River Treatment in Chennai: Utilizing Bioprocessing for Energy Production.

(Technical Paper)

Residents' Responses to Poor Water Cleaning and Preservation in India.

(STS Paper)

A Thesis Prospectus

In STS 4500

Presented to

The Faculty of the

School of Engineering and Applied Science

University of Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science in Chemical Engineering

By

Jacob Gendron

November 1, 2021

Technical Team Members:

Chris Hawkins, Natalie Thomas, Abhilash Mangu, Katarina Liddell

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.

Jacob Gendron

ADVISORS

Professor Sean Ferguson, Department of Engineering and Society

Professor Eric Anderson, Department of Chemical Engineering

Introduction

Water pollution in India has a long history in the country, particularly in the rivers that are considered holy by the people and whose religious purity must be preserved. People bathe and drink from these rivers because of their sacredness, but getting water from these sources has led to the spread of disease. There is a lack of clean water both for residents and for irrigation. The Cooum river near Chennai, India is particularly impacted because industrialization and urbanization of the city has led to increased pollution from sewage, industrial effluents, and agricultural efforts (Gowri et. al., 2007). As the demand for clean water in India continues to grow, so too have research efforts to think of ways to effectively provide clean water to residents and clean up rivers.

The goal of the technical aspect of this capstone research is to implement the necessary processes to convert the Cooum river water into drinking water by removing the pollutants in the water (including metals, sewage and other biohazards, trash, and salt). Several UVA professors are interested in processes to make drinking water treatment more effective and useful, and they will serve as sources of guidance in implementing these processes into the design. This design will provide the drinking water that the city needs, which is especially important when the city cannot obtain it from other sources like monsoons (Frayer, 2019).

Citizen engagement in how India handles its water treatment and preservation has led to unrest and protests. Dams have been used to provide hydroelectric power, but construction of them has caused the unfair eviction of many residents (Chowdhury, 2018). Pushing the government to clean up rivers involves efforts by the public that bring social activists and religious leaders together to enact change. In order to better understand the needs of the citizens in designing the drinking water plant, the focus of the STS research will involve public and citizen engagement in the government's efforts to clean up rivers and build dams with an emphasis on the relation between social movements and government actions regarding providing clean drinking water.

Technical Topic

In the city of Chennai, India, the Cooum River holds high levels of contamination in the form of sewage, biological matter, industrial waste, nutrients, and heavy metals (Gowri et al., 2007). This area of India also faces high levels of water scarcity. Our goal is to design a reverse osmosis (RO) water treatment plant that sources water from the Cooum river as an alternative source of drinking water for Chennai to relieve some of this water scarcity. Water will be directly pumped from the Cooum River, and will go through various stages of pretreatment before RO treatment. These pretreatment steps will include sedimentation of large solids, a macro-filter, and a microfilter. This water will then be pumped through the RO membrane. The permeate water leaving RO will be disinfected and leave the system as potable water.

Hydrothermal liquefaction (HTL) will be a secondary process that uses the biomass from the river to produce an energy rich bio-crude oil as a byproduct. HTL operates at moderate temperatures, typically 200-400°C, and high pressures of 10-25 MPa (Gollakota & Kishore, 2018). At these conditions we expect to generate a biocrude oil sludge, an aqueous wastewater stream, and a gas stream (Chen et al., 2020). We would like to join these processes together in a centralized system by using the sludge streams produced in pretreatment of water as a feed for HTL and recycling the dirty water produced in HTL into our water treatment process. A simple process flow diagram can be seen in Figure 1, with a more in depth illustration for HTL in Figure

2. The final products of this project will be clean drinking water and bio-crude oil.

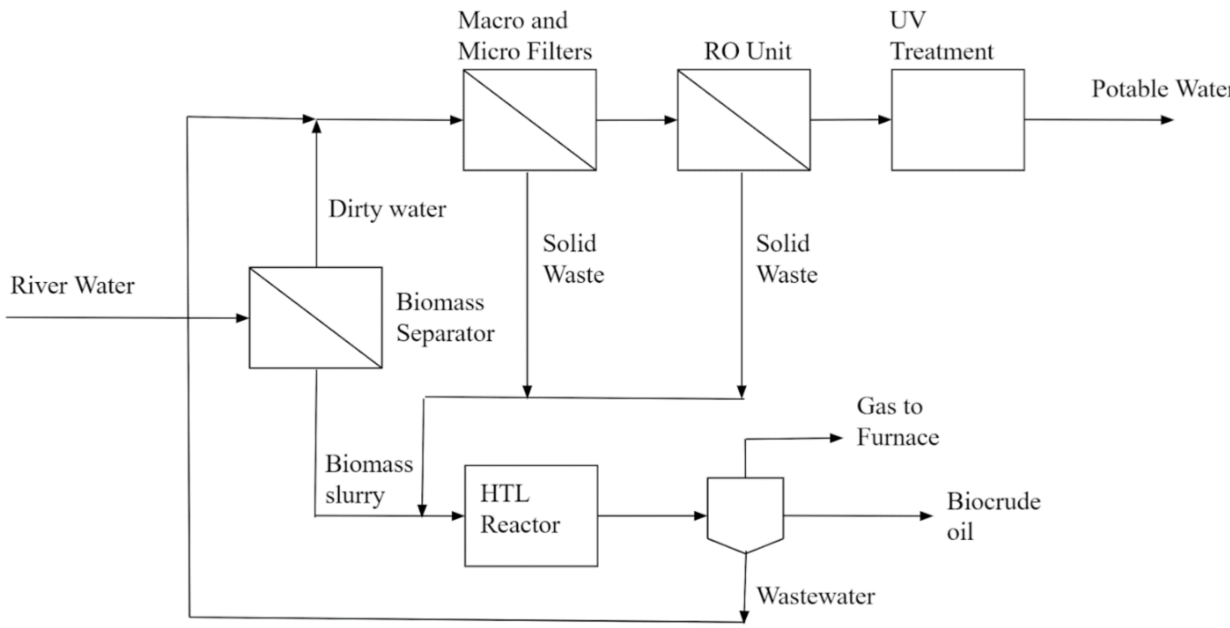

Figure 1: Overall Process Flow Diagram

Chennai gets the majority of its drinking water from the monsoon season, however when this season is short or does not provide enough rain, the city faces serious water scarcity. This is what occurred during the 2019 water crisis of Chennai (Frayer, 2019). The proposed design is worth pursuing as it addresses the problems of water scarcity in Chennai, as well as uses the pollution, specifically the excess of biomass, in the Cooum river as a profitable resource. RO will be used as a promising filtration technology to produce the potable water product. Additionally, HTL is a very new technology that has never been scaled up to larger than in-lab processes. However, industrially sized designs have been proposed, such as the design seen in Figure 2 (Snowden-Swan et al., 2016). Scaling up HTL and connecting it with the RO process streams will be a significant challenge of this design project.

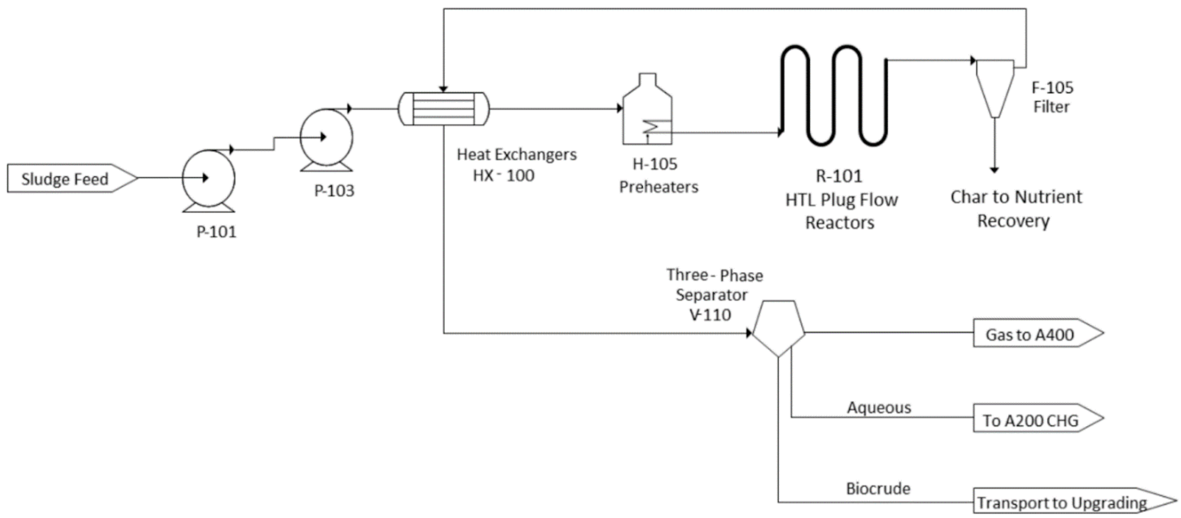

Figure 2: Hydrothermal Liquefaction Process Flow Diagram

The final report will contain complete material and energy balances, the design of major equipment including reactor and membrane filtration designs, an estimation of costs and returns and a discussion of the environmental and social impacts. Information regarding the flow rates of pollutants in the Cooum River will be obtained from sources that analyze the river for its contents in order to understand the components of the feed stream (Gowri et al., 2007). The two-semester technical project will be done amongst a group of five individuals. Calculations will be done using shared Excel spreadsheets, dividing calculations amongst group members as needed. Every calculation will be checked by at least two team members before publishing. Where appropriate, Aspen Plus will be used to simulate certain processes to obtain stream data and thermodynamic properties in the process. The group will meet at least once a week to discuss progress, findings, and future calculations.

STS Topic

Hess and Sovacool define research involving public participation as seeking to understand how the "different aspects of participation are defined or constructed." This includes understanding policy issues, who engages in the implementation of policy, the procedures for doing so, and how the public is affected (Hess and Sovacool, 2020). In the context of water cleaning and preservation practices in India, several areas will be explored regarding the parties that engage in policy implementation, the effects on the public, and how policy is implemented through movements.

Firstly, the actions taken by the government and the current state of drinking water distribution in India will be examined. Secondly, an investigation will be done into how unclean water and dam placement lead to unfair marginalization of different groups of people in India. Lastly, the efforts of these groups of people, motivated by their own expertise and knowledge of risk, to mobilize together to enact change will be researched. At the end of this paper, we should have a better understanding of how water production and containment practices lead to unfair social class divides and how much citizens have to step up to enact changes that the government ultimately makes through policy implementation.

Policies and Background

It is estimated that only 30% of municipal sewage undergoes proper treatment, and 21% of the contagious diseases in the country are related to dirty drinking water (Agoramoorthy, 2014). This is just one of the many reasons why the lack of clean water in India is cause for concern. The government has been influenced to take several courses of action as a result of these concerns.

One of the major policies that was enacted was the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), launched by the government of India in 2005. This policy favored improving water treatment and sewage infrastructure of the big cities in India over rural areas and smaller cities (Kumar, 2015). This policy did not allow less developed areas to flourish because these areas did not have the ability to prepare city development plans and project reports that would have allowed them to qualify for the funds to improve drinking water treatment infrastructure. Therefore, only the largest cities were favored to develop, showing discrimination to residents of India that live in slums and smaller cities.

In recent years, more attention has been given to help less populous areas obtain clean water. For example, the National Rural Drinking Water Programme (NRDWP) established in 2009 is a policy by which the government of India provides financial support for rural drinking water supply operations. The NRDWP came about because many other countries enacted policies beginning in 1996 that lowered the maximum permissible concentration of arsenic in water to 0.01 mg/L, and the Bureau of India Standards (BIS) wanted to provide better water treatment practices to lower concentrations of arsenic in water and keep up with these countries (Shrivastava, 2016).

Power Distribution and Marginalization

With the little drinking water production that India does have in operation, it is no surprise that the “big city bias” in developing drinking water infrastructure leads to marginalization. As a result of this, rural areas and slums are considered the “weaker” parts of the country, and citizens living in these areas are severely limited in using their time productively to improve their living situations. Ultimately, a large social class divide is created, and discrimination of the poor has become prevalent in the country through unequal distribution of many resources beyond just clean water (sewage sanitation and electricity, for example) as a result (Kumar, 2015).

In addition to unequal development of drinking water treatment infrastructure, dam placement in India is another notable cause of inequality that has caused issues for certain groups since the 1970s. The main groups of people that are affected are farmers. The placement of dams in order to provide hydroelectric power has been prioritized over the practice of farming, leading to these farmers losing their land and livelihoods. Many other migrant and low wage workers also have lost their homes due to dam construction (Chowdhury, 2013), which fuels campaigns to stop the government from kicking out all of these people. Social movements have been sparked as a result of the marginalization caused by dams and lack of clean water plants.

Social Movements and Efforts

With the unfair policy making and unequal resource distribution, it is no surprise that many social movements have been developed by the public to make change. The Save the Narmada Movement is an ongoing effort started in 1985 that came about to protest the placement of the Sardar Sarovar Dam in the Narmada river valley. This movement has brought together farmers, migrant workers, tribes, and social activists like Medha Patkar that lead the movement (Chowdhury, 2013). One particular newsletter highlights how she and other activists helped the movement gain momentum to combat the unsustainable ecological and social impacts of the dams, which will help in expanding my research (Right Livelihood, 2021). Their efforts eventually influenced the government of Maharashtra to pass the Maharashtra Resettlement of Project Displaced Persons (MRPDP) Act in 1976, which required that land or money be provided as compensation to those evicted by dam construction projects. However, this act did not apply to all projects because it gave the government too much freedom in deciding which people are “project-affected” people that deserve compensation (Chowdhury, 2018). Therefore, it makes sense that the protesters still demand more and the movement still exists today.

Citizens have become fed up with the lack of clean water in rivers and have demonstrated their own knowledge of science and risk through even more social movements. The Save Ganga Movement, for example, has brought together citizens, Hindu monks, spiritual leaders, journalists, social activists, and even Prime Minister Narendra Modi to clean up “Mother Ganga.” As a result, the government has been influenced to clean up the river in order to increase religious tourism, but efforts are still ongoing. A website that outlines the movement’s goals to provide a “Gandhian solution” to the “ecological crisis” that is river pollution will surely be a good source to expand my research (Devant IT Solutions, 2018). These social movements are not just limited to specific rivers; citizens in the Karnataka state in India have been campaigning to save the Cauvery river from further garbage and sewage dumping (Agoramoorthy, 2014).

Next Steps

In order to better understand the STS topics of social movements and discrimination of groups, I will expand upon my research in several areas. I will first do more research into how rural areas are becoming more assisted in providing clean water to its residents, specifically how effective these efforts have been given the bias towards larger cities. This will be linked to who engages in the cleanup efforts and how these cleanup efforts attempt to limit inequality among residents. Particular attention will be paid to the social movements that have come about from poor dam placement and drinking water cleaning practice. The Save the Narmada Movement will be researched to better understand why efforts to stop dam production continue as a result of corrupt policy. The efforts of the government to clean up rivers, such as the Ganga river, will be explored in order to better understand how certain incentives (such as the potential to increase religious tourism) have motivated the government to clean up these rivers as a result of citizen engagement through the Save Ganga movement. Lastly, understanding policy analysis and how to apply it to the research I have done concerning government policy will be a future area of exploration. Through all of this research, we will better understand how the government uses its power and if power is properly distributed to the government. Regarding the technical portion of the project, material balances and calculations will be completed once an overall process flow diagram is developed.

References

Agoramoorthy, G. (2014). Sacred Rivers: Their Spiritual Significance in Hindu Religion. *Journal of Religion and Health*, *54*(3), 1080–1090. https://doi.org/10.1007/s10943-014-9934-z.

Chen, W.-T., Haque, Md. A., Lu, T., Aierzhati, A., & Reimonn, G. (2020). A perspective on hydrothermal processing of sewage sludge. Current Opinion in Environmental Science & Health, 14, 63–73. https://doi.org/10.1016/j.coesh.2020.02.008.

Chowdhury, A. R. (2013). 'Repertoires of Contention' in Movements Against Hydropower Projects in India. *Social Movement Studies*, *13*(3), 399–405. https://doi.org/10.1080/14742837.2013.830564.

Chowdhury, A. R. (2018). State Formation from below: Social Movements of dam evictees and legal transformation of the local state in India, 1960–76. *South Asia: Journal of South Asian Studies*, *41*(1), 194–211. https://doi.org/10.1080/00856401.2018.1406445.

Devant IT Solutions. (2018, January 24). Home - Save Ganga Movement. Retrieved October 31, 2021, from https://savegangamovement.org/.

Frayer, L. (2019, July 18). *The Water Crisis In Chennai, India: Who's To Blame And How Do You Fix It?*. NPR. Digging Wells, Skipping Showers: Life In A Water Crisis : Goats and Soda : NPR.

Gollakota, A. R. K., Kishore, N., & Gu, S. (2018). A review on hydrothermal liquefaction of biomass. Renewable and Sustainable Energy Reviews, 81, 1378–1392. https://doi.org/10.1016/j.rser.2017.05.178.

Gowri, V. S., Ramachandran, S., Ramesh, R., Pramiladevi, I. R., & Krishnaveni, K. (2007). Application of GIS in the study of mass transport of pollutants by Adyar and Cooum Rivers in Chennai, Tamilnadu. *Environmental Monitoring and Assessment*, *138*(1-3), 41–49. https://doi.org/10.1007/s10661-007-9789-9.

Hess, D. J., & Sovacool, B. K. (2020). Sociotechnical matters: Reviewing and Integrating Science and Technology Studies with energy social science. *Energy Research & Social Science*, *65*, 101462. https://doi.org/10.1016/j.erss.2020.101462.

Kumar, A. (2015). Indian Urban Households' Access to Basic Amenities: Deprivations, Disparities and Determinants. *Margin: The Journal of Applied Economic Research*, *9*(3), 278–305. https://doi.org/10.1177/0973801015579754.

Right Livelihood. (2021, August 10). *Medha Patkar, Baba Amte and Narmada Bachao Andolan*. Retrieved October 31, 2021, from https://rightlivelihood.org/the-change-makers/find-a-laureate/medha-patkar-and-baba-amte-narmada-bachao-andolan/.

Shrivastava, B. K. (2016). Policy intervention for arsenic mitigation in drinking water in rural habitations in India: Achievements and challenges. *Journal of Water & Health*, *14*(5), 827–838. https://doi.org/10.2166/wh.2016.014.

Snowden-Swan, L. J., Zhu, Y., Jones, S. B., Elliott, D. C., Schmidt, A. J., Hallen, R. T., Billing, J. M., Hart, T. R., Fox, S. P., & Maupin, G. D. (2016). Hydrothermal Liquefaction and Upgrading of Municipal Wastewater Treatment Plant Sludge: A Preliminary Techno-Economic Analysis (PNNL--25464, 1258731; p. PNNL--25464, 1258731). https://doi.org/10.2172/1258731.