Desalination Plant and Fertilizer Production Design for New Orleans, Louisiana

Water, Waste, and Society: STS Analysis of Desalination and Brine Repurposing

A Thesis Prospectus

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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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Introduction

In a world where millions lack access to safe drinking water and basic sanitation services, the global water crisis remains a pressing concern. The challenges associated with water scarcity, pollution, and access are not confined to developing nations alone. The United States, despite its status as a developed nation, faces a unique water crisis that is emblematic of the broader socio-technical challenges intertwined with environmental and engineering issues. 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). The technical portion of this project presents a comprehensive solution that addresses a multifaceted problem in New Orleans, Louisiana, blending the realms of chemical engineering and science, technology, and society (STS) research.

Furthermore, the central problem that this capstone technical project aims to tackle is the water scarcity crisis in New Orleans, a city intrinsically linked to the Mississippi River. While the city is famed for its vibrant culture and iconic celebrations, it faces a severe water challenge. The Mississippi River, a lifeline for New Orleans and the surrounding region, is threatened by saltwater intrusion from the Gulf of Mexico. This intrusion not only endangers local ecosystems and marine life but also threatens the city's access to clean, potable water.

Saltwater intrusion into freshwater sources is not a unique problem. As the world grapples with the growing demand for freshwater, desalination has emerged as a critical solution. This technical project explores the design of a desalination plant in New Orleans, which would use advanced processes, including reverse osmosis, to turn saline water from the Gulf of Mexico into clean, drinkable water. While desalination technology offers a promising solution, it comes with its own set of challenges, particularly the production of concentrated brine waste. The brine waste, when not managed properly, can exacerbate environmental issues. Since brine has a high salinity and chemical residuals, it is harmful to the surrounding marine environment(Panagopoulos, 2020).

This is where the sociotechnical problem of this project comes into play. We propose to use this brine waste to produce agricultural fertilizer and road salt, aligning with the principles of sustainable resource management. The interconnection between the technical problem and the sociotechnical problem is evident. On the one hand, the technical project aims to provide clean, safe drinking water to the people of New Orleans, safeguarding them from the worsening threats of saltwater intrusion. On the other hand, the STS research element seeks to turn an environmental challenge into an opportunity by repurposing waste into valuable resources, promoting sustainability and responsible resource management.

The STS research component revolves around transforming the brine waste, which is typically discarded into the ocean, into a valuable resource. The connections between these two topics are rooted in the shared goal of sustainability, environmental responsibility, and the enhancement of human well-being. This not only addresses the environmental concerns associated with brine disposal but also offers a practical solution for enhancing agriculture in New Orleans, ensuring a more holistic and sustainable approach to water treatment. The connections between these topics demonstrates the importance of a multidisciplinary approach to solving real-world problems and emphasizes the critical role of engineers and scientists in shaping a more sustainable and prosperous future for society.

Desalination Plant and Fertilizer Production Design Background

The technical project at hand addresses a pressing problem at the intersection of environmental sustainability, water resource management, and innovative technology. In New Orleans, Louisiana, a profound water scarcity crisis that necessitates an innovative and comprehensive solution. This technical prospectus outlines our proposed project, which is to design a Desalination Plant and Fertilizer Production facility, poised to mitigate the city's water challenges and contribute to sustainable resource management.

The core problem we aim to address centers around New Orleans' vulnerability to saltwater intrusion from the Gulf of Mexico into the freshwater resources of the Mississippi River. Desalination, or the process of removing salt from saline water supplies to produce clean, drinkable water, emerges as a promising solution to address the freshwater scarcity and saltwater intrusion. This technology is not only capable of providing New Orleans residents with a reliable source of clean, potable water but also plays a pivotal role in preventing saltwater from infiltrating the upstream sections of the Mississippi River.

While desalination offers a significant breakthrough, it is not without its intricacies and potential environmental concerns, especially the production of concentrated brine waste. This waste, traditionally disposed of in oceans, not only disturbs marine ecosystems but also intensifies climate change by elevating water salinity. Our innovative approach lies in the reclamation and responsible management of this brine waste. Instead of discarding it, we propose to treat and repurpose it into valuable resources, primarily agricultural fertilizer and road salt.

This technical project leverages the technical capabilities of chemical engineering to engineer a desalination process that treats seawater from the Gulf of Mexico, transforming it into safe drinking water and agricultural fertilizer for New Orleans. The initial stage involves pretreatment, which encompasses coagulation, pH adjustments, filtration, and disinfection, ensuring that the seawater is adequately prepared for desalination. Filtration methods such as granular media and low-pressure membrane filtration have been selected due to their effectiveness and widespread use in the industry (Prihasto, 2009).

The heart of the project lies in the reverse osmosis (RO) process, which efficiently removes salt and contaminants from the seawater. RO yields two key products: fresh water and a brine solution, each serving distinct purposes in our sustainable resource management strategy. The brine solution undergoes further filtration processes and is augmented with phosphoric acid and ammonia, following the innovative approach inspired by William B. Hughes (Hughes, 1984). This process, customized for our project, results in the production of valuable ammonium phosphate precipitate fertilizer and salt. Notably, our approach differs from Hughes's proposal in the use of RO for salt separation, enhancing energy efficiency in the process.

In addition to the technological aspects, post-treatment is crucial to maintaining potable water standards, including recarbonation, chlorination, and pH adjustments. The water's quality and taste are further improved by the addition of fluoride and lime, aligning with the "2022 Annual Water Quality Report" by the Sewerage & Water Board of New Orleans (Reports, 2022).

This project will be executed in a collaborative team setting under the guidance of our advisor, Professor Eric Anderson, across two semesters of Chemical Engineering classes. We will employ sophisticated tools like Aspen Plus and MATLAB alongside traditional hand-written calculations to evaluate the design of the desalination plant, ensuring that the project meets the highest engineering standards.

An STS Analysis of Desalination’s Environmental and Social Implications in New Orleans

The central research question of our STS analysis is as follows: What are the environmental and human effects of implementing a desalination plant, particularly concerning the reclamation of brine waste for fertilizer production in New Orleans, Louisiana? This question is important due to its potential ramifications on both the environment and the community. Latoya Cantrell, the New Orleans Mayor, signed an emergency declaration in September of 2023 in response to the salt water encroachment. Furthermore, Stephen Murphy, an assistant professor at Tulane University's School of Public Health and Tropical Medicine, estimated that almost 1 million people within the greater New Orleans metropolitan area could be affected if water levels in the Mississippi River remain low(Chow, 2023). Drinking water with excess salinity can result in elevated sodium levels in the body and an increase in blood pressure. The successful integration of desalination technology with resource management could offer a holistic solution to the city's water crisis while presenting the opportunity to turn waste materials into valuable resources. However, the impacts on local ecosystems, the management of concentrated brine waste, and the broader societal implications are complex and require in-depth analysis.

To provide context for our STS analysis, it is essential to understand the broader background of desalination technology and its societal and environmental implications. Desalination, while offering a solution to freshwater scarcity, is not without controversy. The brine waste produced as a byproduct of desalination presents environmental challenges when traditionally disposed of in oceans. It disrupts marine ecosystems and escalates water salinity, thus intensifying climate change. As a result a negative narrative has been built surrounding the implementation of desalination projects. Despite the many benefits, it can be harshly opposed by people in society. However, public awareness and acceptance are necessary as most infrastructure projects are built to serve the public good. Studies have shown that many users where desalination plants have been launched, maintained a “sense of distrust” in the desalination technology(Ibrahim et al., 2021).

The potential of repurposing brine waste into valuable resources, such as fertilizer and road salt, is an innovative approach. This sustainable resource management concept aligns with the principles of the circular economy and has the potential to mitigate the environmental impact of brine disposal. A compilation of analyses from facilities around the world illustrate the many ways the reject brine effluent from the process can build a “circular economy”(Jiménez-Arias et al., 2022).

In addition to the benefits of clean drinking water, it's crucial to consider the adverse effects of water with excessive salinity on people. High salinity in drinking water can have detrimental consequences on human health. Consuming water with elevated salt levels can lead to dehydration, as the body needs to excrete the excess salt, causing an increase in urine production. This can further result in mineral imbalances and can be particularly harmful to individuals with underlying health conditions like hypertension and kidney issues. High salinity water can also lead women, especially pregnant women, to be at a higher risk of (pre)eclampsia and infant mortality(Shammi et al., 2019). This untreated water can also have a negative taste, making it less appealing to drink, which can, in turn, lead to reduced water intake and dehydration. Moreover, when salty water is used for cooking, it can affect the taste and nutritional value of food. In regions where desalination is not in place to remove excess salt from water sources, addressing water salinity issues becomes critical for ensuring access to safe and palatable drinking water.

The problem of the hypothetical desalination plant's adoption and its associated socio-political factors will be analyzed using a combination of theoretical models, simulation tools like Aspen and MATLAB, and economic assessments. To evaluate the socio-political aspects, we will conduct a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) and utilize qualitative data from various sources. The strengths and weaknesses will involve an assessment of the social acceptance, economic feasibility, and political implications of the desalination project. Opportunities and threats will consider the potential for job creation, water security, and possible public opposition. On the technical side, Aspen and MATLAB will help simulate the desalination process, calculate the brine's composition, and evaluate the fertilizer production process. We will use economic models to determine the cost-effectiveness of the desalination plant in conjunction with the economic value of the produced fertilizer. For example, the cost of seawater has fallen below US$0.50/$m^3$ for a large-scale seawater reverse osmosis plant(Ghaffour et al., 2013). We can then scale up the amount of water going into our plant. The evidence collected will include data on public acceptance, employment rates, economic growth, water quality, and the fertilizer market. This data will be interpreted by analyzing the quantitative and qualitative results and assessing their implications for the hypothetical plant's viability and socio-political impact.

Conclusion

In conclusion, this project's technical research and STS analysis offer a comprehensive solution to New Orleans, Louisiana's pressing water crisis. The technical deliverable focuses on designing a Desalination Plant and Fertilizer Production facility, addressing water scarcity exacerbated by saltwater intrusion. Through advanced reverse osmosis processes, our aim is to provide safe drinking water to the community while protecting freshwater sources in the Mississippi River. Simultaneously, our innovative approach to manage concentrated brine waste by converting it into valuable agricultural fertilizer aligns with sustainability principles and responsible resource management.

The societal impact of this project is significant, since it has the potential to safeguard human health and mitigate environmental challenges related to brine disposal, all while promoting sustainable agriculture in New Orleans. Looking forward, our future research paper will delve into the detailed design and implementation of this integrated system and analyze its broader socio-political implications. We anticipate that this holistic approach will serve as a comprehensive and sustainable solution to the city's water crisis, setting a precedent for responsible resource management and environmental responsibility in regions facing similar challenges.

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