**River Water Treatment in Chennai: Producing Drinking Water by Reverse Osmosis and Biocrude Oil by Hydrothermal Liquefaction**
(Technical Report)

**Exploring Effects of Public Perception in Jordan on Wastewater Treatment Technology Use**
(STS Research 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

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November 1, 2021

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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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## Prospectus

*Introduction*

Water is a necessity of life, and yet one in nine people lack access to safe, clean drinking water today (The Last Well, 2021). Water is therefore an extremely valuable commodity, and in many regions it has deep ties to religion and culture. Technological advances have made water treatment processes increasingly effective and economically feasible, however many regions still rely on century-old technologies for their water supply. Both in Chennai, India and Jordan, unique technological advances must be made to provide a consistent and reliable source of water while accommodating cultural beliefs.

The city of Chennai, India, relies on monsoon rainwater to supply the city's water reservoirs. This reliance on the monsoon season to provide enough water has caused intermittent water shortages with harsh consequences on the city (Biswas & Uitto, 1999). Three rivers run through the city of Chennai, yet they are so polluted with sewage, trash, industrial waste, etc. that the water is unable to sustain life (Gowri et al., 2008). Th proposed capstone project will investigate a technological solution to Chennai’s unreliable water supply in the form of a reverse osmosis water treatment plant which will use Chennai’s most polluted river, the Cooum, as its source. The final deliverable is a technical report describing the design of a water treatment plant to produce drinking water using the Cooum river as a feed. To offset expenses, the biological waste in the water will be processed to produce biocrude oil.

Jordan, also uses groundwater aquifers as their main source of water, but with an increasing population and decreasing rainfall in the region these aquifers are being depleted faster than they are replenished (Whitman, 2019). Jordan has implemented limited water treatment technologies, such as wastewater treatment, because it is forbidden by Islam to drink treated wastewater, as it is not 'pure' and clean. The STS Research paper will investigate the relationship between culture and technology surrounding wastewater treatment in Jordan, and explore the use of new wastewater technologies to reduce water scarcity within this cultural context.

*Technical Topic*

In the city of Chennai, India, the Cooum River holds extremely high levels of contamination in the form of sewage, biological matter, industrial waste, nutrients, and heavy metals. This area of India also faces high levels of water scarcity. The goal for this technical project 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.

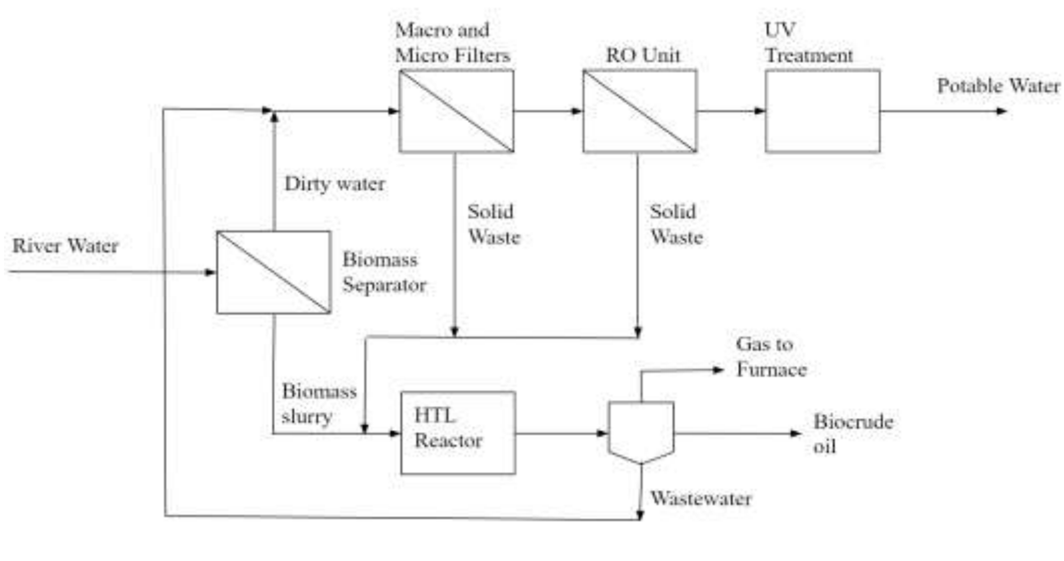


Figure 1: Overall Process Flow Diagram (Thomas, 2021)

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 the expected products are a biocrude oil sludge, an aqueous wastewater stream, and a gas stream (Chen et al., 2020). A centralized system will be designed 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 is demonstrated in Figure 1, with more in depth illustration for HTL in Figure 2. The final products of this project will be clean drinking water and bio-crude oil.

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. Most recently, Chennai faced a water crisis in 2019 where all four of the main reservoirs supplying water to the city ran dry (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.

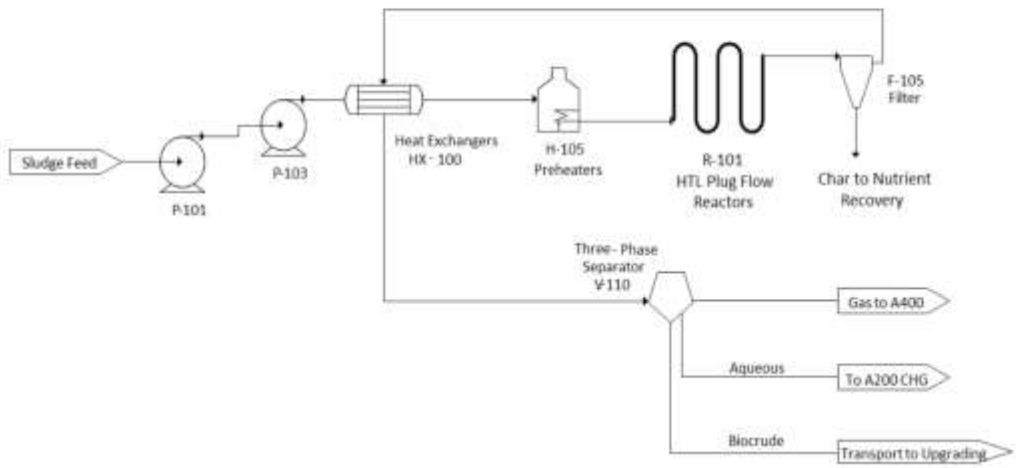


Figure 2: Hydrothermal Liquefaction Process Flow Diagram (Snowden-Swan et al., 2016)

The final report will contain complete flow rates of each material and energy stream, 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 undergraduate chemical engineering students. 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*

Jordan is the second most water scarce country in the world other than Qatar (UNICEF, n.d.). Severe water scarcity is defined as 500 $m^3$ of water per person annually and Jordan has less than $100m^3$ (UNICEF, n.d.). Jordan relies on groundwater aquifers and rainwater collection to supply the majority of its water (Denny et al., 2008). Recent droughts have had serious consequences to agriculture and livestock, with severe impact on social and economic growth (UNW-DPC, 2014). Projections indicate that the Middle Eastern region will continue to face unpredictable rainfall, rising temperatures, and accelerated ground water evaporation as a result of global warming, directly reducing Jordan's primary source of water (Whitman, 2019). Furthermore, Jordan has the ninth highest population growth rate globally, exacerbated by a continuous influx of refugees, so demand for water is only growing (Denny et al., 2008). As a result of these factors, Jordan must take action to develop technological solutions that diversify their reliable sources of water.

With regard to the diversification of water sources, one such possible source of water is treated industrial and municipal wastewater. Modern technologies can treat wastewater to produce potable water at a competitive price. One would expect a country with limited resources like Jordan to take advantage of this technology to recycle and conserve such a valuable resource as water, but because Islam is the primary religion, Jordan does not produce drinking water from wastewater as it is against Islam to drink this treated wastewater. Instead, Jordan must source its water from 'natural' and 'clean' resources such as the groundwater aquifers (Amery & Haddad, 2015). These aquifers, however, are being depleted faster than they are replenished (Whitman, 2019). Jordan has begun importing water from neighboring countries such as Israel, but these sources are also finite and the cost is significantly higher than that of wastewater treatment (Amery, 2015).

Many cultures are hesitant to invest in wastewater technologies, especially when the purpose is to produce drinking water. Wastewater typically consists of sewage, as well as industrial processing effluent, so this hesitation is a natural reaction. As it is stated in The Quran (25: 48) "... We sent down from the heaven tahur water." By The Quran, Islam refers to water directly from rain, snow, springs, seas and other naturally occurring groundwater as *tahur*, or pure. Once this water is mixed with pollutants, including anything that would change its color, taste or odor, the water is no longer pure (Amery & Haddad, 2015). Wastewater treatment has proven to be economically beneficial, and in areas where water is such a valuable commodity, this technology must not be neglected. In order to conserve the maximum amount of water possible, wastewater treatment technology must be implemented, and this must be done in a way that will be accepted by society.

The research question is: how will the public perception of wastewater treatment in Jordan impact the potential technological solutions to the ongoing water crisis of this region? Two frameworks will be used to analyze this research question. First, the concept of technological momentum, which describes how social development both shapes and is shaped by technology. Technological momentum will be used to support an analysis of Jordan's water technology has developed over time, using historical data to understand the relationship between society and technology in this region. Critiques of this framework suggest that it falls short in fully addressing the complexities of technological and social change (Colarossi, n.d.). The second framework that will be used is the social construction of technology (SCOT). This framework describes how human action and society shape technology. Two components of SCOT in particular will be used to support this analysis. The first is the relevant social group, where all members of a certain social group share the same understanding of a specific artifact, in this case water. The second component is the wider context, which applies to water technology development in the larger sociocultural and political environment of Jordan. A criticism of SCOT argues that it does not put enough emphasis on structural influences, such as class, institutions, economic and political systems (Prell, 2009). To address the critiques of both technological momentum and SCOT approaches, the Actor Network Theory will be used to describe the complexities of social perceptions of wastewater treatment in Jordan. The Actor Network Theory will also be used as a tool to organize and contextualize the respond to the research question.

The methods that will be used to answer the research question include documentary research, interviews, and discourse analysis. Documentary research will provide understanding on the technology currently used to provide Jordan with water in both urban and rural areas. Key words that will be used to carry out this research include: “wastewater treatment”, “sewage treatment”, “drinking water”, “Islam”, and “the Quran”. Interviews will support the investigation by providing valuable insight into the current public perception of drinking water in Jordan through individual perspectives. Discourse analysis describes the investigation of published documentation of political opinion, government policy, and media reports, and will support the investigation into public perception of wastewater treatment in Jordan.  . By using these methods, I will try to form a comprehensive understanding of the public perception of wastewater in Jordan.

*Conclusion*

In conclusion, the technical Capstone Project and STS Research Paper will both focus on areas suffering from water scarcity that require non-conventional solutions. In the Capstone Project a design for a wastewater treatment plant will be presented to utilize the Cooum River as a source of both drinking water and biocrude oil. This wastewater treatment plant will utilize two new and innovative technologies to achieve these products: reverse osmosis filtration and hydrothermal liquefaction. The STS Research Paper will further explore the relationship between the public perception of water and wastewater treatment technologies in Jordan. Understanding this relationship will assist future research of culturally appropriate technological solutions to Jordan's increasing water scarcity.

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