Technical Title: Desalination Plant and Salt Production Design for Chennai, India

STS Title: Are the negative effects of desalination plants on the environment in Carlsbad, California outweighed by the demand for clean water?

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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

Human beings can survive only three days without water. Water makes up over 50% of the human body, and without it, bodily functions start to deteriorate. Additionally, communities require water for agriculture and other major industries. Therefore, access to clean water is a necessity, but many areas worldwide do not have the availability required for their population. Providing an economical and environmentally friendly solution to this world water crisis has become the aim of many researchers and scientists. A majority of the areas experiencing a water shortage are impoverished and surrounded by polluted lakes and rivers. One solution to help reduce the water scarcity has been desalination plants.

Desalination plants have been built in areas where the water availability is too low in over 120 countries worldwide ("Desalination Worldwide," n.d.). Desalination is a process by which the salt and other impurities are removed from saltwater to produce purified water for drinking, agriculture, manufacturing, and more. These desalination plants are built near oceans and rivers that provide the plant with seawater or brackish water for salt removal. In the United States, the preferred saltwater for desalination is brackish water because it has a lower salt content than seawater and therefore costs less to desalinate and results in less brine waste.

Other than the expense of desalination plants, the brine waste produced is a major issue associated with them. Many plants deposit the brine back into the surrounding environment which significantly raises the salt content and harms sea life. However, there are options to treat the waste before disposing of it to decrease its harmful effects.

In order to effectively design a desalination plant, there are technical and social aspects that must be addressed. I will address the technical aspects of desalination by designing a desalination plant using chemical process modeling software that includes pretreatment, desalination processes, and posttreatment for use in Chennai, India. As for the societal implications, I will use the organic machines theory to address the social and environmental impacts of the current desalination plant in Carlsbad, California on the surrounding population.

Technical Problem

The availability of freshwater is essential for human survival; however, many areas worldwide are currently experiencing water crises as available freshwater cannot meet the population's demand. Freshwater deficiency has a large impact on agricultural and industrial production, as well as creating a range of social, political, and economic issues. In many cases, freshwater scarcity has produced high levels of poverty in many communities, weakened the health of local ecosystems, generated societal distress, and has occasionally led to violent disputes (Jones, 2019).

Human-induced climate change is a major cause for recent freshwater shortages due to global temperature rise, sea level elevation, and increased natural phenomena. In areas with extreme droughts, freshwater scarcity has become a normal occurrence. There are currently 17 different countries, amounting to roughly 25% of the global population, that are experiencing extreme water stress; India is one of the most highly affected countries experiencing extreme water stress (Palanichamy, 2019). India's population holds approximately 1.3 billion people with over half of the population unable to regularly access freshwater ("India's water crisis," 2020). This is due to high levels of pollution in rivers and lakes throughout the country. Groundwater is currently India's main source for freshwater; however, it is not large enough to meet the country's freshwater demand. In recent years, India has begun to rely on the summer monsoon season in order to fill the gaps that groundwater can not supply. Due to climate change, the monsoon season has declined while droughts have increased, accelerating the severity of the situation. In cities like Chennai, the effect of climate change has become detrimental. Chennai relies heavily on the monsoon season to fill its reservoirs and provide water for the remainder of the year, but with reduced seasonal rainfall and a rapidly growing population, relying solely on their groundwater supply is not a viable long-term solution for Chennai.

A potential solution for Chennai's water crisis is building a desalination plant on the Bay of Bengal. Desalination is a process that removes salt and pollutants from saltwater to produce clean, drinkable water. The most common technology for desalination plants is reverse osmosis, making up 69% of operational desalination facilities in 2019 (Jones, 2019). Reverse osmosis uses pressure to force exclusively water through a semipermeable membrane, leaving impurities such as salt, chlorine, or metals behind. The second and third most common methods are multi-stage flash and multi-effect distillation. Both methods use thermal energy to heat the feed stream and create a progressively more pure water vapor stream. Electrodialysis is another common method of desalination. Like reverse osmosis, electrodialysis uses a membrane to filter out the ions, but instead of pressure, it uses electricity to force ion movement across the membrane. Regardless of method, the water must be treated before and after desalination for the plant to produce saleable water (Jones, 2019).

The pretreatment of seawater is conducted to bring down microorganisms, colloidal contaminants, and total dissolved solids to acceptable levels for the desalination unit. Pretreatment normally involves the use of chemical treatments followed by mechanical filtration methods. Chemical treatments including pH treatment, coagulants, and flocculants are done to precipitate or separate contaminants and suspended solids from the seawater. After chemical pretreatments, mechanical filtration methods such as centrifuges, belt presses, and filter presses are used to remove suspended solids and larger contaminants from the water (Abushaban, 2017).

After desalination, there are two product streams: purified water and concentrated brine. The post-treatment process for purified water involves adjusting water quality to meet product specifications through chemical treatments. The concentrated brine is either deposited into the ground or bodies of water causing environmental damage, or processed through zero liquid discharge systems to produce secondary products like salt (Gies, n.d.). Zero liquid discharge involves utilizing common and emerging desalination methods to extract solid salt or metals from the brine to produce saleable products.

Our proposed desalination plant will create potable water and salt as co-products with the goal of zero liquid discharge. The main method of desalination for this plant will be reverse osmosis, which requires pretreatment to reduce the amount of fouling that occurs on the membrane. A zero liquid discharge system will be implemented in order to treat the concentrated brine and produce salt ("Treatment and Management," n.d.*)*. The salt will be used to sell to other companies or the community as a product. In this project, we will be designing every unit operation in seawater pretreatment, the main desalination units, water post-treatment, and the brine post-treatment and salt production. The completion of this design proposal will allow for a system capable of desalinating seawater and result in two products: sterilized, drinkable water and salt crystals. This design can then be implemented into various water scarce communities and increase their quality of life.

This project will be completed in a team setting with assistance from Professor Anderson through chemical engineering courses 4474 and 4476 during the 2021-2022 academic year. Our team will use Aspen Plus, a process modeling tool, and Microsoft Excel to accomplish the aims of this project. In order to enhance steady progress on this design proposal, the team has decided to meet once a week in-person or through Zoom; during delegated check-ins the group will report any new information, discoveries, or updates regarding the project, and group work will be completed together in order to enhance communication and understanding.

STS Problem

California has a history of droughts, with the current drought lasting since 2011 (“California, ‘America’s garden,’” 2021). According to the United States drought monitor, the majority of California is experiencing a “severe drought” or worse, which not only affects the population, but the major agricultural industry in the state. In addition to harming the agricultural industry, droughts have harmed forests, increased the occurrence of wildfires, and reduced fish populations (“California, “America’s garden,” 2021). With these mounting hazards, California has been looking to alternative methods for obtaining the water they need, including desalination. There are currently twelve desalination plants in California, with the largest residing in Carlsbad.

Since 2015, the desalination plant in Carlsbad, California produces roughly 50 million gallons of water a day, and has produced over 40 billion gallons of water since it became operational (“Home,” n.d.). Given the amount of purified water that the plant produces, the overwhelming response to it has been praise for the progress it has made in providing water and minimizing the effects of drought for the San Diego area. However, I believe that there could be negative effects on the surrounding environment from the plant’s waste that should not be ignored. The Carlsbad desalination plant produces a brine waste that is nearly double the salt content of the ocean (“Carlsbad Desalination Plant,” n.d.). Placing the high salinity brine back into the surrounding ocean could harm wildlife that is not accustomed to that amount of salt.

I will use the Organic Machine framework to view the desalination plant as a man made machine that human beings use to commoditize the environment regardless of the negative effects it may have on the wildlife in the surrounding area. One of the many positive effects of desalination is that it provides water to an area lacking sufficient water sources, however a negative effect is that the brine waste produced can harm marine life when deposited back into the ocean. A study was performed to determine the salt content deposited back into the ocean which determined that there were no significant changes to the wildlife in the area, but that the salinity in the discharge zone was higher than allowed and extended further than specified ("Study of brine discharge"). While this may show that there are no immediate effects, the long-term effects of increased salinity could prove dangerous for the ecosystem the brine is continuously dumped into and that should be taken into account. This is just one example of the overlooked environmental impacts that the Carlsbad desalination plant incurs and through more research, other effects may be uncovered.

Conclusion

The objective of this project will be to design a desalination plant for Chennai, India using detailed process analysis and system modeling in order to reach this goal. The STS research paper will focus on the environmental impacts of desalination in Carlsbad, California, as well as the advantages. This will be accomplished using the Organic Machine theory as the method by which to approach the subject. The desalination plant is a form of organic machine because it uses natural resources like seawater to provide a human commodity. The results of both the technical and STS research will address the issue of water scarcity worldwide and the necessity to find a solution.

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