Desalination Plant and Fertilizer Production Design for New Orleans, Louisiana

Ethiopian Waters: Navigating Diplomacy and Collaboration in Transboundary River Management

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
Jay Duffie

December 1, 2023

Technical Team Members:
Shawn Atzinger
Tatum Lohmar
Al Bashumeel

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.

ADVISORS

Joshua Earle, Department of Engineering and Society

Eric Anderson, Department of Chemical Engineering

Introduction

As climate change is on the rise, the world is faced with the challenge of a dwindling freshwater drinking supply. In general, humans can survive several weeks without food; however, humans are only able to survive around three days without water. Even in today's modern age, people must travel great distances to reach a clean water supply. It is estimated that worldwide, women and children spend around 200 million hours collecting water daily (UNICEF, 2018). However, challenges behind water scarcity often arise from political disputes rather than the geographic characteristics of a region.

Today, several third-world countries struggle with water crises - all of which one country particularly stands out: Ethiopia. The country of Ethiopia stands at the crossroads of a critical challenge that transcends its borders – transboundary river management. Ethiopia's water resources, primarily fed by the Blue Nile and other transboundary rivers, play a pivotal role in the nation's economic, social, and environmental sustainability. As these rivers cross multiple nations, the demand for cooperative and diplomatic frameworks for sustainable management is heightened. The STS portion of this paper will explore the impact of public policy regarding shared transboundary rivers on Ethiopia's water resources.

Additionally, I will draw parallels between the issues of global water scarcity to my secondary technical project. This project will focus on implementing a desalination plant in New Orleans, Louisiana due to rising concerns of increased salt concentrations in the downstream portion of the Mississippi River. Desalination is the process of lowering salt, and other metal contents in saline water to levels pure enough for drinkable, agricultural, and industrial use. Although desalination plants are costly, both environmentally and economically, they can provide clean water supplies to those who lack the resources to reach them.

Technical Topic

Several countries across the globe struggle to access uncontaminated, drinkable water for irrigation, sewage, and industrial means. Of those countries, most of them are considered third world; however, the United States has a water crisis of its own. According to Time Magazine as of 2023, “nearly half a million U.S. households lacked complete plumbing, while many more were living in communities with unclean water.” (Nelson, B et. al., 2023). After further research into America’s potential water crisis, Louisiana seemed to stand out in front of the other forty-nine states all because of one river: the Mississippi.

The Mississippi River begins in Lake Itasca, Minnesota, and runs down the Midwest. It eventually pours into the Gulf of Mexico right below New Orleans, Louisiana (Mississippi Headwaters Board, 2019). Every year, saltwater from the Gulf of Mexico creeps into our nation's freshwater river. Not only does this endanger marine life and local ecosystems located close to the river, but also threatens Louisiana's source of clean water. In recent years, an augmented sill made from sand has been formed to mitigate the Gulf’s saltwater from making its way farther up the river. The US Army Corps of Engineers explains that a sand sill constructed at a proper height of the rivers’ streambed can reduce incoming saltwater flow. (USACE, n.d.). However, this solution is not efficient enough to solve the problem entirely. “That said, the sill is designed to only buy more time and not meant to altogether prevent the saltwater wedge from proceeding upriver. The low flow remains the problem and the wedge will top the sill without more flow.” (SPHTM Communications., n.d.). A desalination plant might just be the right solution for this dilemma.

Desalination is a salt removal process from saline water supplies to produce clean drinkable water. This type of plant will aid in a new source of drinking water for New Orleans given that the Gulf continues to creep. This might be the answer however, one of the main concerns associated with this type of plant is the production of excess brine waste. Currently, the world produces almost 27 billion gallons of water per day using desalination, which leaves a similar volume of concentrated brine leftover; most of which is pumped back out to sea. (MIT News, 2019). Instead of disposing of the brine waste, it could be further treated to produce fertilizer to promote local plant growth. Ultimately, this plant will solve many issues for Louisiana by producing clean water and fertilizers.

Purpose

According to the World Health Organization (WHO), "[approximately] 2.2 billion people around the world do not have safely managed drinking water services, 4.2 billion people do not have safely managed sanitation services, and 3 billion lack basic handwashing facilities" (World Health Organization, 2019). However, the implementation of desalination plants could be a step towards a solution. Today's desalination technology is controversial due to its impending environmental hazards and costly overhead. In general, the quantity of drinking water that these plants produce is almost equivalent to the waste they create. This waste is generally produced in the form of concentrated brine as a byproduct of reverse osmosis (RO). Conventional methods have typically pumped this brine waste back into the ocean; however, this method not only disturbs marine life but also exacerbates climate change by significantly increasing the salinity of the water. Our motivation for this project includes the following: providing a clean water source to residents of New Orleans, LA; and utilizing excess brine waste as a renewable resource. Overall, by the end of this project, our desalination plant will be able to produce sufficient drinking water for the population of New Orleans while also utilizing excess brine waste as a raw material for fertilizer.

Technical Problem

This project consists of treating seawater from the Gulf of Mexico to create drinking water and agricultural fertilizer for the city of New Orleans. To start, the salty seawater will go through a pretreatment process. During this phase, the water will undergo coagulation, pH adjustments, filtrations, and disinfection as shown in Figure 1. Filtration using granular media and low-pressure membrane filtration have been selected as the desired filtration methods due to their regular and supported use (Prihasto, 2009). Following the pretreatment stage, the newly treated seawater will undergo reverse osmosis (RO) to remove the salt and other contaminants from the seawater. RO will result in two outlets: brine solution and fresh water, each to be used for a different purpose.

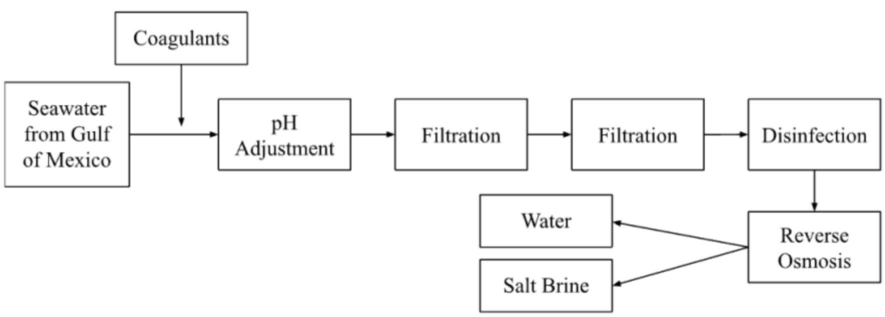

Figure 1. Pretreatment Process for the Seawater to Going Through RO

The salt brine solution will undergo various filtration processes in addition to being mixed with phosphoric acid and ammonia to create fertilizer that can be used in agriculture in New Orleans. Although fertilizer mixtures can be made alone by just mixing ammonium and phosphoric acid, the use of salt brine in fertilizer production aids in solubility, pH adjustments, and nutrients availability. Salt brine can help to dissolve and solubilize the ammonium and phosphoric acid components. This enhances the overall solubility of the fertilizer mixture, making it easier for plant uptake when applied to the soil. Along with this, the pH level of fertilizers is crucial for plant nutrients uptake. By mixing in the salt brine, the salt brine can be used to adjust and control the pH of the mixture, ensuring that the final product is suitable for the targeted crops and soil conditions. The salt brine can also influence the availability of nutrients in the soil. For example, the presence of certain ions from the salt brine may enhance the mobility and uptake of nutrients by plant roots.

This process was inspired by the work of William B. Hughes. He proposed a process that consisted of taking oil field waste brine, adding both phosphoric acid and ammonia, and then drying out the filtered brine to form a result of ammonium phosphate precipitate fertilizer and salt (Hughes, 1984). We will be using a similar approach but instead of using oil field salt brine, we will be using the salt brine from our reverse osmosis process. This process is laid out in more detail in Figure 2.

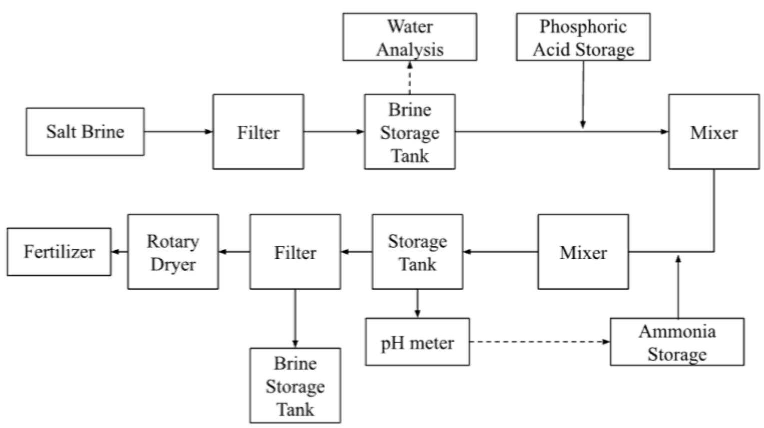

Figure 2. Salt Brine to Fertilizer Process

Furthermore, post-treatment will be required for water exiting the initial RO to maintain potable water standards. Post-treatment consists of recarbonation, chlorination, and pH adjustments. After post-treatment, fluoride and lime will also be added to the water to improve quality of taste as per the “2022 Annual Water Quality Report” put out by Sewerage & Water

Board of New Orleans (Reports, 2022). The proposed idea for the post-treatment process can be found below in Figure 3.

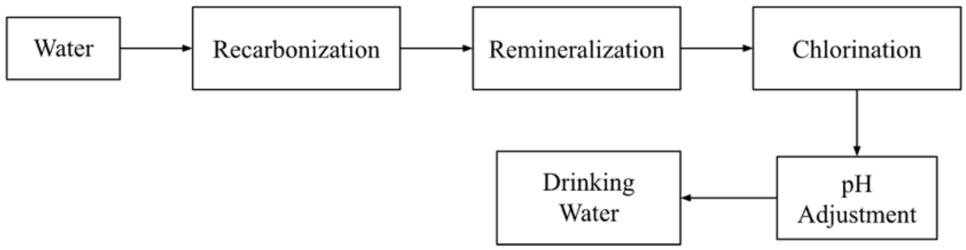

Figure 3. Post Treatment Process Forming Drinking Water

This project will be conducted in a team setting with the help of our advisor, Professor Eric Anderson, over the course of two semesters in Chemical Engineering classes 4474 and 4476. Our group will use Aspen Plus, a chemical process modeling tool, along with MATLAB and other hand-written calculations to evaluate the design of the desalination plant. As a team, we have decided to meet each week to discuss and report new information while also promoting team input for more diverse perspectives. Project-related tasks will be delegated to each member to break up large amounts of research and technical work to ensure each member is playing a part in the design of this plant.

STS Topic

According to Rebecca Shore, "During Colonial times, the Nile River and its tributaries were split up between the nations surrounding it [Sudan and Egypt]. However today, some Ethiopian farmers are finding themselves without access to water for irrigation because of the way the river was divided hundreds of years ago" (Shore, 2023). It's important to understand that even today's politics play a role in Ethiopia's water crisis. This section will focus on the political factors that influence the implementation of diplomatic agreements regarding transboundary river management in Ethiopia. In my paper, I will aim to answer the following question: "How do political factors shape the impact of shared transboundary rivers on Ethiopia's water resources and management strategies?" To achieve this, I will be examining countries that are a part of the Nile Basin Initiative including, but not limited to Egypt, Sudan, South Sudan, and Kenya (*Who We Are*, 2023). It is my goal to find the political motivations of each of these countries and how that affects Ethiopia's access to a freshwater supply. Additionally, I will be using the SCOT, or Social Construction of Technology framework to support my findings. More specifically, I will be using this framework to explore the roles of different political actors in shaping water management and water-related resources across the borders of Ethiopia. Using the SCOT framework, I aim to uncover the intricate relationships and negotiations that occur within the political landscape of Ethiopia and surrounding countries, in hopes of shedding light on how these interactions shape Ethiopia's water policies and management strategies. During my time researching this topic, I expect to come across some challenges or limitations. These challenges may include language barriers in documentation, unbiased government resources, or limited access to data. I plan to overcome these challenges by relying on a diverse range of sources including both international and non-governmental organizations to cross-reference with potentially biased sources. Additionally, I will utilize academic networks to help connect with researchers who are familiar with the policies surrounding water management across Ethiopia's borders.

Finally, my timeline for this project will begin in mid-January 2024, as I continue to search and gather resources that will help convey my argument. I plan to have the first draft done by mid-February 2024 and a finalized copy by March with the help of my STS advisor and other professors who are knowledgeable on the subject.

Key Texts

"The political context of change in transboundary freshwater agreements" by Hussein et. al. is an article that provides insights into how political factors impact agreements and policies related to shared water resources. This will help me incorporate knowledge of the general political dynamics that shape transboundary river management from a holistic perspective, rather than a specific region or country surrounding Ethiopia.

"Ethiopia's Nile Dispute Runs Deeper than Physical Resources" by Holcomb C. Y. is a paper that explains the complexities of Ethiopia's Nile dispute, highlighting that the conflict extends beyond just physical resource allocation. Additionally, it explores the history of both political and socio-economic dimensions that contribute to the ongoing tensions surrounding the Grand Ethiopian Renaissance Dam. This resource will help highlight the factors that influence negotiations and policy changes regarding Ethiopia's river management.

"The Nile Treaty – State Succession and International Treaty Commitments: A Case Study of The Nile Water Treaties" by Arthur Okoth-Owiro. The purpose of this document is to explore the legal positions of successor states regarding international treaty commitments. Moreover, it clarifies the historical significance of why the Nile Treaties were created in the first place and where they are headed as policies change or more states are added. This passage will help provide historical context to my paper, as well as present the validity of colonial-era treaties in today's world.

“Mutually beneficial and sustainable management of Ethiopian and Egyptian dams in the Nile Basin” by Habteyes G. B. et. al. discusses the challenges related to transboundary river management by specifically addressing the Grand Ethiopian Renaissance Dam along with the downstream impacts on Eastern Nile Basin countries. This will help me argue the need for new diplomatic negotiations that align with transboundary water management for Ethiopia.

Conclusion

The objective of the technical project will be to design a desalination plant located off the Mississippi River in New Orleans, Louisiana. Additionally, the brine waste created by this plant will be recycled to form an ammonia phosphate-based fertilizer to help promote local agriculture. The STS research paper will primarily focus on the political factors influencing transboundary river management in Ethiopia. As for methodology, the Social Construction of Technology (SCOT) framework will be used to analyze the role of different political actors that shape water management across Ethiopia’s borders. Finally, the results of both the technical and STS portion of this project will address the need for action against the global water crisis driven by population growth, climate change, and politics.

Bibliography

1, M., & Farley, M. G. (2018, March 1). *How long does it take to get water? For Aysha, eight hours a day*. UNICEF USA. unicefusa.org/stories

About MHB - History. Mississippi Headwaters Board. (2019). https://www.mississippiheadwaters.org/history

An Overview of the Mississippi River's Saltwater Wedge. New Orleans District, U.S. Army Corps of Engineers. (n.d.). https://www.mvn.usace.army.mil/missions

Annual Water Quality Reports. Sewerage and Water Board of New Orleans. (2023, October 4). https://www.swbno.org/reports

Chandler, D. L. (2019, February 13). *Turning Desalination Waste into a Useful Resource*. MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2019

Duranceau, S. J. (2009). Desalination post-treatment considerations. *Florida Water Resources Journal*, 4-18. http://fwrj.com/techarticles

Habteyes, B. G., Hasseen El-bardisy, H. A. E., Amer, S. A., Schneider, V. R., & Ward, F. A. (2015). Mutually beneficial and sustainable management of Ethiopian and Egyptian dams in the Nile Basin. *Journal of Hydrology*, *529*, 1235–1246. https://doi.org/10.1016

Holcomb, C. Y. (2023, September 25). *Ethiopia's Nile Dispute Runs Deeper than Physical Resources*. Columbia Political Review. https://www.cpreview.org/blog

Hughes, William B. (1984). *METHOD OF PROVIDING FERTILIZER FROM BRINES*. Google

Patents. Retrieved October 12, 2023. https://patents.google.com/patent

Hussein, H., Poplawsky, M., & Mohapatra, T. (2023, September). *The political context of change in transboundary freshwater agreements*. ScienceDirect. https://doi.org/10.1016

Nada, N. A., Zahrani, A., & Ericsson, B. (1987). Experience on pre-and post-treatment from sea water desalination plants in Saudi Arabia. *Desalination*, *66*, 303-318.

Nelson, B., & Flush: The Remarkable Science of an Unlikely Treasure. (2023, February 16). *The Water Crisis No One in America is Fixing*. Time. https://time.com/6255560

Okoth-Owiro, A. (2004). *The Nile Treaty - State Succession and International Treaty Commitments: A Case Study of The Nile Water Treaties*. The Nile treaty II . https://www.kas.de/c/document

Pakharuddin, N. H., Fazly, M. N., Sukari, S. A., Tho, K., & Zamri, W. F. H. (2021, October). Water treatment process using conventional and advanced methods: A comparative study of Malaysia and selected countries. In *IOP Conference Series: Earth and Environmental Science* (Vol. 880, No. 1, p. 012017). IOP Publishing.

Prihasto, N., Liu, Q. F., & Kim, S. H. (2009). Pre-treatment strategies for seawater desalination by reverse osmosis system. *Desalination*, *249*(1), 308-316.

Shore, R. (2023). *Water in Crisis - Spotlight Ethiopia*. The Water Project. https://thewaterproject.org/water-crisis

SPHTM Communications. (n.d.). *5 things to know about the saltwater intrusion of the Mississippi River | Tulane School of Public Health and Tropical Medicine.* https://sph.tulane.edu

Who We Are. Nile Basin Initiative (NBI). (2023). https://nilebasin.org/nbi