

Water, Society, and Technology: A Inquiry into New Orleans' Desalination Plant

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Tatum Lohmar

Spring 2024

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

Advisor

Pedro A. P. Francisco, Department of Engineering and Society

STS Research Paper

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 representative 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). This crisis illustrates the urgency of finding innovative solutions that address both immediate water scarcity concerns and long-term environmental sustainability.

New Orleans, Louisiana, stands as an example of the intricate relationship between society, technology, and the environment in the context of water resource management. Situated along the iconic Mississippi River and facing the Gulf of Mexico, New Orleans is renowned for its cultural vibrancy and historical significance. However, beneath the surface lies a pressing water crisis exacerbated by saltwater intrusion, endangering local ecosystems and marine life but also threatening the city's access to clean, potable water (Parent, 2023).

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 project explores the design of a desalination plant in New Orleans, which would use advanced processes, including reverse osmosis, to turn seawater 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.

This brine waste is used 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 plant 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. In essence, there could be a solution to New Orleans' water crisis by designing a desalination plant and fertilizer production facility, utilizing advanced technology to provide safe drinking water while repurposing brine waste into valuable resources, which promotes sustainability and addresses pressing environmental and societal concerns.

Background

The background and significance of a desalination plant and fertilizer production facility for New Orleans, Louisiana, are deeply rooted in the pressing water crisis facing the city. Located along the Mississippi River and bordered by the Gulf of Mexico, New Orleans boasts a rich cultural heritage but grapples with a pressing water scarcity challenge that threatens its residents' well-being and environmental sustainability. Historically, the Mississippi River has been a lifeline for New Orleans, providing a vital source of freshwater for drinking, agriculture, and industrial activities. However, the city's dependence on this freshwater resource is increasingly threatened by saltwater intrusion from the Gulf of Mexico (Parent, 2023). Saltwater

intrusion occurs when saline water from the Gulf infiltrates upstream into freshwater sources, compromising their quality and availability. This phenomenon is exacerbated by factors such as sea-level rise, land subsidence, and anthropogenic activities, posing significant challenges for water resource management in the region. Against this backdrop, the proposed desalination plant and fertilizer production facility represent a proactive approach to addressing the complex challenges posed by water scarcity and saltwater intrusion.

Desalination technology holds immense promise as a solution to mitigate freshwater scarcity and prevent saltwater intrusion in coastal regions like New Orleans. By harnessing advanced processes such as reverse osmosis, desalination plants can effectively remove salt and contaminants from saline water sources, producing clean, potable water for various uses. However, traditional desalination processes generate concentrated brine waste as a byproduct, presenting environmental challenges when disposed of in oceans.

The proposed facility seeks to address this environmental challenge by repurposing brine waste into valuable resources, primarily agricultural fertilizer and road salt. This innovative approach aligns with the principles of the circular economy, wherein waste materials are transformed into valuable commodities, promoting resource efficiency and reducing ecological footprint (Jiménez-Arias et al., 2022). By converting brine waste into agricultural fertilizer, the facility not only mitigates environmental harm but also enhances agricultural productivity, thereby contributing to food security and economic development in the region.

Moreover, the significance of the proposed facility extends beyond environmental sustainability to encompass public health and social equity. Access to safe drinking water is a fundamental human right, yet high salinity levels in water sources can have detrimental effects on human health, particularly for vulnerable populations such as children, the elderly, and

individuals with underlying health conditions (Shammi et al., 2019). By providing a reliable source of clean water, the facility ensures equitable access to essential resources and promotes public health and well-being in the community.

Furthermore, the integration of desalination technology with resource management offers economic benefits by creating job opportunities and supporting sustainable agriculture practices. The production of agricultural fertilizer from brine waste not only reduces the environmental impact of disposal but also contributes to the local economy by enhancing agricultural productivity and supporting rural livelihoods. Additionally, the facility's operation and maintenance create employment opportunities in the region, stimulating economic growth and fostering community resilience.

Overall, this project aims to minimize the environmental impact of desalinating water for drinking purposes while ensuring a sustainable and accessible freshwater supply which encompasses several interdisciplinary themes that are highly relevant to the field of chemical engineering. Firstly, the project integrates principles of environmental sustainability and resource management, emphasizing the importance of minimizing waste and maximizing the efficiency of industrial processes. Chemical engineers play a crucial role in developing innovative technologies and strategies to address environmental challenges, such as water scarcity and pollution, by applying their expertise in process design, optimization, and waste treatment. Additionally, chemical engineers must consider not only the technical feasibility of their designs but also their broader impact on communities, ecosystems, and public health. By repurposing brine waste into valuable resources, the proposed facility demonstrates a commitment to sustainable development and social responsibility, aligning with the ethical principles of the chemical engineering profession.

Thus, the proposed desalination plant and fertilizer production facility underscore the urgent need for innovative solutions to address New Orleans' water crisis while promoting environmental sustainability, public health, and economic prosperity. By harnessing desalination technology and repurposing brine waste into valuable resources, the facility represents a holistic approach to water resource management that sets a precedent for responsible and sustainable development in coastal regions facing similar challenges.

Methodology

To address my research question regarding the minimization of environmental impact in desalinating water for drinking purposes while ensuring sustainability and accessibility, my methodology encompasses several key components rooted in Science, Technology, and Society (STS) analysis. Firstly, I will draw upon the technological momentum theory to understand how society may be affected by the implementation of a desalination plant in New Orleans. This theory posits that once a technology gains momentum and becomes integrated into society, it can be challenging to reverse or change course (*Technological Momentum*, n.d.). By applying this theory to my analysis, I can anticipate potential challenges and barriers to the adoption of desalination technology in New Orleans and explore strategies for fostering societal acceptance and support. Technological momentum theory also prompts me to consider the broader socio-political context surrounding the implementation of desalination projects. Factors such as government policies, public perceptions, and stakeholder interests can influence the trajectory of technological momentum and shape the outcomes of desalination initiatives. By examining these socio-political dynamics, I can better understand the challenges and opportunities associated with

introducing desalination technology in New Orleans and develop strategies to navigate potential obstacles.

Furthermore, my methodology will involve conducting a comprehensive literature review to analyze existing research and case studies related to the integration of desalination technology into different societies. This approach allows me to draw upon empirical evidence and scholarly insights to better understand the potential effects of my project on the environment, economy, public health, and social dynamics of New Orleans. By synthesizing and critically evaluating existing literature, I can identify key trends, patterns, and lessons learned that inform my analysis and guide my recommendations for minimizing environmental impact and ensuring sustainability.

In summary, my methodology for addressing the research question combines the application of technological momentum theory to anticipate societal effects, a literature review to draw upon existing research and case studies, and qualitative data analysis to interpret and contextualize findings. By employing these methods within an STS framework, I aim to provide a comprehensive analysis of the environmental and social implications of desalinating water for drinking purposes in New Orleans and offer recommendations for minimizing environmental impact while ensuring sustainability and accessibility.

Discussion/Results

The discussion and results section is a comprehensive analysis of the pros and cons of desalination plants on society, guided by key methodologies that inform the assessment of societal impacts. The application of technological momentum theory anticipates how society may be affected by the integration of desalination technology. This perspective prompts consideration of the challenges and opportunities associated with adopting desalination plants,

recognizing that once a technology gains momentum, it can significantly influence societal trajectories and behaviors. By exploring the socio-political dynamics, governmental policies, public perceptions, and stakeholder interests related to desalination projects, the analysis better understands potential hurdles and strategies for fostering societal acceptance and support.

Additionally, the analysis incorporates a comprehensive literature review, drawing upon existing research and case studies to inform the understanding of the environmental, economic, and social impacts of desalination plants. This literature review enables the identification of key trends, patterns, and lessons learned from global desalination initiatives, providing a more informed foundation for evaluating the pros and cons specific to the proposed desalination plant in New Orleans.

By synthesizing insights from technological momentum theory and a thorough literature review, the study aims to present a nuanced discussion on how desalination plants can contribute positively or negatively to society. The goal is to provide actionable recommendations for minimizing potential drawbacks and maximizing societal benefits, ensuring that the proposed desalination project aligns with principles of sustainability, accessibility, and environmental stewardship.

Environmental Implications

Desalination, as a response to global water scarcity challenges, has garnered significant attention due to its potential to provide a sustainable and accessible freshwater supply. However, along with its benefits, desalination also presents environmental challenges that must be addressed to ensure long-term sustainability. The environmental impacts of desalination, as analyzed and assessed by various studies, highlight key concerns such as hyper-saline

byproducts, high energy consumption, greenhouse gas emissions, and impacts on marine ecosystems. The discharge of hyper-saline brine into marine environments poses risks to aquatic life, while energy-intensive desalination processes contribute to air pollution and climate change (Panagopoulos & Haralambous, 2020). Thus, one of the key barriers to the expansion of desalination is the management of brine production and disposal. Brine disposal methods such as sewer discharge, evaporation ponds, and deep-well injection have associated environmental risks and costs (Panagopoulos & Haralambous, 2020). Additionally, the high energy consumption of desalination plants, primarily powered by fossil fuels, presents a challenge in achieving sustainability targets.

To address these challenges, mitigation measures have been proposed to minimize the adverse environmental impacts of desalination. Advances in technologies and mineral recovery offer potential solutions to make desalination more sustainable. Technologies like brine concentrators, crystallizers, and spray dryers have been developed exclusively for brine treatment, offering opportunities for resource recovery and waste reduction (Jones et al., 2019).

In the context of the proposed desalination plant for New Orleans, Louisiana, the production of fertilizer from the brine byproduct is a key aspect of the sustainability strategy. The brine leftover from the desalination process contains valuable minerals and nutrients that can be extracted and utilized for agricultural purposes. By implementing advanced brine treatment technologies, we can recover valuable components from the brine while minimizing waste disposal. By integrating these advanced technologies into the desalination plant design, it not only provides a sustainable source of drinking water for New Orleans but also contributes to agricultural sustainability by producing high-quality fertilizers from brine byproducts.

Fertilizers play a critical role in modern agriculture by providing essential nutrients to crops, thereby increasing agricultural productivity. However, it is important to address the widespread use of fertilizers that have raised significant concerns due to their negative environmental effects. One of the primary environmental impacts associated with fertilizers is eutrophication, a process where excessive nutrients, such as nitrogen and phosphorus, enter water bodies, leading to accelerated growth of algae and aquatic plants. This excessive growth can deplete oxygen levels in water, causing harm to aquatic organisms and leading to phenomena like "dead zones" in lakes and coastal areas (NOAA, 2021). Furthermore, fertilizers can contribute to soil degradation, salinization, and nutrient runoff, affecting not only water quality but also soil health and biodiversity (Chandini et al., 2019). These environmental challenges demonstrate the need for sustainable agricultural practices and innovative approaches to fertilizer production and application to minimize their adverse effects on ecosystems and human health.

Recent innovations in desalination technologies, particularly low-energy reverse osmosis (RO) systems, offer promise in reducing energy consumption and environmental footprints. Studies highlight the potential of two-stage RO configurations, dilution methods, and osmotic energy recovery to improve energy efficiency and lower operating costs. However, challenges remain in scaling up these innovations and addressing capital costs (Park et al., 2019).

While desalination offers a viable solution to water scarcity challenges, its environmental impacts must be carefully managed to ensure sustainability. Mitigation measures and technological innovations play crucial roles in minimizing environmental impact and ensuring a sustainable and accessible freshwater supply through desalination.

Socio-economic Effects

Researchers have explored various dimensions of the ethical and human effects associated with such projects. One key area of focus has been the ethical considerations surrounding water resource management and the trade-offs involved in desalination initiatives. The human effects of desalination plants extend beyond environmental considerations to societal and economic aspects.

Environmental impact assessments (EIAs) and environmental monitoring plans (EMPs) play a crucial role in evaluating and mitigating the environmental effects of desalination plants. Long-term monitoring studies demonstrate the importance of collaboration between industry and environmental scientists in ensuring sustainable operation and minimizing impacts on marine ecosystems (Panagopoulos & Haralambous, 2020). Panagopoulos and Haralambous emphasize the need for well-defined EMPs to monitor brine discharge effects and take corrective actions promptly.

Economic factors also influence the sustainability of desalination projects. The cost-effectiveness of desalination, including brine management and water quality parameters, is a critical aspect considered in planning and operation (Yermiyahu et al., 2007). Balancing treatment costs, water quality standards, and agricultural benefits is essential for long-term economic prosperity and environmental sustainability. Additionally, the proposition of a desalination plant being used worldwide is stifled by this large price tag. Therefore, it is not as realistic in less developed countries.

Looking ahead, future research directions should focus on developing cost-effective and energy-efficient desalination technologies, improving brine management practices, and integrating renewable energy sources into desalination plants. Collaboration between

stakeholders, policymakers, and researchers is key to implementing sustainable desalination strategies that meet water demand while safeguarding the environment.

Considering the socio-economic implications of desalination projects, including potential job creation, community resilience, and equitable access to water resources is argued to be important (Pistocchi et al., 2020). However, these benefits must be weighed against potential negative consequences such as increased energy consumption, displacement of traditional water sources, and socio-economic disparities in access to desalinated water as previously stated.

In addition to ethical considerations, the literature emphasizes the importance of assessing the human health effects of desalination plants and associated fertilizer production. There are potential health risks associated with exposure to chemicals and byproducts from desalination processes, highlighting the need for stringent monitoring and regulatory frameworks to protect public health (Pistocchi et al., 2020).

Considering environmental sustainability, social equity, public health, and community engagement is crucial in decision-making processes related to desalination projects. By synthesizing insights from diverse disciplinary perspectives, this review contributes to the ongoing dialogue on responsible water management and ethical technological innovation.

Conclusion

In conclusion, technological momentum theory offered a perspective on how society may be influenced by the integration of desalination technology. This lens prompted considerations of challenges and opportunities, including socio-political dynamics and stakeholder interests, emphasizing the importance of strategies for fostering societal acceptance and support. These

insights underscore the necessity of ongoing research and development to address potential barriers and maximize societal benefits from desalination projects.

The comprehensive literature review complemented these methodologies by drawing upon existing research and case studies, identifying key trends, patterns, and lessons learned. This review highlighted the potential for advanced brine treatment technologies and mineral recovery to make desalination more sustainable and environmentally friendly. Furthermore, it emphasized the importance of collaborative efforts among stakeholders, policymakers, researchers, and communities to implement responsible and ethical desalination strategies.

Looking ahead, continued improvement and innovation in desalination technologies are essential to address environmental challenges, including brine byproducts, high energy consumption, and impacts on marine ecosystems. The proposal to turn brine waste into fertilizer presents an opportunity for resource recovery and waste reduction, aligning with principles of sustainability and environmental stewardship. However, this proposal requires ongoing research and development to optimize processes and minimize environmental impact.

In conclusion, a multifaceted approach that integrates technological advancements, stakeholder collaboration, and ethical considerations is crucial for the successful implementation of desalination projects while ensuring sustainability, accessibility, and environmental responsibility. Continued efforts in research, innovation, and stakeholder engagement are key to realizing the potential benefits of desalination while mitigating its drawbacks and promoting a more sustainable future.

References

- Chandini, Kumar, R., Kumar, R., & Prakash, O. (2019, February). (PDF) *The Impact of Chemical Fertilizers on our Environment and Ecosystem*. ResearchGate.
https://www.researchgate.net/publication/331132826_The_Impact_of_Chemical_Fertilizers_on_our_Environment_and_Ecosystem
- Jiménez-Arias, D., Sierra, S.-M., García-Machado, F. J., García-García, A. L., Borges, A. A., & Luis, J. C. (2022). Exploring the agricultural reutilisation of desalination reject brine from reverse osmosis technology. *Desalination*, 529, 115644.
<https://doi.org/10.1016/j.desal.2022.115644>
- Jones, E., Qadir, M., van Vliet, M. T. H., Smakhtin, V., & Kang, S. (2019). The state of desalination and brine production: A global outlook. *Science of the Total Environment*, 657(657), 1343–1356. <https://doi.org/10.1016/j.scitotenv.2018.12.076>
- 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/water-sanitation-crisis-ohio-train-derailment/>
- NOAA. (2021, February 26). *What is eutrophication?* National Ocean Service; NOAA.
<https://oceanservice.noaa.gov/facts/eutrophication.html>
- Panagopoulos, A., & Haralambous, K.-J. (2020). Environmental impacts of desalination and brine treatment - Challenges and mitigation measures. *Marine Pollution Bulletin*, 161, 111773. <https://doi.org/10.1016/j.marpolbul.2020.111773>
- Parent, M. (2023, November 17). *The Saltwater Crisis in the Mississippi River: Causes, Effects, and Solutions*. Earth.org.
<https://earth.org/the-saltwater-crisis-in-the-mississippi-river-explained/>

Park, K., Kim, J., Yang, D. R., & Hong, S. (2019). Towards a low-energy seawater reverse osmosis desalination plant: A review and theoretical analysis for future directions.

Journal of Membrane Science, 595, 117607.

<https://doi.org/10.1016/j.memsci.2019.117607>

Pistocchi, A., Bleninger, T., Breyer, C., Caldera, U., Dorati, C., Ganora, D., Millán, M. M., Paton, C., Poullis, D., Herrero, F. S., Sapiano, M., Semiat, R., Sommariva, C., Yuce, S., & Zaragoza, G. (2020). Can seawater desalination be a win-win fix to our water cycle?

Water Research, 182, 115906. <https://doi.org/10.1016/j.watres.2020.115906>

Shammi, M., Rahman, Md., Bondad, S., & Bodrud-Doza, Md. (2019). Impacts of Salinity Intrusion in Community Health: A Review of Experiences on Drinking Water Sodium from Coastal Areas of Bangladesh. *Healthcare*, 7(1), 50.

<https://doi.org/10.3390/healthcare7010050>

Technological momentum. (n.d.). [Www.freedomlab.com](http://www.freedomlab.com). Retrieved April 23, 2024, from

<https://www.freedomlab.com/posts/technological-momentum>

Yermiyahu, U., Tal, A., Ben-Gal, A., Bar-Tal, A., Tarchitzky, J., & Lahav, O. (2007).

ENVIRONMENTAL SCIENCE: Rethinking Desalinated Water Quality and Agriculture.

Science, 318(5852), 920–921. <https://doi.org/10.1126/science.1146339>