brown goes further and suggests that there is a *New Deficit Model* that assumes that the difficulties in integrating new technologies can be ameliorated by collecting more data and scientific facts (Brown, 2009). All of these assumptions raise questions about whether Deficit Model thinking is effective and whether or not "… what is needed instead is a public that is more familiar, comfortable with, and trusting of scientists" (Mooney, 2010, p. 3).

This notion of trust, while not as concrete or as amenable to scientific research as collecting more data to show the public, is pivotal when it comes to whether or not reclaimed water is actually drunk. This is because of the "yuck" factor associated with reclaimed water. The yuck factor is the instinctive psychological response to a particular technology. It has been studied in regards to drinking water and has been attributed to have caused the derailment of wastewater-to-drinking water treatment plants in California (Schmidt, 2008). However, Scott and Ormerod argue that the psychological disgust with drinking reclaimed water is not a determinative factor. They support this argument by making the claim that this type of technologically deterministic explanation of the yuck factor "reinforce[s] hierarchical technocratic decision making" (Ormerod and Scott, 2013, p. 354). They offer a counter explanation that looks at the issue from a social constructivist perspective of community trust of reclaimed water rather than an individual gut-level reaction. Social constructivists utilize the framework of Social Construction of Technology (SCOT). SCOT is a theory that describes the development of technology through interactions between different social groups (Bijker, 2017). Building trust in a technology is directly dependent on the types of negotiations and interactions between different groups of people especially when developing suitable reclaimed potable water. This emphasis on the negotiations between social groups is important to consider when researching the relationships and perceptions being built between a community and the authorities that they rely on to provide potable water.

They further validated their socially constructed view through a survey of residents of Tucson, Arizona where reclaimed water is in use for non-potable activities like irrigation. The results showed that people who will drink reclaimed water are also the people who are most trusting of government entities who regulate the water, in addition to locally elected officials.

The way humans calculate risk and make decisions every day when it comes to how they use and interact with certain technologies is much more complex than simply being the most scientifically logical and rational. Additionally, consumers can't know and shouldn't have to know every risk associated with every piece of technology. That is why successful implementation of any technology requires consumer trust. This is especially true when the technology or product that is being implemented has the potential to cause bodily harm to the consumer which is the case with both the example of vaccination and the consumption of reclaimed water.

Social Construction of Technology (SCOT) analysis of trust-building between local water authorities and the public

The research question that will be investigated is: How can engineers and local water authorities build trust with community members to successfully integrate reclaimed drinking water in said communities? This research question builds off the aforementioned work of Scott and Ormerod which concluded that trust was a determinative factor when it came to the willingness of the public to accept and consume reclaimed potable water. This question is worth studying because the results can provide insights in how to develop and integrate more trusted and therefore more effective technologies. SCOT will be used to frame the question over the aforementioned Deficit Model because I'm interested in exploring the interactions and negotiations between social groups in regards to reclaimed potable water rather than the perspective of only the scientific authorities and how they engage the public.

Public trust is an inherently nebulous concept that is hard to quantify and direct collection of public trust is extremely difficult given my time constraints. Therefore, in order to understand the potential willingness of the public towards potable reclaimed water, a literature review of public trust in “toilet to tap” will be conducted as well as an analysis of media accounts of relatively recent wastewater reclamation projects in the United States. For primary evidence collection, interviews with Charlottesville Water authorities will be conducted to understand their perspective on how to engage with the public about reclaimed potable water. The literature and media accounts review will be conducted in early to mid-February. This secondary evidence will inform the questions developed for the interviews with local water authorities that will take place in early March. Once all of these data and evidence are collected, they will be used as a part of a case study analysis of the potential success or failure of Charlottesville authorities implementing a reclaimed, potable water project. From this, proposed implementation and public trust-building strategies for similar projects will be developed.

Conclusion

In many places around the world, lack of WASH is a serious threat to public health. This is especially true in SSA. To address this, the technical deliverable of the project will be a process that turns human solid waste into the desirable outputs of: clean drinking water, electricity, and fertilizing ash. If done successfully, the technical project will be a process that produces a substantial amount of water and valuable electricity and fertilizing ash for citizens of Dakar, Senegal. The social deliverable will investigate how trust between communities and public water authorities can be built to successfully integrate a reclaimed potable water process into said community. It is expected that the results of this investigation will yield that trust should be built in both socially and technically relevant ways that invite the perspectives of the community members into the implementation process.

References

Ahteensuu, M. (2012). Assumptions of the Deficit Model Type of Thinking: Ignorance, Attitudes, and Science Communication in the Debate on Genetic Engineering in Agriculture. *Journal of Agricultural and Environmental Ethics*, *25*(3), 295–313. https://doi.org/10.1007/s10806-011-9311-9

American Osteopathic Association. (2019, June 24). 45% of American adults doubt vaccine safety, according to survey. *American Osteopathic Association*. https://osteopathic.org/2019/06/24/45-of-american-adults-doubt-vaccine-safety-according-to-survey/

Bijker, W. (2017). Constructing Worlds: Reflections on Science, Technology and Democracy (and a Plea for Bold Modesty). *Engaging Science, Technology, and Society, 3*, 315. https://doi.org/10.17351/ests2017.170

Bloom, Barry R., Marcuse, Edgar K., & Mnookin, Seth. (2014). Public Trust in Vaccines: Defining a Research Agenda. *American Academy of Arts and Sciences*. Retrieved from https://www.amacad.org/sites/default/files/publication/downloads/publicTrustVaccines.pdf

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. *Npj Clean Water*, *2*(1), 1–6. https://doi.org/10.1038/s41545-019-0039-9

Brown, S. (2009). The New Deficit Model. *Nature Nanotechnology*, *4*(10), 609–611. https://doi.org/10.1038/nnano.2009.278

Centers for Disease Control. (2015, January). *Water Treatment | Public Water Systems | Drinking Water | Healthy Water | CDC*. https://www.cdc.gov/healthywater/drinking/public/water_treatment.html

Cashman, K. (2020, January 11). The Omni Processor: Turning Sewage Into Drinking Water in Senegal (and Beyond?) | Development. RESET.To. https://en.reset.org/blog/omni-processor-turning-sewage-drinking-water-senegal-and-beyond-01112020

DeNoon, D. J. (2011, March 31). WebMD Survey: Safety Biggest Vaccine Worry for Parents. *WebMD*. https://www.webmd.com/children/vaccines/news/20110329/webmd-survey-safety-biggest-vaccine-worry-parents

Irwin, T., & Wallace, R. (2015, December 15). *UNICEF: 500 children die every day from lack of safe water, sanitation in sub-Saharan Africa*. UNICEF. https://www.unicef.org/infobycountry/media_86521.html

Lippert, S. K., & Davis, M. (2006). A conceptual model integrating trust into planned change activities to enhance technology adoption behavior. *Journal of Information Science*, *32*(5), 434–448. https://doi.org/10.1177/0165551506066042

Mayo Clinc Staff. (2020, October 14). *How much water do you need to stay healthy?* Mayo Clinic. https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/in-depth/water/art-20044256

Mooney, C. (2010). Do Scientists Understand the Public? *American Academy of Arts and Sciences*. https://www.amacad.org/sites/default/files/academy/pdfs/scientistsUnderstand.pdf

Ormerod, K. J., & Scott, C. A. (2013). Drinking Wastewater: Public Trust in Potable Reuse. *Science, Technology, & Human Values*, *38*(3), 351–373. https://doi.org/10.1177/0162243912444736

Rose, C., Parker, A., Jefferson, B., & Cartmell, E. (2015). The Characterization of Feces and Urine: A Review of the Literature to Inform Advanced Treatment Technology. C*ritical*

Reviews in Environmental Science and Technology, 45(17), 1827–1879. https://doi.org/10.1080/10643389.2014.1000761

Schmidt, C. W. (2008). The Yuck Factor When Disgust Meets Discovery. *Environmental Health Perspectives*, *116*(12), A524–A527.

Selatile, M., Sinha Ray, S., Ojijo, V., & Sadiku, R. (2018). Recent developments in polymeric electrospun nanofibrous membranes for seawater desalination. *RSC Advances*, 8, 37915–37938. https://doi.org/10.1039/C8RA07489E

Sanders, J.-G. (2018, November 6). Omni Processor heading to commercial market. GoSkagit. https://www.goskagit.com/news/local_news/omni-processor-heading-to-commercial-market/article_a4dea2ca-4fee-55b5-b2d0-60a14331b7e0.html

Shenvi, S. S., Isloor, A. M., & Ismail, A. F. (2015). A review on RO membrane technology: Developments and challenges. *Desalination*, 368, 10–26. https://doi.org/10.1016/j.desal.2014.12.042

Souza et al. (2018). Sustainable Development Goal 6: Synthesis Report on Water and Sanitation. *United Nations Publications*. https://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018-on-water-and-sanitation/

Tatlock, Christopher W. (2006). Water Stress in Sub-Saharan Africa. *Council on Foreign Relations*. https://www.cfr.org/backgrounder/water-stress-sub-saharan-africa#:~:text=Sub%2DSaharan%20Africa%20suffers%20from%20chronically%20overburdened%20water%20systems%20under,infrastructure%20only%20exacerbate%20the%20problem

United States Geological Survey. (2018, August 30). *A Visit to a Wastewater Treatment Plant*. https://www.usgs.gov/special-topic/water-science-school/science/a-visit-a-wastewater-treatment-plant?qt-science_center_objects=0#qt-science_center_objects