Desalination Plant and Fertilizer Production Design for New Orleans, Louisiana

(Technical Paper)

Environmental and Health Concerns of Water Treatment

(STS Paper)

A Thesis Prospectus
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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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Prospectus

Introduction

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, "Nearly half a million U.S. households lacked complete plumbing, while many more were living in communities with unclean water." (Time, 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 all the way 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. Not only does it provide more freshwater access to Louisiana

residents, but further prevents saltwater from creeping into the Mississippi River upstream. Although, 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 used as a raw material to feed plants, such as soybeans, in a hydroponic environment. Ultimately, producing clean water and fertilizers from this plant solves many issues that Louisiana faces.

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, 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: preventing further salination of the Mississippi River; 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 to the population of New Orleans while also utilizing excess brine waste as a raw material for fertilizer and road salt.

The STS research project will discuss the health concerns of waterborne diseases, specifically Salmonella and Norovirus, and environmental concerns specifically brine waste and salinity levels. These concerns will be researched based on the severity of the harm it poses on humans, animals, and plants; the cost imposed on the water treatment plant. On top of that, mitigation strategies and regulations that currently exist in New Orleans will be discussed along with potential improvement suggestions.

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.

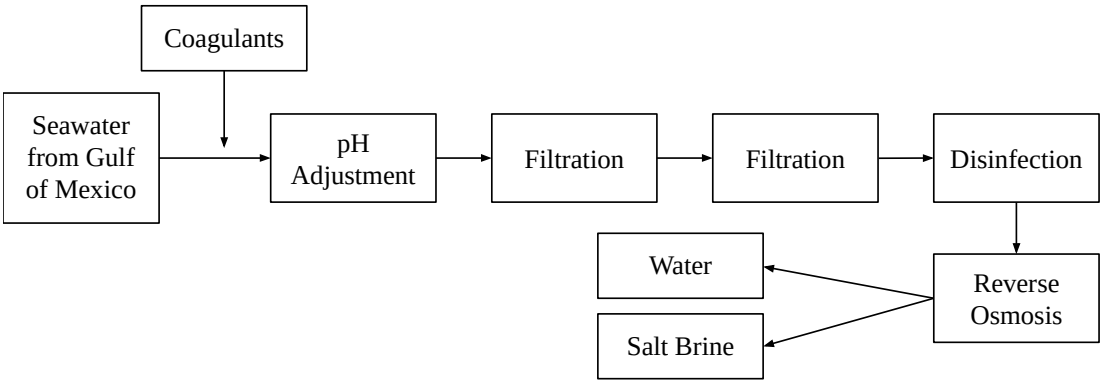

Figure 1. Pretreatment Process for the Seawater to Going Through RO

The salt brine solution will undergo various filtration processes in addition to being mixed with phosphoric acid and ammonia to create both salt that can be used on the roads to melt ice and fertilizer that can be used in agriculture in New Orleans. 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 make fertilizer (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. The difference between our process and Hughes's proposed idea is that we will be using RO to separate the salt from the resulting brine water post-phosphoric acid and ammonia addition. Additionally, we will be using different methods of mixer that will hopefully conserve energy in the process.

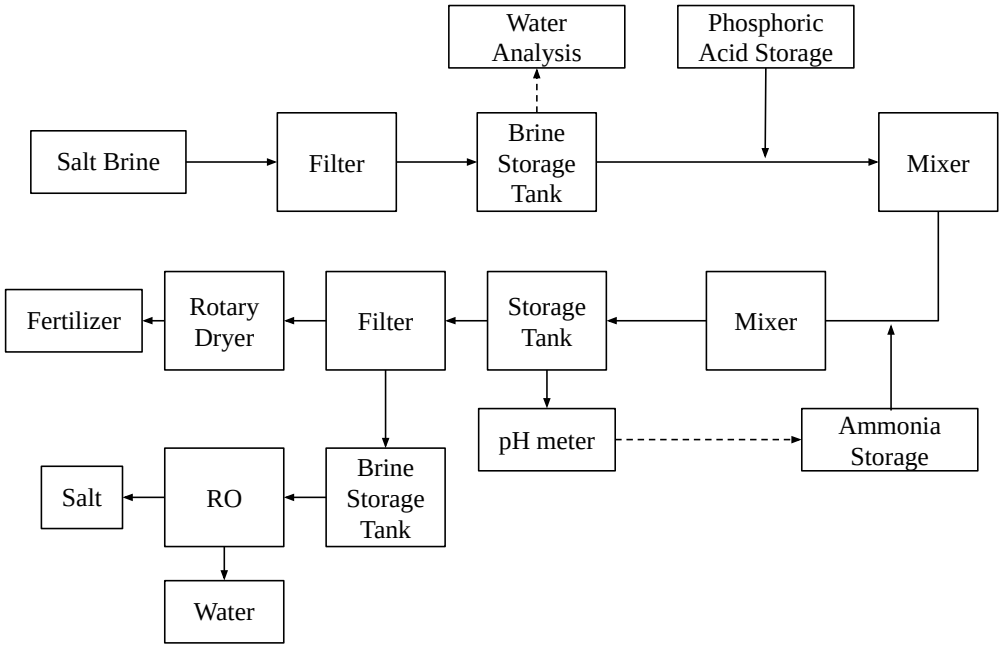

Figure 2. Salt Brine to Fertilizer Process

Furthermore, post treatment will be required for water exiting 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.

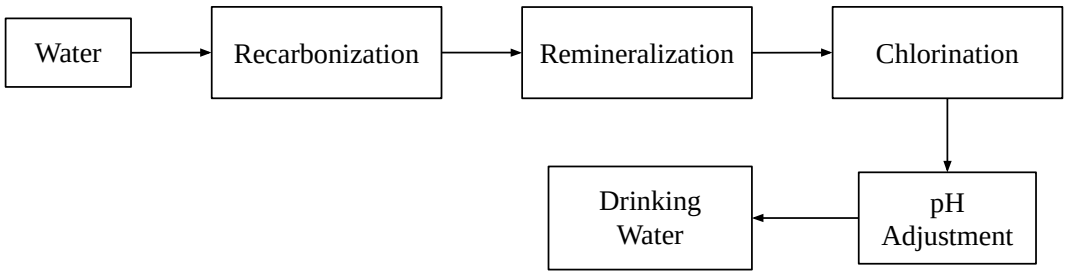

Figure 3. Post Treatment Process Forming Drinking Water

STS Discussion

When designing a plant like a water treatment plant, consumers' health and the environment are the main concerns engineers prioritize. As all engineers hope to make a difference in the world, it has to be a positive rather than a negative difference that could affect millions of people and numerous ecosystems. According to the American Public Health Association, "From 2003 to 2009, the Centers for Disease Control and Prevention (CDC) estimated that up to 477,000 people fell ill and approximately 6,900 died from 13 of the most common waterborne infectious diseases in the United States" (APHA, 2019). Among these diseases are Salmonella and Norovirus.

Salmonella is a genus of rod-shaped gram-negative bacteria from the family Enterobacteriaceae. It is an infectious disease that affects the gastrointestinal tract. The main symptoms are diarrhea, fever, and stomach cramps. "CDC estimates Salmonella bacteria cause about 1.35 million infections, 26,500 hospitalization, and 420 deaths in the United States every year" (CDC, 2023). Salmonella typically infiltrates drinking water through agriculture runoff, sewage leaks, or stormwater runoff. These are common issues in water treatment plants especially when transported to consumers. Due to the high solubility of this bacteria, once dissolved and consumed, symptoms appear within 6 hours to 6 days and last for 4 to 7 days (CDC, 2023). This is a critical concern because not only does it affect drinking water but also fresh produce that harness internal moisture.

Norovirus is a positive-sense, non-enveloped ssRNA virus that is highly contagious. It affects the stomach and intestines by causing inflammation, commonly known as gastroenteritis. This virus can be transmitted by consuming contaminated food or water, or by merely touching a contaminated surface. "About 1 in every 15 people in the US will get norovirus illness annually"

(Dalton, 2023). So far, there are not effective treatments developed to combat against the virus. Vaccines are yet to be available to the public, as research has not been fully completed. The only ways to prevent catching this virus are by consistently washing hands and sanitizing. Norovirus can also affect marine life and the environment.

Brine waste is a common pollutant to water and the environment. Brine waste normally carries considerable amounts of soluble salts that impact soils in numerous ways. Specifically, chloride levels which threaten biological species and marine life due to its excessive toxicity. "More than 90% of seawater desalination facilities use the surface water approach to discharge brine into open water bodies" (Omerspahic et al., 2022). This approach interferes with physiological processes of biotopes such as enzymatic activity, nutrition, photosynthesis, respiration, and reproduction (Omerspahic et al., 2022). Brine waste can also increase the salinity level of the water, which is harmful to marine life.

Salinity levels are a crucial factor in marine life. Salinity is the amount of dissolved salt content in a body of water. Organisms living underwater need to exist in environments with low salinity levels. They tend to disrupt the natural processes that keep them alive as they are considered stressors. "Given the heterogeneous nature and different mechanisms of actions of these stressors (e.g., physical versus chemical stressors), the co-occurrence of several of them can result in additive, synergistic or antagonistic effects on organism traits (e.g., survival, fecundity, metabolic and growth rates, etc.)" (Velasco et al., 2018). Ensuring that the salinity level of any body of water is low enough when designing water treatment facilities is necessary to keep marine life from extinction, and multiple strategies can be implemented to support that.

Conclusion

The technical problem 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 latest information to promote team input for more diverse perspectives. Project-related tasks will be delegated to each member to break up substantial amounts of research and technical work to ensure organized effort distribution in the design of this plant. Not only that, but also further detailed research will be conducted for the STS problem in STS 4600. This will include mitigation strategies and regulations in New Orleans, Louisiana, and valid data available for health and environmental concerns.

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